

# Macro-Temporal Quantum Coherence and Spin Glass Degeneracy

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## Contents

<b>1</b>	<b>Introduction</b>	<b>4</b>
1.1	Macrotemporal Quantum Coherence Is Suggested By Quantum Classical Correspondence . . . . .	5
1.2	Macrotemporal Quantum Coherence From Spin Glass Degeneracy? . . . . .	5
1.3	Dynamical Planck Constant And Dark Matter Hierarchy . . . . .	5
1.4	Implications Of Macrotemporal Quantum Coherence . . . . .	6
<b>2</b>	<b>Background About TGD Inspired Theory Of Consciousness</b>	<b>7</b>
2.1	Quantum Jump As Moment Of Consciousness . . . . .	7
2.1.1	The general structure of quantum jump . . . . .	8
2.1.2	Is the complete localization in zero modes really necessary? . . . . .	9
2.2	The Anatomy Of Quantum Jump In Zero Energy Ontology (ZEO) . . . . .	11
2.3	The Notion Of Self . . . . .	13
2.3.1	Assumptions about the structure of conscious experience of self . . . . .	13
2.3.2	The notion of length scale resolution and self . . . . .	14
2.3.3	NMP and self . . . . .	15
2.3.4	NMP and self . . . . .	15
2.3.5	ZEO and self . . . . .	16
2.3.6	Space-time correlates of self . . . . .	17
2.3.7	Dark matter hierarchy and self . . . . .	17
2.4	General View About Psychological Time And Intentionality . . . . .	18
2.4.1	Why sensory experience is about so short time interval? . . . . .	19
2.4.2	Arrow of time . . . . .	20
2.5	Two Views About Flow Of Time . . . . .	20

<b>3</b>	<b>Macro-Temporal Quantum Coherence And Spin Glass Degeneracy</b>	<b>23</b>
3.1	What Does Quantum Coherence Mean In TGD Universe? . . . . .	23
3.2	Many-Sheeted Space-Time, Topological Field Quantization, And Spin Glass Degeneracy . . . . .	24
3.3	Spin Glass Degeneracy And Classical Gravitation As Stabilizer Of Irreducible Bound State Entanglement . . . . .	24
3.3.1	Probabilistic argument . . . . .	25
3.3.2	The argument based on unitarity . . . . .	25
3.3.3	Color confinement and spin glass degeneracy . . . . .	26
3.3.4	S-matrices associated with a hierarchy of de-coherence times . . . . .	27
<b>4</b>	<b>Macro-Temporal Quantum Coherence, Spin Glass Degeneracy, And Hierarchy Of Planck Constants</b>	<b>27</b>
4.1	Many-Sheeted Space-Time, Topological Field Quantization, And Spin Glass Degeneracy . . . . .	27
4.2	The Evolution Of Ideas About Hierarchy Of Planck Constants . . . . .	28
4.2.1	Quantization of planetary orbits with a gigantic value of Planck constant and dark matter as a macroscopic quantum phase . . . . .	28
4.2.2	Summary about the evolution of ideas about hierarchy of Planck constants . . . . .	29
<b>5</b>	<b>Basic Implications</b>	<b>30</b>
5.1	Information Theoretic Aspects . . . . .	30
5.1.1	Number theoretic information measures . . . . .	30
5.1.2	Quantum computation and quantum problem solving in TGD Universe . . . . .	32
5.1.3	Information concept at space-time level . . . . .	33
5.2	Thermodynamical Aspects . . . . .	33
5.3	Energetic Aspects . . . . .	34
<b>6</b>	<b>Macro-Temporal Quantum Coherence, Consciousness, And Biology</b>	<b>34</b>
6.1	Macro-Temporal Quantum Coherence And Biology . . . . .	35
6.2	Macro-Temporal Quantum Coherence And Long Term Memory . . . . .	36
6.2.1	Mirror mechanism of long term memories and topological light rays . . . . .	37
6.2.2	Order of magnitude estimate for gravitational binding energies . . . . .	37
<b>7</b>	<b>Co-Operation And Competition As Different Aspects Of Quantum Consciousness</b>	<b>38</b>
7.1	Breaking Of Super-Conductivity, Metabolism And Homeostasis . . . . .	38
7.1.1	Leakage mechanism . . . . .	38
7.1.2	New manner to interpret gap energy of bio-super-conductor . . . . .	39
7.1.3	The new view about metabolism . . . . .	39
7.1.4	Many-sheeted laser action . . . . .	40
7.1.5	The special role of microwave photons in homeostasis . . . . .	40
7.2	Combining Macro-Temporal Quantum Coherence And Dissipation . . . . .	41
7.3	Healing By Time Reversal . . . . .	42
7.3.1	Priore's machine . . . . .	42
7.3.2	Searl machine . . . . .	42
7.3.3	Could molecular machines act as Searl machines? . . . . .	43
7.3.4	Could biological rhythms correspond to dissipation-healing cycles? . . . . .	44
7.4	Earth's Magnetic Field As A Structure Analogous To Searl's Machine . . . . .	45

### Abstract

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.

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 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. *Macrotemporal quantum coherence is suggested by quantum classical correspondence*

TGD inspired theory of consciousness 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 (WCW)) level. An especially relevant notion is negentropic entanglement which from the consistency with ordinary quantum measurement theory is described by density matrix proportional to unit matrix. In quantum computation entanglement matrix proportional to a unitary matrix gives rise to negentropic entanglement and by NMP this entanglement is stable against state function reduction by Negentropy Maximization Principle (NMP).

At imbedding space level causal diamonds (CDs) define the correlates for coherence regions. 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  $M^4$ .

#### 2. *Macrotemporal quantum coherence from spin glass degeneracy?*

At WCW 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, 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.

### 3. Hierarchy of Planck constants and dark matter hierarchy

The non-determinism of Kähler action and ensuing quantum criticality strongly suggests a dark matter hierarchy with levels labelled by values of (effective) Planck constant  $h_{eff} = n \times h$ . 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. Also a generalization of the notion of genetic code emerges resolving the paradoxes related to the standard dogma. A particularly fascinating implication is the possibility to identify great leaps in evolution as phase transitions in which new higher level of dark matter emerge.

It seems safe to conclude that the dark matter hierarchy with levels labelled by the values of Planck constants explains the macroscopic and macro-temporal quantum coherence naturally. That this explanation is consistent with the explanation based on spin glass degeneracy is suggested by the fact that both follow from the non-determinism of Kähler action and relate closely to quantum criticality.

## 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 [J4].

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 [J2] 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.

The first version of this chapter was written for more than 15 years ago (I am living now year 2015) and reflects my evolving views at that time. At the that time I had no idea about zero energy ontology (ZEO) and hierarchy of Planck constants, which mean a profound generalization of quantum theory. In fact, the hierarchy of Planck constants labels a hierarchy of quantum criticalities having purely group theoretical interpretation and is closely related to a hierarchy of algebraic extensions of rationals which is at the core of number theoretical universality allowing to construct adelic physics. Also the fusion of real physics and p-adic physics interpreted as physics of intentionality was yet poorly understood: the recent view could be summarized by using the phrase “adelic physics”. Also Negentropy Maximization Principle (NMP) was far from its recent formulation, which I refer to as weak form of NMP. I has become clear that these notions predict macroscopic and even astrosopic quantum coherence and indeed give a connection with quantum gravity but in a manner different from that envisioned by Penrose. ZEO based quantum measurement theory automatically leads to a precise definition of the notion of self, and one can

understand basic aspects of consciousness from this definition.

Instead of rewriting the entire chapter from scratch, I have kept its structure and added comments relating the considerations to the recent views about TGD.

## 1.1 Macrotemporal Quantum Coherence Is Suggested By Quantum Classical Correspondence

Topological Geometro-dynamics inspired theory of consciousness [K22] 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” (WCW)) 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  $M^4$ .

The detailed identification of macro-temporal quantum coherence came much after writing these lines and relies on weak NMP, negentropic entanglement, and hierarchy of Planck constants.

## 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 [K20]. 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.

This rough interpretation of spin glass degeneracy is correct in the sense that it makes possible non-determinism and quantum criticality to which one can assign hierarchy of Planck constants.

## 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 [E1]. 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 [K21, K26, K5]. 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. 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 [K26]. 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 [K6]. Also a generalization of the notion of genetic code emerges resolving the paradoxes related to the standard dogma [K13, K6]. A particularly fascinating implication is the possibility to identify great leaps in evolution as phase transitions in which new higher level of dark matter emerges [K6].

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.

It is now (2014) that the hierarchy of Planck constant follows from the non-determinism of Kähler action:  $n$  in  $h_{eff} = n \times h$  is the number of conformal equivalence of space-time surfaces for which Kac-Moody type quantum critical deformations preserving the light-likeness of partonic orbits vanishes at the ends of space-time surface at light-like boundaries of causal diamond (CD).  $n$  labels the sub-algebras of conformal algebras with weights proportional to  $n$  and infinite hierarchy of conformal breakings is predicted. Spin glass degeneracy follows also from the failure of determinism so that the two views about the origin of macrotemporal quantum coherence are consistent.

The value of  $n$  can be also related to the degree of algebraic extension of rationals. Preferred p-adic primes in turn would correspond to ramified primes of extensions. If one accepts a physical argument based on the idea that gravitational bound states have as correlates fermionic strings connecting partonic 2-surfaces, one ends up with the proposal that ramified primes divide  $n$ . If one assumes only number theory, then  $n$  and ramified primes are independent of each other.

## 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 [J5] and of Gariaev *et al* [I2] ) 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.

What is surprising that strong form of holography is very near to the standard view about it. Partonic 2-surfaces and string world sheets are space-time genes and carry the data characterizing quantum states. Strong form of holography allows to assign to these 2-surfaces space-time surfaces as preferred extremals of Kähler action with the property that the super-symplectic charges in for an isomorphic sub-algebra with conformal weights coming as  $n$ -ples of those for the entire algebra vanish classically and annihilate physical states.

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.

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

- Overall view about TGD [?]
- What TGD is [?]
- Key notions and ideas of TGD [?]
- Space-time as 4-surface in  $M^4 \times CP_2$  [?]
- Geometrization of fields [?]
- Classical TGD [?]
- Topological field quantization [?]

## 2 Background About TGD Inspired Theory Of Consciousness

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 Quantum Jump As Moment Of Consciousness

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

### 2.1.1 The general structure of quantum jump

It seems that TGD involves “holy trinity” of dynamics.

1. The dynamics defined by the preferred extremals of Kähler action corresponds to the dynamics of material existence, with matter defined as “res extensa”, three-surfaces. What preferred extremals really are has been a long standing open question. The recent formulation of the quantum theory using Kähler-Dirac action leads to the proposal that the preferred extremals are critical in the sense that they allow an infinite number of deformations for which the second variation vanishes. At the level of Kähler action this corresponds to the vanishing of classical Noether charges for a sub-algebra of super-symplectic algebra isomorphic with the entire algebra. This serves as space-time counterpart for quantum criticality of TGD Universe fixing the fundamental variational principle uniquely.
2. The dynamics defined by the sequence of state function reductions at fixed boundary of CD defining the life span of self at given level of hierarchy. This time evolution is a discrete counterpart of the ordinary Schrödinger time evolution  $U \equiv U(-t, \cdot)$ ,  $t \rightarrow \infty$  and can be regarded as “informational” time development occurring at the level of objective existence. It is un-necessary and in fact impossible to assign real Schrödinger time evolution with  $U$ .  $U$  defines the S-matrix of the theory. These reductions define the dynamics of sensory perception (passive aspects of consciousness) during which external world is regarded as unchanged in standard framework. Now the part of zero energy state at the fixed boundary of CD remains unchanged and un-entangled.
3. The dynamics of state function reductions at opposite boundary of CD defines the dynamics of volition (active aspects of consciousness).

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

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

$$\Psi_i \rightarrow U\Psi_i \ ,$$

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

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

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

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

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

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



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

$$\Psi_f^0 \rightarrow \dots \rightarrow \Psi_f ,$$

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

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

1. The assumption that localization occurs in zero modes of the WCW would pose very important consistency condition: there is one-one correlation between the quantum numbers in quantum fluctuating degrees of freedom in some state basis and the values of the zero modes. This in fact has interpretation in terms of holography: classical degrees of freedom in space-time interior correlate with fermionic degrees of freedom assignable to string world sheets and partonic 2-surfaces. This together with the fact that zero modes are effectively classical variables, implies that the localization in zero modes corresponds to a state function reduction.
2. Measurement theory requires an entanglement between zero modes and quantum jumps of the physical state. The addition of a measurement interaction term to the Kähler-Dirac action coupling to four-momentum and color quantum numbers of the state and also to more general conserved quantum numbers allows an explicit realization of this coupling and induces the addition of an analogous measurement interaction term to Kähler action [K27]. This term implies the entanglement of the quantum numbers of the physical states with zero modes.

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

### 2.1.2 Is the complete localization in zero modes really necessary?

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

1. QFT picture strongly suggests that sub-system must be defined as a tensor factor of the space of WCW spinors at given point  $Y^3$  of WCW. This suggests that subsystem should be defined as a function of  $Y^3$  and should be a local concept. An important consequence of this definition is that entanglement entropy gives information about space-time geometry.
2. WCW spinor field can be formally expressed as superposition of quantum states localized into the reduced configuration space consisting of 3-surfaces belonging to light cone boundary. Hence WCW spinor field can be formally written as

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

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

3. WCW has fiber space structure. WCW metric is non-vanishing only in the fiber degrees of freedom and since the propagator for small fluctuations equals to the contravariant metric, fiber degrees of freedom correspond to genuine quantum fluctuations. WCW metric vanishes in zero modes, which can be identified as fundamental order parameters in the spirit of Haken's theory of self organization. The requirement that various local symmetries act as gauge symmetries, provides good reasons to expect that *entanglement coefficients in the fiber degrees of freedom are gauge invariants and depend on the zero modes parametrically*. The one-one correlation between quantum numbers of the state assignable to fiber degrees of freedom and classical variables identified as zero modes would encourage the assumption the a complete localization occurs in zero modes. A weaker condition is that localization occurs only modulo a finite measurement resolution.
4. The original argument was that the non-existence of metric based volume element in zero modes forces the wave functions in zero modes to have a discrete locus. There however exists a symplectic measure defined by the symplectic form in zero modes. It does not however allow a complexification to Kähler form as it does in quantum fluctuating degrees of freedom. This symplectic form could define a hierarchy of integration measures coming as restrictions of  $J \wedge J \dots \wedge J$  with  $n$  factors to  $2n$ -dimensional sub-manifolds. Under some additional conditions- maybe the homological non-triviality of  $J$  and the orientability of the sub-manifold are enough, this measure would define a positive definite inner product and one would have a hierarchy finite-dimensional sub-spaces of zero modes. The maxima of Kähler function with respect to zero modes replace naturally the continuum with a discrete set of points and define the counterpart of the spin glass energy landscape consisting of the minima of free energy. Effective finite-dimensionality and even effective discreteness would be achieved.
5. The time development by quantum jumps in zero modes is effectively classical: Universe is apparently hopping around in the space of the zero modes. This looks very attractive physically since zero modes characterize the size, shape and classical Kähler fields associated with 3-surface. Therefore each quantum jump gives very precise conscious geometric information about space-time geometry and about WCW in zero modes. This also means that Haken's classical theory of self-organization generalizes almost as such to TGD context. The probability for localization to given point of zero mode space is given by the reduced probability density  $Q$  defined by the integral of the probability density  $R$  defined by WCW spinor field over fiber degrees of freedom. The local maxima of  $Q$  with respect to zero modes appear as attractors for the time development by quantum jumps. Dissipative time development could be regarded as a sequence of quantum jumps leading to this kind of local maximum.
6. Effective localization in zero modes is completely analogous to spontaneous symmetry breaking in which scalar field attains vacuum expectation value with the difference that the number of degrees of freedom is infinite unlike in typical models of symmetry breaking. Thus the general structure of the WCW spinor field together with TGD based quantum jump concept automatically implies spontaneous symmetry breaking in its TGD version (note however that particle massivation results from both p-adic thermodynamics and coupling to Higgs like field of purely geometric origin in TGD framework). TGD Universe is superposition of parallel

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

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

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

Zero energy ontology (ZEO) emerged around 2005 and has had profound consequences for the understanding of quantum TGD. The basic implication is that state function reductions occur at the opposite light-like boundaries of causal diamonds (CDs) forming a hierarchy, and produce zero energy states with opposite arrows of time. Also concerning the identification of quantum jump as moment of consciousness ZEO encourages rather far reaching conclusions. In ZEO the only difference between motor action and sensory representations is that the arrows of imbedding space time (CDs) are opposite for them. Furthermore, sensory perception followed by motor action corresponds to a basic structure in the sequence of state function reductions and it seems that these processes occur fractally for CDs of various size scales.

1. State function reduction can be performed to either boundary of CD but not both simultaneously. State function reduction at either boundary is equivalent to state preparation giving rise to a state with well defined quantum numbers (particle numbers, charges, four-momentum, etc...) at this boundary of CD. At the other boundary single particle quantum numbers are not well defined although total conserved quantum numbers at boundaries are opposite by the zero energy property for every pair of positive and negative energy states in the superposition. State pairs with different total energy, fermion number, etc.. for other boundary are possible: for instance, the coherent states of super-conductor for which fermion number is ill defined are possible in zero energy ontology and do not break the super-selection rules.
2. The basic objects coding for physics are U-matrix, M-matrices and S-matrix. M-matrices correspond to hermitian square roots of density matrices multiplied by a universal S-matrix which depends on the scale  $n$  of CD in very simple manner:  $S(n) = S^n$  giving thus a unitary representation for scalings. The explicit construction of a unitary U-matrix in terms of M-matrices is carried out in [K28]: U-matrix elements are essentially inner products of M-matrices associated with CDs with various size scales. One can say that quantum theory is formally a square root of thermodynamics. The thermodynamics in question would however relate more naturally to NMP rather than second law, which at ensemble level and for ordinary entanglement can be seen as a consequence of NMP.

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

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

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

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

This brings strongly in mind the old proposal of Fantappie [J3] that in living matter the arrow of time is not fixed and that entropy and its diametric opposite syntropy apply to the two arrows of the imbedding space time. The arrow of subjective time assignable to second law would hold true but the increase of syntropy would be basically a reflection of second law since only the arrow of the geometric time at imbedding space level has changed direction. The arrow of geometric at space-time level which conscious observer experiences directly could be always the same if quantum classical correspondence holds true in the sense that the arrow of time for zero energy states corresponds to arrow of time for preferred extremals. The failure of strict non-determinism making possible phenomena analogous to multi-furcations makes this possible.

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

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

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

1. The earlier view was based on the idea that p-adic space-time sheets can transform to real ones and vice versa in quantum jump and these process correspond to a realization of intention as action and formation of thought. This view is mathematically awkward and has been replaced with the adelic vision in which all systems have both sensory (real space-time sheets) and cognitive (p-adic space-time sheets) space-time correlates. The real and p-adic number fields form a book like structure - adèle- with an algebraic extension of rationals as its back. Same applies at the level of imbedding space, space-time surfaces, and WCW. In this framedwork holography makes it possible to understand real and p-adic space-time surfaces as continuations of string world sheets and partonic 2-surfaces to space-time surfaces, either real or p-adic. The string world sheets themselves are in the intersection of reality and various p-adicities in the sense that the parameters characterizing them belong to an extension of rational numbers.
2. Self having the mental image about intention can be seen as the agent transforming intention to action. By NMP negentropy is typically generated in this transition tending to increase the value of Planck constant  $h_{eff} = n \times h$  and thus reducing quantum criticality and occurring therefore spontaneously. Negentropy Maximization Principle eventually forces the occurrence of volitional action - self experiences the urge to perform the action so strong that cannot resist. Subself representing the mental image about intention tries to prevent it as long as possible because it means death: all living systems try to stay at the existing level of criticality and avoid the fatal final state function reduction by practicing homeostasis and using metabolic energy. Weak form of NMP states that self has freedom to decide whether it performs the reduction producing maximal entanglement negentropy. It can also perform ordinary quantum jump reducing entanglement entropy to zero and destroying entanglement.

The outcome is isolation from the external world. The motivation for the weak form of NMP is that we do not live in the best possible world and have free will to choose between Good and Evil. Strong form of NMP would produce always maximal negentropy gain and would mean best possible world in various length scales in fractal manner.

## 2.3 The Notion Of Self

Self is by definition a sub-system able to remain unentangled in subsequent quantum jumps. The original belief was that this characterizes the notion of self completely. 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).

Originally p-adic regions were interpreted as physical (non-conscious) correlates for imagination and cognition whereas real regions correspond to matter and sensory perception. The original belief was that the transformation of p-adic space-time sheets to real ones in quantum jump would correspond to the realization of intention as action. It is now clear that this hypothesis is both unnecessary and difficult to realize mathematically. Rather, TGD Universe is adelic meaning that both imbedding space, space-time, and WCW are adelic structure containing real sector and various p-adic sectors as correlates of cognition.

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). In the intersection of realities and p-adicities it how does not make sense to distinguish between p-adic and real and the recent view is that string world sheets carrying fermions serving as correlates of Boolean cognition are in this intersection consisting of string world sheets for which the parameters of equations defining them are in some algebraic extension of rationals. One cannot speak about real and p-adic fermions - just fermions.

### 2.3.1 Assumptions about the structure of conscious experience of self

One makes some structural assumptions about the contents of consciousness of self.

1. 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-sub-selves. 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.
2. The sharing of mental images by quantum entanglement is purely TGD based prediction. What happens is rather paradoxical: the sub-selves 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.

This allows a situation in which two systems correspond to disjoint surfaces but smaller space-time sheets glued to them are connected by magnetic flux tubes serving as correlates

for entanglement. Therefore intuitively selves entangled in given length scale can have sub-selves, which are entangled.

3. Thus many-sheeted space-time and the notion of length scale resolution forces to postulate a hierarchy of systems labelled by p-adic primes and to 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.

The mathematical description for this length scale dependent view about sub-systems relies on inclusions of hyper-finite factors of type  $II_1$  (HFFs) [K26].

### 2.3.2 The notion of length scale resolution and self

The rough definition of self is as a subsystem able to remain unentangled during sequential quantum jumps. Self would lose consciousness when it entangles. What this statement really means is far from obvious and I have proposed several interpretations. the following picture represents the recent views.

1. The idea that even slightest entanglement leads to a loss of consciousness does not sound realistic. This suggests that entanglement should be defined only modulo finite measurement resolution. System would be conscious only provided that its entanglement entropy with the external world is below the value defined by the measurement resolution. For hyper-finite factors of type  $II_1$  the notion of finite measurement resolution is unavoidable. The concrete interpretation at space-time level would be that space-time sheets (sub-selves) topologically condensed at larger space-time sheets (selves) can be connected by flux tubes to form an entangled state. The selves represented by the larger space-time sheets would remain unentangled in the resolution applying to the systems themselves (flux tubes would be invisible in this resolution). This invisible entanglement would however give rise to a sharing and fusion of mental images implying what might be called stereo consciousness.
2. How the notion measurement resolution should be defined is far from obvious. p-Adication approach suggests that finite measurement resolution boils down to a pinary cutoff for the p-adic entanglement entropy represented as a series in powers of  $p$ . This pinary cutoff should have also space-time correlate. For hyper-finite factors of type  $II_1$  and type  $III_1$  emerging naturally in quantum TGD entanglement entropy is always defined only modulo finite measurement resolution, which can be characterized in terms of inclusions of hyper-finite factors [K26]. The included factor defines the measurement resolution in the sense that its action creates states not distinguishable from the original in the resolution used. There should exist a connection between the two approaches.
3. A further complication is due to the fact that also the p-adic variants of Shannon entropy obtained by replacing the logarithm of probability with the logarithm of the p-adic norm of probability make sense if entanglement probabilities are rational or have values in some algebraic extension of rationals. The fact that number theoretic entanglement entropy can be negative is especially attractive from the point of view of consciousness theory and also quantum computation since entanglement indeed carries information. There is also a temptation to identify evolution as the emergence of increasingly complex systems having negative entanglement entropy. The generation of negative entanglement entropy might correspond to a kind of enlightenment experience - fusion to a sea of consciousness - instead of a loss of consciousness.
4. This forces to reconsider the original vision that everything is conscious but consciousness can be lost as the system entangles in  $U$  process.  $U$  process generates highly entangled states and the sub-sequent state function reduction (possibly modulo measurement resolution) repeatedly decomposes the Universe (or CD) into unentangled pairs of subsystems. The process stops for any subsystem for which all subsystem pairs have either bound state entanglement or negentropic entanglement (see **Fig.** <http://tgdtheory.fi/appfigures/cat.jpg> or **Fig.** ?? in the appendix of this book). If the bound state entanglement is entropic, the entangled

subsystems lose consciousness. If the entanglement between the subsystems in negentropic the process stops but subsystems remain conscious. Mystics might associate the entropic entanglement to what they call attachment and negentropic entanglement to a relationship which they might characterize as love.

### 2.3.3 NMP and self

### 2.3.4 NMP and self

The development of the view about Negentropy Maximization Principle (NMP) [K14] has meant also development of the notion of self.

- (a) The original formulation of NMP was in positive energy ontology and made same predictions as standard quantum measurement theory. The only new element was that the density matrix of sub-system defines a fundamental observable and the system goes to its eigenstate in state function reduction.
- (b) p-Adic physics led to the realization that for rational and even algebraic entanglement probabilities it is possible to define number theoretic entanglement negentropy satisfying the same basic axioms as the ordinary Shannon entropy but having negative values and therefore having interpretation as information. NMP would force the generation of negentropic entanglement and stabilize it. Negentropic entanglement resources of the Universe - one might call them Akashic records- would steadily increase.
- (c) It turned out that the consistency with the quantum measurement theory demands that the density matrix for the final state is projector as also in the standard quantum measurement theory but can project also to a higher-dimensional space. This additional condition allows also to identify negentropic entanglement uniquely: without this restriction one could not really say whether this is the case since rationals form dense set of reals.
- (d) The next step was to realize that this form of NMP is not realistic. NMP would force the Universe to be the best possible one, and this does not seem to be the case. Also ethically responsible free will would be very restricted since self would be forced always to do the best deed that is increase maximally the negentropy serving as information resources of the Universe. This led to the notion of weak form of NMP. Instead of maximal negentropy corresponding to  $n$ -dimensional projector self can choose also lower-dimensional sub-spaces and 1-D sub-space corresponds to the vanishing entanglement and negentropy assumed in standard quantum measurement theory.

Weak form of NMP suggests how to understand the notions of Good and Evil. Various choices in the state function reduction correspond to Boolean algebra, which suggests an interpretation in terms of what might be called emotional intelligence [K24]. Also it turns out that one can understand how p-adic length scale hypothesis - actually its generalization - emerges from NMOP [K31].

- (a) One can start from ordinary quantum entanglement. It corresponds to a superposition of pairs of states. Second state corresponds to the internal state of the self and second state to a state of external world or biological body of self. In negentropic quantum entanglement each is replaced with a pair of sub-spaces of state spaces of self and external world. The dimension of the sub-space depends on the which pair is in question. In state function reduction one of these pairs is selected and deed is done. How to make some of these deeds good and some bad?
- (b) Obviously the value of  $h_{eff}/h = n$  gives the criterion in the case that weak form of NMP holds true. Recall that weak form of NMP allows only the possibility to generate negentropic entanglement but does not force it. NMP is like God allowing the possibility to do good but not forcing good deeds.

Self can choose any sub-space of the subspace defined by  $n$ -dimensional projector and 1-D subspace corresponds to the standard quantum measurement. For  $n = 1$  the state

function reduction leads to vanishing negentropy, and separation of self and the target of the action. Negentropy does not increase in this action and self is isolated from the target: kind of price for sin.

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

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

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

### 2.3.5 ZEO and self

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

The most important input from ZEO is that state function reductions can occur to both boundaries of CD. The natural identification of self is as a sequence of state functions occurring at fixed boundary of CD leaving the state at it invariant but affecting the opposite position of opposite boundary. This if one has superposition of CDs with zero energy states associated with them and of unitary process generates quantum superposition of CDs in the moduli space of CDs and if the unitary process is followed by a localization in this moduli space. The first quantum jump to opposite boundary corresponds to a state function reduction in ordinary sense and has interpretation as volitional act. Self dies and reincarnates at the opposite boundary of CD.

In this picture one can assign to self a definite age as the increase of the proper time distance between the tips of CD. Also the experience of time flow can be understood. In each death of self a reversal of geometric time occurs. This conforms with the old proposal of Fantappie that the notion of syntropy makes sense in living systems [J3],



### 2.3.6 Space-time correlates of self

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

1. If space-time sheets serve as correlates for selves, the space-time correlate for the entanglement is the presence of magnetic flux tubes connecting the space-time sheets serving as correlates for selves. The entanglement which corresponds to join along boundaries bonds associated with sub-selves (smaller space-time sheets topologically condensed at the space-time sheet representing self) is below the measurement resolution assignable to self. In this kind of situation selves remain conscious whereas sub-selves lose consciousness for positive entanglement entropy and fuse to form single stereo mental image of self. For negative entanglement entropy sub-selves would remain conscious.
2. In zero energy ontology [K4] one is forced to ask whether the correlates of self should be identified also at the level of imbedding space rather than only at the level of space-time sheets so that a given CD would serve as a correlate for self. This identification leads to a beautiful argument for how the arrow of subjective time, the flow of subjective time, and the localization of the contents of conscious experience around a narrow time interval takes place [K1]. There is no reason for why CDs should not be allowed to overlap and this overlap would be a natural correlate for the sharing and fusion of mental images. Both of these identifications look natural and one can argue that the geometric correlates of self exist at both imbedding space and space-time level.
3. If both space-time sheets and CDs serve as correlates for selves, the magnetic flux tube contacts could connect space-time sheets associated with the two. CDs and would belong to their intersection. One can also require that the CDs are at the same p-adic level of hierarchy. In other words, CDs correspond to the same value of p-adic prime near a power of two meaning that the temporal distance between the tips of CDs is same octave of  $CP_2$  time for the standard value of Planck constant. The hierarchy of Planck constants [K8] means an additional complication in this picture but does not bring in anything essentially new.

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

### 2.3.7 Dark matter hierarchy and self

The notion of dark matter hierarchy has dramatically improve the understanding of the notion of self and together with NMP [K14] allows to even answer questions concerning Good and Evil and Life and Death [K24].

1. The idea about hierarchy of Planck constants emerged from anomalies of biology and the strange finding that planetary orbits could be regarded as Bohr orbits but with a gigantic value of Planck constant. This led to the vision that dark matter corresponds to ordinary particles but with non-standard value of Planck constant and to a generalization of the 8-D imbedding space to a book like structure with pages partially characterized by the value of Planck constant. Using the intuition provided by the inclusions of HFFs one ends up to a prediction for the spectrum of Planck constants. This inspires the proposal that dark matter could be in quantum Hall like phase localized at light-like 3-surfaces with macroscopic size and behaving in many respects like black hole horizons.
2. The physical interpretation for the hierarchy of Planck constants would be in terms of a hierarchy of quantum criticalities concretizing the vision about quantum criticality of TGD Universe. TGD Universe would be like a hill at the top of a hill at .... The larger the Planck constant the larger the size scale of the hill. Criticality involves crucially the notion of conformal gauge symmetry. The conformal symmetries correspond to some sub-algebra

of the full algebra isomorphic to it acting as gauge symmetries and with conformal weights coming as  $n$ -multiples of those for the full symmetry algebra.  $h_{eff} = n \times h$  would label the levels of the hierarchy. This hierarchy would correspond directly to the hierarchy of measurement resolutions and to hierarchy of HFFs. Also now one obtains infinite hierarchies of symmetry breakings and the identification with the hierarchies of inclusions of HFFs is compelling. Hence various hierarchies reflect the same underlying phenomenon.

3. The phase transitions reducing criticality would take place spontaneously unlike opposite phase transitions. This vision is especially powerful in biology, where homeostasis could be seen as mechanisms preventing the reduction of criticality but at expense of metabolic energy. The basic goal of living system would be staying at criticality. Eastern philosophies would formulate this fight for staying at criticality using the notions of ego and Karmic cycle. In the phase transition increasing  $h_{eff} = n \times h$  part of gauge degrees of freedom assignable to a sub-algebra of the full super-symplectic algebra are transformed to physical ones and this implies better measurement resolution. The new HFF contains the previous one as a sub-factor. Evolution understood as increase of  $h_{eff}$  forced by Negentropy Maximization Principle as also interpretation improvement of measurement/cognitive resolution.

Dark matter hierarchy turns out to be crucial for the deeper understanding of the notion of self. In particular, the evolution of mental images as sequences of births and deaths of sub-selves correspond to state function reductions at opposite boundary of CD. These reductions are forced by NMP and can be said to occur spontaneously. The value of  $h_{eff}$  increases in these state function reductions while it remains constant during the sequence of state function reductions at fixed boundary defining self. Quantum criticality is reduced in these phase transitions and self has to fight to stay at fixed level of criticality. Self achieves this by the use of metabolic energy and homeostasis. As long self stays at criticality - that is alive- it's sub-selves can evolve by deaths and re-incarnations.

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.

## 2.4 General View About Psychological Time And Intentionality

A natural guess is that the resolution of the problems related to the preferred role of single moment of time for conscious experience could be 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 like phenomenon giving rise to what we call life? The front of phase transition could correspond to volitional consciousness. In Zero Energy Ontology (ZEO) volitional action begins with the first state function reduction to the opposite boundary of causal diamond (CD) involving "death" of corresponding self and re-incarnation at opposite boundary [K25, K1]. Volition can be also seen as a transformation of intention to action. In the original vision this transformation was identified as p-adic-to-real phase transitions of space-time sheets taking place in quantum jumps. It has however turned out that this assumption creates

more problems than it solves and that it is unnecessary if one accepts the the adelic view meaning that the physics associated with all number fields form a coherent whole and p-adic physics is correlate for cognition . One can say that cognition is in the intersection of reality and various p-adicities defined by strong form of holography as string world sheets with the property that the parameters involved with their mathematical characterization are in algebraic extensions of rational numbers and can be thus algebraically continued to real and various p-adic number fields.

This view about time is the view of self about time as it shows itself as birth and death of mental images (sub-selves). The experienced continuous flow of time corresponds to a sequence of state function reductions at a fixed boundary of CD not changing the state at this boundary [K25, K1]. The sequences of these reductions defines self as conscious entity. Also the emergence of experienced time and its connection with the flow of geometric time can be understood in this framework. Thus the sequences of death/births of sub-selves define one time and second time corresponds to the continuous flow associated with state function reductions at the same boundary.

The phase transition like character of life has also more concrete interpretation. The hierarchy of Planck constants labelling phases of dark matter can be interpreted as a realization of quantum criticality of TGD Universe. The phase with a given value of  $h_{eff} = n \times h$  corresponds to a phase in which super-symplectic conformal symmetry is broken in the sense that only the sub-algebra for which the conformal weights are  $n$ -ples for those of the entire algebra act as gauge symmetries. These phases are quantum critical and the phase transitions increasing  $n$  by integer multiple occur spontaneously. Living systems are fighting against this phase transition in all scales and try to stay at criticality with the help of metabolic energy and homeostasis. At the moment of death of self this phase transition is expected to occur. For sub-selves of self it occurs all the time as birth and death of mental images which evolve gradually.

#### 2.4.1 Why sensory experience is about so short time interval?

The picture based on CDs implies automatically the 4-D character of conscious experience and memories form part of conscious experience even at elementary particle level. Amazingly, the secondary p-adic time scale of electron is  $T = 0.1$  seconds defining a fundamental time scale in living matter. The problem is to understand why the sensory experience is about a short time interval of geometric time rather than about the entire personal CD with temporal size of order life-time. The explanation would be that sensory input corresponds to sub-selves (mental images) with  $T \simeq .1$  s at the upper light-like boundary of CD in question. This requires a strong asymmetry between upper and lower light-like boundaries of CDs.

The localization of the contents of the sensory experience to the upper light-cone boundary and local arrow of time could emerge as a consequence of self-organization process involving conscious intentional action. Sub-CDs would be in the interior of CD and self-organization process would lead to a distribution of CDs concentrated near the upper or lower boundary of CD. The local arrow of geometric time would depend on CD and even differ for CD and sub-CDs.

1. The localization of contents of sensory experience to a narrow time interval would be due to the concentration of sub-CDs representing mental images near the either boundary of CD representing self.
2. Phase conjugate signals identifiable as negative energy signals to geometric past are important when the arrow of time differs from the standard one in some time scale. If the arrow of time establishes itself as a phase transition, this kind of situations are rare. Negative energy signals as a basic mechanism of intentional action and transfer of metabolic energy would explain why living matter is so special.
3. Geometric memories would correspond to sub-selves in the interior of CD, the oldest of them to the regions near "lower" boundaries of CD. Since the density of sub-CDs is small there geometric memories would be rare and not sharp. A temporal sequence of mental images, say the sequence of digits of a phone number, would correspond to a temporal sequence of sub-CDs.
4. Sharing of mental images corresponds to a fusion of sub-selves/mental images to single sub-self by quantum entanglement: the space-time correlate could be flux tubes connecting space-time sheets associated with sub-selves represented also by space-time sheets inside their CDs.

### 2.4.2 Arrow of time

TGD forces a new view about the relationship between experienced and geometric time. Although the basic paradox of quantum measurement theory disappears the question about the arrow of geometric time remains. There are actually two times involved. The geometric time assignable to the space-time sheets and the  $M^4$  time assignable to the imbedding space.

The emergence of the arrow of time at the level of imbedding space reduces to a modification of the oldest TGD based argument for the arrow of time which is wrong as such. If physical objects correspond to 3-surfaces inside future directed light-cone then the sequence of quantum jumps implies a diffusion to the direction of increasing value of light-cone proper time. The modification of the argument goes as follows.

1. CDs are characterized by their moduli. In particular, the relative coordinate for the tips of CD has values in past light cone  $M^4$  if the future tip is taken as the reference point. An attractive interpretation for the proper time of  $M^4$  is as cosmic time having quantized values. Quantum states correspond to wave functions in the modular degrees of freedom and each  $U$  process creates a non-localized wave function of this kind. Suppose that state function reduction implies a localization in the modular degrees of freedom so that CD is fixed completely apart from its center of mass position to which zero four-momentum constant plane wave is assigned. One can expect that in average sense diffraction occurs in  $M^4$  so that the size of CD tends to increase and that the most distant geometric past defined by the past boundary of CD recedes. This is nothing but cosmic expansion. This provides a formulation for the flow of time in terms of a cosmic redshift. This argument applies also to the positions of the sub-CDs inside CD. Also their proper time distance from the tip of CD is expected to increase.
2. One can argue that one ends up with contradiction by changing the roles of upper and lower tips. In the case of CD itself is only the proper time distance between the tips which increases and speaking about “future” and “past” tips is only a convention. For sub-CDs of CD the argument would imply that the sub-CDs drifting from the opposite tips tend to concentrate in the middle region of CD unless either tip is in a preferred position. This requires a spontaneous selection of the arrow of time. One could say that the cosmic expansion implied by the drift in  $M^4$  “draws” the space-time sheet with it to the geometric past. The spontaneous generation of the asymmetry between the tips might require the “curious” conscious entities.

## 2.5 Two Views About Flow Of Time

One can consider two alternative views about how the subjectively experienced flow of time emerges.

1. The first view would identify the flow of time with life cycle of period and essentially with sensory perception defining the passive aspects of consciousness. This view is consistent with the ZEO based about self and looks rather feasible. One can wonder how repeated state function reduction give rise to the increase of the average size of CD (possibly in superposition of CDs). Why the entire zero energy state and CD do not remain unchanged in state function reduction? What is the unitary process defining the dynamics of dispersion in the moduli space of CDs? One must admit that this aspect is not well-understood yet and more detailed view about what the sequences of state function reductions really means.
2. Second view that I have considered assigns the flow of time with active aspects of consciousness.
  - (a) The acts of volition would give rise to an experience about flow of time. The proposal is that in ZEO act of volition corresponds to the first state function reduction at the opposite boundary of some sub-CD. Some self in the hierarchy dies in this process and NMP forces it to occur although it does not fix the outcome. Time mirror mechanism for motor action assumes that the phase transition gives rise to negative energy space-time sheets representing propagation of signals to geometric past,

where they induce neuronal activities. From Libet's experiments relating to neuronal correlates of volition the time scale involved is a fraction of second but an infinite hierarchy of time scales is implied by fractality. Perhaps the most logical interpretation is that state function reduction sequences with opposite arrows of time correspond to sensory perception and motor action from the point of view of a higher level self with larger CD.

- (b) Skeptic can argue that the act of volition in this sense is only a choice between alternative outcomes of state function reduction rather than a realization of intention as action creating something genuinely new: a new real space-time sheet from p-adic space-time sheet. One can however argue that genuine volitional acts are realizations of intentions. The reason is that NMP defines the goal of the dynamics and means that total quantum randomness does not prevail anymore.

One can also argue that there is no actual choices between good and evil. This is certainly not the case if weak form of NMP which only allows the reduction to any subspace of the subspace with the dimension of the projection operator appearing in density matrix.

These view can be understood as mutually consistent manners to understand the flow of time. The first flow would be pseudo-continuous and correspond to translation in time and second one would occur in discontinuous steps and correspond a scaling of CD. These time developments corresponds to time evolutions in ordinary QFT and in conformal field theory respectively.

Consider first how the smooth flow of subjective time during the life cycle of self emerges.

1. One can argue that the value of  $h_{eff}$  associated with a given self cannot increase during the lifetime of self since this would scale up also the size of the passive boundary of CD and thus also the sizes of 3-surfaces there. The explanation for the flow of geometric time however demands that the size of CDs in the superposition increases.

This requires a linear increase in which CD size increases by integer rather than being scaled by integer: shift instead of scaling. This criterion would suggests that the increase of the size of CD is below scaling by factor two - below a more flexible option is considered - and relate the lifetime of self to the size scale of CD.

2. The basic mathematical challenge is to formulate the transition amplitudes between different CDs. Is the transition amplitude essentially an overlap of fermionic lines associated with the two CDs? In Yangian approach the transition amplitude would reduce to an overlap integral associated with the string world sheets belonging to both CDs. This would favor the increase of the size of CD. It is not clear whether it makes sense to assume a localization to single CD to take place at every step localizing only its active boundary. Certainly state function reduction in the degrees of freedom associated with this boundary of CD cannot occur since this would reverse the direction of time.

The time evolution during the single step keeping passive boundary of CD corresponds to a shift for the integer specifying the size scale of CD. Can one interpret this shift as a fractional scaling  $n \rightarrow n(1 + \Delta n/n)$  or does this shift correspond to translation by representable in terms of Poincare energy as Noether charge? The latter option looks more natural. This time evolution would be the one usually studied in quantum field theories.

3. Interesting questions relate to the constraints coming from number theoretical universality forced by adelization. Could the increase of  $h_{eff}$  correspond to the increase of p-adic prime characterizing the system? What about p-adic counterpart of unitary evolution: the existence of the exponential  $exp(iP_0 t)$  requires that  $t$  has p-adic norm below some upper bound. This could give an upper bound to the life time of self as a real number since the p-adic counterpart of life-time would be below this upper bound.

What happens in the first reduction to the opposite boundary of CD changing the arrow of time?

1. The reduction should be forced by NMP and involve scaling of  $h_{eff}$  generating negentropic entanglement. Thus the scaling of  $h_{eff}$  and reduction of quantum criticality would be possible

only in the first reduction to the opposite boundary - biological death. Life cycle would end when the transition increasing  $h_{eff}$  would occur and at least tend increase negentropic entanglement. The tendency of living system to stay at criticality using metabolism and homeostasis would translate to the urge to maximize the life span, which looks indeed natural.

2. At the level of sub-selves this scalings can occur for self and would correspond to mental images with are born and die. Also motor action would correspond to a transition changing the arrow of time for a mental image representing the intention and will to perform the motor action.
3. One can argue that the increase of  $h_{eff}$  giving also rise to an increase in negentropy becomes unavoidable eventually. This criticality could mean that the size scale of CD becomes integer multiple of the original one.

For instance, when the size scale of personal CD approaches to a value which is twice that of the original one, the situation is expected become highly critical for  $h_{eff} \rightarrow 2 \times h_{eff}$  transition. Could it be possible to avoid this phase transition so that the biological death could correspond to  $h_{eff} \rightarrow n \times h_{eff}$ ,  $n > 2$ ? The manner to avoid the phase transition would be by the generation of negentropic entanglement at the level of mental images and by the corresponding phase transitions for them - can one see spiritual thoughts as a manner to live longer?

4. In the first reduction to the opposite boundary the negentropy increases and also the value of  $h_{eff}$  presumably does (by NMP). Does this mean that self can gain wisdom only by dying! The intuitive idea is that ageing is accompanied by increase of wisdom of some kind. But *if* one assigns negentropic entanglement with the passive boundary, negentropy associated with the length scale of CD remains unchanged.

There is however a loophole. For the sub-selves associated with sub-CDs the situation is different. Given mental image of self/sub-self can live several life-cycles meaning that it generates (or can generate) negentropic entanglement. Mental images of self get wiser even if self does not! The refusal of self to grow spiritually would make possible for sub-selves to grow spiritually: one cannot cheat NMP!

5. The scaling of CD inducing the increase of  $h_{eff} = n \times h$  occurring spontaneously represented as an exponential of scaling generator - call it  $L_0$  - seems to be precede the first reduction. I have already considered conditions on this dynamics. Note that translations are replaced with scalings by integer valued ratios  $m = n_f/n_i$ , which predicts that periodicity is replaced by periodicity with respect to the logarithm of ordinary imbedding space time. A unique signature of dynamics of consciousness, which I have proposed as an explanation for the hyperbolic decay law for the emission of bio-photons.
6. The scaling of CD inducing the increase of  $h_{eff} = n \times h$  occurring spontaneously is naturally represented as an exponential of scaling generator - call it  $L_0$ . Translations are replaced with scalings by integer valued ratios  $m = n_f/n_i$ , which predicts that periodicity is replaced by periodicity with respect to the logarithm of ordinary imbedding space time. A unique signature of dynamics of consciousness, which I have proposed as an explanation for the hyperbolic decay law for the emission of bio-photons.
7. The phase transitions increasing  $h_{eff}/h = n$  can be said to begin from some prime value  $n = p$  - the smallest prime power appearing in  $n$ : one could even say that the basic label for the sequences of breakings of super-symplectic symmetries are labelled by primes. This strongly suggests a connection with p-adicity.

These two views are consistent with each other. The first view corresponds to a flow of time as shifts in the integer characterizing the size of CD and corresponds to the flow of time experienced by self during its life-cycle. The second view corresponds to time evolution as a sequence of state function reductions at opposite boundary involving scalings of  $h_{eff}$  by integer. The tick for this clock would be a phase transition reducing quantum criticality. Self experiences this time flow as sequence of mental images which live and die.

### 3 Macro-Temporal Quantum Coherence And 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 WCW 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  $\Psi_i \rightarrow U\Psi_i$ , where  $\Psi_i$  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  $\Psi_f$ .

1. What happens in the state function reduction is a localization in zero modes, which do not contribute to the line element of the WCW 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 flux tubes 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 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 point-like 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 fact that only the extremals of Kähler action allowing infinite number of deformations with a vanishing second variation, 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 Feynman 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 WCW (of 3-surfaces) level: WCW 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 [K12, K11].

The basic variational principle underlying quantum TGD states that the space-time surface associated with a given 3-surface is preferred extremal 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.

### 3.3 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 quantum 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.

### 3.3.1 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 flux tubes 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.

### 3.3.2 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

$$i(T - T^\dagger) = TT^\dagger . \quad (3.1)$$

For diagonal elements one has

$$2 \times \text{Im}(T_{mm}) = \sum_r |T_{mr}|^2 \geq 0 . \quad (3.2)$$

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

$$\begin{aligned} 2\text{Im}(T_{mm}) &= \sum_r |T_{mr}|^2 + \sum_R |T_{mR}|^2 \geq 0 , \\ 2\text{Im}(T_{MM}) &= \sum_R |T_{MR}|^2 + \sum_r |T_{Mr}|^2 \geq 0 . \end{aligned} \quad (3.3)$$

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 flux tubes. 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

$$i(T_{Mm} - \bar{T}_{mM}) = \sum_r T_{Mr} \bar{T}_{mr} + \sum_R T_{MR} \bar{T}_{mR} . \quad (3.4)$$

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

$$\begin{aligned} i(T_{mn} - \bar{T}_{nm}) &= \sum_r T_{mr} \bar{T}_{nr} + \sum_r T_{mR} \bar{T}_{nR} , \\ i(T_{MN} - \bar{T}_{NM}) &= \sum_R T_{MR} \bar{T}_{NR} + \sum_r T_{Mr} \bar{T}_{Nr} . \end{aligned} \quad (3.5)$$

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 except the one with the non-vanishing eigen value of  $T$  are infinitely long in this idealization.

### 3.3.3 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 flux tubes 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.

### 3.3.4 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, Spin Glass Degeneracy, And Hierarchy Of Planck Constants

The original vision was that spin glass degeneracy is behind macroscopic quantum coherence. A more concrete vision emerged around 2005 when it was realized that ordinary quantum theory as such is probably not enough to understand macroscopic quantum coherence. In the following I summarize the original ideas and then summarize the later development of the ideas about hierarchy of Planck constants.

### 4.1 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 point-like 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.

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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 WCW (of 3-surfaces) level: WCW 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.

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The basic variational principle underlying quantum TGD states that the space-time surface associated with a given 3-surface is preferred extremal 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.

## 4.2 The Evolution Of Ideas About Hierarchy Of Planck Constants

The evolution of ideas about about Planck constant began around 2005. The following brief summary represents the original ideas and short summary about their later evolution to the recent (2015) vision. Contrary to the original expectation TGD in its original form can accommodate the idea and one could also say that the spectrum of Planck constants is only effective.

### 4.2.1 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 [E1]. 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 [K21, K26, K5].

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 [K17].

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.

The large values of  $\hbar$  mean macroscopic and macrottemporal quantum coherence. Various quantum scales such as Compton time and length are proportional to  $\hbar$  and are scaled up by  $n$  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  $n$  but not affecting particle densities can lead to a situation in which the space-time sheets associated with particles zoomed up by  $n$  overlap so that the criterion for macroscopic quantum coherence is satisfied.

#### 4.2.2 Summary about the evolution of ideas about hierarchy of Planck constants

The following summarizes the recent bird's eye of view about the evolution of the ideas about the hierarchy of Planck constants.

1. The hierarchy of Planck constants labelling levels of dark matter hierarchy was the proposed generalization. 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 [E1] introducing the notion of gravitational Planck constants but in classical context. My own proposal was that astro-scopic quantum coherence could be something very real. The vision was that when the coupling parameter (now gravitational coupling strength  $GMm/h$ ) becomes strong, a transition to dark phase with  $h$  replaced with  $h_{eff}$  occurs: Nature takes in this manner care that the situation remains perturbative. In the case of gravitation this gives  $h_{eff} = h_{gr} = GMm/v_0$ ,  $v_0$  a parameter with dimensions of velocity.
2. Second stimulus came from the quantal looking effects of ELF radiation on vertebrate brain [?] at frequencies which correspond to cyclotron frequencies for  $Ca^{++}$  ion in magnetic field which is about  $2/5$  fraction of nominal value .5 Gauss of the magnetic field of Earth. Large value of  $h_{eff} = n \times h$  (this hypothesis emerged later) would raise the cyclotron energies proportional to  $h_{eff}$  above thermal energy. Years later  $h_{eff} = h_{gr}$  idea was revived [K30] and led to a model of bio-photons identified as dark cyclotron photons transformed to ordinary photons with the same energy and satisfying  $h_{eff} = h_{gr}$  implying that the energy spectrum does not depend on the mass of the charged particle so that biophoton energy spectrum is universal and in visible and UV range characterizing bio-molecules and reflecting the spectrum of magnetic field strengths.
3. The original proposal was that the hierarchy of Planck constants accompanies a hierarchy of singular  $n$ -sheeted coverings of imbedding space assignable to CDs. Later it became clear the non-determinism of Kähler action suggests the existence of space-time surfaces, which are singular  $n$ -sheeted coverings with sheets collapsing to single 3-surface at the boundaries of CD ( $n$ -braches at both ends of space-time). An important step in the progress was the interpretation in terms of hierarchy of quantum criticalities [K29]. One cannot exclude even the possibility that also thermodynamical criticality involves large values of Planck constant. A good example is provided by the fountain effect of super-fluidity, where macroscopic

quantum gravitation might become manifest. Hierarchy of Planck constants labels these phases and sub-algebra of super-symplectic algebra with conformal weights  $n$ -ples of those for the full algebra acts as a gauge algebra. TGD Universe is like ball at the top of hill at the top of hill at...

The phase transitions increasing  $h_{eff}$  appear spontaneously in the first state function reductions to the opposite boundary of CD meaning death of self. Living systems are doing their best to stay at criticality and metabolism and homeostasis help to achieve this goal.

4. One of the dramatic predictions is that the formation of gravitationally bound states is not possible in TGD Universe - and maybe also in that predicted also by string models - if fermionic strings connecting partonic 2-surfaces serve as correlates for their formation and implying macroscopic quantum gravitational coherence. In string models it is impossible to say anything about the situation since long length scale limit is just an ad hoc assumption rather than something following from the basic theory. The most natural guess is that the only bound states have size scale of order Planck length in string models.
5. The most recent discovery is that the hierarchy of Planck constants relates closely to the number theoretical hierarchy of algebraic extension of rational numbers at the core of adelic TGD. String world sheets and partonic 2-surfaces characterized by parameters in algebraic extensions of rationals define the genes of space-time. They must allow continuation to space-time surfaces in various number fields. For real space-time surfaces this need not always be possible whereas p-adic pseudo constants make the continuation easy in various p-adic cases. The 2-surfaces not continuable to real space-time surface would be correlates for pure imagination: imaginable but not realizable.

4-D spin glass degeneracy is the prerequisite for the hierarchy of Planck constants. The hierarchy of  $n$ -sheeted singular coverings reflects the non-determinism accompanying the degeneracy (and criticality in general) and the proposal is that there is genuine gauge degeneracy in the sense that each space-time sheet is replaced by conformal gauge equivalence class. For light-like 3-surfaces, which would correspond to transforms of the 3-surface keeping it light-like and singular in the sense that the metric of induced metric vanishes at the surface because it serves as boundary of regions with Minkowskian and Euclidian signatures of the induced metric. This gauge invariance can be realized by demanding that classical Noether charges associated with the sub-algebra of super-symplectic algebra characterized by  $n$  vanish at the ends of space-time. This realizes also strong form of holography.

## 5 Basic Implications

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

### 5.1 Information Theoretic Aspects

TGD framework forces to reconsider also the notion of information itself, and the new number-theoretic view about information suggests a profoundly new view about the distinction between dead and living matter and about about consciousness as the basic driving forces behind evolution. At practical level this might have radical implications for quantum computation [K7]. These aspects are discussed in detail in [K14, K20] and in the following only the main points are discussed. What is important that weak form of NMP [K14], which is information theoretic variational principles, allows together with ZEO to deduce the basic predictions of TGD inspired theory of consciousness and quantum biology. In this picture the hierarchy of Planck constants (quantum criticalities), p-adic physics, the notion of negentropic entanglement are very tightly interwoven.

#### 5.1.1 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  $p$ ;  $\text{Log}_p(x) = \log_p(|x|_p) = -n$  [K14]. 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 heureka 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 [K14] 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.

Weak form of NMP which allows non-maximal negentropy gain allows also a further maximization of negentropy gain. The price paid is that the world is not the best possible one: conscious entities get free will and can make also choices reducing the negentropic resources of the Universe. These deviations are however analogous to thermodynamical fluctuations and the statistical trend is that world gets a better place in that its negentropy increases. An interesting question which I remember of having encountered in a russian scifi book (do not remember its author) is whether second law could actually reflect also the presence of an intentional bad will? What is especially nice is that the weak form of NMP predicts generalization of  $p$ -adic length scale hypothesis which I ended up from  $p$ -adic mass calculations.

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

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

1. The facts that fermionic oscillator operators are correlates for Boolean cognition and that induced spinor fields are restricted to string world sheets and partonic 2-surfaces suggests that the intersection consists of these 2-surfaces.
2. Strong form of holography allows a rather elegant adelization of TGD by a construction of space-time surfaces by algebraic continuations of these 2-surfaces defined by parameters in algebraic extension of rationals inducing that for various  $p$ -adic number fields to real or  $p$ -adic number fields. Scattering amplitudes could be defined also by a similar algebraic continuation. By conformal invariance the conformal moduli characterizing the 2-surfaces would defined the parameters.

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

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

A good guess is that algebraic entanglement is essential for quantum computation, which therefore might correspond to a conscious process. Hence cognition could be seen as a quantum computation like process, a more appropriate term being quantum problem solving [K7]. Living-dead

dichotomy could correspond to rational-irrational or to algebraic-transcendental dichotomy: this at least when life is interpreted as intelligent life. Life would in a well defined sense correspond to islands of rationality/algebraicity in the seas of real and p-adic continua. Life as a critical phenomenon in the number theoretical sense would be one aspect of quantum criticality of TGD Universe besides the criticality of the space-time dynamics and the criticality with respect to phase transitions changing the value of Planck constant and other more familiar criticalities. How closely these criticalities relate remains an open question [K20].

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

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

### 5.1.2 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/flux tubes 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.

Quantum-classical correspondence suggests that the notion of information is well defined also at the space-time level. The non-determinism of Kähler action and p-adic non-determinism plus algebraic information measures suggest a natural approach to 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.

### 5.1.3 Information concept at space-time level

For years ago I ended up with the idea that space-time surface should somehow code for the preferred p-adic primes so that it would be a representations for an integer and considered some naive proposals how this could be realized. Since the ramified primes identifiable as preferred p-adic primes characterize the algebraic extension of rationals assignable to string world sheets and partonic 2-surfaces defining “space-time genes” - or more precisely, the ideal for algebraic extension - to which the parameters characterizing string world sheets and partonic 2-surfaces belong, they characterize by strong form of holography also the space-time region containing them. In fact, the integer defined by the product of ramified primes characterizes the space-time region.

One can say that in very abstract sense space-time region represents factorization of integer and p-adic space-time region corresponding to ramified primes define a similar adelic factorization. The reason for the preferred character of the ramified primes is that for them  $n$  separate space-time surfaces obtained by the action of Galois group on the parameters of 2-surfaces co-incide at the boundaries of CD (criticality!) so that one obtains analog of bound state [K31]. The different branches correspond to  $n$  discrete of freedom, and one can assign to them many-fermion states: at most 1 fermion at single sheet of the covering.

## 5.2 Thermodynamical Aspects

During macro-temporal quantum coherence dissipation is absent in the quantum coherent degrees of freedom. This suggests 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 [D1]. 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.

The recent view about NMP suggests strongly breaking of second law. The breaking however is due to the generation of negentropic entanglement stable under NMP (or more precisely under weak form of NMP which does not require maximal negentropy gain in state function reductions and in this manner allows free will). Entanglement negentropy (number theoretic Shannon entropy [K14]) tends to increase by NMP - also for weak form of NMP but in statistical sense. Number theoretic negentropy is however not equivalent with thermodynamical entropy which characterizes average

member of ensemble rather than the pair formed by system and its complement so that second law need not be broken. An essential point is that the density matrix is projector for negentropically entangled states and the corresponding entanglement matrix is unitary matrix.

However, in a phase transition transforming thermal ensemble to negentropically entangled state, second law is broken. A more precise formulation for the second law would be that it holds for visible matter in processes in which visible matter does not transform permanently to dark matter. In order to test the TGD version of second law, or rather NMP, one should be able to detect and manipulate dark matter. Quantum criticality are ideal tool to generate dark matter phases. This might be possible even in thermodynamically critical systems, which are indeed problematic from the point of view of thermodynamic description.

### 5.3 Energetic Aspects

The vision about energetic aspects of quantum coherence as evolved gradually.

1. 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 [J1] 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.
2. Later the notion of negentropic entanglement emerged. Entanglement negentropy tends to increase by NMP and it is not at all clear whether there is any need to assume that there is any binding energy involved. One could even play with metaphors and consider the possibility that NE is like genuine love: it keeps people together without any violence as in organized marriage. Negentropic entanglement is very special: density matrix is projector so that its occurrence in standard quantum theory is extremely implausible. Even slightest perturbation can destroy it. In TGD framework however the hierarchy of Planck constants accompanied by n-sheeted coverings predicts it and NMP not only stabilizes it but favors its generation. As a matter fact, negentropic entanglement is the essence of quantum criticality.

NMP leads also to the vision that metabolism is basically transfer of NE. This applies not only to energy metabolism but also to other forms of metabolism. Living systems must be able to generate NE to satisfy the demands of NMP. They can get NE by stealing the NE generated by other living systems- that is by eating them - One manner is to generate it by the Karma’s cycle of mental images (subelves) in which subelves are repeatedly born, live by performing a sequence of repeated state function reductions at the same boundary of CD (Zeno effect) and die as they perform the first reduction to the opposite boundary of CD and re-incarnate as a time-reversed mental image at the opposite boundary. Sensory-motor cycle would be fundamental realization of this cycle.

## 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 Biology

The increase of Planck constant as reduction of quantum criticality transforming supersymplectic gauge degrees of freedom to dynamical ones is a generic mechanism for gener-

ating new quantum fluctuating degrees of freedom. This process occurs spontaneously and generation of NE accompanies this process.

Living systems are however doing their best to keep their level of quantum criticality rather allowing spontaneous increase of  $h_{eff}$ . The paradoxical looking behavior is created by the fact that the generation of NE and phase transition increasing  $h_{eff}$  is associated with the first state function reduction to the opposite boundary of CD. This means death of self followed by a re-incarnation at opposite boundary. Selves are doing their best to avoid this and at the same time give for the sub-selves (mental images) opportunity to long Karma's cycle leading to a high negentropy gain.

Metabolic energy transfer and other forms of metabolism can be seen as mechanisms allowing to steal existing negentropy resources in order to avoid the unavoidable forced eventually by NMP. Also homeostasis can be seen as a collection of mechanisms allowing to keep the existing level of criticality.

At the macro-level sexual organism could be a basic example of a multi-verse state of oneness generated by the formation of a macroscopic quantum bound state of partners. Neuroscientists 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.

- (a) The binding of molecules by lock and key mechanism is a fundamental process in living matter. The first idea to come in mind is that it 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.
- (b) It however seems that biochemistry is not enough. Also the notion of magnetic body is needed and topological field quantization provides it: the essential point is that physical systems in TGD Universe have also field identify unlike in Maxwellian theory. Magnetic flux tubes of magnetic bodies carrying dark matter could be the manner how living matter generates negentropic entanglement. Living matter could have a network of magnetic flux tubes analogous to a coordinate grid making it a coherent structure. Magnetic flux tubes would connect molecules and even larger structures to connected networks. One can imagine several mechanisms involving flux tubes and dark photons at them.
  - i. The reduction of Planck constant for magnetic flux tubes brings the molecules near to each other in the molecular crowd and makes possible the occurrence of various biochemical reactions such as replication of DNA, transcription, and translation of mRNA to proteins. The dark cyclotron photons at flux tubes provide a fundamental communication and control mechanism.
  - ii. Besides  $h_{eff}$  changing phase transitions, reconnection of flux tubes is a key process. For instance, the basic mechanism of attention could be reconnection for U-shaped flux tubes forming a flux tube pair connecting to molecules or larger systems.
  - iii. A further key process would be replication of magnetic bodies serving as templates of organisms. This replication is completely analogous to what happens in 3-vertex of Feynman diagram. Visible living matter would self-organize around magnetic bodies carrying dark matter and even basic biopolymers (DNA, mRNA, and amino-acid sequences) would have dark counterparts realized as dark proton sequences at dark magnetic flux tubes parallel to the visible part of biopolymer.
  - iv. Cyclotron resonance for dark cyclotron photons propagating parallel to flux tubes would be a key mechanism of communication and control and bio-photons could

be seen as ordinary photons resulting from dark photons in Planck constant reducing transformations. For instance, EEG could consist of dark photons at EEG frequencies but energies at visible photon energies.

- (c) 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 oneness in the receptor-neurotransmitter complex or perhaps even in larger-sized structures. If neurotransmitters have flux tubes 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.
- (d) One could even 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.
- (e) 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.

## 6.2 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 are very near to vacuum extremals and in the simplest situation have  $CP_2$  projection belonging to a homologically trivial geodesic sphere of  $CP_2$ . They would carry vanishing induced Kähler fields (U(1) field in standard model). Another basic kind of MEs would carry classical em,  $W$  fields, and gravitational fields and would correspond to  $CP_2$  projection in homologically non-trivial geodesic sphere. The transitions for MEs near vacuum extremals could realize the mirror mechanism of long term memories.

It is now clear that MEs are double sheeted at least: quite generally, the two sheets are connected by a pair of wormhole throats defining the elementary particle in question. This applied in the case of photons too.

A few years old realization [K27] is that the condition that the em charge of induced spinor modes is well-defined forces them in the generic case to string world sheets carrying vanishing  $W$  gauge fields and in suitable gauge also  $W$  gauge potentials. The interpretation is in terms of strong holography. The string world sheets and partonic 2-surface which they intersect at discrete points carry the information needed to build quantum states in ZEO. Induced spinor fields would not feel the presence  $W$  fields at all but just the condition that this is the case would determined the dynamics of string world sheets! Avoidance behavior implies also strong correlation with that which causes avoidance behavior! The fundamental 2-surfaces provide also the basic understanding in living matter.

### 6.2.1 Mirror mechanism of long term memories and 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.

Dark 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 human long term memories. Most naturally MEs correspond to dark photons. The original belief was that only gravitonic MEs should be considered. Here the problem is that amplitudes for the generation gravitons are incredibly weak unless one has macroscopic quantum coherence replacing the factor  $N$  (number of emitters) with  $N^2$ . This of course occurs also for the electromagnetic case. In any case, the macroscopic coherence for gravitation emission implies it also for em emission.

The electromagnetic between a huge number of almost degenerate spin glass states could be coded to the fundamental frequencies of MEs. The value of Planck constant  $\hbar_{gr} = GMm/v_0$  would be large but for  $m$  in the mass range of elementary particles and atomic and molecular structures  $\hbar_{eff} = \hbar_{gr}$  would be consistent with the values of  $\hbar_{eff}$  proposed to be realized in living matter.

In particular, structures with sizes slightly above cell membrane thickness, such as micro-tubules, could generate MEs as a topological correlate for dark photon 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 gauge boson exchange with vacuum.

- (a) The light reflected in mirror corresponds to topological light rays assignable to photons and is reflected from the curved vacuum. Topological counterpart of virtual photon is emitted by (say) a tubulin, reflected by the vacuum, and finally absorbed by the tubulin. Curved vacuum acts as a mirror for photons and self can see the self of the geometric past in this mirror.
- (b) One could interpret the low energy topological light 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. Dark photon  $1/f$  noise would be emitted in the transitions between almost degenerate spin glass states and would be kind of analog for 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. Interestingly, the gravitational binding energy associated with  $L(139) \sim .1$  nm (atomic physics) corresponds to the age of the universe: perhaps this explains why Schrödinger 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.

### 6.2.2 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 scaled up electron Compton length  $L_e(k)$  is

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

Gravitational binding energy is larger than the p-adic energy  $\pi/L_e(k)$  for  $L_e(k = 179) \simeq .169$  mm. In the range  $L_e(163) = 640$  nm and  $L_e(167) = 2.56 \mu m$  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 Merseuses. 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  $d = x^2 L_e^2(151)$ ,  $L_e(151) = 10$  nm, one has

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

This gives for  $L_e(k) \sim 1$  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 degeneration of the long micro-tubuli first with shortest micro-tubuli being the most stable ones. In [K19] 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 [K10] ).

### 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 [I2] 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 [K2, K3].

#### 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.

- (a) 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.

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



value of magnetic field and possibly also of Planck constant  $h_{eff}$  so that cyclotron energy would be liberated. In the following only the “dropping” option is discussed.

- (b) 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.

- (a) 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).
- (b) 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 [K15, K16]. 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 [K9]. 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 mass-less 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 [K18] 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.

The following considerations reflect the situation for about 15 years ago and the examples represent “fringe physics”. I hope that this does not mask the generality of the mechanism of healing about which I had no idea when the following sections were written.

#### 7.3.1 Priore’s machine

The TGD based model [K18] of Priore’s machine [I3, I1] 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 [H1, H2] (see [K23]). Needless to say that academic physicists do not take Searl machine seriously: this would be quite too dangerous for the career. Personally I do not believe or not-believe in it, and just admit that it might involved the notions of magnetic body, generation of dark matter, and quantum criticality in very interesting manner.

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 [K9].

Several new physics effects seem to be involved.

- (a) 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.

- (b) 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.
- (c) 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.
- (d) The generation of  $Z^0$  magnetic field explains the presence of the strange magnetic walls.
- (e) 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. After 15 years I would like to rephrase this in somewhat different manner: biological rhythms correspond to repeated birth and death for subselves defining mental images. These cycles occur in several length and time scales. Sensory motor rhythms, EEG rhythms, mental images popping up and dying, sleep-wake-up rhythm, even annual biorhythms, ... serve as examples. The following summary is somewhat out-of-date but I decided to keep it as such.

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 of 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 [D1].

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 [K23], [H3]). 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 induce Darwinian selection of 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 Searl's machine of [H3] ). 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 [K12]. 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 [F1].

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