Macro-Temporal Quantum Coherence and Spin Glass Degeneracy

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Abstract

The neural realization of long term memories has remained to a high extent a mystery in the framework of the standard brain science. The TGD based quantum model for memory have developed gradually from the basic realization that in TGD framework the identification of quantum states as quantum histories makes it un-necessary to store information about the geometric past to the geometric now. This has deep implications.

a) It is possible to separate genuine geometric memory recall from apparent memory recalls such as feature recognition, associations, and implicit and procedural memories. There are no memory storages in brain and only memory representations abstracting the essential aspects of experience are needed.

b) The models of long term memory based on the assumption that information about the geometric past is stored in the recent state of the system predict that the new memories should mask the old ones. It is however known that childhood memories are the stablest ones. In TGD framework this ceases to be a problem.

Mirror mechanism provides a very general mechanism of long term memory. To remember something at a temporal distance T in the geometric past is to look at a mirror at a distance $cT/2$. If the mirror is quantum mirror only a timelike entanglement (allowed by the non-determinism of Kähler action) of the mental image of the geometric past with a mental image in brain now is needed. The un-necessity to communicate memories classically implies extreme generality of the mechanism: all kinds of memories: sensory, cognitive, verbal,.... can be recalled in this manner. Even the mechanism of memory recall by cue can be generalized since the notion of tele association makes in principle sense.

The basic objections against this over-simplified picture is that there is no guarantee that the reflected ME returns to the brain and that there is no control over the time span of long term memories. The notion of magnetic body allows a more realistic formulation. Brain or the personal magnetic body generates spontaneously negative energy MEs with all fundamental frequencies. These MEs can be also curved and are parallel to the closed flux tubes defining the personal magnetic body and connect geometric now with the brain of the geometric past: multiple reflections are probably required to achieve this. The length of the closed magnetic loop defines the time span of the corresponding long term memory. The sharing of mental images by timelike entanglement allows to communicate the desire to remember to the geometric past, and gives rise to the memory recall in the case of episodal memories. In the case of non-episodal/declarative memories the memory is communicated from the brain of the geometric past by classical communications using positive positive energy MEs which propagate with an effective phase velocity much lower than light velocity along closed magnetic flux tubes and generate in the receiving end symbolic representation of the memory.

Macrotemporal quantum coherence is further important piece of the model. The understanding of how macrotemporal quantum coherence is made possible by the spin glass degeneracy led to a concrete realization of the mirror model and also provided a connection with the ideas of Hameroff and Penrose. When a bound state is formed the zero modes of the bound state entangled subsystems become quantum fluctuating degrees of freedom. This means that state function reduction and state preparation cease to occur in these degrees of freedom. The bound state is in a kind of long-lasting multiverse state, or state of 'oneness' experientially, and the sequence of quantum jumps defined by the duration of the bound state behaves effectively as a single quantum jump. Macrotemporal quantum coherence making possible supercomputer like activities becomes possible.

The spin glass degeneracy associated with the join along boundaries bonds (the space-time correlates for the bound state formation) lengthens the lifetimes of the bound states dramatically and solves thus the basic objections against quantum consciousness. The spin glass degeneracy is due to classical gravitational energy of the system. The quantum jumps between different classical gravitational configurations involve the emission of gravitational (equivalently Z^0) MEs and the intention to remember is realized as a transformation of p-adic ME to negative energy gravitational ME. The fact that classical gravitational fields couple to classical gauge fields with a coupling which is about 10^8 stronger than the ordinary gravitational coupling, could play an important role too. Water clusters and macromolecules with

sizes in the range of cell membrane thickness and cell size are good candidates for generating gravitonic MEs responsible for all geometric memories. Also classical Z^0 interaction might be involved since gravitonic MEs can be regarded also as Z^0 MEs.

A rather detailed neuro level model of long term memory is developed and the model conforms nicely with the basic facts known about the relationship of hippocampus and long term memory.

1 Introduction

The basic objection against quantum consciousness theories is that the de-coherence times for macroscopic quantum states are quite too short. This argument has been put in quantitative form by Mark Tegmark [17].

These counter arguments are however problematic. First of all, the notions of quantum coherence and de-coherence are problematic in standard physics framework since the non-determinism of the state function reduction is in conflict with the determinism of Schrödinger equation. The intuitive idea is however that one can estimate the de-coherence times as essentially lifetimes of quantum states. Secondly, the estimates for de-coherence times are based on standard physics, and it is quite possible that new physics is essential for understanding living matter. The belief that standard physics is enough is based only on the reductionistic dogma.

Penrose and Hameroff [18] have proposed that some future theory of quantum gravitation makes it possible to replace the phenomenological notion of state function reduction with a more fundamental notion which they call Orch OR, that quantum gravitational effects make possible macroscopic quantum states of required long de-coherence time, and that micro-tubules are the systems, where these effects are especially important so that one might even speak about reduction of the consciousness to the micro-tubular level. Penrose and Hameroff have also proposed that micro-tubules could act as quantum computers. The quantum states involved would be quantum superpositions of tubulin conformations and quantum gravitation would somehow make these quantum superpositions stable. Long enduring quantum superpositions of the conformations of (say tubulin) molecules would allow to perform a multi-verse simulation for the conformational behaviour of the molecules and this would certainly have evolutionary value.

1.1 Macrotemporal quantum coherence is suggested by quantum classical correspondence

Topological Geometrodynamics inspired theory of consciousness [10] leads to a first principle theory of state function reduction and preparation free of the logical paradoxes, allows precise definitions for the notions of quantum coherence and de-coherence, and predicts a mechanism making the lifetimes of macroscopic bound states much longer than predicted by the standard physics. By quantum-classical correspondence the argument can be formulated at space-time level and configuration space (world of classical worlds) level.

At the space-time level coherence regions are identifiable as space-time sheets. They indeed are coherence regions for both classical fields and induced spinor fields defining single particle limit of the quantum theory. By quantum criticality of TGD Universe there is no upper bound for neither the spatial or temporal size of the space-time sheet and one obtains a p-adic hierarchy of coherence lengths and de-coherence times. Finiteness of de-coherence time corresponds to the fact that energy flows to the space-time sheet from larger space-time sheet first and then back. Note that in the standard quantum field theory the entire Minkowski space M^4 is the natural identification for the coherence region, and it is difficult to understand how to describe the reduction to a smaller region of M^4.

1.2 Macrotemporal quantum coherence from spin glass degeneracy?

At configuration space level the argument supporting macroscopic and macrotemporal quantum coherence goes as follows. The basic distinction between TGD and standard physics is quantum spin glass degeneracy [I1], which among other things implies that quantum bound states of, say, two molecules have enormous spin glass degeneracy absent in the free state. The intuitive expectation is that the system spends much longer time in bound states than in free states and this implies much longer de-coherence time than expected otherwise.

One can formulate this argument more rigorously using unitarity conditions implying that forward scattering amplitude for bound states is very large due to the spin glass degeneracy. The almost degenerate spin glass states differ only by their classical gravitational energy so that gravitation is indeed important. The importance of quantum gravitation is also obvious from the fact that genuine quantum gravitational states are state functionals in the world of worlds rather than in world so that they are expected to represent in some sense higher abstraction level than ordinary quantum states in the hierarchy of consciousness.

1.3 Dynamical Planck constant and dark matter hierarchy

Towards the end of 2004 I learned that there is evidence that planetary orbits obey Bohr quantization rules with a gigantic value of Planck constant [27]. Nottale does not assume that this quantization is genuine but regards it as a hydrodynamical effect. In TGD framework the most natural interpretation is in terms of a dynamical Planck constant, and TGD predicts correctly the basic dimensionless parameter involved [D6, J6, C6]. TGD also forces to identify the matter in a phase with large Planck constant as dark matter.

This identification led to a vigorous evolution of ideas still continuing while I am writing this. 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 [C6]. Also a good educated guess for the spectrum of Planck constants emerges. The implications are non-trivial already at the level of hadron physics and nuclear physics and imply that condensed matter physics and nuclear physics are not completely disjoint disciplines as reductionism teaches us. One condensed matter application is a model of high T_c superconductivity predicting that the basic length scales of cell membrane and cell as scales are inherent to high T_c superconductors.

Living matter as ordinary matter quantum controlled by the dark matter hierarchy has turned out to be a particularly successful idea. The hypothesis has led to models for EEG predicting correctly the band structure and even individual resonance bands and also generalizing the notion of EEG [M3]. Also a generalization of the notion of genetic code emerges resolving the paradoxes related to the standard dogma [L2, M3]. 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 [M3].

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

1.4 Implications of macrotemporal quantum coherence

The idea that the brain and perhaps all bio-matter, and even the entire Universe, can be regarded as a hologram of some type (see for instance, the articles of Miller and Webb [20] and of Gariaev *et al* [21]) has a long history but the question about the precise physical sense in which this holds true has remained without a satisfactory answer.

The concrete Maxwellian idea about hologram plate resulting as an outcome of interference of the reference beam and light scattered from an object can serve only as a guiding metaphor. First of all, coherence occurs only in what are called coherence regions and the problem is that Maxwellian theory does not really provide a first principle definition for the coherence regions. In quantum theory similar problem is encountered. Secondly, in living matter it is not at all clear whether reference beam exists at all. Third, living matter is a dynamic granular structure and far from a homogeneous hologram plate. Fourth, the idea about storing memories, one of the basic motivations of the hologram paradigm, has its own problems although multi-holograms are certainly possible.

In TGD framework topological quantization provides a precise first principle description of coherence. Topological quanta are the coherence regions of the classical field and classical decoherence means the splitting of the space-time surface to topological quanta. This process gives rise to the granular structure of matter and space-time sheets in various length scales are excellent candidates for basic units of hologrammic structures at the this level of the p-adic length scale hierarchy. At quantum level bound state quantum entanglement having join along boundaries bonds as a space-time correlate is responsible for the macroscopic and macro-temporal quantum coherence. The new view about time means that there is no need for storing large number of holograms in the same physical substrate.

In the sequel I will discuss the following topics related to the macroscopic and macro-temporal quantum coherence.

1. The notion of the many-sheeted space-time and basic ideas of TGD inspired quantum theory of consciousness and bio-systems.

2. How macroscopic and temporal quantum coherence is made possible by the spin glass degeneracy in TGD Universe.

3. How a hierarchy of dark matter with levels labelled by the values of Planck constant emerges in TGD framework and how it implies macrotemporal quantum coherence.

4. Macro-temporal quantum coherence from the point of view of physics (thermodynamical, energetic and information theoretic aspects) with some comments about the implications for quantum computing.

5. Macro-temporal quantum coherence from the point of view of biology and conscious experience, in particular micro-tubular model for long term memories.

2 Background

To make things easier for the reader the basic ideas of TGD inspired theory of consciousness are summarized before the discussion of the macro-temporal quantum coherence.

2.1 The notions of quantum jump and self

The basic notions of TGD inspired theory of consciousness are quantum jump between quantum histories (rather than time=constant snapshots of single quantum history) as moment of consciousness, and the notion of self as sub-system able to remain unentangled in subsequent quantum jumps [H1, H3]. There is deep structural analogy with physics: quantum jump is the elementary particle of consciousness and selves are atoms, molecules,.... of consciousness.

2.1.1 Quantum jump as a moment of consciousness

Each quantum jump replaces the solution of field equations (universe) with a new one. Quantum jump involves three steps:

1. The unitary time development U giving rise to the S-matrix summarizing quantum physics as it is understood by particle physicist;

2. the counterpart of state function reduction;

3. and state preparation involving a sequence of self measurements.

U can be said to generate multi-verse, quantum superposition of potentialities, a state of oneness in which everything is entangled with everything. State function reduction and preparation in turn mean gradual decomposition of universe to maximally disentangled subsystems interpretable as conscious analysis. Thus oneness and separation are both basic aspects of consciousness. The sequence of quantum jumps defines subjective time whereas geometric (or physicist's) time corresponds to the fourth spatial coordinate. The distinction between these times allows to resolve the basic paradoxes of modern physics and philosophy of mind.

2.1.2 Self

Self is by definition a sub-system able to remain unentangled in subsequent quantum jumps. Only bound state entanglement is stable in quantum jump and selves correspond to regions of the space-time surface having local topology in a given number field (real or p-adic number fields labelled by primes). p-Adic regions are interpreted as physical (non-conscious) correlates for imagination, intention and cognition whereas real regions correspond to matter. The unitary operator U could in principle generate entanglement also between p-adic and real regions (rational entanglement coefficients make sense in any number field), which is destroyed in the state function reduction step. This might be crucial for the generation of cognitive maps assigning to the states of matter (say reading of physical measurement apparatus) cognitive states (say mental image about the reading of the measurement apparatus).

The contents of consciousness of self are determined as the average over the quantum jumps occurred after it was created (the real or p-adic space-time region corresponding to self appeared in quantum jump). Selves can have sub-selves and self experiences them as mental images. Self can represent a mental image of a higher level self. Self experiences only the average of its sub-subselves. Thus statistical averaging is involved in both subjecto-temporal sense and spatially and is of central importance in the theory of qualia. This suggests that the foundations of, not only quantum measurement theory, but also statistical physics, reduce to the theory of consciousness. Quantum entanglement between sub-selves means fusion of mental images. The simplest assumption is that entangling self loses its consciousness.

The sharing of mental images by quantum entanglement is purely TGD based prediction. What happens is rather paradoxical: the subselves of unentangled selves bound state entangle so that the resulting fused mental image is shared by both selves. This is not possible if one applies the standard notion of quantum mechanical sub-system as a tensor factor. The p-adic hierarchy of

space-time sheets forces to generalize the notion of sub-system (note that also real space-time sheets are characterized by p-adic prime determining the size scale).

Smaller space-time sheets glued to larger space-time sheets are glued to it by wormhole contacts having size of order CP_2 length and having Euclidian signature of the induced metric. This implies the presence of elementary particle horizons at which metric around wormhole contacts changes its signature from Minkowskian to Euclidian. At these 3-dimensional surfaces the induced metric is degenerate so that these surfaces are effectively 2-dimensional and allow conformal invariance crucial for the construction of the quantum theory. The analogy with black hole horizon is obvious. Black holes cannot be described as tensor factors of the entire universe and the same holds true for topologically condensed space-time sheets. The reason is that the elementary particle horizon, which from the view point of the imbedding space has one time-like direction, becomes a causal determinant for the field equations. One must just postulate a hierarchy of systems labelled by p-adic primes and allow entanglement between sub-systems of unentangled systems. In terms of length scale thinking of quantum field theories, one can say that the entanglement between sub-systems is not visible in the p-adic length and time scales of the systems themselves.

2.1.3 Dark matter hierarchy and the notion of self

The vision about dark matter hierarchy leads to a more refined view about self hierarchy and hierarchy of moments of consciousness [J6, M3]. The hierarchy of dark matter levels is labelled by the values of Planck constant having quantized but arbitrarily large values. It seems that the basic hierarchy comes as $\hbar(k) = \lambda^k \hbar_0$, where $\lambda \simeq 2^k$ is integer. Also sub-harmonics and integer valued sub-harmonics of λ are possible [C6]. The larger the value of Planck constant, the longer the subjectively experienced duration and the average geometric duration $T(k) \propto \lambda^k$ of the quantum jump.

Dark matter hierarchy suggests also a slight modification of the notion of self. Each self involves a hierarchy of dark matter levels, and one is led to ask whether the highest level in this hierarchy corresponds to single quantum jump rather than a sequence of quantum jumps. The averaging of conscious experience over quantum jumps would occur only for sub-selves at lower levels of dark matter hierarchy and these mental images would be ordered, and single moment of consciousness would be experienced as a history of events. One can ask whether even entire life cycle could be regarded as a single quantum jump at the highest level so that consciousness would not be completely lost even during deep sleep. This would allow to understand why we seem to know directly that this biological body of mine existed yesterday.

The fact that we can remember phone numbers with 5 to 9 digits supports the view that self corresponds at the highest dark matter level to single moment of consciousness. Self would experience the average over the sequence of moments of consciousness associated with each sub-self but there would be no averaging over the separate mental images of this kind, be their parallel or serial. These mental images correspond to sub-selves having shorter wake-up periods than self and would be experienced as being time ordered. Hence the digits in the phone number are experienced as separate mental images and ordered with respect to experienced time.

2.1.4 General view about psychological time and intentionality

A natural resolution of the problems related to the preferred role of single moment of time for conscious experience is based on the idea that biological growth and self-organization is a 4-dimensional phase transition proceeding in the direction of the geometric future quantum jump by quantum jump. And, in particular, that the dominating contribution to the conscious experience comes from the front of the phase transition where the volition is.

What is then this fundamental phase transition giving rise to what we call life? The front of phase transition corresponds naturally to volitional consciousness. Volition as a transforma-

tion of intention to action in TGD universe corresponds to the p-adic-to-real phase transitions of space-time sheets taking place in quantum jumps (for more detailed arguments see [K1]). Thus the natural conclusion is that p-adic-to-real phase transition is the fundamental phase transition guiding the biological self-organization.

At least the selves at the same level of the self hierarchy possess the same value of psychological time. It might even be that the entire living biosphere (with magnetosphere included) could be seen as a phase transition front proceeding to the direction of the geometric future. This conclusion is of utmost importance since it leaves no other possibility that to accept that even biosphere defines conscious self and we correspond to only single level in the self hierarchy. In particular, the notion of collective consciousness is more or less 'a must' in this framework. A more detailed discussion of the notion of time can be found in [K1].

The real-to p-adic transition can occur in situations in which there is an energy feed providing the energy for the materialized real systems. Systems with a small or vanishing rest mass are favoured.

1. Cognitive neutrino pairs of almost zero energy are the first candidate in this respect since the neutrinos at $k = 169$ space-time sheet have negative Z^0 interacting energies (because of their lightness) [L1]. It however seems that configuration space spin degrees of freedom (that is fermionic degrees of freedom), in particular cognitive neutrinos are related to the cognition rather than intention. In this case p-adic-to-real transformation corresponds to the transformation of cognitive representation to a symbolic one. Symbolic representation could of course induce some physical effect: for instance, the symbolic representation in terms of real neutrinos could induce a nerve pulse pattern.

2. p-Adic-to-real phase transition could also occur for massless extremals (MEs) and perhaps also for the flux tubes of the magnetic fields. MEs are ideal for communication and control purposes and thus taylor-made for the realization of intentions. Besides MEs TGD counterparts of Teslas's scalar waves propagating with light velocity and representing pulses of electric field in the direction of propagation [G3] are good candidates in this respect. Also wormhole magnetic fields consisting of pairs of magnetic flux tubes with opposite time orientations and having vanishing net energies must be considered [J5]. Similar pairs of MEs are also possible.

To concretize the picture it is good to ask how intentions could be realized at the atomic level. Obviously the intentions of atom are very simple: make a transition to another energy level. These transitions involve the emission of photon, which can be also a negative energy virtual photon. Clearly, the generation of a p-adic ME is the most natural candidate for the space-time correlate of the atomic intention. If atomic transition occurs, it can provide the energy to transform p-adic ME to real one but the energy can also come from some other source. The p-adic-to-real transition is expected to occur with a considerable probability only if the p-adic ME resembles real ME sufficiently: for instance, p-adic and real ME could go through the same rational points in an appropriate p-adic resolution. In the presence of a real ME with fundamental frequency equal to the atomic transition frequency the probability for the atom to emit radiation in the direction of ME is enhanced so that intention is realized without conflict with the quantum statistical determinism. Intention only modifies quantum statistical probabilities by modifying the system.

MEs and Tesla's scalar wave pulses are not only ideal communication lines but also ideal control tools since they can form temporary bridges between space-time sheets making possible the leakage of ions between them. The leakage implies recoil effect and MEs and scalar wave pulses can act as switches inducing a coherent locomotion in direction of ME as a recoil effect. The findings of Modanese and Podkletnov [28] discussed in [G3] provide a support this mechanism. MEs can also act as Josephson junctions between cell interior and exterior and induce soliton sequences giving rise to nerve pulse sequences in turn allowing to control motor actions [M2].

It is important to notice that p-adic intentionality does not mean randomness. A complete localization in p-adic configuration space ("world of classical worlds") degrees of freedom must occur in each quantum jump. Hence each quantum jump leads to a state in which p-adic space-time sheets are completely fixed (whereas real space-time sheets are fixed only modulo a resolution defined by an appropriate p-adic lengths scale). It is however not possible to say that the localization occurs with some probability to a given configuration of p-adic space-time sheets. System can freely intend arbitrarily many times in the same manner. Thus p-Adic MEs (and less probably magnetic fields and wormhole magnetic fields) might represent a plan for the evolution of the biological system, and induce biological self-organization of matter around the resulting electromagnetic hologram like templates.

2.2 Many-sheeted space-time, topological field quantization, and spin glass degeneracy

Many-sheeted space-time allows to understand topologically the generation of structures. Even the macroscopic objects of every-day world correspond to space-time sheets. The replacement of pointlike particles with 3-surfaces of arbitrarily large implies the crucial non-locality at space-time level. Concerning the understanding of bio-super-conductivity, the basic observation is that the space-time sheets, which are much larger than atomic space-time sheets, contain very low densities of ordinary particles so that the temperature can be extremely low and macroscopic quantum phases are possible.

Topological field quantization, which is implied both by topological reasons and by the absolute minimization of the Kähler action, implies that space-time surfaces are counterparts of Bohr orbits and have complex topology. This means that topologically relatively featureless linear Maxwell fields are replaced by extremely complex topological structure, which can be regarded as kind of a generalized Feynmann diagram obtained by thickening the lines to four-dimensional space-time sheets.

Quantum-classical correspondence has been a basic guideline in the construction of the theory and states that classical space-time physics provides classical correlates for various quantum aspects of physical system leads to the view that the topological field quanta accompanying a given material system provide a representation for its quantum structure, kind of a manual.

The topological self-referentiality generalizes further to the idea that the inherent non-determinism of the p-adic dynamics makes possible space-time representation of quantum jump sequences and classical non-determinism of Kähler action the non-determinism inherent to the linguistic representations for the contents of consciousness of self. This in turn implies feedback loop to the configuration space (of 3-surfaces) level: configuration space spinor fields can represent (not faithfully) quantum jump sequences and thus the contents of consciousness associated with a sequence of quantum jumps (self), so that the ability to become conscious about being conscious about something can be understood.

One can also speak about 'field body' (or actually hierarchy of them) as being associated with the material system. This field body, which is much larger than the material system, serves as a sensory canvas at which sensory representations are realized and could also perform motor control. This means radical modification of the neuro-science view about brain as the sole seat of consciousness [M1, N1].

The basic variational principle underlying quantum TGD states that the space-time surface associated with a given 3-surface is absolute minimum of so called Kähler action, which is essentially Maxwell action for a Maxwell field, which is obtained by projecting CP_2 Kähler form to space-time surface. Thus primary dynamical variables are CP_2 coordinates rather than vector potential. This implies huge vacuum degeneracy: any space-time surface having CP_2 projection, which is Legendre manifold, that is at most a 2-dimensional surface of CP_2 having vanishing induced Kähler form,

is a vacuum extremal. New vacua are obtained by the canonical transformations of CP_2 acting as $U(1)$ gauge transformations on Kähler gauge potential. This symmetry is also approximate for non-vacuum extremals and broken only by classical gravitation represented by the induced metric.

Physically this means spin glass degeneracy: the geometric $U(1)$ gauge invariance ceases to be gauge invariance (nothing to do with ordinary gauge invariance) and implies huge almost-degeneracy of physical states. Gravitational energy distinguishes between these almost physically equivalent states. The standard manner to visualize the situation is by using the notion of the energy landscape. Spin glass energy landscape (now energy corresponds to Kähler function) is a fractal structure containing valleys inside valleys inside... This symmetry is responsible for a very large class of phenomena distinguishing between TGD and standard physics and also makes possible macro-temporal quantum coherence.

3 Macro-temporal quantum coherence from spin glass degeneracy

At the space-time level the generation of macroscopic quantum coherence is easy to understand if one accepts the identification of the space-time sheets as coherence regions. Quantum criticality and the closely related spin glass degeneracy are essential for the fractal hierarchy of space-time sheets. The problem of understanding macro-temporal and macroscopic quantum coherence at the level of configuration space (of 3-surfaces) is a more tricky challenge although quantum-classical correspondence strongly suggests that this is possible. In the sequel the notion of macro-temporal quantum coherence is discussed in quantum TGD framework and the argument for how quantum spin glass degeneracy implies macro-temporal quantum coherence is developed.

3.1 What does quantum coherence mean in TGD Universe?

Concerning macro-temporal quantum coherence, the situation in quantum TGD seems at the first glance to be even worse than in standard physics. The problem is that simplest estimate for the increment in psychological time in single quantum jump is about 10^{-39} seconds derived from the idea that single quantum jump represent a kind of elementary particle of consciousness and thus corresponds to CP_2 time of about 10^{-39} seconds. If this time interval defines coherence time one ends up to a definite contradiction with the standard physics. Of course, the average increment of the geometric time during single quantum jump could vary and correspond to the de-coherence time. The idea of quantum jump as an elementary particle of consciousness does not support this assumption.

To understand how this naive conclusion is wrong, one must look more precisely the anatomy of quantum jump. The unitary process $\Psi_i \to U\Psi_i$, where Ψ_i is a prepared maximally unentangled state, corresponds to the quantum computation producing maximally entangled multi-verse state. Then follows the state function reduction and after this the state preparation involving a sequence of self measurements and given rise to a new maximally unentangled state Ψ_f.

1. What happens in the state function reduction is a localization in zero modes, which do not contribute to the line element of the configuration space metric. They are non-quantum fluctuating degrees of freedom and TGD counterparts of the macroscopic, classical degrees of freedom. There are however also quantum-fluctuating degrees of freedom and the assumption that zero modes and quantum fluctuating degrees of freedom are correlated like the direction of a pointer of a measurement apparatus and quantum numbers of the quantum system, implies standard quantum measurement theory.

2. Bound state entanglement is assumed to be stable against state function reduction and preparation. Bound state formation has as a geometric correlate formation of join along

boundaries bonds between space-time sheets representing free systems. Thus the members of a pair of disjoint space-time sheets are joined to single space-time sheet. Half of the zero modes is transformed to quantum fluctuating degrees of freedom and only overall center of mass zero modes remain zero modes. These new quantum fluctuating degrees of freedom represent macroscopic quantum fluctuating degrees of freedom. In these degrees of freedom localization does not occur since bound states are in question.

Both state function reduction and state preparation stages leave this bound state entanglement intact, and in these degrees of freedom the system behaves effectively as a quantum coherent system. One can say that a sequence of quantum jumps binds to form a single long-lasting quantum jump effectively. This is in complete accordance with the fractality of consciousness. Quantum jumps represent moments of consciousness which are elementary particles of consciousness and in macro-temporal quantum coherent state these elementary particles bind to form atoms, molecules, etc. of consciousness.

3. The properties of the bound state plus its interaction with the environment allow to estimate the typical duration of the bound state. This time takes the role of coherence time. This suggests a connection with the standard approach to quantum computation.

3.2 Spin glass degeneracy and classical gravitation as stabilizer of irreducible bound state entanglement

This picture gives connection with the standard physics view but does not yet explain why decoherence times are so long. New physics is required to explain why the life times of bound states are much longer than predicted by the standard physics. Spin glass degeneracy provides this physics. There are two arguments: probabilistic argument based on intuition and the more rigorous argument based on unitarity.

3.2.1 Probabilistic argument

The probabilistic argument goes as follows.

1. Suppose that spin glass degeneracy gives rise to a huge number of almost degenerate bound states for which only the classical gravitational energy is different, and that for non-bound states this degeneracy is much smaller. The dominant part of the binding energy is of course something else than gravitational. If this is the case, the number of the bound states is so large as compared to the number of unbound states that the branching ratio for the decay to unbound state is very small. This means that the time spent in bound states is much longer than the time spend in free states and this means that de-coherence time is much longer than without spin glass degeneracy.

2. If the join along boundaries bonds are sufficiently near to vacuum extremals, they indeed allow immense spin glass degeneracy with slightly different gravitational interaction energies and the desired situation can be achieved.

3.2.2 The argument based on unitarity

A more refined argument is based on unitarity of S-matrix. The S-matrix can be written as sum of unit matrix and reaction matrix T: $S = 1 + iT$.

1. The unitarity conditions $SS^\dagger = 1$ read in terms of T-matrix as

$$i(T - T^\dagger) = TT^\dagger \quad . \tag{1}$$

For diagonal elements one has

$$2 \times Im(T_{mm}) = \sum_r |T_{mr}|^2 \geq 0 \ . \tag{2}$$

What is essential that the right hand side is non-negative and closely related to the total rate of transitions. If this rate is high also the imaginary part at the left hand side of the equation is large and therefore also the rate for the diagonal transition. For instance, in the case of low energy strong interactions this implies that the total reaction rates are high but transitions occur mostly in the forward direction. In this case the mere large number of final many-hadron states implies that most transitions occur in the forward direction.

In the recent case one must consider both free states and bound states. Let us use capitals M, N as labels for bound states and small letters m, n as labels for free states.

2. The diagonal unitarity conditions can be written for both of these states as

$$\begin{aligned} 2Im(T_{mm}) &= \sum_r |T_{mr}|^2 + \sum_R |T_{mR}|^2 \geq 0 \ , \\ 2Im(T_{MM}) &= \sum_R |T_{MR}|^2 + \sum_r |T_{Mr}|^2 \geq 0 \ . \end{aligned} \tag{3}$$

In both cases there is a large number of the degenerate states involved at the right hand side so that one expects that the right hand side has a large value. For bound states the number of degenerate states is much higher due to the additional degeneracy brought in by the join along boundaries bonds. Thus the lifetime and de-coherence time should be considerably longer than expected on basis of standard physics.

3. For the non-diagonal transitions from bound states to free states one has

$$i(T_{Mm} - \overline{T}_{mM}) = \sum_r T_{Mr}\overline{T}_{mr} + \sum_R T_{MR}\overline{T}_{mR} \ . \tag{4}$$

The right hand side is not positive definite and since a large number of amplitudes between widely different free and bound states are involved, one expects that a destructive interference occurs. This is consistent with a small value of the non-diagonal amplitudes T_{Mm} and with the long lifetime of bound states.

4. What happens for non-diagonal transitions between degenerate states? The unitarity conditions read as

$$\begin{aligned} i(T_{mn} - \overline{T}_{nm}) &= \sum_r T_{mr}\overline{T}_{nr} + \sum_r T_{mR}\overline{T}_{nR} \ , \\ i(T_{MN} - \overline{T}_{NM}) &= \sum_R T_{MR}\overline{T}_{NR} + \sum_r T_{Mr}\overline{T}_{Nr} \ . \end{aligned} \tag{5}$$

The right hand side is not anymore positive definite and there is a very large number of summands present. Hence a destructive interference could occur and the amplitude would be very strongly restricted in the forward direction. This need not however be true in the case of degenerate states since they are expected to be very similar to each other.

5. One can indeed play with the idealization that the transition amplitudes between degenerate states are identical $T_{MN} = T$ and that the amplitudes T_{Mr} are independent of M and given by $T_{Mr} = T_r$.

   In this case T-matrix would have the form $T = t \times X$, where X is a matrix for which all elements are equal to one. t can be written as $|t|exp(i\phi)$. T-matrix is maximally degenerate and the diagonalized form T^D of T-matrix has only a single non-vanishing element equal to Nt, N the number of degenerate states. t must satisfy the unitarity condition $|t| = 2 \times sin(\phi)/N$. S-matrix would reduce to an almost unit matrix for the diagonalized bound states.

   What about the stability of the bound states in this case? The decay amplitudes for bound states corresponding to the vanishing eigen values of T are given by $T^D(M,r) = \sum c_M T_{Mr} = \sum_M c_M \times T_r = 0$ by the orthogonality of these states with the state with a non-vanishing eigen value. Thus the lifetimes of all bound states expect the one with the non-vanishing eigen value of T are infinitely long in this idealization.

3.2.3 Color confinement and spin glass degeneracy

This mechanism has applications also outside consciousness theory. For instance, one can understand color confinement. When quarks form color bound states, their space-time sheets are connected by color flux tubes (this is the aspect of confinement which goes outside QCD). Also color flux tubes possess huge spin glass degeneracy. Free quark states do not possess this degeneracy since join along boundaries bonds are absent. Thus the time spent in free states in which color flux tubes are absent is negligible compared with the time time spent in color bound states so that the states consisting of free quarks are unobservable.

A more precise phrasing of this idea relies on unitarity conditions and the assumptions $T_{MN} \simeq T$ and $T_{Mr} \simeq T_r$. Here capital subscripts refer to degenerate hadronic states and small letter subscripts to free many-quark states. In this idealization hadronic degenerate states are stable against decay to free many-quark states with only single exception. The exceptional state should act as a doorway making possible the transition to quark-gluon plasma phase.

3.2.4 S-matrices associated with a hierarchy of de-coherence times

The Hamiltonian time evolution would more or less correspond to a unitary operator resulting as a product of the actions of the unitary operators U associated with the quantum jumps of the sequence. The interpretation is as a length/time scale dependent time development operator obtained by integrating over the spin glass degrees of freedom. This is natural since spin glass degrees of freedom represent hidden variables and degenerate bound states correspond to one and the same bound state in the standard physics view about Universe. Discretized time development emerges automatically in this framework. The Schrödinger equation at the infinitesimal level does not make sense but this is of course not a practical problem. One could say that the sequence of quantum jumps defining the conscious experience of self is able to simulate the unitary time evolution associated with single quantum history.

One might argue that this kind of description is unsatisfactory since unitarity might be only approximate. The fractality of consciousness however suggests that the unitary might be exact. First of all, the standard definition of sub-system must be replaced with a length scale dependent one involving length scale cutoff (sharing of mental images is one important implication). This is expected to be true also in the temporal domain so that also S-matrices form a hierarchy characterized by the durations of macro-temporal quantum coherence. The spatial and temporal resolutions would not be due to the limitations of the theorist or of the experimenter but basic properties of the subjective, physical, and mathematical existences, and p-adic length scale hierarchy would provide

the natural hierarchy of resolutions. The finite geometro- and subjecto-temporal resolutions might make possible exact unitarity for the S-matrices appearing in this hierarchy.

S-matrix would be replaced by a collection of S-matrices. At space-time level this presumably means the possibility and necessity to assign S-matrices to space-time sheet defining coherence regions. De-coherence, which would involve the decay of the space-time sheet to smaller space-time sheets representing outgoing particles and the generation of coherence as a time reversal of this process involving incoming particles would be an essential part of the construction of S-matrix. The relationship between hadronic physic and quark physics brings strongly in mind this situation.

4 Macro-temporal quantum coherence and dynamical $\hbar$

Neither the classical argument nor spin-glass degeneracy based argument in favor of macroscopic and macro-temporal quantum coherence need be consistent with ordinary quantum theory as such. Planck constant is usually regarded as a universal constant which can be taken to be $\hbar = 1$ if units are chosen suitably. For some reason that possibility that Planck constant might be dynamical has not been considered as a possible option by quantum consciousness theorists. My own views changed profoundly as I learned about the work of Laurent Nottale [27].

4.1 Quantization of planetary orbits with a gigantic value of Planck constant and dark matter as a macroscopic quantum phase

There is evidence that planetary orbits obey Bohr quantization rules with a gigantic value of Planck constant [27]. Nottale does not assume that this quantization is genuine but regards it as a hydrodynamical effect. In TGD framework the most natural interpretation is in terms of dynamical Planck constant and TGD even predicts correctly the basic dimensionless parameter involved [D6, J6, C6].

The notion of a macroscopic Bohr orbit is not a problem in TGD framework since the basic variational principles implies that space-time surfaces can be regarded as generalized Bohr orbits. The assignment of a Schrödinger amplitude to ordinary matter in astrophysical length and time scales is of course non-sensible in standard physics approach. The resolution of the paradox comes from the identification of dark matter in terms of a hierarchy of macroscopically quantum coherent large $\hbar$ phases around which visible matter condenses. There is no direct interaction between phases of matter with different values of $\hbar$ since all particles in fundamental vertices have same value of $\hbar$. De-coherence phase transition reducing the value of $\hbar$ and the reverse of this phase transition are possible. At classical level intricate interaction mechanisms are possible due to the properties of the many-sheeted space-time. For instance, this kind of mechanism plays key role in the model of nerve pulse generation [M2].

4.2 Criterion for the occurrence of a phase transition changing Planck constant

One ends up also to a criterion for the occurrence of the the phase transition increasing the value of the Planck constant. The idea is that when perturbation theory in powers of the gauge coupling constants fails, a phase transition increasing the value of $\hbar$ occurs so that coupling constant strength which is proportional to $1/\hbar$ is reduced and the resulting perturbation theory converges rapidly. Somewhat paradoxically, the large value of Planck constant implying formation of macroscopic quantum phases means also that the resulting system behaves more classically in the sense that higher order contributions in perturbation theory become small.

This picture leads to a rather precise vision about what happens in color confinement (valence quarks correspond to large value of $\hbar$). The implications are highly nontrivial also at the level of

nuclear physics and lead to an identification of nuclei as highly folded stringlike structures. The model also forces to give up the assumption that nuclear physics and condensed matter physics have nothing to do with each other.

4.3 Hierarchy of Planck constants and physics as a generalized number theory

The work done during the last year has led to a rather detailed view about the quantization of Planck constant in TGD Universe. It is possible to understand what the quantization Planck constant means in physics as a generalized number theory approach [C6]. The spectrum of Planck constants emerges in a more precise formulation of the generalized imbedding space concept relying on the generalization of the number concept obtained by gluing together reals and algebraic extensions of various p-adic number fields along common rationals much like pages of a book along their common rim. The gluing operation for various extensions of rationals with rationals corresponds to the identification of the point m^k of rational M^4 with the point λm^k of an algebraic extension of rational M^4.

The value of λ depends on the value of the algebraic extension and is determined from the requirement that the value of the Kähler coupling strength α_K, which is analogous to critical temperature and is determined by the requirement of quantum criticality, is same for both sectors. The exponent of Kähler function, and thus also α_K, is in turn determined in terms of a Dirac determinant defined as a product of eigenvalues of the modified Dirac operator including only the eigenvalues belonging to the algebraic extension of rationals considered. This identification means that the scaling factor λ^{-2} of M^4 metric appearing in the induced metric appears extremely nonlinearly in Kähler function. Therefore Kähler function plays a role of effective action coding arbitrarily high quantum corrections coming as powers of $1/\lambda$.

It is possible to make an educated guess about the spectrum of Planck constants respecting the empirical input from the findings of Nottale [27]. An especially important hierarchy from the point of view of TGD inspired theory of consciousness and quantum biology corresponds to $\hbar(k) = \lambda^k \hbar_0$, $k = 01, 2, ...$, $\lambda \simeq 2^{11}$. Quite generally, λ is integer and also harmonics and integer valued harmonics of λ are in principle possible.

The requirement that Poincare symmetries commute with the scalings of Planck constant by λ leads to a rather detailed view about what scaling by λ at space-time level means. In particular, the invariance of spin under the scaling of λ means a fractionization of spin quantum number m by scaling $m \to m/\lambda$. λ must be integer and the interpretation at space-time level is that space-time sheet becomes λ-fold covering of M^4 analogous to λ-sheeted Riemann surface. The interpretation of the sequence $\hbar$ increasing phase transitions $\hbar \to \lambda\hbar$ as an analog of a Feigenbaum sequence of period λ-foldings instead of period doublings is highly suggestive.

4.4 The interpretation of the phase transition $\hbar \to \lambda\hbar$ at configuration space level

At configuration space level the phase transition $\hbar \to \lambda\hbar$ and its reversal means going from one sector of the configuration space to another one. Quantum superpositions of states restricted to different sectors of configuration space can result in the first part of quantum jump referred to as "unitary process". State function reduction is expected to reduce the quantum superposition to a sector with definite value of Planck constant.

Quantum states correspond in TGD framework to the modes of configuration space spinor field. The phase transition can be understood at this level in the following manner [C6].

Configuration space Clifford algebra at a given point of the configuration space (3-surface) defines so called hyper-finite factor of type II_1, which is a special kind of von Neumann algebra.

The so called Jones inclusions of these infinite-dimensional algebras define a key part of the theory of these algebras.

For the Jones inclusions $\mathcal{N} \subset \mathcal{M}$ of these algebras $\mathcal{M}$ can be regarded as $\mathcal{M} : \mathcal{N}$-dimensional $\mathcal{N}$-module. The values of $\mathcal{M} : \mathcal{N}$ can be regarded as non-integer valued fractal dimensions and are given in terms of Beraha numbers:

$$\mathcal{M} : \mathcal{N} = 4cos^2(\pi/n) \ , \ \ n \geq 3 \ .$$

Beraha numbers appear in many contexts such as the knot theory and classification of 3-manifolds, braid groups, quantum groups, minimal conformal field theories, etc... so that configuration space spinor structure alone implies the basic mathematical structures associated with conformal field theories.

Denote by $\mathcal{N}$ the Clifford algebra associated with a given sector of the configuration space CH before algebraic extension, and by $\mathcal{R}$ the Clifford algebra resulting from this Clifford algebra in the transition induced by an algebraic extension bringing in d generating units which are not phases. It is assumed that this corresponds to a scaling $\hbar \to \lambda^d \hbar$.

An unproven hypothesis reproducing the desired formula for the Planck constant as a function of Beraha number is that $\mathcal{R}$ can be regarded as $(\mathcal{M} : \mathcal{N})^{\lambda^d}$-dimensional module over $\mathcal{N}$, where $\mathcal{M} : \mathcal{N}$ represents ordinary Jones inclusion. What this says that $\mathcal{M}$ defining ordinary Jones inclusion is replaced by $\mathcal{R} = \mathcal{M}^{\lambda^d}$, where $\mathcal{M}$ defines some Jones inclusion $\mathcal{N} \subset \mathcal{M}$ and that this corresponds at the space-time level to the replacement of space-time sheet with its λ^d-fold covering.

4.5 Large value of Planck constant implies macroscopic and macrotemporal quantum coherence

The large values of $\hbar$ mean macroscopic and macrotemporal quantum coherence. Various quantum scales such as Compton time and length are proportional to $\hbar$ and tare scaled up by λ in the phase transitions increasing $\hbar$. Also de-coherence times and lengths are scaled up. These scales correspond at the space-time level the scales of the space-time sheets involved. Thus a phase transition increasing λ but not affecting particle densities can lead to a situation in which the space-time sheets associated with particles zoomed up by λ overlap so that the criterion for macroscopic quantum coherence is satisfied.

4.6 Are the two explanations for the macro-temporal quantum coherence consistent?

The dark matter hierarchy with levels labelled by the values of Planck constants explains 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.

1. The argument based on spin glass degeneracy does not involve the value of $\hbar$ at all. 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 assignable to increased spin glass degeneracy.

2. The phase transition increasing Planck constant has a concrete topological interpretation in terms of the replacement of space-time sheet with its λ-fold covering so that the phase transition is analogous to a period doubling and thus brings in new degrees of freedom as is clear from school examples for what happens in the transition to chaos via period doublings. For instance, the replacement of the integers m characterizing angular momentum with m/λ means that the number of angular momentum eigen states becomes λ-fold.

3. A hypothesis bringing in number theory is that the phase transition increasing λ is induced by an algebraic extension of rationals induced by the introduction of d generating units of extension which do not reduce to phases. At the space-time level the phase transition $\hbar \to \lambda^d \hbar$ means that the eigenvalues of the modified Dirac operator belonging to an algebraic extension of rationals are included to the definition of the Dirac determinant defining Kähler function and thus also the Riemann surface like space-time sheet defining λ-fold covering of M^4 as its particular extremal.

4. At the configuration space level the phase transition $\hbar \to \lambda^d \hbar$ corresponds to the emergence of new degrees of freedom since the Clifford algebra of the new configuration space sector can be written as a tensor power $\mathcal{R} = \mathcal{M}^{\lambda^d}$, where $\mathcal{M}$ defines a Jones inclusion $\mathcal{N} \subset \mathcal{M}$.

5 Basic implications

In the sequel the physical aspects of the macro-temporal quantum coherence are discussed.

5.1 Thermodynamical aspects

During macro-temporal quantum coherence dissipation is absent in the quantum coherent degrees of freedom. This implies the breaking of the second law of thermodynamics in time scales shorter than the duration of bound states in the sense that entropy does not grow. [It is also possible that the geometric arrow of psychological time is reversed at the space-time sheets having negative time orientation: in this case second law holds true with respect to subjective time but corresponds to a decrease of entropy with respect to the geometric time of the external observer.]

p-Adic length scale hypothesis suggests a hierarchy of time scales for bound state lifetimes so that a hierarchical structure for the breaking of the second law is predicted. At space-time sheet characterized by p-adic prime p the second law would be broken below the time scale $T_p = L_p/c$, $L_p = \sqrt{p} \times l_0$, where l_0 is essentially CP_2 length scale about 10^4 Planck lengths. Breaking could also occur only below n-ary p-adic time scales $T_p(n) = p^{(n-1)/2} L_p$.

Quite recently it has been found that second law is indeed broken below .1 seconds for certain systems [29]. This time scale corresponds to the secondary p-adic time scale $T_p(2)$ associated with the Mersenne prime $M_{127} = 2^{127} - 1$ defining the p-adic length scale of electron. This time scale is fundamental in the TGD based model of living system and corresponds to the time scale of alpha band and the time resolution of the sensory experience (duration of sensory mental images). The reversal of the arrow of geometric time below p-adic time scale might be fundamental aspect of living systems and this point will be discussed later in more detail.

5.2 Energetic aspects

The generation of quantum bound state involves liberation of the binding energy as a usable energy. This might provide a new kind of metabolic mechanism in which co-operation by the formation of macroscopic quantum bound states allows a liberation of metabolic energy. The energy bill must be paid sooner or later, and the energy feed from environment takes care of this by destroying the bound state in average time defined by the duration of the bound state. The fact that oxidative metabolism is anomalously low during the neuronal synchrony [19] supports the view that neuronal synchrony might give rise to bound-state entangled multineuron states. This mechanism is quite general and even ordinary metabolism could be based on this mechanism as will be proposed later. Also the bound state entanglement between different organisms might be possible and liberate energy. Thus the notion of 'synergy' might be much more than a mere metaphor.

5.3 Information theoretic aspects

TGD framework forces to reconsider also the notion of information itself, and the new number-theoretic view about information might have radical implications for quantum computation.

5.3.1 Number theoretic information measures

The notion of information in TGD framework differs in some respects from the standard notion.

1. The definition of the entropy in p-adic context is based on the notion p-adic logarithm depending on the p-adic norm of the argument x only ($x = p^n r/s$, r and s not divisible by p; $Log_p(x) = log_p(|x|_p) = -n$) [H2]. For rational- and even algebraic number valued probabilities this entropy can be regarded as a real number. The entropy defined in this manner can be negative so that the entanglement can carry genuine positive information. Thus p-adic bound state entanglement giving rise to a fusion of cognitive mental images is a natural correlate for the experience of understanding, and one can assign to heurekas a well defined amount of information. Rationally entangled p-adic system has a positive information content only if the number of the entangled state pairs is proportional to a positive power of the p-adic prime p.

2. This kind of definition of entropy works also in the real-rational and even real-algebraic cases and makes always sense for finite real world ensembles and for entanglement between real (p-adic) systems. Entanglement probabilities are indeed algebraic numbers for both rational and algebraic entanglement coefficients. Here the problem is how to fix the value of the prime p and the only reasonable criterion is maximization of information.

3. The modified definition of entropy would have deep implications. For the ordinary definition of the entropy NMP [H2] states that real entanglement is minimized in the state preparation process. For the number theoretic definition of entanglement entropy NMP stabilizes the entanglement with positive information content. The fragility of quantum coherence is the basic problem of quantum computation and the good news would be that Nature itself (according to TGD) tends to stabilize quantum coherence if entanglement is rational/algebraic.

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

The possibility to define entropy differently for rational/algebraic entanglement raises the question about which kind of systems can possess this kind of entanglement. There are several options.

1. Only the entanglement between different number fields is rational/algebraic

This option is maximally conservative and would bring nothing new into the real physics. $R-R_p$ and $R_{p_1} - R_{p_2}$, $p_1 \neq p_2$ entanglement is indeed necessary algebraic (and rational unless one allows an algebraic extension of p-adic numbers, which is however forced by the diagonalization of the density matrix in the general case). For $R_{p_1} - R_{p_2}$ entanglement there are two natural entropies S_{p_1} and S_{p_2}. One can define the total entropy uniquely as the sum $S = S_{p_1} + S_{p_2}$: similar definition applies to $R - R_p$ case. This definition generalizes to the situation when more than two systems belonging to different number fields are entangled.

This kind of entanglement could be called cognitive, and it would be natural to assign a positive or negative information with cognitive entanglement. Cognition could be seen as a quantum computation like process, more approriate term being quantum problem solving. Intelligent life would metaphorically reside at the rational/algebraic intersection of reals and p-adics/algebraic extensions of p-adics. Quantum-classical correspondence suggests that life is a boundary phenomenon at

the space-time level: real and p-adic space-time sheets, action and intention, meet along common rational/algebraic points at the boundaries of the real space-time sheets so that these regions are indeed space-time correlates for the presence of cognitive entanglement.

Since intentionality (and thus p-adicity) is an essential aspect of life, one could say that living-dead dichotomy corresponds to rational-irrational or to algebraic-transcendental dichotomy. Life would in a well defined sense correspond to islands of rationality/algebraicity in the seas of real and p-adic continua.

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.

2. Other options

There are also other options besides the maximally conservative option.

1. Physics could be quite generally rational/algebraic at Hilbert space level. This would mean that the state space has algebraic numbers as coefficient field. In this case everything would be living. A milder constraint is that $R_p - R_p$ entanglement is always algebraic. For non-algebraic $R_p - R_p$ entanglement the entanglement entropy is p-adic valued and must be mapped to real number by canonical identificiation $x = \sum x_n p^n \to \sum x_n p^{-n}$: the resulting entropy is non-negative. If only algebraic $R_p - R_p$ entanglement is allowed, one can use $I = -S_p$ as an information measure.

2. Bound state entanglement is rational/algebraic. If this view is correct, one is led to ask whether life corresponds to rational or algebraic entanglement. The algebraic option would maximize the size of the living sector of the state space. Rational numbers are common for reals and all p-adics: in algebraic case this holds true only if one introduces algebraic extensions of p-adics. This might make rationals preferred.

The objection against both options is that in the case of algebraic $R-R$ entanglement it is not clear which prime p should define the information measure. The only reasonable looking criterion fixing the value of p is the maximization of information. One could also argue that information is associated with only cognitive entanglement which by definition is between different number fields. Also the hypothesis that all entanglement/bound state entanglement is always algebraic, might pose too strong restrictions on quantum dynamics. For instance, S-matrix elements would be rational- or algebraic number valued.

5.3.3 Quantum computation and quantum problem solving in TGD Universe

Macro-temporal quantum coherence makes also quantum computation like processes possible since a sequence of quantum jumps effectively binds to a single quantum jump with a duration, which corresponds to the lifetime of the bound state. Quantum computation like process starts, when the quantum bound state is generated and halts when it decays. Spin glass degeneracy increases the

duration of the quantum computation to time scales which are sensical for human consciousness. In case of cognitive quantum computation like processes the quantum coherence is stabilized by NMP.

1. Spin glass degeneracy provides the needed huge number of degrees of freedom making quantum computations very effective. These degrees of freedom are associated with the join along boundaries bonds and are essentially gravitational so that a connection with Penrose-Hameroff hypothesis emerges.

2. Bio-systems would be especially attractive candidates for performers of both non-cognitive and cognitive quantum computation like processes. The binding of molecules by lock and key mechanism is a basic process in living matter and the binding of information molecules to receptors is a special case of this process. All these processes would involve new physics not taken into account in the standard physics based biochemistry.

3. The possibility of cognitive quantum computation like information processing forces generalize the standard quantum computer paradigm also because ordinary quantum computers represent only the lowest, 2-adic level of the p-adic intelligence. Qubits must be replaced by qupits since for algebraic $R - R_p$ entanglement two-state systems are naturally replaced with p-state systems and for $R_{p_1} - R_{p_2}$ entanglement with $p_1 \times p_2$ state systems. For primes of order say $p \simeq 2^{167}$ (the size of small bacterium) this means about 167 bits, which means 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 idea about neuron as a classical bit might be a little bit wrong!

4. 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.

5.3.4 Information concept at space-time level

Quantum-classical correspondence suggests that the notion of information is well defined also at the space-time level. The non-determinism of Kähler aciton and p-adic non-determinism plus algebraic information measures suggest a natural approach tot the problem of defining the information concept. This approach provides also a new light to the problem of assigning a p-adic prime to a given real space-time sheet.

1. How to assign an information measure to a space-time sheet

In the presence of the classical non-determinism of Kähler action and p-adic non-determinism one can indeed define ensembles, and therefore also probability distributions and entropies. For a given space-time sheet the natural ensemble consists of the deterministic pieces of the space-time sheet regarded as different states of the same system. The probability for the appearance of a given value of observable is of the general form $p_i = m_i/N$, $m_i < N$, where N is the number of deterministic pieces and S_p is always negative, when p divides N.

Obviously the primes dividing N define natural candidates for the information measures but the problem is which criterion selects one of them. There are three options.

1) Require that the information measure corresponds to the prime p for which S_p is smallest. Obviously p must divide N.

2) Define the information as sum

$$I = -\sum_{p|N} S_p \ ,$$

(here $p|N$ means that p divides N) so that all contributions are positive.

3) Include all primes dividing N or m_i in $p_i = m_i/N$:

$$I = -\sum_{p|N \ or \ p|m_i} S_p \ ,$$

In this case also negative contributions are present. This defition is actually equivalent with a definition

$$I = -\sum_{p} S_p \ ,$$

in which the summation appears over all primes. One could say that the information decomposes into different kinds of informations labelled by primes.

What is interesting is that, the ordinary Shannon entropy S for rational probabilities can be expressed as a sum of all p-adic entropies using the adelic decomposition $|x| = \prod_p |x|_p^{-1}$:

$$S = -\sum_p S_p = I \ .$$

The sum of real and p-adic entropies vanishes. Real dis-information and the p-adic information would compensate each other completely. Whether the adelic formula for information theory might have some deeper interpretation remains open.

2. How to assign p-adic prime or primes to a real space-time sheet?

A long-standing problem of quantum TGD is how to associate to a given *real* (not only p-adic) space-time sheet a unique p-adic prime (or possibly several of them) as required by the p-adic length scale hypothesis.

1. One could achieve this by requiring that for this prime the negentropy associated with the ensemble is maximal. The simplest hypothesis is that a real space-time sheet consisting of N deterministic pieces corresponds to the p-adic prime defining the largest factor of N.

2. One could also consider a more general possibility. If N contains p^n as a factor, then the real fractality above n-ary p-adic length scale $L_p(n) = p^{(n-1)/2}L_p$ corresponds to smoothness in the p-adic topology. This option is more attractive since it predicts that the fundamental p-adic length scale L_p for a given p can be effectively replaced by any integer multiple NL_p, such that N is not divisible by p. There is indeed a considerable evidence for small p p-adicity in long length scales. For instance, genetic code and the appearance of binary pairs like cell membrane consisting of liquid layers suggests 2-adicity in nano length scales. This view means that the fractal structure of a given real space-time sheet represents both an integer N and its decomposition to prime factors physically. This would also mean that one can assign several p-adic information measures to the real space-time sheet. This obviously conforms with the physics as a generalized number theory vision.

3. Intuitively it seems obvious that there must be a physical mechanism selecting one prime amongst all possible primes which characterizes the information measure associated with the ensemble of the deterministic pieces associated with the real space-time sheet. Conscious information requires the presence of cognition: the real space-time sheet must be entangled with a p-adic space-time sheet. Quantum-classical correspondence means that the ognitive

entanglement of the real system with p-adic system has as a space-time correlate join along boundaries bond connecting the real and p-adic space-time sheet and glued to the boundary of the real space-time sheet along common rational points. One could argue that the p-adic join along boundaries bonds are most probable when the p-adic prime is such that it defines an effective p-adic topology for the real space-time sheet. This would mean that the prime-power factors of N define preferred p-adic length scales to the real space-time sheet.

4. The hypothesis that the prime factorization of N determines the effective p-adic topologies associated with the real space-time sheet inspires the hypothesis that the rational (or algebraic) p-adic-real entanglement necessary for cognitive quantum measurements is probable/possible only for the p-adic primes dividing N.

3. Does classical space-time physics represent factorization of integers?

Quantum-classical correspondence suggests that quantum computation processes might have counterparts at the level of space-time. An especially interesting process of this kind is the factorization of integers to prime factors. The classical cryptography relies on the fact that the factorization of large integers to prime factors is a very slow process using classical computation: the time needed to factor 100 digit number using modern computer would take more than the recent age of the universe. For quantum computers the factorization is achieved very rapidly using the famous Shor's algorithm. Does the factorization process indeed have a space-time counterpart?

Suppose that one can map the integer N to be factored to a real space-time sheet with N deterministic pieces. If one can measure the powers $p_i^{n_i}$ of primes p_i for which the fractality above the appropriate p-adic length scale looks smoothness in the p-adic topology, it is possible to deduce the factorization of N by direct physical measurements of the p-adic length scales characterizing the representative space-time sheet (say from the resonance frequencies of the radiation associated with the space-time sheet). If only the p-adic topology corresponding to the largest prime p_1 is realized in this manner, one can deduce first it, and repeat the process for N/p_1^n, and so on, until the full factorization is achieved. A possible test is to generate resonant radiation in a wave guide of having length which is an integer multiple of the fundamental p-adic length scale and to see whether frequencies which correspond to the factors of N appear spontaneously.

Seeing the prime factorization might be also possible via a direct sensory perception. Oliver Sacks tells in his book 'The man who mistook his wife for a hat' [16] about twins, John and Michael, who had a mysterious ability to 'see' large numbers and their prime factorizations despite the fact that their intelligence quotient was about 60 and they did not have any idea about the notions of integer and prime. For instance, matchbox was dropped from the table and its contents were spread along the floor. Both twins shouted immediately '111!'. Then John mumbled '37', Michael repeated it and John said '37' third time. Obviously this was their sensory representation for the decomposition $111 = 3 \times 37$ of number 111 to a product of primes! The explanation of these strange feats suggested in the [H3] is a less general idea about physical representation of the factorization. The proposed mechanism could indeed explain prime factorization as a sensory perception involving no algorithmic cognition at all.

6 Macro-temporal quantum coherence, consciousness, and biology

This section is devoted to a brief discussion of the aspects of macro-temporal quantum coherence related to consciousness and biology.

6.1 Macro-temporal quantum coherence and states of "one-ness"

Selves can be regarded as ensembles of quantum jumps with contents of conscious experience determined by qualia identified as statistical averages over increments of quantum numbers *resp.* zero modes over quantum jumps (non-geometric *resp.* geometric qualia such as colors *resp.* geometric shape. In general selves, and in particular sub-selves representing mental images of self become fuzzy during ageing since the entropies associated with the distributions of quantum number/zero mode increments increase with the increasing size. Macro-temporal quantum coherence allows to avoid this problem and mental image stays sharp as long as the bound state lasts.

The formation of quantum bound states corresponds to the fusion of mental images (subselves) to form large mental images and in the ideal situation all mental images fuse to single mental image. The fusion of the right and left visual fields to a single visual field giving rise to stereo vision is basic example of this process. Quite generally, the fusion of more or less identical mental images gives rise to a 'stereo-consciousness'. Synchronous neuronal firing is the physical correlate for the fusion of mental images and is made possible by the formation of join along boundaries bonds. In case that the mental images are too different this kind of fusion is not useful, and at least in the case of vision, sensory rivalry selects either of the visual images as a conscious percept [19].

An interesting question is what kind of conscious experience this process corresponds. A natural guess is that the fusion of mental images to single mental images gives rise to a mystic experience of 'one-ness'. In p-adic context rational bound state entanglement can have negative p-adic entanglement entropy under rather natural definition of entanglement entropy. Perhaps the fusion of p-adic mental images representing cognitive mental images gives rise to the experience of understanding. As found, the definition of entanglement entropy used in p-adic-rational context applies as such in real-rational context. Thus also sensory mental images could carry positive information.

Bound state entanglement for mental images means sharing and fusion of mental images and this kind of mechanism could be crucial for the formation of social structures and establishment of common value systems and moral rules. The experience of love might be the conscious experience associated with the sharing of mental images. TGD predicts also the possibility of bound state quantum entanglement even in astrophysical length scales and sharing of mental images provides a basic mechanism of remote mental interactions by making remote system effectively a part of the system. The realization of sensory representations at the magnetic body and probably also at magnetosphere is based on this kind of remote mental interaction. Rather paradoxically, paranormal phenomena would be completely normal.

6.2 Macro-temporal quantum coherence and biology

The formation of bound states is a generic mechanism for generating new quantum fluctuating degrees of freedom and could make possible quantum computation like processes and multi-verse states of consciousness containing large amounts of conscious information. At the macro-level sexual organism could be a basic example of a multi-verse state of one-ness generated by the formation of a macroscopic quantum bound state of partners. Neuro-scientists are used to talk about rewards and punishments, and one might argue that life involves kind of sexual or spiritual pleasure as a reward for the formation of bound states at all levels of hierarchy. Spiritual experiences would represent the most abstract experiences of this kind involving the formation of bound states of the field bodies by MEs serving as field bridges.

Some examples are in order.

1. The binding of molecules by lock and key mechanism is a fundamental process in living matter and could generate large number of quantum fluctuating degrees of freedom and generate conscious intelligence. This could explain why long linear macro-molecules are so important

for life. From the viewpoint of classical chemistry it is not obvious why DNA is arranged into long chromosomes rather than separate short threads. In TGD universe the reason why would be that for chromosomes the number of quantum fluctuating degrees of freedom and thus the amount of conscious intelligence is maximized.

2. The binding of the information molecules to receptors is a universal control mechanism in the living matter. In TGD universe information molecule would initiate genuine quantum information processing lasting for the lifetime of the information molecule-receptor complex. In particular, neurotransmitters could induce molecular states of one-ness in the receptor-neurotransmitter complex or perhaps even in larger-sized structures. If neurotransmitters have join along boundaries bonds to other neurons mediated by magnetic flux tube structures or MEs, they could act as conscious quantum links in quantum web and induce quantum computation like processes involving distant neurons just as the links in the web induce classical computations involving distance computers.

3. One could see information molecules and receptors as representatives of opposite molecular sexes: information molecules would be active quantum binders free to move from flower to flower whereas receptors would be the passive party attached to some structure. The binding of the information molecule to the receptor would be the molecular analog of the sexual intercourse. Usually the receptors are bound to larger structures such as cell membrane and also the zero modes for some parts of these larger structures could become quantum fluctuating in the process.

4. As found, the new number-theoretic definition of entropy is very attractive from the point of view of consciousness theory also in the real context. An especially interesting biological application of the number-theoretic entropy would be to the genetic code: in this case the number of bases is proportional to at least $p = 3$. Does the number N of DNA triplets of gene or of information bearing fragments of gene have a tendency to be proportional to powers of some relatively large primes? Could one order the genes hierarchically by the prime number decomposition of the number N so that large primes would correspond to high level bio-control and small primes to low level bio-control? Could the prime number decomposition of N define natural decompositions of gene to sub-modules of the biological program defined by the gene? For instance, $N = 10 = 2 \times 5$ would correspond to 5 (2) sub-modules consisting of 2 (5) DNA triplets.

6.3 Macro-temporal quantum coherence and long term memory

The energies liberated in the transitions between spin glass states should correspond to gravitational binding energies. MEs would be the space-time correlates for the radiation emitted in these transitions. These MEs could be electromagnetically neutral and carrying only classical Z^0 fields and gravitational fields (it is a matter of taste whether one speaks of Z^0 or gravitational MEs). It turns out that these transitions could realize the mirror mechanism of long term memories.

6.3.1 Mirror mechanism of long term memories and gravitonic topological light rays

To remember what happened (more precisely, happens subjectively now) in the geometric past at a temporal distance of one year is to look at a quantum mirror at a distance of one half light year. To have an intention is to look at a p-adic quantum mirror which is in the geometric future.

MEs (topological light rays) with fundamental frequencies with a time scale measured using year as a natural unit are needed in the mirror model of long term memories. The gravitational transitions between a huge number of almost degenerate spin glass states could be coded to the fundamental frequencies of MEs. In particular, structures with sizes slightly above cell membrane

thickness, such as micro-tubules, could generate these MEs as a topological correlate for graviton emission with frequency (length) of ME equal to the increment of the gravitational binding energy in quantum jump involved. Thus there would be a direct correlation with long term memories and micro-tubules: micro-tubule conformations could code for long term memories.

The mirror mechanism of long term memory allows a beautiful interpretation in terms of topological correlates for virtual graviton exchange with vacuum.

1. The light reflected in mirror corresponds to topological light rays assignable to gravitons and is reflected from the curved vacuum. Topological counterpart of virtual graviton is emitted by (say) a tubulin, reflected by the vacuum, and finally absorbed by the tubulin. Curved vacuum acts as a mirror for gravitons and self can see the self of the geometric past in this mirror.

2. Why gravitons are the only possibility in time scale of years is simply that they interact so weakly that they can propagate light years before absorbed by curved vacuum. Note however that Z^0 MEs interact classically with the matter and this interaction is especially strong in cellular length scales and presumably makes possible the reflection of the ME from the vacuum. Time scales come out correctly and micro-tubules are known to be crucial for long term memories (Altzheimer's disease involves changes at the micro-tubular level).

3. One could interpret the low energy topological graviton rays responsible for long term memory as a particular kind of $1/f$ noise accompanying all critical systems, in particular TGD Universe, which can be regarded as a quantum critical quantum spin glass. Gravitonic $1/f$ noise would be emitted in the transitions between almost degenerate spin glass states and would be kind of analog for gravitational brehmstrahlung.

If this view is correct, the time scales of long term memory at DNA level would correspond to very long time scales characterizing consciousness at the level of species. This in fact conforms with the role of DNA as a species memory. As a matter fact, the gravitational binding energy associated with $L(139) \sim .1$ nm (atomic physics) corresponds to the age of the universe: perhaps this explains why Schröedinger equation applies to the description of atom. $1/R$ dependence of the gravitational interaction energy would explain why very short length scales code biological information about very long time scales rather than vice versa.

6.3.2 Order of magnitude estimate for gravitational binding energies

A rough order of magnitude estimate for the gravitational binding energy for a cubic blob of water (that is living matter) having size given by p-adic length scale $L(k)$ is

$$E_{gr}(cubic,k) \sim \frac{GM^2}{L(k)} = G\rho^2 L^5(k) \sim \frac{Gm_p^2}{L(137)} \frac{L^5(k)}{L^5(137)} \simeq 2^{-127} 2^{5/2(k-137)} \frac{1}{L(137)} \quad .$$

Gravitational binding energy is larger than the p-adic energy $2\pi/L(k)$ for $L(k = 179) \simeq .169$ mm. In the range $L(163) = 640$ nm and $L(167) = 2.56$ μm gravitational binding frequency varies between 1 Hz and 1 kHz, that is over EEG range up to the maximal frequency of nerve pulses. If the binding energy gives estimate for the lifetime of the gravitationally bound states, this might fit nicely with EEG energies in typical cell length scales!

For $k = 157$ and $k = 151$ (the range from cell 10 nm-80 nm, micro-tubules are at the lower end of this range) the gravitational binding frequency corresponds to a time scale of 8.5 hours and 32 years respectively so that the time scales relevant for life are spanned by the Gaussian Mersennes. What sounds paradoxical is that short length scales would correspond to long time scales but this indeed follows from the inverse square law for the gravitational force.

One can perform a similar estimate for linear structures. Parameterizing the micro-tubular transversal area to be $d = x^2L^2(151)$, $L(151) = 10$ nm, one has

$$E_{gr}(lin, k) = x^5 \times E_{gr}(cubic, 151)\frac{L(k)}{L(151)} \quad .$$

This gives for $L(k) \sim 1$ meter, the frequency of $.1 \times x^5$ Hz. The time scale varies between $10/x^5$ seconds and $32/x^5$ years and certainly covers the time scale for human long term memories. Of course, this rough estimate involves numerical factor which can increase the upper bound. One must also remember that the change of the classical gravitational energy for spin glass transitions is in question and this energy is smaller than binding energy itself so that actual time scales are considerably longer.

Together with the known facts about the correlations of micro-tubuli with long term memories this leads to the idea that micro-tubuli represent long term memories. What is so beautiful in this idea is that there is no need for long term static storage of memories since memory is represented in the geometric past. The instantaneous configurations of the micro-tubuli define the memories and they are allowed to change in quite rapid time scales. The two conformations of tubulin dimers are ideal for representing declarative memories as bit sequences and micro-tubuli provide huge information storage capacities. One can also understand why sensory pathways tend to maximize their length. The loss of long term memories at old age respects the oldest memories and this naturally corresponds to the degeneation of the long micro-tubuli first with shortest micro-tubuli being the most stable ones. In [H6] the model for long term memories is developed in detail.

7 Co-operation and competition as different aspects of quantum consciousness

7.1 Breaking of super-conductivity, metabolism and homeostasis

The assumption that magnetic flux tubes of say Earth's magnetic field serve as carriers of supra currents in living manner leads to concrete views about breaking of super-conductivity as a basic mechanism of metabolism and homeostatic control.

7.1.1 Leakage mechanism

The basic mechanism for the breaking of super-conductivity is the generation of 'bridges' between super-conducting magnetic flux tubes and some smaller space-time sheets, which need not be atomic space-time sheets as assumed in the earlier formulation of the model. The energy of photons inducing the bridges corresponds naturally to the difference for the energies of the ion at atomic space-time sheet and super-conducting magnetic flux tube. In the case that the energy at magnetic flux tube is very small as compared to the zero point kinetic energy at smaller space-time sheet, the energy of photon must be the zero point kinetic energy at least. This option will be discussed in the sequel. The ions at the smaller space-time sheet dissipate their energy and end up to having only zero point kinetic energy plus possible thermal energy.

Quantum-classical correspondence suggests that it should be possible to understand how the absorption of photons corresponds to the process in which 'bridges' are generated by MEs. MEs carry transversal electric and magnetic fields. There is infinity variety of various kinds of MEs but for the simplest MEs electric and magnetic fields have constant linear direction orthogonal to each. Electric field defines a potential difference which is constant in length scales much shorter than the wave length of ME. By generalizing the quantization of magnetic flux to that for electric flux one obtains that the the potential difference satisfies

$$eV = n\omega = nf \times 2\pi \ .$$

This means that an ion having a charge e accelerating in the radial field gets energy $E = n\omega$. Thus absorption of photon with energy $n\omega$ corresponds classically to an acceleration in the electric field of ME and getting same energy. For ion having opposite charge acceleration would be replaced by deceleration and one must speak of emission of photon with energy $E = n\omega$. The model for ADP-ATP process is indeed based on the assumption that metabolic energy generates an electric potential in which protons are accelerated to get energy of .5 eV. for TGD based model see [K6]).

7.1.2 New manner to interpret gap energy of bio-super-conductor

The values of the gap energies of super conductors are identifiable as differences of zero point kinetic energies for the space-time sheets, which correspond to the value of p-adic prime nearest to that associated with the magnetic flux tubes in question and present in the topological condensate. For Earth's magnetic field one has $k = 169$ from flux quantization. For proton the zero point kinetic energy at $k = 151$ space-time sheet is about $E_0 = 2^{137-151} \times .5$ eV, which corresponds to a critical temperature of about $T_{cr} \sim E_0 = .3$ K. For $k = 149$ the critical temperature is about 1.2 K. For $k = 139$ the critical temperature would be 1250 K. If this picture is correct, high T_c super conductors result, when the intermediate space-time sheets between those representing super-conducting magnetic flux tubes and atomic space-time sheets are eliminated somehow from the material. This goal could be achieved by using strong enough magnetic fields for which the p-adic prime is larger than $k = 151$ so that there are not so many p-adic primes to be eliminated. Also secondary p-adic primes are allowed. For instance, $L_2(71)$ *resp.* $L_3(37)$ corresponds effectively to $k = 142$ *resp.* $k = 141$ and critical temperature of 156 K *resp.* 312 K.

7.1.3 The new view about metabolism

This picture about breaking of bio-super-conductivity leads to a new view about metabolism. .5 eV is the value of the quantum of metabolic energy and corresponds to the zero point kinetic energy of proton. The interpretation is that this energy is the minimum energy needed to kick proton from magnetic flux tube of the Earth's magnetic field (say) to the atomic space-time sheets and is liberated in the reverse process. Irradiation by coherent IR photons with energy of .5 eV induces both the formation of the bridges making possible the transfer of protons to atomic space-time sheet and dropping them back. The first process is like pumping of atoms to excited states and the second process is like laser emission of coherent light amplified by the presence of IR photons (also absorption of negative energy photons could be involved as will be discussed below). The process is also accompanied by cyclotron radiation (scaling law of homeopathy). When glucose is metabolized IR photons of energy of .5 eV are liberated and these photons induce both pumping and induced emission. This process involves the $F_0 - F_1$ machine responsible for the metabolic control. Phase conjugates of IR laser waves should reverse the functioning of $F_0 - F_1$ machine if this view is correct.

Also other ions, even electrons, can be involved in this kind of metabolic cycles and the process can occur between other pairs of space-time sheets. For instance, $k = 151$ space-time sheets microwave photons could induce similar metabolic cycle for protons or of their Cooper pairs and also other ions. The value of the zero point kinetic energy depends on the details of the local environment and this would make possible very effective control of the process. For a given microwave energy the ions associated with only particular kind of the molecular environment would participate in the cycle. Thus microwaves could make possible very precise quantum control. The inducing microwaves could be emitted by the conformational transitions of proteins and other bio-molecules and this would make possible precise and selective bio-control from protein level since the thermal widths of states would be extremely narrow at $k = 151$ space-time sheet. The

phase conjugates of microwaves would induce the time reversal of this process making possible healing by time reversal of the biological programs. This would boil down to a very elegant and economical control of the metabolism and homeostasis combining both many-sheeted laser physics and super-conductivity. The analysis of the findings of P. Gariaev's group [21] suggests that biological microwave lasers are only example of bio-lasers.

7.1.4 Many-sheeted laser action

There is strong analogy with the functioning of laser. The transfer of ions to smaller space-time sheets is analogous to the pumping of atoms to higher energy state. The presence of coherent photons at this energy implies also the many-sheeted analog of the induced emission: the ions having only thermal energy drop back to the magnetic flux tube by emitting photon at energy corresponding to the zero point kinetic energy. If the energy obtained in the kicking is exactly the zero point kinetic energy and the smaller space-time sheet is very cold no dissipation occurs and the situation is especially favorable for laser action.

The irradiation of system with phase conjugate beam of coherent light at this frequency could help to restore the super-conductivity: this hypothesis might be tested for high T_c super-conductors, which might be based on the same mechanism as bio-super-conductors [J1, J2, J3].

7.1.5 The special role of microwave photons in homeostasis

Microwaves are certainly not the only players in homeostasis but it seems that they have a special role. Plasmoids consisting of closed magnetic flux tube structures carrying supra currents plus atomic space-time sheets associated with them, are good candidates for primitive electromagnetic life-forms. Ordinary bio-matter is assumed to self-organize around these structures and nerve circuit represents a good example of a structure resulting in this manner.

Plasma balls are known to be accompanied by microwaves. This suggests that microwave photons could induce these bridges, break super-conductivity, and induce energy feed and self-organization. A similar breaking of super-conductivity might be also involved with the driving of the super-conducting ions to the atomic space-time sheets in the living matter. It is also possible that the process does not involve much dissipation ($k = 151$ space-time sheet should be very cold and in this case many-sheeted maser would result.

There are several candidates for the source of microwaves in case of plasmoids. What makes these sources so interesting from the point of view of biology is that the frequency spectrum is almost universal.

1. For instance, the ionic currents between $k = 151$ space-time sheets and Earth's magnetic flux tubes makes possible masers. The dropping of electron Cooper pairs from $k = 157$ space-time gives rise to microwave photons with energy about 10^{-3} eV, wavelength of 1.24 mm. More generally, the frequency is $f(A, k) = 2^{157-k} \times .25$ GHz with the assumption that the size of space-time sheet is given by $L(k)$. The dropping of ion of mass number A from space-time sheet k gives rise to photons with frequencies $f(k) = 2^{151-k} \times .15/A$ GHz frequency.

2. The multiple-coiled structure of DNA is expected to give rise to a hierarchy of magnetic flux tubes, and cyclotron transitions at these magnetic flux tubes serve as sources of microwaves. Electronic cyclotron frequency, assuming p-adic scaling of the Earth's magnetic field strength ($k = 169$), is equal to $f_c(k) = 2^{163-k} \times .038$ GHz, whereas ionic cyclotron frequency is $f_c(A, k) = 2^{151-k} \times .8/A$ GHz. As will be found, the transitions between cyclotron states at different space-time sheets allow to understand the radio-wave emission from DNA induced by laser light.

There are also more conventional sources of microwaves.

1. Coherently occurring protein conformal transitions could generate microwaves and could be also amplified by the many-sheeted masers. Also molecular masers are possible (say OH maser).

2. The rotational transitions of clusters of water molecules could emit microwaves and perhaps mimic and amplify the microwaves generated by proteins. The clusters of water molecules forming liquid crystals can mimic the conformational and rotational spectrum of various molecules, and that the ability to reproduce the rotational frequency spectrum of the medicine molecule is an essential element of homeopathic healing. The level of self-organization of water would thus be measured by how complex mimicry it is able to perform.

Why rotational microwave energy spectrum is so important for healing, might be understood as follows. The many-sheeted current circuitry, involving atomic space-time sheets and magnetic flux tubes and also other space-time sheets, is extremely complex control structure [I4, I5]. The continual regeneration of bridges between, say, atomic space-time sheets and magnetic flux tubes by microwaves emitted by proteins is necessary to sustain this circuitry. An important category of diseases is due to the failure to generate the bridges between super-conducting and atomic space-time sheets so that this control circuitry suffers shortcuts. Perhaps the genetic expression of some proteins responsible for the microwaves generating particular bridges fails. The medicine or its homeopathic counterpart would help to generate (or even re-establish the generation of) the microwave spectrum responsible for the generation of the lacking bridges in the circuitry.

7.2 Combining macro-temporal quantum coherence and dissipation

The question is how the saint and sinner aspects combine. The needed piece of the puzzle comes from the scaling law of homeopathy [K5]. The law states that high and low frequencies accompany each other, the frequency ratio being $f_{high}/f_{low} \simeq 2 \times 10^{11}$ in the simplest situation when the ions leak to atomic space-time sheet from the magnetic flux tubes of Earth's magnetic field. The ratio is essentially the ratio of zero point kinetic energy of the ion at the smaller space-time sheet and the cyclotron energy of the ion at magnetic flux tube. Radiation with frequency f_{high} is produced when ions drop to the magnetic flux tube. The ions drop to cyclotron states such that the magnetic quantum number n is usually larger than $n = 0$, which in turn decay and produce cyclotron radiation with frequency f_{low} and its harmonics.

The TGD based interpretation is that ELF MEs are responsible for quantum entanglement in macroscopic, even astrophysical, length scales. Microwave MEs propagating effectively as massless particles along ELF MEs in turn induce self-organization by serving effectively as 'food' of the plasmonic life forms at the receiving end. This mechanism is behind both the endo- and exogenous realizations of intentions as actions, that is ordinary motor actions and phenomena like remote healing and psychokinesis. Also sensory representations at the personal magnetic canvas and magnetosphere rely on this mechanism, and in this case life-forms are mental images getting at least partially their metabolic energy from brain. The law generalizes also to pairs formed by kHz radio wave MEs and MEs corresponding to visible light.

7.3 Healing by time reversal

I have proposed in [H9] that time reversal is the basic mechanism of healing. The biological programs simply run backwards to the point, where the error occurred, and a new trial is made. De-differentiation is the counterpart of this mechanism at the cellular level. Stem cells are indeed increasingly used for healing purposes, leukemia being one example of this. The following arguments inspire the question whether biological rhythms could quite generally correspond to dissipation-healing (by time reversal) cycles.

7.3.1 Priore's machine

The TGD based model of Priore's machine [22, 23] [H9] is based on this idea and involves phase conjugates of microwaves perhaps inducing time reversal mode of molecular machines at DNA level and thus leading to the correction of the genetic error responsible for the cancer. Irradiation by phase conjugate microwaves at critical frequencies might induce the time reversed mode and thus provide a possible general healing mechanism affecting directly the DNA level. Later an alternative interpretation for the functioning of Priore's machines as a mechanism of "stealing" metabolic energy from the cancer cells will be proposed.

7.3.2 Searl machine

The work with various anomalies involved with free energy phenomena has revealed a deep connection between quantum bio-control, remote mental interactions, and free energy phenomena. This connection has become especially clear during the development of a model for so called Searl machine [24, 25] (see [G2]). Searl machine involves stationary ring magnet along which smaller cylindrical magnets spontaneously start to rotate provided the parameters of the system are in suitable range. Several anomalous effects are involved: weight loss, over unity energy production, generation of magnetic walls, generation of plasma phase, effects on radio-active decay rates, and strong parity breaking.

The TGD based model of the Searl effect is based on essentially the same mechanisms as applied in the quantum models for homeostasis and remote mental interactions (see the chapter "Homeopathy in the Many-Sheeted Space-Time").

Several new physics effects seem to be involved.

1. The rotating magnetic system develops em and Z^0 charges and experiences the classical em and Z^0 electric forces created by Earth so that the effective weight is reduced or increases (depending on the direction of rotation) as much as 35 per cent. The charging is due to the flow of electrons and neutrinos from the rolling magnets to the surrounding air induced by the radial electric and Z^0 electric fields generated by the Faraday effect inducing vacuum charge density (not possible in Maxwell's electrodynamics). The fact that critical frequencies are different for clockwise and counter clockwise spontaneous rotation implies that classical Z^0 force and neutrino currents must be present.

2. The spontaneous accelerating rotation above critical frequency can be understood as being to a Lorentz torque acting on the radial Ohmic em and Z^0 currents in rollers and roller ring. Above the critical frequency the Lorentz torque, which is proportional to rotation frequency, becomes larger than frictional torque, and spontaneous accelerating rotation becomes possible due to the positive feedback.

3. The radial ohmic current of electrons leaking from the atomic space-time sheets of rollers to the space-time sheet of environment explains the presence of plasma around the system. The ionization of the molecules is caused by the electrons from rollers gaining keV energy as they drop from atomic space-time sheets of rollers to the space-time sheets of the environment.

4. The generation of Z^0 magnetic field explains the presence of the strange magnetic walls.

5. A remote metabolism based on the emission of negative energy (phase conjugate) microwave photons and realized in terms of the generalized four-wave mechanism based on magnetostatic waves provides the energy needed by the accelerating system and explains the cooling of the air around the system.

For some time I believed that the reduction of the inertial mass gives rise to a spontaneous accelerated rotation of the rollers by pirouette effect: also the generation of gravitational mass was necessary in order to understand the qualitative behavior. The required reduction of inertial mass is however measured in kilograms and means generation of corresponding positive inertial mass outside the system: this seems implausible. This does not however exclude the generation of gravitational mass in a much smaller scale defined by the magnetic energy density of the magnetic walls appearing in the system.

A further interesting aspect is that the presence of ELF waves at 10 Hz implied by rotation of the Searl machine means that the interaction with the experimenter's brain might interfere with the experiment. The importance of the experimenter's intention would conform with the finding that free energy effects are not fully re-producible. This only adds to the fascination of these effect if one is ready to give up the reductionist and materialistic dogmas and accept the possibility of remote mental interactions. For instance, Searl's machine might provide be ideal for studying mind-machine interaction.

7.3.3 Could molecular machines act as Searl machines?

One can ask whether the time reversal of the mechanism leading to the leakage of supra currents could be central also for the functioning of bio-systems, and whether the living matter might utilize Searl effect routinely. If so, the time-reversed modes of various molecular machines such as $F_0 - F_1$ machine responsible for the metabolism (and its variants suggests by the many-sheeted space-time concept) might be a routine part of the functioning of the living matter. They would induce time reversals of biological programs and thus healing. The generation of negative energy MEs would induce bound state entanglement and the liberated binding energy would compensate the lack of the metabolic energy feed during the time reversed mode. They could also induce "anti-gravitational" effects, which together with the macroscopic quantum coherence induced by negative energy MEs, could be an essential aspect of the locomotion of the living organism. Molecules, which have temporarily reduced their effective weights, would be ideal for the catalysis in the many-sheeted space-time. For instance, Coulomb wall could be easily circumvented by leaving the electromagnetic charge temporarily to the larger space-time sheet.

One can thus ask whether some molecular machines are actually Searl machines in their time reversed mode. For instance, the $F_0 - F_1$ machine driving protons to atomic space-time sheet from (presumably) magnetic flux tubes of Earth, is much like a power plant containing a rotating shaft. In time reversed mode, in which it acts like a motor, the shaft might have reduced effective weight. The parity breaking effect induced by the classical Z^0 force would also favor second direction for rotation, this is obviously essential in order to achieve a synchronous action.

As noticed, Searl machine could be sensitive to remote mental interactions induced by ELF ME induced entanglement. Interestingly, the rotation frequency of $F_0 - F_1$ machine is about 300 Hz, which is the cyclotron frequency of proton in Earth's magnetic field with nominal value .5 Gauss. The rate for translation of DNA is 20/s and also this is ELF frequency. The possibility of remote mental interaction in bodily length scales by ELF ME induced entanglement could be absolutely essential for the possibility to realize intention by using molecular machines.

7.3.4 Could biological rhythms correspond to dissipation-healing cycles?

The following argument leads to suggestion that biological rhythms quite generally correspond to dissipation-healing cycles involving time reversal in the healing period.

Time reversal means that the second law of thermodynamics is broken. Since p-adic topology does not allow ordering of events, it is natural to expect that time reversals can occur only below the time scale defined by n-ary p-adic time scale $T_n(k)$, $p \simeq 2^k$, k prime or power or prime. An especially important p-adic time scale is the secondary time scale $T_2(127) \simeq .1$ seconds associated

with electron. There is already evidence for the breaking of the second law below this time scale [29].

The time reversal for the leakage of supra currents is predicted to involve anomalous radiation. Rotating magnetic systems (Searl machine in particular) generate visible light, which must be due to the transitions of excited N_2 and N_2^+ molecules to their ground state (see [25, G2]. This strange radiation has no standard physics explanation. The radiation could result in a geometric time reversal of the process in which electron drops from an atomic space-time sheet by emitting its zero point kinetic energy of about 1 keV as an X ray; X ray in turn ionizes atoms of air and creates electrons, which in turn induce electronic transitions of N_2 and N_2^+ molecules to excited states. For the time reversal excitation of nitrogen molecules occurs first by emission of negative energy photons, which in turn induce geometric time reversal for the ionization process, and finally there is a single negative energy X ray inducing the dropping of electron from atomic space-time sheet to the magnetic flux tube. The system absorbs energy from the environment in this manner, breaks second law, and is able to transform thermal energy to usable energy with efficiency larger than one.

Rotating magnetic system is also found to be surrounded by a series of magnetic walls and a lowering of the temperature is observed at the magnetic "walls": a signature for the pumping of energy from environment. Anomalous radiation usually generated by ionization of air by electrons and magnetic walls with lowered temperature might be signatures of also remote healing by time reversal.

Also metabolic cycle involves the dropping of protons to some larger space-time sheet, presumably a super-conducting magnetic flux tube of Earth, and a liberation of about .5 eV zero point kinetic energy as a usable energy (the universal "energy currency"). Buy-now pay later principle and temporary time reversal could be involved also now and provide enormous flexibility (think only how easy it is to travel abroad if you have a credit card!). The molecular system utilizing the metabolic energy quantum would emit negative energy photon being thus excited to a higher energy state, and a proton at the atomic space-time would absorb the negative energy photon and "drop" to the magnetic flux tube to be driven back by $F_0 - F_1$ machine. Thus metabolism would repeat a cycle involving dissipation and healing. Fractality suggests that other biorhythms correspond to similar dissipation-healing cycle.

Even sensory perception and motor action could be seen as time reversals of each other in a relevant time scale. Motor action would be like carving a four-dimensional statue by starting from a rough sketch and adding the details gradually. The dissipation in both ordinary and reversed direction of the geometric time would Darwinially select a final state with only a rough dependence on the details of the sketch. No detailed planning would be required. Dissipation would act as an ally instead of an enemy. Motor actions could be imagined by initiating the time reversed process, not from the muscle cells as in case of actual motor action, but from some higher level of the central nervous system and proceeding to the level of cortex. Sensory imagination would also be a process starting from some level above sensory receptors and propagate up to the cortical level: this would mean that sensory qualia would be absent. During dreaming and hallucinations sensory qualia would be assigned to the imagined experience by feedback to the primary sensory organs involving entanglement and sharing of mental images.

7.4 Earth's magnetic field as a structure analogous to Searl's machine

Earth's magnetic field rotates and this suggests that it is also kind Searl's machine. The frequency of rotation is one cycle per 24 hours (10 cycles per second for the Searls' machine of [25]). If Searl's machine indeed involves a time reversal, one might expect that similar time reversal occurs in the case of the Earth's magnetic field. Therefore one expects a bio-rhythm with a period of 24 hours decomposing to dissipative self-organization period and a healing period.

Wake-sleep cycle is obvious candidate for this bio-rhythm. During sleep brains and perhaps entire organism entangles with the magnetosphere to give rise to self-organizing collective magnetospheric consciousness, which is something else than a mere passive sensory representation and draws actively energy from the biosphere by buy now -let others pay mechanism by emitting negative energy MEs.

The outer magnetosphere, in particular plasma sheet corresponds to theta and delta bands for protons from the requirement that the length of ME defines an appropriate magnetic transition frequency at a given point. Theta and delta bands indeed dominate during sleep. Alpha band is at the boundary between the inner and outer magnetosphere and dominates during hypnagogic states during which conscious experience involves transpersonal components.

The prediction is that EEG corresponds to negative energy photons and time reversed MEs during sleep. During daytime the inner magnetosphere is activated and in a role of passive computer monitor. Thus brain would generate during the wake-up period positive energy MEs inducing self-organization at magnetosphere and personal magnetic canvas responsible for the sensory representations. Night-day dichotomy would correspond to negative-positive energy dichotomy for MEs, and this dichotomy might be detectable from EEG (during night time coherent EEG laser beams would transform to their phase conjugates). That night side magnetosphere corresponds structurally and functionally to motor areas and frontal lobes, and day side magnetosphere to the sensory areas, was proposed already earlier in [N1]. Although this picture is bound to an over-simplification, it might be a good starting point.

The anomalous radiation associated with the Searl's machine should correspond to a self-organization of the magnetospheric plasma by remote metabolism using the metabolic resources of the sleeping brain and body. From the point of view of biosphere this process would be a healing process since time reversals of dissipative processes occur. Magnetic transitions of superconducting charged particles (protons and electrons) are good candidates for generating anomalous ELF radiation. Negative energy EEG MEs carry high (negative) frequency MEs resulting when ions jump from magnetic flux tubes to smaller space-time sheets. In self-organizing plasma regions an entire hierarchy of space-time sheets is expected to be present, and could give rise to wide range of negative energy photons, microwave photons in particular. This vision provides a tentative model for how the highly self-organization plasma sheet at the night side of the magnetosphere uses the metabolic energy from sleeping brain to self-organize and to construct sensory representation about biosphere [26].

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