

Matter, Mind, Quantum

M. Pitkänen,

February 14, 2018

Email: matpitka6@gmail.com.

http://tgdtheory.com/public_html/.

Recent postal address: Rinnekatu 2-4 A 8, 03620, Karkkila, Finland.

Contents

1	Introduction	5
1.1	Basic Ideas Of TGD Inspired Theory Of Consciousness	6
1.1.1	Identification of quantum states as quantum histories and the notion of quantum jump	6
1.1.2	The notion of self	6
1.1.3	Generalization of quantum measurement theory to a theory of consciousness	7
1.2	P-Adic Numbers And Consciousness	8
1.2.1	Negentropy Maximization Principle and the notion of self	8
1.2.2	Positive entanglement negentropy is possible in the intersection of real and p-adic worlds	9
1.3	TGD Inspired New Physics And Consciousness	11
1.3.1	TGD based space-time concept and the existence of macroscopic quantum phases	11
1.3.2	Quantum criticality	11
1.3.3	Dark matter hierarchy	12
2	What Are The Problems Of Quantum Mind Theories?	13
2.1	Some Philosophical Problems Of Quantum Physics	13
2.2	Basic Philosophical Problems Of Quantum Mind Theories	14
2.3	Basic Problems Of Quantum Biology And Quantum Neuroscience	15
2.4	Could Anomalies Help?	16

3	Some Aspects Of Quantum TGD	17
3.1	New Space-Time Concept	17
3.2	Zero Energy Ontology	18
3.3	The Hierarchy Of Planck Constants	19
3.4	P-Adic Physics And Number Theoretic Universality	20
3.4.1	p-Adic number fields	21
3.4.2	Physical and biological motivations for p-adic number fields	21
3.4.3	Life as something in the intersection of real and p-adic worlds	21
4	Consciousness Theory As Extension Of Quantum Measurement Theory	22
4.1	Quantum Jumps As Moment Of Consciousness	23
4.2	The Notion Of Self	23
4.3	How Experienced Time And The Geometric Time Of Physicist Relate To Each Other?	25
4.3.1	Basic questions	25
4.3.2	The recent view about arrow of time	25
4.4	Quantum Correlates For Various Aspects Of Conscious Experience	26
4.5	Self Referentiality Of Conscious Experience	28
4.5.1	Many-sheeted space-time and self-referentiality	28
4.5.2	Infinite primes and self-referentiality	29
4.5.3	Quantum Mathematics and self referentiality of consciousness	29
5	Various Types Of Conscious Experiences	30
5.1	Basic Structure Of Conscious Experience	31
5.1.1	Real and imagined experiences	31
5.1.2	Whole-body consciousness and ordinary consciousness	31
5.1.3	Active and passive aspects of conscious experience	31
5.2	Cognition And P-Adic Physics	33
5.3	Reflective- And Proto-Levels Of Consciousness	33
5.3.1	Boolean mind as reflective mind?	33
5.3.2	Symbolic and cognitive representations as means of becoming conscious about being conscious about?	34
5.4	General Model For Sensory Experiences	34
5.4.1	Macroscopic quantum phases are needed	34
5.4.2	The functions of nerve pulses	35
5.4.3	How qualia are associated with neural pathways?	36
5.4.4	Only changes are perceived	37
5.4.5	Are the ultimate sensory representations realized outside brain?	37
5.5	Emotions	37
5.5.1	Emotions and comparisons	37
5.5.2	Emotions and entropy	38
5.6	Directed Attention	40
5.7	Altered States Of Consciousness	41
5.7.1	Whole-body consciousness and ordinary consciousness	41
5.7.2	That-which-is experiences	42
5.7.3	Zen type experiences and negentropic entanglement	43
5.7.4	Extended states of consciousness	43
6	Boolean Mind And Cognition	46
6.1	Fermions And Boolean Cognition	46
6.2	Fuzzy Logic, Quantum Groups, And Jones Inclusions	46
6.3	P-Adic Physics As Physics Of Cognition	47
6.4	Infinite Primes And Cognition	47
6.4.1	Infinite primes very briefly	47
6.4.2	Algebraic Brahman=Atman identity	48

7	Quantum Correlates Of Qualia	49
7.1	Development Of Ideas	49
7.1.1	Music metaphor at axonal level	50
7.1.2	ME's and qualia	50
7.1.3	MEs, magnetic superconductors, and many-sheeted ionic flow equilibrium	51
7.1.4	The role of super-symplectic algebra	51
7.2	Qualia And Thermodynamics	52
7.2.1	Boolean qualia	54
7.3	Geometric Qualia And Zero Modes	54
8	Solutions To Some Paradoxes	55
8.1	Paradoxes Related To Quantum Physics	55
8.2	Paradoxes Related To The Theories Of Consciousness	56
8.3	Logical Paradoxes And Concept Of Time	57

Abstract

This chapter is devoted to the TGD inspired theory of consciousness. TGD inspired theory of consciousness could be seen as a generalization of quantum measurement theory to make observer, which in standard quantum measurement theory remains an outsider, a genuine part of physical system subject to laws of quantum physics. The basic notions are quantum jump identified as moment of consciousness and the notion of self: zero energy ontology (ZEO) is essential for the notion of self. Negentropy Maximization Principle (NMP) defines the dynamics of consciousness and as a special case reproduces standard quantum measurement theory.

1. Quantum jump as moment of consciousness

TGD suggests that the quantum jump between quantum histories could be identified as moment of consciousness and could therefore be for consciousness theory what elementary particle is for physics.

This means that subjective time evolution corresponds to the sequence of quantum jumps $\Psi_i \rightarrow U\Psi_i \rightarrow \Psi_f$ consisting of unitary process followed by state function process. In zero energy ontology (ZEO) U defines a unitary matrix between zero energy states and is naturally assignable to intentional actions whereas the ordinary S-matrix telling what happens in particle physics experiment (for instance) generalizes to M-matrix defining time-like entanglement between positive and negative energy parts of zero energy states. One might say that U process corresponds to a fundamental act of creation creating a quantum superposition of possibilities and the remaining steps generalizing state function reduction process select between them.

2. Negentropy Maximization Principle and the notion of self

U -process is followed by a cascade of state function reductions. Negentropy Maximization Principle (NMP) states that in a given quantum state the entangled subsystem-complement pair with largest entanglement entropy can perform the quantum jump. More precisely: the reduction of the entanglement entropy in the quantum jump is as large as possible. This selects the pair in question and in case of ordinary entanglement entropy leads the selected pair to a product state. The interpretation of the reduction of the entanglement entropy as conscious information gain makes sense. The sequence of state function reductions decomposes at first step the entire system to two parts in such a manner that the reduction entanglement entropy is maximal. This process repeats itself for subsystems. If the subsystem in question cannot be divided into a pair of entangled free system the process stops since energy conservation does not allow it to occur (binding energy) or the resulting entanglement is negentropic for all sub-system-complement divisions.

The original definition of self was as a subsystem able to remain unentangled under state function reductions associated with subsequent quantum jumps. Everything is consciousness but consciousness can be lost. Second aspect of self was assumed to be the integration of subsequent quantum jumps to coherent whole giving rise to the experienced flow of time.

What is the precise identification of self allowing to understand both of these aspects turned out to be difficult problem. I became aware the solution of the problem in terms of ZEO only quite recently (2014). Self indeed corresponds to a sequence of quantum jumps integrating to single unit, but these quantum jumps correspond to state function reductions to a fixed boundary of causal diamond (CD) leaving the corresponding parts of zero energy states invariant. In positive energy ontology these repeated state function reductions would have no effect on the state but in TGD framework there occurs a change for the second boundary and gives rise to the experienced flow of time and its arrow and gives rise to self. The first quantum jump to the opposite boundary corresponds to the act of free will or wake-up of self.

p-Adic physics as correlate for cognition and intention leads to the notion of negentropic entanglement possible in the intersection of real and p-adic worlds involves experience about expansion of consciousness. Consistency with standard quantum measurement theory forces negentropic entanglement to correspond to density matrix proportional to unit matrix. Unitary entanglement typical for quantum computing systems gives rise to unitary entanglement.

The first state function reduction - wake-up of self- at given boundary of CD is a hierarchical cascade proceeding from long to short scales. The reduction process can stop also if the self in question allows only decompositions to pairs systems with negentropic entanglement. This does not require that the system forms a bound state for any pair of subsystems so that the systems decomposing it can be free (no binding energy). This defines a new kind of bound state not describable as a jail defined by the bottom of a potential well. Subsystems are free but remain correlated by negentropic entanglement.

Ordinary state function reductions imply dissipation crucial for self organization and quantum jump could be regarded as the basic step of an iteration like process leading to the asymptotic self-organization patterns. One could regard dissipation as a Darwinian selector as in standard theories of self-organization. NMP predicts that self organization and hence presumably also fractalization can occur inside selves. NMP would favor the generation of negentropic entanglement. This notion is highly attractive since it could allow to understand how quantum self-organization generates larger coherent structures. Note that state function reduction for negentropic entanglement is highly deterministic since the number of degenerate states with same negative entanglement entropy is expected to be small. This could allow to understand how living matter is able to develop almost deterministic cellular automaton like behaviors. In ZEO this self-organization is for 4-D spatio-temporal patterns since 3-surfaces are pairs of space-like surfaces at the boundaries of CD and maxima of Kähler function are selected in the process. These temporal patterns correspond to behaviors and functions in living matter.

The chapter is devoted to the discussion of detailed implications of these general ideas. The topics to be discussed include following basic questions.

1. How the general structure for the contents of consciousness of self are determined? The basic assumption is that self hierarchy in which subselves define mental images of self is responsible for the general structure of conscious experience. ZEO allows to derive the space-time correlates of selves.
2. How the physical realization of the hardware of consciousness differs from that assumed in neuroscience? Here the notion of magnetic body as intentional agent using biological body as motor instrument and sensory receptor is central.
3. What is the precise relationship between the geometric time of physicist and subjective time identified in terms of a sequence of quantum jumps? ZEO gives the most convincing answer to this question found hitherto.
4. What can one say about various types of conscious experience in the proposed framework. This includes p-adic description of cognition and intentional action, model for sensory experience and sensory qualia, model for Boolean mind in terms of fermions, a model for directed attention, ideas about emotions, and also a general interpretation for altered states of consciousness based on the special features of negentropic entanglement.
5. Can one provide solutions to the paradoxes of quantum physics, theories of consciousness, and logic in the proposed conceptual framework?

The discussion differs considerably from the earlier one. The reason is that the developments occurred during period 2005-2010 (ZEO, hierarchy of Planck constants assigned to dark matter, hyper-finite factors of type II_1 , the implications of the number theoretical negentropies) are introduced from the beginning to the formulation of the theory rather than as additions to the existing text so that the representation is more coherent and the number of internal inconsistencies is minimized. The latest progress relates to the understanding of the notions of psychological time and self (2012-2014).

1 Introduction

Topological Geometro-Dynamics (TGD) is a unified theory of fundamental interactions. TGD involves a quite far-reaching generalization of the space-time concept and, apart from the notion of quantum jump, reduces quantum theory to infinite-dimensional geometry. Quantum TGD requires the introduction of several new mathematical tools and concepts, in particular p-adic numbers.

TGD based theory of consciousness has developed gradually during the last fifteen years side by side with TGD based quantum measurement theory. For a summary of TGD and p-adic aspects of TGD see [K38, K20].

The emergence of the notions of zero energy ontology (ZEO) and hierarchy of Planck constants together with the increased understanding of the special features of number theoretical universality have led to a considerable deepening of the understanding during last half decade. The basic concepts and ideas of TGD based theory of consciousness as I would have formulated them around 2005 are introduced first. After that the ideas that have appeared during the period 2005-2014 are briefly summarized.

1.1 Basic Ideas Of TGD Inspired Theory Of Consciousness

In the following basic ideas of TGD inspired theory of consciousness as they were formulate for about half decade ago are summarized.

1.1.1 Identification of quantum states as quantum histories and the notion of quantum jump

General coordinate invariance (GCI) forces the identification of the quantum states as quantum histories rather than time=constant snapshots of single quantum history. Quantum history can be regarded as a classical spinor field in the world of all classical worlds (WCW) so that rather abstract concept is in question. This identification has several important consequences.

1. The possibility to regard unitary process followed by state function collapse as a quantum jump between quantum histories solves the basic paradox posed by the determinism of the Schrödinger equation contra non-determinism of the state function collapse.
2. A radical reconsideration of the concepts of psychological time and observer becomes necessary and forces a profound generalization of the standard views about time.

If quantum jump occurs between two different time evolutions of Schrödinger equation (understood here in very metaphorical sense) rather than interfering with single deterministic Schrödinger evolution, the basic problem of quantum measurement theory finds a resolution. The interpretation of quantum jump as a moment of consciousness means that volition and conscious experience are outside space-time and state space and that quantum states and space-time surfaces are “zombies”. Quantum jump would have actually a complex anatomy corresponding to unitary process U , state function reduction and state preparation at least.

Negentropy Maximization Principle (NMP) codes for the dynamics of standard state function reduction and states that the state function reduction process following U -process gives rise to maximal reduction of entanglement entropy at each step. In the generic case this implies decomposition of the system to unique unentangled systems and the process repeats itself for these systems. The process stops when the resulting subsystem cannot be decomposed to a pair of free systems since energy conservation makes the reduction of entanglement kinematically impossible in the case of bound states.

1.1.2 The notion of self

The original definition of self was as a subsystem able to remain unentangled under state function reductions associated with subsequent quantum jumps. Everything is consciousness but consciousness can be lost if self develops bound state entanglement during U process so that state function reduction to smaller un-entangled pieces is impossible. A second aspect of self was assumed to be the integration of subsequent quantum jumps to coherent whole giving rise to the experienced flow of time.

What is the precise identification of self allowing to understand both of these aspects turned out to be difficult problem. I became aware the solution of the problem in terms of ZEO only quite recently (2014). Self indeed corresponds to a sequence of quantum jumps integrating to single unit, but these quantum jumps correspond to state function reductions to a fixed boundary of CD leaving the corresponding parts of zero energy states invariant. In positive energy ontology these repeated state function reductions would have no effect on the state but in TGD framework there occurs a change for the second boundary and gives rise to the experienced flow of time and its arrow and gives rise to self. The first quantum jump to the opposite boundary corresponds to the act of free will or wake-up of self.

There exists an infinite hierarchy of number theoretical entropies making sense for rational or even algebraic entanglement probabilities. In this case the entanglement negentropy can be negative so that negentropy maximization principle (NMP) favors generation of negentropic entanglement, which need not be bound state entanglement in standard sense. This leads to the vision that negentropic entanglement defines kind of Akashic records, kind of library storing potentially conscious information becoming conscious in interaction free measurement. Akashic records could define self model as opposed to self. Consistency with standard quantum measurement theory

requires that density matrix for negentropic entanglement is projector and thus equal to a unit matrix associated to a unitary entanglement matrix characterizing quantum computation.

Self is assumed to experience sub-selves as mental images identifiable as “averages” of their mental images. This implies the notion of ageing of mental images as being due to the growth of ensemble entropy as the ensemble consisting of quantum jumps (sub-sub-selves) increases.

The sub-selves of two unentangled selves can entangle although selves remain unentangled. This is possible by the modification of the subsystem concept forced by the p-adic length scale cutoff. The entanglement of sub-selves means fusion and sharing of mental images providing a universal telepathy like quantum communication mechanism and presumably making possible both molecular, cellular, and human societies.

1.1.3 Generalization of quantum measurement theory to a theory of consciousness

One must reformulate quantum measurement theory. The hypothesis that each quantum jump involves localization in the so called zero modes having interpretation as classical variables characterizing the observable geometric properties of the space-time surface, and thus of external macroscopic observer, together with an additional condition guaranteeing that the density matrix characterizing the entanglement between quantum fluctuating degrees of freedom and zero modes is diagonal, implies standard quantum measurement theory. Needless to emphasize, the reduction of the standard quantum measurement theory to fundamental quantum physics is a triumph of TGD approach.

This is however not the whole story. The standard quantum measurement is followed by a cascade self measurements inside self, which reduces entanglement between some subsystem and its complement in quantum fluctuating degrees of freedom: again a measurement of the density matrix is in question. This cascade is equivalent with the process of state preparation which is a phenomenological notion in the standard quantum measurement theory. The dynamics of self measurement is governed by Negentropy Maximization Principle (NMP), which specifies which subsystems are subject to quantum measurement in a given quantum jump. NMP can be regarded as a basic law for the dynamics of quantum jumps and states that the information content of the conscious experience is maximized. In p-adic context NMP dictates the dynamics of cognition.

Zero energy ontology changes considerably the interpretation of the unitary process and state function reduction. In zero energy ontology quantum states are replaced with zero energy states defined as superpositions of pairs of positive and negative energy states identified as counterparts of initial and final states of a physical event such as particle scattering. Zero energy ontology is ideal from the point of view of consciousness and intentionality. Everything can be in principle be created from vacuum so that several frustrating paradoxes plaguing positive energy ontology disappear. Also the quantum jumps between p-adic and real quantum states suggested to correspond to intentional action are mathematically sensible in zero energy ontology.

The matrix defining entanglement between positive and negative - christened as M -matrix- is the counterpart of the ordinary S -matrix but need not be unitary. It can be identified as a “complex square root” of density matrix expressible as a product of positive square root of diagonal density matrix and unitary S -matrix. Quantum TGD can be seen as defining a “square root” of thermodynamics, which thus becomes an essential part of quantum theory.

U -matrix is defined between zero energy states and cannot therefore be equated with the S -matrix used to describe particle scattering events. Unitary conditions however imply that U -matrix can be seen as a collection of M -matrices labelled by zero energy states so that the knowledge of U -matrix implies the knowledge of M -matrices. A natural guess is that U is directly related to consciousness and the description of intentional actions. For positive energy ontology state function reduction would serve as a state preparation for the next quantum jump. In zero energy ontology state function preparation and reduction can be assigned to the positive and negative energy states defining the initial and final states of the physical event. The reduction of the time-like entanglement during the state function reduction process corresponds to the measurement of the scattering matrix. In the case of negentropic time-like entanglement the reduction process is not random anymore and the resulting dynamics is analogous to that of cellular automata providing a natural description of the dynamics of self-organization in living matter.

Zero energy ontology leads to a precise identification of the subsystem at space-time level. General coordinate invariance in 4-D sense means that 3-surfaces related by 4-D diffeomorphisms

are physically equivalent. It is convenient to perform a gauge fixing by introducing a natural choice for the representatives of the equivalence classes formed by diffeo-related 3-surfaces.

1. Light-like 3-surfaces identified as surfaces at which the Minkowskian signature of the induced space-time metric changes to Euclidian one - wormhole contacts- are excellent candidates in this respect. The intersections of these surfaces with the light-like boundaries of CD defined 2-D partonic surfaces. Also the 3-D space-like ends of space-time sheets at the light-like boundaries of CDs are very natural candidates for preferred 3-surfaces.
2. The condition that the choices are mutually consistent implies effective 2-dimensionality. The intersections of these surfaces defining partonic 2-surface plus the distribution of 4-D tangent spaces at its points define the basic dynamical objects with 4-D general coordinate invariance reduced to 2-dimensional one. This effective 2-dimensionality was clear from the very beginning but is only apparent since also the data about 4-D tangent space distribution is necessary to characterize the geometry of WCW and quantum states. The descriptions in terms of 3-D light-like or space-like surfaces and even in terms of 4-D surfaces are equivalent but redundant descriptions. This has far reaching implications for the concrete mathematical realization of number theoretic universality [K19].

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

1.2 P-Adic Numbers And Consciousness

p-Adic number fields R_p (one number field for each prime $p = 2, 3, 5, \dots$) are analogous to real numbers but differ from them in that p-adic numbers are not well-ordered. p-Adic numbers play an absolutely essential role in the formulation of quantum TGD and of TGD inspired theory of consciousness. The inherent non-determinism of p-adic differential equations motivates the identification of the p-adic space-time sheets as cognitive representations of ordinary matter with p-adic non-determinism identified as non-determinism of imagination. Mind-matter duality is realized at the level of space-time geometry and mind stuff corresponds to p-adic regions of space-time. TGD Universe performs self mimicry in all length scales. Besides p-adic nondeterminism there is nondeterminism of Kähler action: these two nondeterminisms allow to represent some aspects of quantum jump sequences, that is contents of consciousness of selves, at space-time level cognitively and symbolically (language). This in turn makes possible self referentiality of consciousness: it is possible to become conscious about being conscious about...

1.2.1 Negentropy Maximization Principle and the notion of self

U -process is followed by a cascade of state function reductions. Negentropy Maximization Principle (NMP) states that in a given quantum state the most quantum entangled subsystem-complement pair can perform the quantum jump. More precisely: the reduction of the entanglement entropy in the quantum jump is as large as possible. This selects the pair in question and in case of ordinary entanglement entropy leads the selected pair to a product state. The interpretation of the reduction of the entanglement entropy as conscious information gain makes sense. The sequence of state function reductions decomposes at first step the entire system to two parts in such a manner that the reduction entanglement entropy is maximal. This process repeats itself for subsystems. If the subsystem in question cannot be divided into a pair of entangled free system the process stops since energy conservation does not allow it to occur (binding energy).

The original definition of self was as a subsystem able to remain unentangled under state function reductions associated with subsequent quantum jumps. Everything is consciousness but consciousness can be lost if self develops bound state entanglement during U process so that state function reduction to smaller un-entangled pieces is impossible. A second aspect of self was assumed to be the integration of subsequent quantum jumps to coherent whole giving rise to the experienced flow of time.

What is the precise identification of self allowing to understand both of these aspects turned out to be difficult problem. I became aware the solution of the problem in terms of ZEO only quite recently (2014). Self indeed corresponds to a sequence of quantum jumps integrating to single

unit, but these quantum jumps correspond to state function reductions to a fixed boundary of CD leaving the corresponding parts of zero energy states invariant. In positive energy ontology these repeated state function reductions would have no effect on the state but in TGD framework there occurs a change for the second boundary and gives rise to the experienced flow of time and its arrow and gives rise to self. The first quantum jump to the opposite boundary corresponds to the act of free will or wake-up of self.

p-Adic physics as correlate for cognition leads to the notion of negentropic entanglement possible in the intersection of real and p-adic worlds involves experience about expansion of consciousness. Consistency with standard quantum measurement theory forces negentropic entanglement to correspond to density matrix proportional to unit matrix. Unitary entanglement typical for quantum computing systems gives rise to unitary entanglement.

The first state function reduction - wake-up of self- at given boundary of CD is a hierarchical cascade proceeding from long to short scales. The reduction process can stop also if the self in question allows only decompositions to pairs systems with negentropic entanglement. This does not require that the system forms a bound state for any pair of subsystems so that the systems decomposing it can be free (no binding energy). This defines a new kind of bound state not describable as a jail defined by the bottom of a potential well. Subsystems are free but remain correlated by negentropic entanglement.

The ordinary state function reductions imply dissipation crucial for self organization and quantum jump could be regarded as the basic step of an iteration like process leading to the asymptotic self-organization patterns. One could regard dissipation as a Darwinian selector as in standard theories of self-organization. NMP thus predicts that self organization and hence presumably also fractalization can occur inside selves. NMP would favor the generation of negentropic entanglement. This notion is highly attractive since it could allow to understand how quantum self-organization generates larger coherent structures. Note that state function reduction for negentropic entanglement is highly deterministic since the number of degenerate states with same negative entanglement entropy is expected to be small. This could allow to understand how living matter is able to develop almost deterministic cellular automaton like behaviors. In ZEO this self-organization is for 4-D spatio-temporal patterns since 3-surfaces are pairs of space-like surfaces at the boundaries of CD and maxima of Kähler function are selected in the process. These temporal patterns correspond to behaviors and functions in living matter.

1.2.2 Positive entanglement negentropy is possible in the intersection of real and p-adic worlds

Positive entanglement negentropy is possible in the intersection of real and p-adic worlds and is stable against NMP. Giving up the original ad hoc interpretation as a counterpart for bound state entanglement leads to a beautiful vision about the role of negentropic entanglement in cognition and functioning of living matter.

1. The first form of NMP was rather naive. There was no idea about the anatomy of quantum jump and NMP only stated that the allowed quantum jumps are such that the information gain of conscious experience measured by the reduction of entanglement entropy resulting in the reduction of entanglement between the subsystem of system and its complement is maximal. Later it became clear that quantum jump has a complex anatomy consisting of unitary process U followed by the TGD counterpart of state function reduction serving as a state preparation for the next quantum jump.
2. The attempts to formulate NMP in p-adic physics led to the realization that one can distinguish between three kinds of information measures.
 - (a) In real physics the negative of the entanglement entropy defined by the standard Shannon formula defines a natural information measure, which is always non-positive.
 - (b) In p-adic physics one can generalize this information measure to p-adic valued information measure by replacing the logarithms of p-adic valued probabilities with the p-based logarithms $\log_p(|P|_p)$ which are integer valued and can be interpreted as p-adic numbers. This p-adic valued entanglement entropy can be mapped to a non-negative real

number by the so called canonical identification $x = \sum_n x_n p^n \rightarrow \sum_n x_n p^{-n}$. In both cases a non-positive information measure results.

- (c) When the entanglement probabilities are rational numbers or at most finitely algebraically extended rational numbers one can still define logarithms of probabilities as p-based logarithms $\log_p(|P|_p)$ and interpret the entropy as a rational or algebraic number. In this case the entropy can be however negative and positive definite information measure is possible. Irrespective of number field one can in this case define entanglement entropy as a maximum of number theoretic entropies S_p over the set of primes. The first proposal was that the algebraic entanglement corresponds to bound state entanglement turned out to be wrong.
3. At some stage the importance of the almost trivial fact that bound state entanglement must be kinematically stable against NMP became obvious. One can imagine that the state function reduction proceeds step by step by reducing the state to two parts in such a manner that the reduction of entanglement entropy is maximal.
 - (a) If a resulting subsystem corresponds to a bound state having no decomposition to free subsystems the process stops for this subsystem. The natural assumption is that subsystems lose their consciousness when U process leads to bound state entanglement whereas bound state itself can be conscious.
 - (b) If the entanglement is negentropic (and thus rational or algebraic) a more natural interpretation consistent with the teaching of spiritual practices is that subsystems experience a fusion to a larger conscious entity. The negentropic entanglement between free states is stabilized by NMP and negentropically entangled states need not reside at the bottom of potential well forbidding the reduction of entanglement. This makes possible new kinds of correlated states for which binding energy can be negative. Bound state entanglement would be like the jail of organized marriage and negentropic entanglement like a love marriage in which companions are free to leave but do not what it. The existence of this kind of negentropic entanglement is especially interesting in living matter, where metabolism (high energy phosphate bond in particular) and the stability of DNA and other highly charged polymers is poorly understood physically: negentropic entanglement could be responsible for stabilization making possible the transfer of metabolic energy [K12].
 4. For the negentropic entanglement the outcome of the state function reduction ceases to be random as it is for the standard definition of entanglement entropy. Note however that U process as a creative act yielding superposition of possibilities from which state function reduction selects leaves means non-determinism. This has far reaching consequences. Ordinary state function reductions for an ensemble of systems lead to a generation of thermodynamical entropy and this explains the second law of thermodynamics. In the case of negentropic entanglement situation changes and the predicted breaking of second law of thermodynamics provides a new view to understand self-organization [K29]. and living matter could be identified as something residing in the intersection of real and p-adic worlds where p-adic intentions can be transformed to real actions.
 5. One particular choice involved with state function reduction process could be the choice between generic entanglement and number theoretic entanglement possible only in the intersection of p-adic and real WCWs. If the choice is the generic entanglement, system ends up either to an unentangled state with maximal conscious freedom or to a bound state with a loss of consciousness. If the choice is algebraic entanglement, system ends up to negentropic entanglement and correlations with external world and experiences an expansion of consciousness. Maybe ethical choices are basically choices between these two options. Also positive emotions like love and experience of understanding could directly relate to various aspects of the negentropic entanglement.

1.3 TGD Inspired New Physics And Consciousness

ZEO, number theoretical universality, and hierarchy of Planck constants represent ideas, which have developed strongly during last half decade and have led to a considerable refinement of the overall view about consciousness and inspired also a vision about life as something residing in the intersection of real and p-adic worlds [K19].

1.3.1 TGD based space-time concept and the existence of macroscopic quantum phases

TGD implies a radical generalization of the space-time concept in all length and time scales. The concept of many-sheeted space-time leads to fresh proposals for how biosystems manage to be macroscopic quantum systems. Examples of these mechanisms are so called wormhole superconductivity, electronic high T_c super-conductivity, neutrino super-conductivity, ionic and a mechanism for generating coherent light and gravitons [K3, K4, K4, K23]. The notion of many-sheeted ionic equilibrium summarizes the basic vision about quantum control and coordination according to which the space-time sheets associated with the superconducting magnetic flux tube structures control ordinary biomatter at the atomic space-time sheets.

The so called massless extremals (MEs), which can be regarded as “topological light rays”, are carriers of especially important example of macroscopic quantum states. The lightlike boundaries of MEs act as quantum holograms and carry representations of the superconformal and super-symplectic algebras. These states have gigantic almost-degeneracies, and are genuine quantum gravitational states (state functionals in the configuration space of 3-surfaces, “the world of classical worlds”) and thus correspond to higher abstraction level than ordinary quantum states. MEs can control the supercurrents at superconducting magnetic flux tube structures by magnetic interactions, act as Josephson junctions, and induce magnetic quantum phase transitions. Therefore the quantum holograms associated with MEs are excellent candidates for quantum correlates of higher level consciousness.

1.3.2 Quantum criticality

The systems possessing self correspond to macroscopic quantum phases. In standard physics context the existence of the required macroscopic quantum phases is not at all obvious whereas the new physics implied by TGD predicts their existence. The point is that the Universe according to TGD is a quantum critical system. Quantum criticality is mathematically very similar to thermodynamical criticality and implies long range quantum correlations in all length scales. This in turn implies the existence of macroscopic quantum phases with large value of effective Planck constant and able to have negentropic entanglement - say entanglement characterized by a unitary matrix. TGD Universe is also quantum spin glass with state degeneracy broken only by the classical gravitational energy of the space-time sheets having same induced Kähler field.

This degeneracy basically makes it possible to have quantum coherence over time periods longer than CP_2 time of order 10^{-39} seconds characterizing the duration of single quantum jump so that biosystems can act as quantum computers in macroscopic time scales.

The understanding of quantum criticality has developed dramatically after writing the above lines.

1. 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 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 hyperfinite factors of type II_1 (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.

2. 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 sub-factor. Evolution understood as increase of h_{eff} forced by Negentropy Maximization Principle as also interpretation improvement of measurement/cognitive resolution.

1.3.3 Dark matter hierarchy

Basic objection against quantum theories of consciousness and biology relate to the smallness of Planck constant making difficult to imagine macroscopic quantum coherence in the scales of living matter. Zero energy ontology partially resolves the problem by assigning to elementary particles macroscopic length and time scales. For instance, the time scale assignable to the CD of electron is 1 seconds defining the fundamental bio-rhythm.

The anomalies related to the interaction of ELF em fields on living matter and Nottale's observation that planetary orbits correspond approximately to Bohr orbits with a gigantic value of Planck constant led to the hypothesis that Planck constant has a discrete spectrum and can have arbitrarily large values [K31, K9]. The identification of dark matter as phases having large value of Planck constant [K31, K11, K8] 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 [K11].

The hierarchy of Planck constants is realized in terms of a generalization of the causal diamond $CD \times CP_2$, where CD is defined as an intersection of the future and past directed light-cones of 4-D Minkowski space M^4 . $CD \times CP_2$ is generalized by gluing singular coverings and factor spaces of both CD and CP_2 together like pages of book along common back, which is 2-D sub-manifold which is M^2 for CD and homologically trivial geodesic sphere S^2 for CP_2 [K11]. The value of the Planck constant characterizes partially the given page and arbitrary large values of \hbar are predicted so that macroscopic quantum phases are possible since the fundamental quantum scales scale like \hbar . The most general spectrum comes in rational multiples of standard value of Planck constant which corresponds to the unit of rationals. For CDs the scaling of Planck constants means scaling of the size of CD. This could explain why the rational multiples of the fundamental frequency are so special for music experience.

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

It seems safe to conclude that the dark matter hierarchy with levels labelled by the values of Planck constants explains the macroscopic and macro-temporal quantum coherence naturally. That this explanation is consistent with the explanation based on spin glass degeneracy is suggested by the following observations. First, the argument supporting spin glass degeneracy as an explanation of the macro-temporal quantum coherence does not involve the value of \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.

At least dark matter could be a key player in quantum biology.

1. Dark matter hierarchy and p-adic length scale hierarchy would provide a quantitative formulation for the self hierarchy. To a given p-adic length scale one can assign a secondary p-adic time scale as the temporal distance between the tips of the CD. For electron this time scale is 1 second, the fundamental bio-rhythm. For a given p-adic length scale dark matter hierarchy gives rise to additional time scales coming as \hbar/\hbar_0 multiples of this time scale.
2. The predicted breaking of second law of thermodynamics characterizing living matter - if identified as something in the intersection of real and p-adic worlds - would be always below the time scale of CD considered but would take place in arbitrary long time scales at appropriate levels of the hierarchy. The scaling up of \hbar also scales up the time scale for the breaking of the second law.
3. The hypothesis that magnetic body is the carrier of dark matter in large \hbar phase has led to models for EEG predicting correctly the band structure and even individual resonance bands and also generalizing the notion of [J7] [K9]. Also a generalization of the notion of genetic code emerges resolving the paradoxes related to the standard dogma [K17, K9]. 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 [K9].

If one accepts the hierarchy of Planck constants [K11], it might be unnecessary to distinguish between self and quantum jump. The hierarchy of Planck constants interpreted in terms of dark matter hierarchy predicts a hierarchy of quantum jumps such that the size of space-time region contributing to the contents of conscious experience scales like \hbar . Also the hierarchy of space-time sheets labeled by p-adic primes suggests the same. That sequence of sub-selves/sub-quantum jumps are experienced as separate mental images explains why we can distinguish between digits of phone number. The irreducible component of self (pure awareness) would correspond to the highest level in the "personal" hierarchy of quantum jumps and the sequence of lower level quantum jumps would be responsible for the experience of time flow. Entire life cycle could correspond to single quantum jump at the highest(?) level of the personal self hierarchy and pure awareness would prevail during sleep: this would make it possible to experience directly that I existed yesterday.

There are thus two definitions of self. The first definition introduces self as a notion separate from quantum jump. Second definition reduces the notion of self to a fractal hierarchy of quantum jumps. The equivalence between two definitions of the notion of self will be proposed.

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

2 What Are The Problems Of Quantum Mind Theories?

In the following I list briefly the basic problems of physics and quantum mind theories using a classification which is rather natural from the point of view of physics.

2.1 Some Philosophical Problems Of Quantum Physics

"Monism, dualism, or something else?" is the first basic question. Monism appears as two variants which are mirror images. Materialism has the problem that consciousness becomes something totally reducible to the state of material system so that free will must be an illusion if one believes in the deterministic laws of physics. This is in a sharp contrast to what we directly experience. In the idealistic framework one loses completely physics. The difficulty of dualism- pointed out very clearly by Chalmers [J5] - is that it is very difficult to achieve consistency with the basic laws of physics which do not allow free will. It seems that one must have something new allowing to achieve consistency of the determinism of field equations with (partially) free will.

“Reductionism or not?” is second key question. For me personally the realization that reductionism is a mere dogma was a painful process although it was from the beginning clear that TGD based view about space-time forces to challenge this belief. It was especially painful to take seriously the fact that even the reduction of chemical bond to wave mechanics alone is nothing but a belief since it is not yet testable by performing numerical calculations. Gradually I became conscious about the many non-existing bridges of reductionism: the bridge from quarks and gluons to hadrons; the bridge from nucleons to nuclei; the bridge from atoms to molecules; the bridges from inorganic chemistry to organic chemistry to biochemistry: all these bridges are just figments of wishful thinking and implications of the reductionistic dogma rather than support for it. Also the widely accepted argument about living matter as something which is just complex fails to be distinguishable from a rhetoric trick.

“Determinism or not?” is the third question. Also here it took time to realize that the belief that free will is an illusion does not reflect the reality but our limited tools for describing it. The physicists of previous centuries did not have any conceptual and mathematical tools to describe free will without giving up the idea about laws of physics. Most importantly, they did not know anything about quantum non-determinism. Perhaps it is some kind of cognitive inertia that physicists have been ready to give up even the very notion of objective reality instead of accepting the fact that non-determinism is real and concluding that one should find an ontology consistent with both quantum non-determinism and Schrödinger equation.

- The notion of time is highly problematic.
 - The relationship between experienced time and the geometric time of physicist is poorly understood. Subjective time is irreversible and has only recent moment and past, geometric time is reversible and spans entire eternity. The assignment of experienced time with a 3-D wave front shifting in the direction of geometric time direction is in conflict with Lorentz symmetry and general coordinate invariance, which do not allow to identify a unique time coordinate as the subjective time. The natural basic object in general relativity is 4-dimensional space-time region, not time=constant snapshot.
 - In physics conceptual difficulties are encountered already in the phenomenological description of dissipation by adding to the reversible field equations phenomenological dissipation terms. Rather remarkably, the quantum mechanical formulas for the reaction rates in terms used to calculate dissipation coefficients involve integral over entire space-time so that quantum events have at least formally an infinite duration. Finite duration is certainly necessary by Uncertainty Principle. Somehow quantum jump seems to involve entire geometric eternity: as if it would take place between two geometric eternities.
 - There is also the problem of initial state. If the dynamics is deterministic and conservation laws hold, only a single solution of field equations is realized in classical physics and theoretical physics becomes useless waste of time since it cannot be tested. If quantum non-determinism is allowed, conservation laws still restrict the physical states to those having fixed net values. “What was the initial state at the moment of Big Bang?” is the question which cannot be answered in the framework of physics alone and one ends up doing metaphysics. Indeed, the recent crisis of M-theory- meant to be the final jewel in the crown of materialistic and reductionistic science- has led to the landscape problem, and many colleagues have given up the hope that ultimate theory could predict anything so that anthropic principle would be the only manner to connect theory with experiment.

2.2 Basic Philosophical Problems Of Quantum Mind Theories

At least the following problems could be seen as basic philosophical problems of quantum mind theories.

- What are the quantum correlates for consciousness? Entanglement has been proposed as a correlate of consciousness. For instance, in the orchestrated reduction approach of Hameroff

and Penrose the period of consciousness ends with a state function reduction and quantum gravitation is believed to play a fundamental role in the understanding of consciousness. The believer in free will could see state function reduction or its generalization as a natural quantum correlate for a moment of consciousness. The basic objection is that the randomness of state function reduction does not allow genuine goal directed free will. One could also argue that state function reduction generates entropy at least at the level of ensemble whereas intentional action should do just the opposite. Here one must however remember that entropy generation at the level of aspect need not mean entropy generation at the level of the member of ensemble.

- How the determinism of field equations and Schrödinger equation can be consistent with the non-determinism of the state function reduction? This question must be answered unless one is ready to give up the notion of objective reality completely or to believe in multiverse interpretation. These manners to circumvent the basic problem do not however leave much room for quantum consciousness theorizing. The closely related question about the relationship between experienced time and time of physicist has been already mentioned.
- What is the quantum correlate for the notion of self? The quantum notion of self should be a generalization of the notion of observer which in quantum measurement theory still remains a structureless outsider.
- What conscious information is? Can one give it a mathematical measure? Can one measure physically the amount of conscious information? Unfortunately the recent day physics can only provide measure for dis-information as Shannon entropy and the best that subsystem can achieve is no information at all if this picture is accepted.
- There is a bundle of questions about the quantum correlates of various aspects of conscious experience. For instance, what is the quantum correlate of mental image, and what are the quantum correlates of cognition, Boolean mind, sensory qualia, memory, and of emotions?
- An especially challenging question relates to the quantum correlate for the self referentiality of consciousness making possible reflective levels of consciousness. What it means physically to be conscious about what one is (or perhaps only “was”) conscious? Jack Sarfatti was well aware about this problem and in his dualistic approach talked about feedback loop but still used a trick in which one divides various fields to matter-like and mind-like.

2.3 Basic Problems Of Quantum Biology And Quantum Neuroscience

The basic problems of quantum biology and neuroscience are closely related unless one is ready to believe that consciousness reduces to one particular function assignable to some particular part of brain (“consciousness module”). This kind of assignment can be imagined in engineerish neuroscience identifying brain as electric circuitry but does not have much sense in quantum mind approach.

The first list of first principle questions includes at least the following ones.

- What distinguishes between living and dead matter is certainly the fundamental question. In standard biology based on materialistic philosophy one tries to reduce the distinction to a list of properties which as such can be possessed by inanimate matter. Ability to replicate, to process information, to communicate, to form representations about the external world, the ability to self-organize to increasingly complex configurations, intentional behavior, ability to co-operate, could be properties of this kind. Up to self-organization the reduction seems plausible. It is easy to model self-organization (by say cell automatons) but it this dynamics is like the dynamics of traffic rules and neither classical nor quantum dynamics resembles it. Intentional behavior is impossible to understand in classical physics unless one claims that it is a mere illusion. This is the case also in quantum physics as we understand it since the randomness of the outcome of state function reduction seems to be in conflict with intentional behavior. Here one must however keep in mind that the individual subsystem performing a state function reduction could quite well experience it as an intentional action. In any case, standard view about state function reduction makes it difficult to co-operative behavior.

- What distinguishes between biochemistry and organic chemistry? For instance, how biomolecules can find themselves in the dense soup of biomolecules and how can one understand the effectiveness of bio-catalysts? One might think that these problems are well-understood since we have learned what happens in DNA replication, transcription, and translation and we know the complex reaction pathways. The dynamics involved is very much like the symbolic dynamics of society (one can predict the day of practicing professional from knowing his profession but not from the knowledge of initial data of every possible elementary particle in his body). But what makes the soup of biomolecules a molecular society obeying a dynamics based on symbols? The description of biochemistry in terms of kinematics allows to construct complex reaction pathways based on the idea that each step of the reaction pathway requires a key which fits to a lock of a room containing a key to the lock to the next room [I6] but can one really deduce this kind of kinematics from standard quantum theory?
- Both biology and neuroscience characterizes subsystems of biological systems and brain in terms of functions they possess and one should also understand whether and how the quantum counterparts of functions emerge. The identification of various functions as time evolution of standard self-organization patterns is certainly a part of the answer. But what self-organization means? Conscious information is certainly the key notion but is the existing quantum theory able to characterize it?
- At the level of brain one of the key questions concerns EEG. Since EEG correlates strongly with the contents of consciousness it is difficult to believe that it is random side product of neural activity. What is then the real role of neuronal activity and EEG and its variants? Why EEG is needed? Signalling related to communication and control is what comes first in mind. But why this kind of signalling would be needed. Brain sends (receives) information but who receives (sends) it?
- How macroscopic quantum coherence is achieved allowing quantum super-positions in long time scales? How stable quantum entanglement is achieved? These are difficult problems if one wants to understand quantum mind without generalizing quantum theory itself. Planck constant is simply too small so that dissipation rates are too high and coherence times and lengths are too short. Should physicists adopt a humbler attitude and consider seriously the possibility that the existing physics is not enough and try to learn from biology instead of saying that living systems are just complex?

2.4 Could Anomalies Help?

Anomalies are the best way to end up with a discovery of something new. Of course, living matter as such is a gigantic anomaly but this does not help much. One should pick up the anomalies which are in sharp conflict with the existing physics and give a clear hint about what is wrong with our cherished assumptions.

- In quantum mind approach EEG should be a quantal phenomenon since it correlates with consciousness. From the basic formula $E = hf$ of quantum mechanics the energies of EEG photons are however ridiculously small as compared to the thermal energy at physiological temperatures. The strange quantal looking effects of ELF photons on vertebrate (why just vertebrate?!) brain at frequencies which correspond to cyclotron frequencies of biologically important ions such as Ca^{++} are however an experimental fact (see for instance [J4]). The effects of magnetic field patterns on brain studied by Persinger and collaborators represent also an example of this kind of strange effects [J14]. The strange findings about the behavior of cell membrane [I5] suggest that ionic currents do not dissipate much. The recently discovered burning of water when irradiated by radio wave photons [D4, D1] suggests that energetically these photons behave like photons of visible light. The recent findings about photosynthesis [I3] suggest quantum coherence in cellular length scale.

Is standard quantum theory able to explain these findings? Should one challenge the belief that Planck constant is just a conversion factor between units which can be put equal one with a suitable choice of units? Could Planck constant have a spectrum of discrete values? This would explain the strange findings since by $E = hf$ relation low frequencies could

correspond to high energies and dissipation rates -in the first guess inversely proportional to \hbar - could be very small. Large values of Planck constant would also increase the spatial and time scales of quantum coherence and might solve the basic technical problem of quantum consciousness theories.

- Also bio-photons [I4] correlate with the state of living system but are poorly understood in the existing theoretical framework.
- Libet's findings about strange time delays associated with the passive aspects of consciousness serve also as a hint. Our sensory data has age which is a fraction of second and corresponds to a photon wavelength $\lambda = cT$ to a length scale, which is of order of Earth size. As if sensory data would be communicated somewhere. Where?
- Cyclotron frequencies of biologically important ions in a magnetic field. 2 Gauss (smaller than the nominal value of 5 Gauss of the Earth's magnetic field) are involved with the effects of ELF radiation on vertebrate brain. Also Schumann resonances are reported to have effects on brain. Are some kind of magnetic field structures involved? Earth's magnetic field and perhaps also the magnetic field patterns associated with biological system itself with $B = 2B_E/5$ for one important level in the hierarchy? As noticed in [J18], the cyclotron energy scale of electron in pT range is in EEG range and pT range indeed characterizes the magnetic field associated with brain activity. Do also these magnetic structures carry Cooper pairs of electrons?
- ADP-ATP machinery is the core of energy metabolism and its description involves the problematic notion of high energy phosphate bond [I2]. Does this notion really reduce to standard quantum theory?
- The chiral selection of biomolecules in living matter [I1, I7] means a large parity breaking. This is a complete mystery in standard model which predicts extremely small parity breaking effects. Therefore chiral selection is extremely valuable anomaly helping to guess what kind of new physics might be involved with living matter. Somehow it seems that the parity breaking effects which are large in electro-weak scale appear in immensely zoomed up scales (scaling factors of order 10^{10} would be involved)

3 Some Aspects Of Quantum TGD

In the following I summarize very briefly those basic notions of TGD which are especially relevant for TGD inspired consciousness theory and quantum biology. The representation will be practically formula free. The article series published in Prespace-time Journal [?, ?, ?, ?, ?, ?, ?, ?] describes the mathematical theory behind TGD. The seven books about TGD [K38, K27, K22, K40, K33, K28, K32] provide a detailed summary about the recent state of TGD.

3.1 New Space-Time Concept

The physical motivation for TGD was what I have christened the energy problem of General Relativity. The notion of energy is ill-defined because the basic symmetries of empty space-time are lost in the presence of gravity. The way out is based on assumption that space-times are imbeddable as 4-surfaces to certain 8-dimensional space by replacing the points of 4-D empty Minkowski space with 4-D very small internal space. This space -call it S - is unique from the requirement that the theory has the symmetries of standard model: $S = CP_2$, where CP_2 is complex projective space with 4 real dimensions [?], is the unique choice.

The replacement of the abstract manifold geometry of general relativity with the geometry of surfaces brings the shape of surface as seen from the perspective of 8-D space-time and this means additional degrees of freedom giving excellent hopes of realizing the dream of Einstein about geometrization of fundamental interactions.

The work with the generic solutions of the field equations assignable to almost any general coordinate invariant variational principle led soon to the realization that the space-time in this framework is much more richer than in general relativity.

1. Space-time decomposes into space-time sheets with finite size: this lead to the identification of physical objects that we perceive around us as space-time sheets. For instance, the outer boundary of the table is where that particular space-time sheet ends. Besides sheets also string like objects and elementary particle like objects appear so that TGD can be regarded also as a generalization of string models obtained by replacing strings with 3-D surfaces.
2. Elementary particles are identified as topological inhomogeneities glued to these space-time sheets. In this conceptual framework material structures and shapes are not due to some mysterious substance in slightly curved space-time but reduce to space-time topology just as energy- momentum currents reduce to space-time curvature in general relativity.
3. Also the view about classical fields changes. One can assign to each material system a field identity since electromagnetic and other fields decompose to topological field quanta. Examples are magnetic and electric flux tubes and flux sheets and topological light rays representing light propagating along tube like structure without dispersion and dissipation making em ideal tool for communications [K23]. One can speak about field body or magnetic body of the system.

Field body indeed becomes the key notion distinguishing TGD inspired model of quantum biology from competitors. The magnetic body inherits from the biological body an onion-like fractal structure. Each part of the magnetic body can be seen as an intentional agent using the corresponding part of the biological body as a motor instrument and sensory receptor. The size scale of the magnetic body is in general much larger than that of biological body. Cyclotron frequency identified as frequency of photons able to exist as oscillations at magnetic body gives an estimate for the size of the magnetic body corresponding to a particular magnetic field strength. For 10 Hz frequency the size scale is of order Earth size. In this framework a fractal generalization of EEG and its variants provides a communication and control tool for magnetic body. The findings of Libet about time delays associated with the passive aspects and meaning that sensory data is a fraction of second old [J10] could be understood as delays due to the finite velocity of light: it takes finite time for the signal to propagate from biological body to the magnetic body.

This obviously means a profound modification of the views about what we are. The identification with the biological body could be understood as an illusion: a child looking a movie assimilates completely with the hero. There is a rich variety of illusions related to this identification of observer with the region of space from which the dominating contribution to consciousness comes from.

3.2 Zero Energy Ontology

In standard ontology of quantum physics physical states are assumed to have positive energy. In zero energy ontology physical states decompose to pairs of positive and negative energy states such that all net values of the conserved quantum numbers vanish. The interpretation of these states in ordinary ontology would be as transitions between initial and final states, physical events. By quantum classical correspondences zero energy states must have space-time and imbedding space correlates.

1. Positive and negative energy parts reside at future and past light-like boundaries of causal diamond (CD) defined as intersection of future and past directed light-cones and visualizable as double cone. The analog of CD in cosmology is big bang followed by big crunch. CDs for a fractal hierarchy containing CDs within CDs. Disjoint CDs are possible and CDs can also intersect.
2. p-Adic length scale hypothesis [?]otivates the hypothesis that the temporal distances between the tips of the intersecting light-cones come as octaves $T = 2^n T_0$ of a fundamental time scale T_0 defined by CP_2 size R as $T_0 = R/c$. One prediction is that in the case of electron this time scale is .1 seconds defining the fundamental biorhythm. Also in the case u and d quarks the time scales correspond to biologically important time scales given by 10 ms for u quark and by 2.5 ms for d quark [K2]. This means a direct coupling between microscopic and macroscopic scales.

Zero energy ontology conforms with the crossing symmetry of quantum field theories meaning that the final states of the quantum scattering event are effectively negative energy states. As long as one can restrict the consideration to either positive or negative energy part of the state ZEO is consistent with positive energy ontology. This is the case when the observer characterized by a particular CD studies the physics in the time scale of much larger CD containing observer's CD as a sub-CD. When the time scale sub-CD of the studied system is much shorter than the time scale of sub-CD characterizing the observer, the interpretation of states associated with sub-CD is in terms of quantum fluctuations.

ZEO solves the problem of initial state since in principle any zero energy state is obtained from any other state by a sequence of quantum jumps without breaking of conservation laws. The fact that energy is not conserved in general relativity based cosmologies can be also understood since each CD is characterized by its own conserved quantities. As a matter of fact, one must speak about average values of conserved quantities since one can have a quantum superposition of zero energy states with the quantum numbers of the positive energy part varying over some range.

For thermodynamical states this is indeed the case and this leads to the idea that quantum theory in ZEO can be regarded as a “complex square root” of thermodynamics obtained as a product of positive diagonal square root of density matrix and unitary S -matrix. M -matrix defines time-like entanglement coefficients between positive and negative energy parts of the zero energy state and replaces S -matrix as the fundamental observable. In standard quantum measurement theory this time-like entanglement would be reduced in quantum measurement and regenerated in the next quantum jump if one accepts Negentropy Maximization Principle (NMP) [K19] as the fundamental variational principle. Various M -matrices define the rows of the unitary U matrix characterizing the unitary process part of quantum jump. From the point of view of consciousness theory the importance of ZEO is that conservation laws in principle pose no restrictions for the new realities created in quantum jumps: free will is maximal.

3.3 The Hierarchy Of Planck Constants

The motivations for the hierarchy of Planck constants come from both astrophysics and biology. The biological motivations have been already discussed. In astrophysics the observation of Not-tale [?] that planetary orbits in solar system seem to correspond to Bohr orbits with a gigantic gravitational Planck constant motivated the proposal that Planck constant might not be constant after all [K31, K24].

This led to the introduction of the quantization of Planck constant as an independent postulate. It has however turned that quantized Planck constant in effective sense could emerge from the basic structure of TGD alone. Canonical momentum densities and time derivatives of the imbedding space coordinates are the field theory analogs of momenta and velocities in classical mechanics. The extreme non-linearity and vacuum degeneracy of Kähler action imply that the correspondence between canonical momentum densities and time derivatives of the imbedding space coordinates is 1-to-many: for vacuum extremals themselves 1-to-infinite.

A convenient technical manner to treat the situation is to replace imbedding space with its n -fold singular covering. Canonical momentum densities to which conserved quantities are proportional would be same at the sheets corresponding to different values of the time derivatives. At each sheet of the covering Planck constant is effectively $\hbar = n\hbar_0$. This splitting to multi-sheeted structure can be seen as a phase transition reducing the densities of various charges by factor $1/n$ and making it possible to have perturbative phase at each sheet (gauge coupling strengths are proportional to $1/\hbar$ and scaled down by $1/n$). The connection with fractional quantum Hall effect [D2] is almost obvious. At the more detailed level one finds that the spectrum of Planck constants would be given by $\hbar = n_a n_b \hbar_0$.

This has many profound implications, which are wellcome from Quantum Mind perspective.

1. Quantum coherence and quantum superposition become possible in arbitrary long length scales. One can speak about zoomed up variants of elementary particles and zoomed up sizes make it possible to satisfy the overlap condition for quantum length parameters used as a criterion for the presence of macroscopic quantum phases. In the case of quantum gravitation the length scale involved are astrophysical. This would conform with Penrose's intuition that

quantum gravity is fundamental for the understanding of consciousness and also with the idea that consciousness cannot be localized to brain.

2. Photons with given frequency can in principle have arbitrarily high energies by $E = hf$ formula, and this would explain the strange anomalies associated with the interaction of ELF em fields with living matter [J4]. Quite generally the cyclotron frequencies which correspond to energies much below the thermal energy for ordinary value of Planck constant could correspond to energies above thermal threshold.
3. The value of Planck constant is a natural characterizer of the evolutionary level and biological evolution would mean a gradual increase of the largest Planck constant in the hierarchy characterizing given quantum system. Evolutionary leaps would have interpretation as phase transitions increasing the maximal value of Planck constant for evolving species. The space-time correlate would be the increase of both the number and the size of the sheets of the covering associated with the system so that its complexity would increase.
4. The phase transitions changing Planck constant change also the length of the magnetic flux tubes. The natural conjecture is that biomolecules form a kind of Indra's net connected by the flux tubes and \hbar changing phase transitions are at the core of the quantum bio-dynamics. The contraction of the magnetic flux tube connecting distant biomolecules would force them near to each other making possible for the bio-catalysis to proceed. This mechanism could be central for DNA replication and other basic biological processes. Magnetic Indra's net could be also responsible for the coherence of gel phase and the phase transitions affecting flux tube lengths could induce the contractions and expansions of the intracellular gel phase. The reconnection of flux tubes would allow the restructuring of the signal pathways between biomolecules and other subsystems and would be also involved with ADP-ATP transformation inducing a transfer of negentropic entanglement [K12] (see **Fig.** <http://tgdtheory.fi/appfigures/cat.jpg> or **Fig. ??** in the appendix of this book). The braiding of the magnetic flux tubes could make possible topological quantum computation like processes and analog of computer memory realized in terms of braiding patterns [K10].
5. p-Adic length scale hypothesis and hierarchy of Planck constants suggest entire hierarchy of zoomed up copies of standard model physics with range of weak interactions and color forces scaling like \hbar . This is not conflict with the known physics for the simple reason that we know very little about dark matter (partly because we might be making misleading assumptions about its nature).

Dark matter would make possible the large parity breaking effects manifested as chiral selection of bio-molecules [I1]. What is required is that classical Z^0 and W fields responsible for parity breaking effects are present in cellular length scale. If the value of Planck constant is so large that weak scale is some biological length scale, weak fields are effectively massless below this scale and large parity breaking effects become possible.

For the solutions of field equations which are almost vacuum extremals Z^0 field is non-vanishing and proportional to electromagnetic field. The hypothesis that cell membrane corresponds to a space-time sheet near a vacuum extremal (this corresponds to criticality very natural if the cell membrane is to serve as an ideal sensory receptor) leads to a rather successful model for cell membrane as sensory receptor with lipids representing the pixels of sensory qualia chart. The surprising prediction is that bio-photons [I4] and bundles of EEG photons can be identified as different decay products of dark photons with energies of visible photons. Also the peak frequencies of sensitivity for photoreceptors are predicted correctly [K25].

3.4 P-Adic Physics And Number Theoretic Universality

p-Adic physics [K35, K40] has become gradually a key piece of TGD inspired biophysics. Basic quantitative predictions relate to p-adic length scale hypothesis and to the notion of number theoretic entropy. Basic ontological ideas are that life resides in the intersection of real and p-adic worlds and that p-adic space-time sheets serve as correlates for cognition.

3.4.1 p-Adic number fields

p-Adic number fields Q_p [A3] -one for each prime p - are analogous to reals in the sense that one can speak about p-adic continuum and that also p-adic numbers are obtained as completions of the field of rational numbers. One can say that rational numbers belong to the intersection of real and p-adic numbers. p-Adic number field Q_p allows also an infinite number of its algebraic extensions. Also transcendental extensions are possible. For reals the only extension is complex numbers.

p-Adic topology defining the notions of nearness and continuity differs dramatically from the real topology. An integer which is infinite as a real number can be completely well defined and finite as a p-adic number. In particular, powers p^n of prime p have p-adic norm (magnitude) equal to p^{-n} in Q_p so that at the limit of very large n real magnitude becomes infinite and p-adic magnitude vanishes.

p-Adic topology is rough since p-adic distance $d(x, y) = d(x - y)$ depends on the lowest binary digit of $x - y$ only and is analogous to the distance between real points when approximated by taking into account only the lowest digit in the decimal expansion of $x - y$. A possible interpretation is in terms of a finite measurement resolution and resolution of sensory perception. p-Adic topology looks somewhat strange. For instance, p-adic spherical surface is not infinitely thin but has a finite thickness and p-adic surfaces possess no boundary in the topological sense. Ultra-metricity is the technical term characterizing the basic properties of p-adic topology and is coded by the inequality $d(x - y) \leq \text{Min}\{d(x), d(y)\}$. p-Adic topology brings in mind the decomposition of perceptive field to objects.

3.4.2 Physical and biological motivations for p-adic number fields

The physical motivations for p-adic physics came from the observation that p-adic thermodynamics -not for energy but infinitesimal scaling generator of so called super-conformal algebra [A1] acting as symmetries of quantum TGD [K27] - predicts elementary particle mass scales and also masses correctly under very general assumptions [K40]. In particular, the ratio of proton mass to Planck mass, the basic mystery number of physics, is predicted correctly. The basic assumption is that the preferred primes characterizing the p-adic number fields involved are near powers of two: $p \simeq 2^k$, k positive integer. Those nearest to power of two correspond to Mersenne primes $M_n = 2^n - 1$. One can also consider complex primes known as Gaussian primes, in particular Gaussian Mersennes $M_{G,n} = (1 + i)^n - 1$.

It turns out that Mersennes and Gaussian Mersennes are in a preferred position physically in TGD based world order. What is especially interesting is that the p-adic length scale range 10 nm-5 μm contains as many as four scaled up electron Compton lengths $L_e(k) = \sqrt{5}L(k)$ assignable to Gaussian Mersennes $M_k = (1 + i)^k - 1$, $k = 151, 157, 163, 167$ [K25]. This number theoretical miracle supports the view that p-adic physics is especially important for the understanding of living matter.

p-Adic length scale hypothesis suggests the identification of metabolic energy currencies as energy quanta liberated as particle drops from space-time sheet to a larger one. These energy quanta correspond to increments of zero point kinetic energy. Metabolic energy currencies would be completely universal and exist already during the prebiotic era so that metabolic machinery would build up around this pre-existing structure. A simple (and also rough) model based on p-adic length scale hypothesis allows to estimate the increments of zero point kinetic energy. The quantum corresponding to about 5 eV has place in this hierarchy for which basic energies (those for which larger space-time sheet is very large) come as octaves of basic energy quantum [K2, K15]. These energy quanta do not have interpretation in terms of molecular transitions and there exist anomalous lines of radiation from interstellar space both in IR, visible, and UV region [K2].

3.4.3 Life as something in the intersection of real and p-adic worlds

The philosophical for p-adic numbers fields come from the question about the possible physical correlates of cognition [K21]. Cognition forms representations of the external world which have finite cognitive resolution and the decomposition of the perceptive field to objects is an essential element of these representations. Therefore p-adic space-time sheets could be seen as candidates of thought bubbles, the mind stuff of Descartes.

Rational numbers belong to the intersection of real and p-adic continua. An obvious generalization of this statement applies to real manifolds and their p-adic variants. When extensions of p-adic numbers are allowed, also some algebraic numbers can belong to the intersection of p-adic and real worlds. The notion of intersection of real and p-adic worlds has actually two meanings.

1. The intersection could consist of the rational and possibly some algebraic points in the intersection of real and p-adic partonic 2-surfaces at the ends of CD. This set is in general discrete. The interpretation could be as discrete cognitive representations.
2. The intersection could also have a more abstract meaning. For instance, the surfaces defined by rational functions with rational coefficients have a well-defined meaning in both real and p-adic context and could be interpreted as belonging to this intersection. There is strong temptation to assume that intentions are transformed to actions only in this intersection. One could say that life resides in the intersection of real and p-adic worlds in this abstract sense.

Additional support for the idea comes from the observation that Shannon entropy $S = -\sum p_n \log(p_n)$ allows a p-adic generalization if the probabilities are rational numbers by replacing $\log(p_n)$ with $-\log(|p_n|_p)$, where $|x|_p$ is p-adic norm. Also algebraic numbers in some extension of p-adic numbers can be allowed. The unexpected property of the number theoretic Shannon entropy is that it can be negative and its unique minimum value as a function of the p-adic prime p it is always negative. Entropy transforms to information!

In the case of number theoretic entanglement entropy there is a natural interpretation for this. Number theoretic entanglement entropy would measure the information carried by the entanglement whereas ordinary entanglement entropy would characterize the uncertainty about the state of either entangled system. For instance, for p maximally entangled states both ordinary entanglement entropy and number theoretic entanglement negentropy are maximal with respect to R_p norm. Entanglement carries maximal information. The information would be about the relationship between the systems, a rule. Schrödinger cat would be dead enough to know that it is better to not open the bottle completely.

Negentropy Maximization Principle [K19] coding the basic rules of quantum measurement theory implies that negentropic entanglement can be stable against the effects of quantum jumps unlike entropic entanglement. Therefore living matter could be distinguished from inanimate matter also by negentropic entanglement possible in the intersection of real and p-adic worlds. In consciousness theory negentropic entanglement could be seen as a correlate for the experience of understanding or any other positively colored experience, say love.

Negentropically entangled states are stable but binding energy and effective loss of relative translational degrees of freedom is not responsible for the stability. Therefore bound states are not in question. The distinction between negentropic and bound state entanglement could be compared to the difference between unhappy and happy marriage. The first one is a social jail but in the latter case both parties are free to leave but do not want to. The special characteristics of negentropic entanglement raise the question whether the problematic notion of high energy phosphate bond citebbioHEP central for metabolism could be understood in terms of negentropic entanglement. This would also allow an information theoretic interpretation of metabolism since the transfer of metabolic energy would mean a transfer of negentropy [K12].

4 Consciousness Theory As Extension Of Quantum Measurement Theory

TGD inspired theory of consciousness [K18] could be seen as a generalization of quantum measurement theory. The notions of quantum jump and self self are the key notions. Negentropy Maximization Principle (NMP) [K19] is the basic dynamical principle. NMP is mirror image for the second law of thermodynamics and states that the amount of conscious information gain in quantum jump is maximal. NMP reproduces standard quantum measurement theory for entropic entanglement and is in this case consistent with the second law since the non-determinism of state function reductions implies the increase of ensemble entropy.

4.1 Quantum Jumps As Moment Of Consciousness

The starting point of TGD inspired theory of consciousness was the identification of quantum jump as a moment of consciousness [K18].

1. Quantum jump has a complex anatomy which however simplifies in ZEO. Quantum jump involves unitary time evolution leading from a state resulting in state function reduction to a quantum superposition of states: one could speak of multiverse. This step is described by the counterpart of the unitary process of Penrose and is coded by a unitary matrix U in the state space formed by zero energy states. U is therefore not identifiable directly as S -matrix of quantum field theories but contains as its rows all possible M -matrices which are what particle physicist tries to measure in laboratory. State function reduction and state preparation can be assigned to the opposite light-like boundaries of CD.

A good metaphor is Djinn in the bottle. In U -process bottle is opened and Djinn comes out and creates a quantum superposition of all possible worlds. The wish of the observer is fulfilled and leads to a state function reduction. Actually there is an entire cascade of state function reductions starting from the level of the entire universe which splits the entanglement sub-systems already obtained in a step-wise manner to pairs un-entangled sub-systems. The splitting for a given sub-system occurs only if it is consistent with NMP.

For the ordinary definition of entanglement entropy the process would lead to a completely unentangled situation. If the number theoretic entanglement entropy making sense for rational (and even algebraic) entanglement probabilities is allowed, the process stops unless the reduction of entanglement reduces the entanglement entropy. Therefore the number theoretic entanglement possible in the intersection of real and p -adic worlds can be stable and living systems are able to preserve their coherence.

2. Since the reduction cascade proceeds from top to bottom, one can speak about fractal formed by quantum jumps within quantum jumps. One cannot assign to the steps of this sequence any duration of geometric time. One can however associate to it an experienced duration and it is very tempting to assume that the experienced duration increases as one climbs up in the self hierarchy.
3. Quantum jump replaces the quantum superposition of classical histories (space-time surfaces, classical worlds) with a new one whereas ordinary state function reduction would do this for time=constant snapshot of Schrödinger evolution. Quantum jump does not spoil the determinism of classical dynamics or of Dirac equation since it occurs entirely outside space-time and Hilbert space. In quantum jump both the geometric future and past (defined only within measurement resolution) are replaced with new ones. The mysterious finding of Libet [J1] that intentional action is preceded by neural activity can be interpreted in this framework without giving up the notion of free will. This raises a fascinating question about time scales in which the geometric past can be affected in quantum jump. Also memories stored in the geometric past can be affected in quantum jumps and the fact that memories are highly unstable suggest that the time scale is measured in years.

It must be added that the notion of classical determinism in its standard form fails due to the special properties of Kähler action (vacuum degeneracy mathematically analogous to a gauge degeneracy but physically analogous to 4-D spin glass degeneracy). This failure provides a space-time correlate for the non-determinism of the quantum jump sequence.

4.2 The Notion Of Self

The notion of self can be seen as a generalization of the notion of observer. The original definition of self was as a subsystem able to remain unentangled under state function reductions associated with subsequent quantum jumps. Everything is consciousness but consciousness can be lost if self develops bound state entanglement during U process so that state function reduction to smaller un-entangled pieces is impossible. A second aspect of self was assumed to be the integration of subsequent quantum jumps to coherent whole giving rise to the experienced flow of time.

What is the precise identification of self allowing to understand both of these aspects turned out to be difficult problem. I became aware the solution of the problem in terms of zero energy

ontology (ZEO) only quite recently (2014). Self indeed corresponds to a sequence of quantum jumps integrating to single unit, but these quantum jumps correspond to state function reductions to a fixed boundary of causal diamond CD leaving the corresponding parts of zero energy states invariant. The parts of zero energy states at second boundary of CD change even the position of opposite boundary changes: one actually has wave function over positions of second boundary (CD sizes roughly) and this wave function changes. In positive energy ontology these repeated state function reductions would have no effect on the state but in TGD framework there occurs a change for the second boundary and gives rise to the experienced flow of time and its arrow and gives rise to self. The first quantum jump to the opposite boundary corresponds to the act of free will or wake-up of self. Hence act of free will means change of the arrow of psychological time at some level of hierarchy of CDs.

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

There exists an infinite hierarchy of number theoretical entropies [K19] making sense for rational or even algebraic entanglement probabilities. In this case the entanglement negentropy can be negative so that Negentropy Maximization principle (NMP) favors generation of negentropic entanglement, which need not be bound state entanglement in standard sense.

In the case of negentropic entanglement (see **Fig.** <http://tgdtheory.fi/appfigures/cat.jpg> or **Fig. ??** in the appendix of this book) a more natural interpretation is that expansion of consciousness rather than loss of it is experienced as self entangles with second system negentropically. Only entropic entanglement would lead to a loss of consciousness. Second condition would be that self is stable against splitting to unentangled subsystems. This criterion is satisfied if self corresponds to a system for which the entanglement between its subsystems is negentropic.

This leads to the vision that negentropic entanglement defines kind of Akashic records, kind of library storing conscious or potentially conscious information. According to the recent view, Akashic records could define self as opposed to self model defined in terms of memory representations relying on bits. Consistency with standard quantum measurement theory [K19] requires that density matrix for negentropic entanglement is proportional to unit matrix associated to unitary entanglement matrix associated with quantum computation. “Akashic records” would define self and would be consciously experienced.

Self experiences its sub-selves as mental images and even we would represent mental images of some higher collective self. Everything would be conscious but consciousness could be only lost. The flow of consciousness for a given self could be due to the quantum jump sequences performed by its sub-selves giving rise to mental images.

By quantum classical correspondence self has also space-time correlates. One can visualize sub-self as a space-time sheet “glued” by topological sum to the space-time sheet of self. Subsystem is not described as a tensor factor as in the standard description of subsystems. Also sub-selves of selves can entangle negentropically and this gives rise to a sharing of mental images about which stereo vision would be basic example. Quite generally, one could speak of stereo consciousness. Also the experiences of sensed presence [J18] could be understood as a sharing of mental images between brain hemispheres which are not themselves entangled. This is possible also between different brains. In the normal situation brain hemispheres are entangled.

At the level of 8-dimensional imbedding space the natural correlate of self would be CD (causal diamond). At the level of space-time the correlate would be space-time sheet or light-like 3-surface. The contents of consciousness of self would be determined by the space-time sheets in the interior of CD. Without further restrictions the experience of self would be essentially four-dimensional. Memories would be like sensory experiences except that they would be about the geometric past and for some reason are not usually colored by sensory qualia. As already noticed, .1 second time scale defining the duration of moment for sensory experience corresponds to that of electron’s CD which suggests that Cooper pairs of electrons are essential for the sensory qualia.

4.3 How Experienced Time And The Geometric Time Of Physicist Relate To Each Other?

The relationship between experienced time and time of physicist is one of the basic puzzles of modern physics. In the proposed framework they are certainly two different things and the challenge is to understand why the correlation between them is so strong that it has led to their identification. One can imagine several alternative views explaining this correlation [K36, K37, K1] and it is better to keep mind open.

4.3.1 Basic questions

The flow of subjective time corresponds to quantum jump sequences for sub-selves of self having interpretation as mental images. If mind is completely empty of mental images subjectively experienced time ceases to exist. This leaves however several questions to be answered.

1. Why the contents of conscious of self comes from a finite space-time region looks like an easy question. If the contents of consciousness for sub-selves representing mental images is localized to the sub-CDs with indeed have defined temporal position inside CD assigned with the self the contents of consciousness is indeed from a finite space-time volume. This implies a new view about memory. There is no need to store again and again memories to the “brain now” since the communications with the geometric past by negative energy signals and also time-like negentropic quantum entanglement allow the sharing of the mental images of the geometric past.
2. There are also more difficult questions. Subjective time has arrow and has only the recent and possibly also past. The subjective past could in principle reduce to subjective now if conscious experience is about 4-D space-time region so that memories would be always geometric memories. How these properties of subjective time are transferred to apparent properties of geometric time? How the arrow of geometric time is induced? How it is possible that the locus for the contents of conscious experience shifts or at least seems to be shifted quantum jump by quantum jump to the direction of geometric future? Why the sensory mental images are located in a narrow time interval of about .1 seconds in the usual states of consciousness (not that sensory memories are possible: scent memories and phantom pain in leg could be seen as examples of vivid sensory memory)?

4.3.2 The recent view about arrow of time

The basic intuitive idea about the explanation for the arrow of psychological time has been the same from the beginning - diffusion inside light-cone - but its detailed realization has required understanding of what quantum TGD really is. The replacement of ordinary positive energy ontology with zero energy ontology (ZEO) has played a crucial role in this development. The TGD based vision about how the arrow of geometric time is by no means fully developed and final. It however seems that the most essential aspects have been understood now.

1. What seems clear now is the decisive role of ZEO and hierarchy of CDs, and the fact that the quantum arrow of geometric time is coded into the structure of zero energy states to a high extent. The still questionable but attractively simple hypothesis is that U matrix two basis with opposite quantum arrows of geometric time: is this assumption really consistent with what we know about the arrow of time? If this is the case, the question is how the relatively well-defined quantum arrow of geometric time implies the experienced arrow of geometric time. Should one assume the arrow of geometric time separately as a basic property of the state function reduction cascade or more economically- does it follow from the arrow of time for zero energy states or only correlate with it?
2. The state function reductions can occur both boundaries of CD. If the reduction occurs at given boundary is immediately followed by a reduction at the opposite boundary, the arrow of time alternates: this does not conform with intuitive expectations: for instance, this would imply that there are two selves assignable to the opposite boundaries!

Zero energy states are however de-localized in the moduli space CDs (size of CD plus discrete subgroup of Lorentz group defining boosts of CD leaving second tip invariant). One has quantum superposition of CDs with difference scales but with fixed upper or lower boundary belonging to the same light-cone boundary after state function reduction. In standard quantum measurement theory the repetition of state function reduction does not change the state but now it would give rise to the experienced flow of time. Zeno effect indeed requires that state function reductions can occur repeatedly at the same boundary. In these reductions the wave function in moduli degrees of freedom of CD changes. This implies “dispersion” in the moduli space of CDs experienced as flow of time with definite arrow. This view lead to a precise definition of self as sequence of quantum jumps to the reducing to the same boundary of CD.

3. This approach codes also the arrow of time at the space-time level: the average space-time sheet in quantum superposition increases in size as the average position of the “upper boundaries” of CDs drift towards future state function reduction by state function reduction.
4. In principle the arrow of time can temporarily change but it would seem that this can occur in very special circumstances and probably takes place in living matter routinely. Phase conjugate laser beam is a non-biological example about reversal of the arrow of time. The act of volition would correspond to the first state function reduction to the opposite boundary so that the reversal of time arrow at some level of the hierarchy of selves would take place in the act of volition.

4.4 Quantum Correlates For Various Aspects Of Conscious Experience

The identification of quantum correlates of cognition and intentionality, of sensory qualia, Boolean mind, and of emotions [K13] represents one challenge for Quantum Mind theories. As already explained, p-adic physics, the vision about life as something residing in the intersection of real and p-adic worlds, and the notion of number theoretic entropy provide a plausible starting point when one tries to say something about the geometric and quantum correlates of cognition and intentionality. Zero energy ontology makes possible the transitions transforming p-adic zero energy states to their real counterparts and having interpretation in terms of intentional action.

1. Quantum numbers characterize quantum states. Therefore the increments ΔQ of quantum numbers for a subsystem should characterize quantum jumps and it is attractive to assign classify fundamental qualia in terms of quantum number increments. “The increments of quantum numbers for a sub-system representing self” looks innocent but what it really means is surprisingly difficult to make precise. The following attempt relies on ZEO.
 - (a) For the positive energy part of state located at “lower” boundary of CD self - subsystem S - and environment E are un-entangled. At the “upper” boundary there is entanglement between S and E , and it should be able to assign qualia as quantum number increments to this entanglement.
 - (b) Consider increments of color quantum numbers identified in terms of visual colors as an example. In the positive energy state color quantum numbers for an unentangled subsystem S vanish by color confinement. In negative energy state they can be non-vanishing for S but vanish for $S \otimes E$. The experienced qualia for S are determined as quantum averages of color quantum numbers in the entangled state and expressible in terms of the sub-system density matrix. One can indeed assign to the zero energy state increments ΔQ_{ZEO} of color quantum numbers as difference of color quantum numbers for S at “upper” and “lower” boundaries of C . These increments characterize zero energy state rather than quantum jump.
 - (c) In state function reduction the entanglement at upper boundary is reduced if the entanglement is entropic whereas negentropic entanglement can be stable. Quale is experienced sensorily as long as quantum jumps preserve negentropic entanglement. When entanglement is eventually reduced, the experience can be only a memory about the experienced quale. The increments ΔQ of color quantum numbers in quantum jump can be identified as $\Delta Q = \Delta Q_{ZEO}$. Hence this notion is indeed well-defined.

- (d) This interpretation allows to assign to the quantum jump also space-time evolution changing the quantum numbers in the same manner as they change in quantum jump. This is what quantum-classical correspondence indeed requires.

One application is the identification of basic colors in terms of color quantum number increments of quantum states [K13]. This identification makes sense if one accepts the fractal hierarchy of QCD like dynamics allowed by p-adic length scale hierarchy and by the hierarchy of Planck constants. The original concrete model was provided by the capacitor model of sensory qualia in which a large number of particles which same quantum numbers flows to a subsystem during quantum jump inducing the analog of di-electric breakdown (note the analogy with nerve pulse). Bose-Einstein condensation provides one possible realization. In this case one can say that the quantum numbers of the particle in question represent the basic quale which is amplified.

The above picture forces to modify this view by replacing a color capacitor with a fixed size with that of a variable size corresponding to the size of system S and $S \otimes E$: the second plate of capacitor either in S or environment. The flow of charges associated with the transition generating quale still makes sense and generates strong color polarization in the scale $S \otimes E$. In the model the increase of the size of the color capacitor means a formation of flux tubes between the sensory receptor and environment such that net color is non-vanishing only for these flux tubes. In state function reduction reducing entanglement the flux tubes are split and S become color neutral but can represent a memory about the quale as negentropic color neutral entanglement in the scale of S : some sub-system of S can now experience the color quale. This suggests a holographic memory in which quale eventually is represented in very small scale in terms of negentropic entanglement.

The argument involves assumption about color confinement. In the case of qualia assignable to electromagnetic charges, spin, etc... similar assumption makes sense. Even in case of momentum and angular momentum this assumption makes sense and means that subsystem in the state of experiencing momentum or angular momentum increment as quale is in a real accelerated motion in the scale of CD. As a matter fact, the vanishing of quantum numbers of S in absence of entanglement might not be necessary for the interpretation.

2. One could also speak about Boolean qualia and fermions provide possible correlates for them. The 2^N many-fermion states of fermionic Fock space for N fermionic qubits define a basis of Boolean algebra. The entangled pairs of fermionic states associated with the positive and negative energy parts of zero energy states define quantal Boolean functions as sums over entangled pairs of many fermion states. Negentropic entanglement could define a representation of a rule with entangled pairs representing various instances of the rule. Time-like entanglement would define a representation for a "law of physics" and M -matrices would be fundamental representations of this kind. The increments of the fermionic quantum numbers could define Boolean qualia and one can imagine Boolean capacitor mechanism allowing to amplify a given Boolean statement.

One should be also able to say something about the quantum correlates of emotions. Here the notion of negentropic entanglement might be the key concept.

1. Emotions have a quale like character. For instance, psychological pleasure and pain resemble their physiological counterparts- and quite generally there is a tendency to assign to emotions the attributes of sensory experience. It would be attractive to assign this positive/negative dichotomy to the increase/reduction of entanglement negentropy. Emotion would represent Boolean bit as the sign of negentropy increment. The destruction of generation of negentropic entanglement would therefore be the core element of emotional quale. The character of entanglement involved would determine whether the emotion corresponds to pleasure or pain, joy or sorrow, pride or shame.

In the case of physiological pain or pleasure it is easy to imagine that the cause of pain destroys/creates negentropic entanglement. Pain and pleasure at this level relates directly to what happens to metabolism. This is easy to understand if the basic function of energy metabolism is to transfer negentropic entanglement. For higher level emotions the negentropy

reduction or increase could be produced artificially to give an emotional content for something regarded as important.

2. Very often emotions are characterized by good-bad/right-wrong dichotomy characterizable by single binary digit. Perhaps emotions provide a representation of a high level summary about large amounts information, a kind of Boolean function of very many qubits. The function of neural transmitters can be often interpreted in terms of reward or punishment. Information and emotions seem to be closely related: peptides are often regarded as both information molecules and molecules of emotion [J3]. This can be understood if the function of information molecule is to induce emotional response representing the information.
3. Comparison to a standard -be it moral rule, expected or desired behavior, or something else- is rather often an essential aspect of emotion. Comparison can in principle be represented as a quantal Boolean function involving the standard (say moral rule) represented in terms of negentropic entanglement. If the Boolean instance compared with the rule corresponds to an instance allowed by the rule, positive emotion results. Otherwise the emotion is negatively colored. One might also think that there is expectation for the result of comparison. If the outcome differs from expected- which corresponds to a flip of bit, positive or negative emotion results but could do so as a secondary representation. The above argument suggests that the outcome of comparison does not represent the emotion as such but there is a neural circuitry encoding the outcome to reward or punishment.

4.5 Self Referentiality Of Conscious Experience

Self referentiality of consciousness is one of its most mysterious looking aspects. In a loose formulation one could say that system is able to be conscious what it *is* conscious of. This formulation however leads to an infinite hierarchy of reflective levels and therefore to a paradox. One can however milder the formulation by saying that self-referential system is able to be conscious about what it *was* conscious of (with respect to subjective time of course!)

In this formulation quantum classical correspondence gives hopes about the understanding of self-referentiality. Quantum classical correspondence means in TGD framework that not only quantum states but also quantum jump sequences have space-time correlates. The failure of classical determinism for Kähler action in standard sense of the word is responsible for this and relates directly to the basic properties distinguishing TGD Universe from that of standard model. This allows to imagine that quantum jump leading from a superposition of space-time surfaces to a new one also gives rise to a representation of the conscious experiences which preceded the last quantum jump at the level of space-time geometry. Reductio ad absurdum would transform to evolution of consciousness able to add to the existing hierarchy a new reflective level in each quantum jump.

I have proposed several correlates for the self-referentiality of consciousness. Many-sheeted space-time would provide the physical representation (see **Fig. <http://tgdtheory.fi/appfigures/manysheeted.jpg>** or **Fig. 9** in the appendix of this book).

4.5.1 Many-sheeted space-time and self-referentiality

The fractal hierarchy of magnetic flux tubes giving rise to braids, which in turn make possible topological quantum computation would be a rather realization of this representation, A possible concrete physical realization of self-referentiality is suggested by DNA as quantum computer model [K10]. One assumes that DNA nucleotides and lipids are connected by magnetic flux tubes. Since the lipid layer of the cell membrane is 2-dimensional liquid crystal, the lipids are in continual hydrodynamical motion and this means in time direction entanglement of the orbits. The events in nearby environment and also nerve pulses affect this flow. This braiding in time direction defines a topological quantum computation. This motion entangles also the flux tubes connecting the lipids to DNA nucleotides so that when the topological quantum computation halts it becomes stored into memory as space-like entanglement. In TGD framework also the time-like braiding provides a space-time representation of the quantum computation which also gives to a conscious experience at some level of the hierarchy.

4.5.2 Infinite primes and self-referentiality

The hierarchy of infinite primes (and of integers and rationals) [K34] was the first mathematical notion stimulated by TGD inspired theory of consciousness. The construction recipe is equivalent with a repeated second quantization of a super-symmetric arithmetic quantum field theory with bosons and fermions labeled by primes such that the many-particle states of previous level become the elementary particles of new level. At a given level there are free many particle states plus counterparts of many particle states. There is strong structural analogy with polynomial primes. For polynomials with rational coefficients free many-particle states would correspond to products of first order polynomials and bound states to irreducible polynomials with non-rational roots.

The hierarchy of space-time sheets with many particle states of space-time sheet becoming elementary particles at the next level of hierarchy. For instance, the description of proton as an elementary fermion would be in a well defined sense exact in TGD Universe. Also the hierarchy of n : th order logics are possible correlates for this hierarchy.

This construction leads also to a number theoretic generalization of space-time point since a given real number has infinitely rich number theoretical structure not visible at the level of the real norm of the number a due to the existence of real units expressible in terms of ratios of infinite integers. This number theoretical anatomy suggest a kind of number theoretical Brahman=Atman identity stating that the set consisting of number theoretic variants of single point of the imbedding space (equivalent in real sense) is able to represent the points of WCW or maybe even quantum states assignable to causal diamond. One could also speak about algebraic holography.

The correspondence between the quantum states defined by WCW spinor fields and wave functions in the infinite-dimensional discrete space of hyper-octonionic units can be made more concrete [K34]. These wave functions must transforming irreducibly under discrete subgroup $SU(3)$ of octonion automorphisms transforming ordinary hyper-octonionic prime to a new hyper-octonionic prime. $SU(3)$ has interpretation as color group. One can assign standard model quantum numbers to these wave functions and prime property in principle fixes the spectrum of possible quantum states- in particular the spectrum of masses. Therefore the extremely esoteric looking notion of infinite prime might turn out to be very practical calculational tool.

4.5.3 Quantum Mathematics and self referentiality of consciousness

In Quantum Mathematics numbers are replaced with Hilbert spaces and the dimension of Hilbert space - in appropriately. generalized sense - characterizes the number.

1. This suggests a generalization of calculus for Hilbert spaces. Mathematical objects which are defined for numbers in various number fields become well defined when these numbers are replaced with Hilbert spaces. One can speak of the Hilbert space analogs of algebraic numbers, transcendentals, p -adic numbers and their extensions. Anything having as a building brick rationals, algebraic numbers, real or p -adic numbers or finite fields generalizes. Even the notions like matrix group, algebras, and ring generalize. Also the notion of manifold generalizes as well as the notion of calculus.
2. The Hilbert space in associated with the element of number field characterizes its number theoretic anatomy and therefore could be a correlate of cognition. The crucial step in the generalization of this process to the level of the Hilbert space representing points. Points of Hilbert spaces can be replaced with Hilbert spaces and process can be repeated ad infinitum. This suggests that the self-referentiality at the deepest level corresponds to this fractal view about space-time based on assignment of quantum dynamics to numbers. Also a connection with the hierarchy of n : th order logics. A close relationship to infinite primes would not be surprising since in both cases one an infinite hierarchy of processes analogous to second quantization is involved. A natural question is whether many-sheeted space-time provides a dynamical representation in terms of space-time sheets for the number theoretic anatomy so that kind of Brahman=Atman identity or algebraic holography would hold true. This correspondence could be see as a cognitive representation of external world and one could also see the external world as symbolic representation of the world of cognition.
3. A connection with generalized Feynman diagrams and hierarchy of Planck constants is suggestive and the idea was originally inspired by the observation that the two vertices of gen-

eralized Feynman diagrams identifiable as generalizations of the basic stringy 3-vertex for closed strings and basic 3-vertex for Feynman diagrams correspond naturally to direct sum and tensor product in turn having natural correspondence with $+$ and \times of the usual arithmetics. This correspondence motivates the introduction of co-operations of direct sum and tensor product meaning that quantum dynamics is brought into the game through these vertices. This suggests that Quantum Mathematics is actually Quantum dynamics in which generalized Feynman diagrams define sequences of arithmetic or even more general algebraic operations.

If so, the basic structures of Quantum Mechanics (QM) might reduce to fundamental mathematical and metamathematical structures, and that one even consider the possibility that Quantum Mechanics reduces to Quantum Mathematics with mathematician included or expressing it in a concise manner: QM=QM!

The fractal character of the Quantum Mathematics is what makes it a good candidate for understanding the self-referentiality of consciousness. The replacement of the Hilbert space with the direct sum of Hilbert spaces defined by its points would be the basic step and could be repeated endlessly corresponding to a hierarchy of statements about statements or hierarchy of n^{th} order logics. The construction of infinite primes leads to a similar structure.

What about the step leading to a deeper level in hierarchy and involving the replacement of each point of Hilbert space with Hilbert space characterizing it number theoretically? What could it correspond at the level of states?

1. Suppose that state function reduction selects one point for each Hilbert space $x_n \times p^n$. The key step is to replace this direct sum of points of these Hilbert spaces with direct sum of Hilbert spaces defined by the points of these Hilbert spaces. After this one would select point from this very big Hilbert space. Could this point be in some sense the image of the Hilbert space state at previous level? Should one imbed Hilbert space $x_n \times p^n$ isometrically to the Hilbert space defined by the preferred state $x_n \times p^n$ so that one would have a realization of holography: part would represent the whole at the new level. It seems that there is a canonical manner to achieve this. The interpretation as the analog of second quantization suggest the identification of the imbedding map as the identification of the many particle states of previous level as single particle states of the new level.
2. Could topological condensation be the counterpart of this process in many-sheeted space-time of TGD? The states of previous level would be assigned to the space-time sheets topologically condensed to a larger space-time sheet representing the new level and the many-particle states of previous level would be the elementary particles of the new level.
3. If this vision is correct, second quantization performed by theoreticians would not be a mere theoretical operation but a fundamental physical process necessary for cognition! The above proposed unitary imbedding would imbed the states of the previous level as single particle states to the new level. It would seem that the process of second quantization, which is indeed very much like self-reference, is completely independent from state function reduction and unitary process. This picture would conform with the fact that in TGD Universe the theory about the Universe is the Universe and mathematician is in the quantum jumps between different solutions of this theory.

5 Various Types Of Conscious Experiences

In the following the general structure and classification of conscious experiences is discussed. Most predictions are brain independent. Assuming that zero modes of the configuration space, characterizing the geometry of macroscopic classical space-time, determine the geometric information contents of conscious experience and identifying macroscopic quantum phases as quantum correlates of various sensory modalities, one can make rather far reaching predictions about basic aspects of, say, sensory experience of any experiencer, be it human brain or some strange life form in distant galaxy.

5.1 Basic Structure Of Conscious Experience

Before continuing, it is perhaps useful to recall the basic anatomy of the quantum jump: $\Psi_i \rightarrow U\Psi_i \rightarrow \Psi_{f_0} \rightarrow \dots \Psi_f$, where the final quantum history Ψ_f is a superposition of space-time surfaces, which are macroscopically equivalent and only bound state entanglement is present. Every space-time surface of the superposition consists of parallel space-time sheets (connected by wormhole contacts). Some of these space-time sheets have infinite time extension and some have not. The latter ones are “mindlike space-time sheets”. One must make a clear distinction between the quantum superposition of the space-time surfaces and the decomposition of the space-time surface to space-time sheets.

5.1.1 Real and imagined experiences

The assumption that p-adic physics is physics of imagination means division of qualia to real qualia and imagined qualia. There are good arguments based on mathematical consistency that in p-adic WCW degrees of freedom complete localization occurs in each quantum jump (see Appendix). This means that there are no quantum fluctuations in p-adic degrees of freedom and since non-geometric sensory qualia like color correspond to quantum number increments in quantum fluctuating degrees of freedom, there are no p-adic non-geometric qualia. This however leaves p-adic geometric qualia determined by the increments of p-adic WCW coordinates. This view is certainly consistent with intuitive notion that cognitive qualia are only about the geometric aspects, like shape and size, of the objects of the external world.

One could debate about whether cognition can be identified as imagination but this is the working hypothesis made. The transformations of thoughts into actions or sensory experiences and of sensory inputs into thoughts correspond to p-adic–real phase transitions for mindlike space-time sheets so that one can speak about matter-mind interaction in a well-defined sense. Cognition is predicted to be present already at elementary particle length scales and this assumption is crucial for understanding the success of the p-adic length scale hypothesis works and p-adic mass calculations.

One can identify p-adic space-time sheets as correlates of memes [J20] and relate them to the morphic fields of Sheldrake. The p-adic vision about cognition is discussed in [K21].

5.1.2 Whole-body consciousness and ordinary consciousness

TGD predicts two basic modes of consciousness.

1. Reducible self is the state in which sub-selves are “falling asleep” and “waking up” all the time, corresponds naturally to the ordinary state of consciousness. Sub-selves represent mental images which pop out and disappear all the time.
2. In case of irreducible self quantum jumps do not lead to a generation of sub-selves. Thus the sub-systems of irreducible self have only bound state entanglement and self measurement cascade stops at irreducible self. This state is presumably accompanied by the experience of “oneness” and could therefore be called a state of “whole-body consciousness”. The absence of the sub-selves means the absence of mental images so that the identification as a state of pure self awareness without any contents is natural. Less ideal situation is that sub-selves are generated but are very short lived and represent short flashes against background awareness. “Whole-body-consciousness” presumably means abnormally low metabolism since dissipation inside sub-selves is not present.

5.1.3 Active and passive aspects of conscious experience

Conscious experience involves two fundamental contributions.

1. The “non-classical” contribution from the quantum measurement reducing quantum entanglement associated with the fermionic degrees of freedom and with the quantum fluctuating configuration space degrees of freedom (as opposed to zero modes).
2. The “classical” contribution determined by the localization in zero modes and by the selection between different degenerate preferred extremals.

The natural guess is that the experienced free will corresponds to the non-determinism of the quantum jump somehow. The standard objection is that the non-determinism of the quantum measurement gives rise to randomness rather than volition. Quantum numbers relate to microscopic aspects of the quantum jump and the average quantum numbers measured in quantum jumps probably sum up to zero in the presence of energy feed and external perturbations. Indeed, if temporal binding for the experiences of self involves averaging, this component of experience need not give rise to an experience of volition since it is expected to average out for large number of quantum jumps (10^{38} per second by the argument for the arrow of psychological time). Therefore the time averaging involved with the temporal binding smooths out this non-determinism.

Here the special features of TGD however come in rescue.

1. The first candidate for the quantum correlate of volition is the localization in zero modes. This localization corresponds to the spontaneous symmetry breaking of quantum field theories which selects one classical configuration among many degenerate ones. Spontaneous symmetry breaking has been suggested to be a basic aspect of the quantum jump also by Joel Henkel [J12]. Asymptotic localization in zero modes seems to be however determined statistically by the self-organization process taking the system to the bottom of some valley of the spin glass energy landscape. Hence volition need not be in question.
2. The second candidate for volition is classical non-determinism of Kähler action (which gives rise to the geometric model of thought as “association sequence”). The selection between the different degenerate alternative classical time evolutions, that is different degenerate absolute minima $X^4(Y^3)$ going through a given 3-surface Y^3 , is an excellent candidate for the volitional act. The reason is that absolute minima differ macroscopically so that the choice between degenerate minima dramatically affects the entire geometric future. Note also that the selection between branches of a multifurcation of macroscopic space-time is in question, the choice can be done only when mindlike space-time sheet is located in a narrow time interval around multifurcation and is hence irreversible.

The identification of the classical non-determinism as a geometric correlate of the volitional non-determinism is in nice accordance with the “ontogeny recapitulates phylogeny” principle stating that the geometric time evolution at the level of the space-time surface reflects the time evolution by quantum jumps at the level of the configuration space. One can however argue that this kind of volition is still passive in that it is only a selection between given alternatives rather than a transformation of an intention to action. The second objection is that there are actually infinite number of options between which to select in the state function reduction: why do we not experience these alternatives consciously?

3. The third candidate for volition is a quantum jump in which p-adic-to-real transformation for a p-adic space-time sheet representing cognitively intention occurs so that it becomes an action. For long time I believed that this identification of the volitional act is the most realistic one. It does not however explain why intention develops as a plan and will to do something and leads to horrible mathematical challenges which might be impossible to meet.
4. The recent view is implied by zero energy ontology (ZEO). In ZEO self corresponds to a sequence of state function reductions at fixed boundary of causal diamond (CD) changing only the situation at the opposite boundary (in standard quantum measurement theory nothing would happen to the state). This sequence can also give also rise to the development of intention. The volitional action begins with the first state function reduction to the opposite boundary of CD and means that the sub-self (mental image, we are also mental images) dies and reincarnates at the opposite boundary of CD. This picture leads to a simple answer to the basic questions and is certainly the most feasible one found hitherto. The strong prediction is that the arrow of time is not fixed and the behavior of living systems can be interpreted by accepting that the arrow of time can change.

An interesting possibility is that the zero modes characterizing the macroscopic features of the macroscopically equivalent space-time surfaces present in the *final* quantum state of quantum jump determine the contents of at least sensory experiences. This would be in accord with the idea that pure sensory experiences represent quantities which indeed “are in the world”, the world being

identified as the macroscopic space-time associated with the final quantum history of the quantum jump. One could however argue that it is only *the increments of zero modes* in quantum jump, which are perceived directly consciously: this claim is consistent with the fact that insects are able to see only the motion and that also human visual consciousness is crucially dependent on saccadic motion. Localization in the zero modes involves the fixing of the parameters characterizing the shape and size of the 3-surface X^3 as well as the Kähler field of $X^4(X^3)$. Kähler field can reduce to a purely electromagnetic or Z^0 type classical gauge field and is in general also accompanied by a classical color field. The spatio-temporal patterns of the induced Kähler field should correlate strongly with the contents of the conscious experience.

5.2 Cognition And P-Adic Physics

p-Adic non-determinism follows from the fact that functions with vanishing derivatives are piecewise constant functions in the p-adic context. More precisely, p-adic pseudo constants depend on the pinary cutoff of their arguments and replace integration constants in p-adic differential equations. In case of field equations this means roughly that the initial data are replaced with initial data given for a discrete set of time values chosen in such a manner that a unique solution of field equations results. Solution can be fixed also in a discrete subset of rational points of the imbedding space. Presumably the uniqueness requirement implies some unique pinary cutoff.

Thus the space-time surfaces representing solutions of p-adic field equations are analogous to space-time surfaces consisting of pieces of solutions of the real field equations. Thus p-adic reality is much like the dream reality consisting of rational fragments glued together in illogical manner or pieces of child's drawing of body containing body parts in more or less chaotic order.

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

5.3 Reflective- And Proto-Levels Of Consciousness

The decomposition into proto consciousness and reflective consciousness (consciousness about being conscious) is one of the fundamental features of conscious experience. Logical thinking is also a fundamental component of conscious mind and probably also the mind unconscious-to-us, in fact so fundamental one that it has inspired the computationalistic approach to consciousness. One can consider two alternative identifications for the reflective level of consciousness.

5.3.1 Boolean mind as reflective mind?

The state basis of the Fock space generated by N fermionic creation operators is isomorphic with the Boolean algebra consisting of 2^N possible statements about N basic statements. This follows from the simple observation that by Pauli exclusion principle the fermion number associated with a given fermion state can have only two values: 0 (false) or 1 (true). This observation leads to the idea that many fermion states give representation for what might be called reflective consciousness in the sense that the information contents for experiences about conscious experiences could correspond to the quantum jumps in the fermionic sector.

A more convincing interpretation is that Boolean mind is only a special case of reflective mind. In p-adic case only quaternion conformal degrees of freedom are possible for WCW spinors (see appendix) and since pure cognition involves no emotions and no values it must correspond to logic (true/false). In real case the spin associated with the WCW metric correlates with the sensory experience and naturally corresponds to the logic of aesthetics (beautiful/ugly) whereas real quaternion conformal degrees of freedom having no correlation with the sensory experience correspond naturally to the logic of ethics (right/wrong), or more generally the true/false logic of belief system having strong right/wrong emotional coloring. Thus the Goodness-Truth-Beauty trinity would thus have a reduction to the Boolean algebra defined by the Fock basis for the WCW spinors.

TGD based model of abstraction process involves a hierarchy of statements about statements about.... starting from 2 basic statements such that the statement represented by empty set in the set theoretic realization of Boolean algebra is thrown away at each step. The model predict besides the genetic code also a memetic code consisting of 127-bit code words such that 126-bit statements form a maximal number of mutually consistent statements. In case of genetic code 7-bit code words represent all possible statements and 64-bit codewords represent statements consistent with a fixed atomic statement (single bit fixed).

In real context, 6-bit code words for the genetic code and 126 bit code words for the memetic code form a maximal number of mutually consistent “this is right thing to do” beliefs. 7-bit resp. 127-bit code words can be interpreted as coding these statements and their negations: all bits must be realized in p-adic case since formal logic requires also the negations of the basic statements. Lying is a cognitive skill. Genetic code would represent in case of the molecular society the moral and social rules whereas memetic code would represent these rules in case of the ordinary society. DNA would provide a symbolic representation for the 64 fundamental truths, kind of a legal code.

5.3.2 Symbolic and cognitive representations as means of becoming conscious about being conscious about?

An alternative identification of the reflective mind is in terms of language and cognitive representations made possible by the nondeterminism of Kähler action and inherent nondeterminism of p-adic differential equations. These nondeterminisms allow to represent contents of consciousness of self (quantum jump sequence) cognitively and symbolically and to become conscious these representations: this is nothing but becoming conscious about being conscious about...

The (inconvincing) Boolean identification of reflective mind predicts a single directly experienced reflective level. In the second case given quantum jump allows the emergence of only single new reflective level. Indeed, it is easy to become conscious about seeing red but one cannot have direct experience of being conscious about being conscious about seeing red. It is also easy to build theorems about theorems (or imagine what happens under given circumstances) but deriving theorems about theorems about theorems looks impossible without paper and pencil.

Zero energy ontology allows to realize the vision about the reflective hierarchy of consciousness in a concrete manner. The basic building blocks would be negentropically entangled systems representing rules with state pairs defining the entangled state interpreted as instances of the rule. One can construct rules about rules as states formed from this kind of states. The many-sheeted space-time would provide geometric correlates for these rules about rules. The hierarchy of infinite primes would also relate to this abstraction hierarchy.

5.4 General Model For Sensory Experiences

The concept of self provides considerable insight to the model of sensory experiencing.

1. If temporal binding involves averaging over the experiences occurred after the wake-up, experiences are reliable.
2. Also the averaging over the experiences of separate sensory subsub-selves implied by the summation hypothesis could be involved.
3. Sensory experiences can involve more than the direct experiencing: also a comparison with the earlier sensory data could quite well be involved and is made possible by subjective and geometric memories. Sensory experiences certainly involve computational aspects.

In the following the general model of sensory experiencing is discussed only briefly [K30].

5.4.1 Macroscopic quantum phases are needed

Self must be able to remain unentangled in subsequent quantum jumps. The presence of the macroscopic quantum condensate means usually energy gap between ground state and excited states. This can make the generation of real entanglement very slow process and self can exist.

The fact that macroscopic quantum phases have coupling to the classical gauge fields, suggests that the order parameters of the macroscopic quantum phases are completely determined by the

localization in the zero modes. Thus the contents of the sensory experience should correlate with these order parameters. This motivated the original attempt to identify macroscopic quantum phases as quantum correlates of the sensory qualia. A more refined approach identifies quantum phase transitions of the macroscopic quantum phases as correlates of sensory qualia so that the increments of quantum numbers in the phase transition label various qualia. This identification is completely general and almost brain independent (cell length scale turns however be crucially important p-adic length scale).

Many-sheeted space-time concept makes possible large number of macroscopic quantum phases not possible in standard physics context. In particular, the so called massless extremals (MEs) representing “topological light rays” provide a model for how linear structures such as DNA and microtubules could act as quantum antennae emitting and absorbing coherent photon distribution fixed completely by localization in zero modes. Coherent photons could realize the concept of global workspace [J2] and could make possible “mass media” at neural level. Also the concept of “neural window” abstracting the notion of holographic brain suggests itself [K5, K13]. MEs form a fractal hierarchy and are carriers of super-symplectic representations for which states are genuine functionals in the space of 3-surfaces (“world of worlds”) and thus correspond to higher abstraction level than ordinary quantum states. Super-symplectic states have also gigantic almost degeneracies. MEs act also as quantum holograms.

For these reasons MEs are ideal candidates for a hierarchy of life forms [K13]. In particular, the assignment of “our” sensory qualia with super-symplectic quantum transitions looks reasonable whereas magnetic quantum phase transitions might well correspond to more primitive chemical qualia not directly conscious to us.

5.4.2 The functions of nerve pulses

The identification of the sensory qualia in terms of the quantum phase transitions associated with macroscopic quantum phases is in conflict with the general belief that neuronal activity determines completely the contents of the sensory experiences. In TGD framework one can understand the role of the nerve pulse activity differently. Brain is quantum spin glass and the evolution of sub-selves/mental images is a dissipative self-organization process leading to some asymptotic self-organization patterns which correspond to the valleys of the spin glass energy landscape. The contents of the sensory experiences are determined by the zero modes which in turn determine the ground state patterns of the order parameters of various macroscopic quantum phases.

The crucial element of the self-organization is external energy feed making possible interesting self-organization patterns. One role of the nerve pulses is to provide this metabolic energy feed. This suggests that the axons are seats of the self-organization patterns coding at least part of the neuronal experience. Brain seems to systematically maximize the length of the axons feeding sensory data (for instance, right ear feed its sensory input to the left hemisphere). Brain anatomy seems also to favour long pyramidal axons. This phenomenon, which seems to be in conflict with the principles of good metabolic economy, is consistent with the maximization of the expressive power of the sensory pathways. Microtubule conformations are excellent candidates for realizers of declarative memory and this would also explain why the lengths of sensory axons tend to be maximized. Myelin sheets guarantee that external perturbations do not affect the self-organization patterns. It is also possible that myelin sheets form together with the axon Josephson junctions for various super conductors predicted by TGD and are thus essential for the generation of neuronal sensory experiences.

Nerve pulses affect also the postsynaptic cell: typically excitation or inhibition is in question. The interpretation is that the incoming nerve pulses push and pull the postsynaptic cell in different directions and in this manner cause frustrations typical for spin glass like systems. The assumption that neural transmitters give rise to some kind of chemical senses at neuronal level as well as neuronal emotions is in accordance with this. Also frequency coding is consistent with the identification of the nerve pulse activity as a control function.

Of course, spatio-temporal patterns of nerve pulses might also code information about sensory experience. There is indeed evidence that various odours are coded into spatio-temporal nerve pulse patterns [J13]. For instance, for the neurons of the associative regions of cortex receiving inputs from several sensory modalities this kind of discrimination is obviously highly desirable. One can even consider the possibility that nerve pulse patterns, in some parts of brain at least (in

output axons of association regions), provide a precise naming for axonal experiences.

The model for sensory qualia and sensory representations [K13, K16] assumes that nerve pulse patterns generate EEG MEs (massless extremals) entangling brain with the sensory magnetic canvas. The question where the mental images responsible for the sensory qualia are located, still lacks a convincing answer. Primary qualia could even correspond to mental images associated with the sensory receptors and sensory pathways could serve as cortex-receptor entanglers. Brain would give names for sensory inputs and percepts rather than creating the primary qualia. This would require feedback from brain to the sensory organs.

Frequency coding is not the only manner to code information to nerve pulse patterns and delicate temporal coding mechanisms exist. For instance, frequencies can be coded to peaks of the spike interval distribution by stochastic resonance [D3]. Also the coding of spike interval distribution to EEG frequencies is possible (a kick to a harmonic oscillator at the correct half period leads to a resonant amplification [K26]).

5.4.3 How qualia are associated with neural pathways?

Since TGD predicts entire hierarchy of selves, it is important to specify whose sensory experience one is talking about. In TGD framework nerve pulse patterns as such need not give rise to our sensory experience and it is quite possible that also primary sensory organs have sensory experiences.

Frustratingly, the question about the seat of qualia mental images remains unanswered.

1. The assumption that primary qualia are somehow associated with or determined by the sensory receptors would resolve a difficult question about how sensory pathways, which do not seem to have any obvious differences at the level of brain, give rise to qualia. The entanglement of the sensory receptors with brain in turn entangled with the magnetic body would give rise to the sensory representations. Our sensory experience would not be localizable to what happens in the brain region: indeed, MEs in EEG frequency region have size of order Earth size.

Various objections (hallucinations, experiences generated by the stimulation of the sensory pathways, phantom leg phenomenon, dreams) against this view can be circumvented if there is a feedback between brain and sensory organs (as there indeed is), and if sensory experiences can also correspond to geometric memories (say in the case of phantom leg experience).

For instance, pain in phantom leg would be sensory memory of pain in the leg, which still existed. The memory feats of idiot savants and people with left brain damage would be most naturally also due to sensory (visual or auditory) memories. Also ordinary people can have sensory memories when neurons in temporal lobes are stimulated electrically.

If sensory receptors are the experiencers of the primary sensory qualia, then conscious experience can precede the neural activity in the cortex, as observed by Libet in his classical experiments concerning the timing of the sensory experiencing [J10].

2. A more general view is that the neuronal receptors (also “field receptors” responsible for neuronal vision and hearing can be present) along the sensory pathway are specialized to experience only special sensory qualia characterizing the sensory pathway.

How the primary and possible also secondary sensory receptors or sensory pathways could then give rise to particular qualia? Quite generally qualia correspond to average increments of quantum numbers for the quantum jump sequence defining sub-self. In the case of color qualia one has a partial answer. For MEs super-symplectic quantum transitions are characterized by WCW Hamiltonians carrying spin and color ($SU(3)$) quantum numbers. For WCW photons state functional in WCW degrees of freedom is nontrivial and characterized by WCW Hamiltonian with quantum numbers characterizing a particular quale. This suggests that somehow neural pathway or sensory receptor should be able to generate “WCW photons” (MEs) BE condensing on larger MEs and inducing visual color qualia at least. This would mean that WCW photons would in a well-defined sense carry qualia: the photons generated by sensory receptors and brain could be colored after all!

The educated guess is that the EEG transition frequencies coded the spike interval distributions associated with the sensory pathway characterize the sensory pathway partially. EEG frequencies

in turn determine partially the quantum phase transitions which can be stimulated by that particular sensory pathway. The minimal option is that these transitions relate only with what parts of magnetic body the sensory pathway is entangled with. This would make possible very high functional flexibility in accordance with the observed plasticity of brain.

5.4.4 Only changes are perceived

One of the basic laws about sensory experiencing is that only changes and novelties are perceived. For instance, totally monochromatic illumination is experienced as darkness. The zero modes characterizing the macroscopic space-time associated with the final quantum history of the quantum jump should determine the contents of the sensory experience. Part of the zero modes corresponds to the induced Kähler of CP_2 which is nonlinear Maxwell field closely related to the classical electromagnetic and Z^0 fields. There are also zero modes representing the size and shape of 3-surface: these might be related to the discriminative sense of touch. A possible generalization of the law is that sensory stimulus generates Kähler electric field proportional to the gradient of the stimulus. This creates however a problem. Kähler electric flux must be conserved in the approximation that vacuum Maxwell's equations are satisfied (they are not exactly satisfied since vacuum can carry currents of Kähler charge). Suppose that stimulus has a strong gradient: where does the Kähler electric flux go in this kind of situation?

The solution of the problem might be very simple: mindlike space-time sheet is generated and the flux goes to the mindlike space-time sheet through wormhole contacts. Since sensory stimulus varies rapidly at the boundaries of the objects of the external world, this means that the objects of the perceptive field are automatically represented by mindlike space-time sheets and give rise to selves, mental images already at the level of the sensory organ or the sensory pathway leading to thalamus.

The extreme generality of the mechanism suggests that it could be at work also at the level of brain. Understanding of the computational aspects of sensory experience (say stereovision) is not possible unless one assumes that mindlike space-time sheets in sensory pathway combine with the primary sensory organs to form coherent quantum systems. "Ontogeny recapitulates phylogeny" principle requires that these space-time sheets are connected by flux tubes most naturally associated with axons leading from sensory organ to brain.

5.4.5 Are the ultimate sensory representations realized outside brain?

One of the dramatic almost predictions of TGD inspired theory of consciousness is that our physical body is accompanied by a hierarchy of field bodies, in particular magnetic body. A given field body provides abstract representations about quantum aspects of the physical body, kind of a manual. This prediction plus some general arguments lead to the view that sensory representations are most naturally realized outside the physical body at the personal magnetic body (first person aspect of consciousness) and at the magnetic body of Earth (third person aspect of consciousness).

This vision leads to the interpretation of EEG as being involved with MEs projecting sensory data to the magnetic body. EEG ME would generate quantum entanglement between two mental images: a feature inside brain and a "simple feeling of existence" mental image at the magnetic body and representing a point of the external world. Thus the main function of brain would be the construction of features and sensory representations would be completely separated from their construction. Note that also in the case of computers the representation of the data is separated from the generation of the data.

5.5 Emotions

TGD suggests several visions about emotions and it is not yet completely clear whether these views are really mutually consistent.

5.5.1 Emotions and comparisons

The basic element of mentality is the comparison between the expectations of future and what actually occurred. In TGD framework this tension between potential and actual can be understood. Subjective and geometric memories make it possible to compare the expectations with what really

occurred during the time interval since subjective memory is kind of heap of predictions of future arranged with respect to the value of the psychological time. Many higher emotions such as sorrow, depression, frustration, desire, happiness, feeling of relief, pain, fear, anger, envy, hatred, etc... clearly involve comparison of expectations and reality. This could perhaps mean that these emotions are created by the comparison of the predicted or desired geometric time history and subjective time history (what really happened). This would mean that at least higher emotions differ from the sensory qualia, which seem to be determined solely by the localization into zero modes representing the non-quantum fluctuating aspects of space-time geometry.

One might however argue that very primitive emotions such as rage without any object and involving only the activity of the limbic brain could be quale like and that hormones are the quantum correlates of these emotions. These emotions involve however a change of behaviour (e-motion!) so that one could argue that also now there is a simple comparison involved. Perhaps changes in the hormone concentrations could be regarded as consequences of the change of the emotional state. Or vice versa, if hormones are messengers telling to very simple selves of limbic brain whether the real course of events was the desired one or not, then hormones indeed effectively control the emotional state and can be regarded as quantum correlates of emotions.

It is difficult to assign any comparison to an emotion like deep love since it involves a complete acceptance of the object of love and is free of desires. Perhaps the claim of mystics that deep experience of love means that subject and object of love cease to exist as separate objects, makes sense. Lovers quantum entangle and die as separate selves (for some fraction of time only, of course!) and the higher self consisting of lovers experiences whole-body consciousness. Perhaps more mundane love means that my sub-selves representing me and the loved one entangle to form a sub-self experiencing whole-body consciousness. Perhaps also feelings like empathy belong to this class of emotions.

5.5.2 Emotions and entropy

The concrete model of qualia to be developed in [K13] provides an alternative general vision about emotions which allows to understand the difference between comparison type emotions and other emotions as well as the role of emotions in control.

1. The statistical physics approach to qualia leads to the hypothesis that emotions correspond to rates for the generation of various type of entropies for the sub-selves of self. The sign of the rate tells whether emotion is positive or negative. Negative emotions would thus be conscious control variables warning self when some sub-system is generating entropy. The holistic nature of the emotions can be understood easily in this picture and also the fact that they are not directly related to sensory input. One could perhaps also understand higher level emotions like sorrow as reflecting the growing disorder of the virtual world of brain resulting from the primary cause of sorrow.
2. It is known that peptides correlate strongly with emotions and moods [J3] and they are even called molecules of emotions. Peptides are also regarded as information molecules. This connection between information and emotions fits nicely with the fact that peptides and other important biomolecules certainly induce strong entropy gradients with respect to subjective time.
3. Sensory qualia can be divided to geometric and non-geometric ones. One can classify also emotions in this manner. Emotions corresponding to the localization in zero modes would perhaps correspond to “higher level emotions” about external world (say, aesthetic qualia) whereas the non-geometric emotions associated with the state preparation would correspond to “self-centered” emotions about the state of body (pain, physical pleasure, ...).
4. Also pure emotions which seem to involve no obvious comparison (love, joy, excitement, ..) are possible. For instance, the emotions produced by music might represent this kind of emotions. The view about emotions as entropy gradients allows to understand also emotions of this kind. In state of deep love, self enters into very low-entropy state and mental images (not necessarily even present in “enlightened states”) become very pure.

5. An interesting question is whether the entropy growth of our sensory sub-selves is only sensory representation for the entropy growth occurring at the level of atomic space-time sheets or corresponds directly to it. The enormous difference of the temperatures associated with the atomic space-time sheets (ordinary matter) and superconducting magnetic flux tube structures would suggest that the growth rates for these entropies are of totally different order of magnitude and our emotions serve have the role of conscious control variables telling whether things are going well at the atomic space-time sheets.

Consider now the comparison type emotions and the relation of emotions to control in more detail.

1. Many emotions are comparison type emotions. These emotions tend to be negative (say envy). The first option is that comparison type emotions result from the comparison of geometric and subjective memories occurring automatically in any quantum jump and thus to some degree with any quale. Unfortunately, it is very difficult to imagine how to concretely test this kind of hypothesis and it is also difficult to see how the connection with entropy gradient could emerge.
2. One must also seriously consider the possibility that emotions result from the comparison of remembered/anticipated experience and real experience rather than the fundamental comparison involved with anticipation and memory: kind of quasi-computerized version of geometric memory would be in question. The result of comparison would be coded to the sign of the growth rate of some entropy variable. The comparison could perhaps be realized in such a manner that subsequent quantum jumps for comparing sub-system could represent either the anticipated or real quale. If this were the case, the difference between anticipated and real would automatically induce growth of entropy and negative emotion would result. This would be the basic mechanism of disappointment. In this picture comparison type emotions could be seen as a system of rewards and punishments used to control the self (the controller could be higher level self (conscience) or higher levels selves which also want to survive (the emotions generated by hunger, first, and physical pain). Punish/reward mechanisms could basically involve negentropy/entropy feed to some sub-self.
3. One could also regard emotion as induced by generalized sensory qualia giving information about CNS itself rather than external world or the boundary between external world and body. The regulation involved with the homeostasis involves comparison in an essential manner so that one could perhaps regard emotions as analogous to control variables representing consciously the result of comparison of expected and desired forcing the organism to behave in a manner to reduce this difference and end up to a rest and digest state. This aspect is consistent with the statistical interpretation since the entropy gradients associated with the organism are stronger than those associated with the surrounding world. Also amplification mechanisms exaggerating the entropy gradients might have developed. For instance, our reactions to some odours or tastes could involve this kind of amplification.
4. A hypothesis consistent with these views is that emotional component is involved with all sensory experiences and that we are used to call generalized sensory experiences emotions when they are about body. The emotionality of qualia indeed increases in the sequence of perceptive fields external world – CNS-world boundary – body. The degree of emotionality of experience should be characterized by the deviation of real from expected or desired and this suggests that the emotional component is much stronger for sensory experiences about CNS itself, since the system in question is much less predictable than the external world consisting of dead objects. Interpretation of emotion as measure for entropy gradient explains also this hierarchy.
5. Depression could be seen as a lost ability to experience emotions, be they positive or negative. Depression indeed involves emotional flatness. This state results when mental images become maximally entropic (emotional counterpart of heat death). That depression can follow deep sorrow is natural since negative emotions tend to increase the entropy of the mental images. It is known that depression involves over-activity of the amygdala and under-activity of some forebrain regions and an abnormally small population of glial cells known to be closely

involved with metabolism and “cleansing activities” at brain level. This supports the view that glial cells might be warriors in the war against second law at the level of atomic space-time sheets and the loss of this war is sensorily mapped to the level of mental images and leads to depression. One function of serotonin, dopamin and various other neuropharmaca tending to produce pleasant experiences could be a reduction of entropy either at atomic space-time sheets or, less probably, directly at the level of our sensory sub-selves.

5.6 Directed Attention

The possibility to interpret self as a statistical ensemble suggests that the entropy of the mental image measures its fuzziness. Thus both attentiveness, alertness and level of arousal should relate very closely to the entropy of the mental images. Attention to a mental image could mean fight against second law to keep the mental image in a low entropy state and this requires metabolism (the icons on the computer screen provide a good example of this). Also alertness means mental images with low entropy content. 7 ± 2 rule of cognitive science suggests that the maximum number of our cognitive sub-selves which can be awake simultaneously, is rather limited. The rule might be based on the metabolic limitations: sub-selves can have low entropy content only in the presence of an external negentropy feed and metabolism must provide the needed negentropy feed. Note however that the needed metabolic energy might be extremely low.

Directed attention is one of the basic processes of consciousness occurring continually. Directed attention seems to involve free choice but focusing of attention could also occur spontaneously. One can imagine several models for the focusing of attention.

1. One possibility is that subsub-self inside sub-self representing mental image (say “monitor screen” as average over subsub-selves representing the visual objects) somehow pops up one level higher in the self hierarchy so that it becomes mental image. Geometrically this could correspond to the re-gluing of the corresponding space-time sheet to the space-time sheet of self instead of that of sub-self. In this case attended object would not pre-exist.
2. A further aspect of the focused of attention is as a wake-up of sub-self and keeping it in wake-up state and hence in short term memory. This could occur at the expense of the other sub-selves, which would be in wake-up state for only short times. A possible mechanism of selection is a phase transition changing the topology of chosen region (say from p -adic to real or from p_1 -adic to p_2 -adic) so that a new sub-self pops up from the background.
3. Self directs automatically its attention only to sub-systems immediately below it in the hierarchy. It seems however possible to direct attention to lower levels of the self hierarchy. For instance, I can direct my attention to the entire sentence, which I am writing here or to some word of this sentence or to individual letters of this word. The phenomenon of bio-feedback demonstrates that it is possible to learn to direct the attention to even single neuron. This suggests that selves are able to modify the hierarchy of selves by raising some sub...sub-self to the role of sub-self temporarily and thus experience the former sub...sub-self as a direct mental image. Formation of the flux tubes between mindlike space-time sheets at various levels of the self hierarchy provides a general geometric mechanism making possible temporary changes of the structure of the self hierarchy. Also the learning taking place during sleep [J11] might involve interaction between different levels of the self-hierarchy.

Anyone can do a simple but thought provoking experiment suggesting the presence of the macroscopic quantum entanglement at the level of brain and a change of the level of sub-self in the self hierarchy. Look at a mirror, direct your attention at your left eye, and redirect the gaze to the right eye. What you find that it is impossible to perceive the change in the direction of the eye gaze.

1. Consider first what probably happens when we perceive a moving object. A negentropic binding of the mental images of the visual field to single mental image implies that both the parts and the whole can be experienced so that the motion is perceived. If the direction of the gaze is stationary, the object moves relative to the background, and if the direction of the gaze follows the object the background moves with respect to the direction of gaze. In both cases the motion can be perceived.

2. If the eye follows its own rotating mirror image, neither of these options is realized if the environment to which the attention is directed is restricted to be the eye itself. The direction of the gaze should remain the same in order to perceive the change of the direction of the gaze but this is impossible.
3. The perceptive field however contains also other objects and one could argue that if the attention is directed also to these simultaneously, it should be possible to perceive the changing direction of gaze as they move relative to the changing direction of gaze. Does the very act of directing attention to the mirror image of eye separate it from the negentropic entanglement with the other mental images so that the conscious comparison with them is not possible anymore? Or is the visual mental image representing eye at a different level of hierarchy as mental images from the very beginning and cannot negentropically entangle with the other visual mental images? Eye cannot perceive itself! Not even in mirror.

One should also understand what it means to direct the attention to an object of perceptive field. Certainly this process is directed and selective. Could the direction of attention to an object of perceptive field separate the corresponding mental image from the negentropic fusion of mental images as a separate mental image? Could it be that the motion of object can be perceived only if the attention is fixed only temporarily to the object? There are almost incredible sounding experiments demonstrating that the attention directed intensely to a fixed object makes it impossible to perceive what happens in environment.

5.7 Altered States Of Consciousness

The proposed concept of self provides allows rather rich a palette of altered states of consciousness and one cannot avoid the temptation to a concrete modelling of various altered states of consciousness. It seems that negentropic entanglement provides a general explanation for the reported characteristic of these experiences.

5.7.1 Whole-body consciousness and ordinary consciousness

Krishnamurti has described in his books states of consciousness having natural identification as states of “whole-body consciousness”. For instance, according to Krishnamurti, one can achieve this state only if one is able to stop thinking entirely. If thoughts correspond to cascades of selves decomposing into sub-selves during state function reduction process, then this is just what is required. The characteristic of this state of consciousness as reported by meditators are the experience of one-ness and the absence of all separations. The absence of separation would conform with negentropic entanglement. One-oneness could correspond to irreducible selfness without subselves or to the negentropic fusion of mental images to single mental image. Also “timelessness” characterizes these experiences: the explanation is that internal clock is provided by some sub-self waking up periodically and since there are no sub-selves there can be no time. Note also that negentropic time like entanglement fuses the subselves assignable to the future and past boundaries of CD to single self.

I have personally experienced states of whole-body consciousness and also states in which whole-body consciousness is limited to some part of body. These states begin with a sudden fall of silence: all the usual “noise” from the body disappears suddenly although ordinary physical sounds are still heard. This could be interpreted as disappearance of sub-selves from body or as generation of negentropic entanglement stable under quantum jumps. There is experience like thrill in spine going through the entire body. Interesting experience of this kind occurred when my cat was sleeping over my breast: I woke up and realized that my breast was in the state of whole-body consciousness. Could this mean that sleeping cat was also in this state and that my breast had entangled with the quantum state of cat? Could this in turn mean that during sleep we indeed are in a state of whole-body consciousness or even that our entire body is entangled with some large self? Could the absence of neuronal quantum jumps explain why we do not remember anything about these states? Are remembered states of whole-body-consciousness always such that at least some part of brain is awake?

Possession of ego defined as a collection subselves, which repeatedly unentangle themselves from the external world means dissipation, aging and eventual physical death (note however that self

lives as a conscious memory realized as a sub-self of higher level self providing kind of summary about the lifetime of self). There would be two manners to getting rid of ego. Get rid of sub-selves or try to achieve a state in which they negentropically entangle to single mental image.

The absence of neuronal and cell level dissipation during states of whole-body consciousness provides a possible test for the phenomenon. Test persons could be trained meditators and test should involve the measurement of neural or cellular dissipation occurred during the state of whole-body consciousness. Reduced rate of metabolism could be a measurable signature of whole-body consciousness. Dissipation should be absent or should be very small during this state at least if it is present for sufficiently large fraction of time. The absence of dissipation means that all changes suffered by the cells during whole-body consciousness are reversible and curable. This could explain various miraculous healings. Whole-body consciousness, if possible to arrange artificially, could provide medical means of saving the lives of victims of accidents (say of victim of heart attack or bleed in brain).

Negentropic entanglement allows the component systems to be free in the sense that there is no binding energy. Even more, negentropic systems could carry metabolic energy but would not liberate it or liberate it in much longer time scale than usually (also large \hbar could be involved). As a matter fact, the high energy phosphate bond assumed in the model of metabolism could correspond to negentropic entanglement carrying metabolic energy [K12].

Synchronous neural firing is a possible candidate for whole-body consciousness at the level of brain.

1. The anomalously low value of neuronal oxidative metabolism during synchronous neuronal firing in cortex could be interpreted in terms of negentropic inter-neuronal entanglement during which ATP-ADP Karma's cycle is absent and dissipation is reduced.
2. One could of course argue that metabolic energy is liberated but from other source than ATP. For instance, the formation of bound state entanglement between the group of firing neurons could liberate the binding energy as metabolic energy. The formation of hydrogen bonds could be the counterpart for the process at molecular level. This mechanism would however imply dissipation and there is no strong reason to assign whole-body consciousness to this kind of state (of course, synchronous neural firing need not corre.

Whole-body consciousness could explain some spectacular phenomena (not of course taken seriously by skeptics).

1. The claimed ability of yogis to survive for months without eating anything and even without oxygen could have explanation in terms of whole-body consciousness. Oxygen consumption compensates the loss of chemical energy caused by the quantum jumps in biochemical length scales. These quantum jumps occur only if neuronal and lower level chemical selves exist. Under usual circumstances the continuous supply of oxygen makes the ageing of cells slow and the lack of oxygen leads to rapid dissipation and neuronal death. The situation is analogous to Benard flow: if heat feed is stopped, the beautiful flow pattern rapidly dissipates away. If all cells are entangled during whole-body consciousness, no dissipation occurs and the lack of the oxygen supply does not have any irreversible effects and possible effects might be cured automatically. An alternative explanation for the mystery of yogis who need not eat is that the generation of bound state entanglement involves the liberation of the binding energy as a usable energy possibly compensating for the ordinary metabolic energy.
2. In certain cultures people in trance are able to dance with their bare feet on burning charcoals without any disastrous effects. The disastrous effects of the interaction of heat from burning charcoals with cells in soles of foot must be irreversible changes. If these persons are in a state of whole-body consciousness, then the changes of the individual cells would be reversible.

5.7.2 That-which-is experiences

Irreducible self does not possess any sub-selves. The absence of sub-selves in turn means the absence of mental images. This kind of situation could correspond to that-which-is experience. The reports of Buddhist meditators about pure awareness with discrete twinkles of consciousness identifiable as short-lived sub-selves are in accord with this view.

In principle meditation could make possible to silence the hierarchy sub-selves and make it possible to directly experience quantum jumps occurring at elementary particle level! In zero energy ontology the temporal size scales assignable to elementary particles are time scales of human consciousness (electron corresponds to .1 second time scale and u and d quarks to millisecond time scale) plus the hierarchy of Planck constants as a realization of dark matter hierarchy crucial for living matter and predicting scaled up variants of these time scales, this idea need not be so crazy at it looks at first sight. In this speculative spirit one could even consider the possibility that the abstract theories of elementary particle physics result basically as a summation of the experiences of matter-mind sub-systems entangled with elementary particles! One can even consider the possibility that genetic code is realized in terms of the sub-CDs assignable to the electronic CDs and could form first level realization of the phonemes of language.

One can also consider a weaker notion of one-ness in which self has only single mental image. In this case sub-selves would fuse to single subself either by bound state entanglement or negentropic entanglement. The formation of these states is accompanied by the formation of flux tubes -say magnetic flux tubes- between space-time sheets representing binding sub-systems. State function reduction does not occur in these degrees of freedom anymore, macroscopic quantum coherence is preserved from quantum jump to quantum jump, and the system behaves as macroscopic multiverse with new macroscopic degrees of freedom making possible macroscopic quantum computation. This might be the mechanism for how water, DNA, protein, tubulin, ... molecules and even neurons bind to quantum computing macroscopic multiverses [K10].

5.7.3 Zen type experiences and negentropic entanglement

Negentropic entanglement is possible in the intersection of real and p-adic worlds. Negentropic states are not eigenstates of measured observables giving information about the quantum numbers of the system or its complement but about the entire system. Conscious experience is an abstraction about the correlation between states of entangled systems- a rule with instances of the rule being represented as state pairs. Negentropic entanglement can be also time-like and between systems corresponding to space-time sheets in different number fields in the intersection of real and p-adic worlds. The simplest example about negentropic entanglement are fuzzy qubits. Zero energy ontology allows to imagine entire hierarchies of negentropic entanglements between negentropic states and an attractive interpretation is in terms of a reflective hierarchy producing statements about statements.

The reported experience about disappearance of illusions would conform with the interpretation about experience of understanding assignable to the state. The disappearance of the decomposition to observer and observed would correspond to the experience of oneness. Zen Buddhists experiences are often characterized as states of consciousness in which no selection is made between mutually exclusive alternatives. Hofstadter has described this aspect of Zen in hilarious manner in his book "Gödel, Escher, Bach". Also this aspect conforms with the basic properties of negentropic entanglement.

The absence of external-world-me separation and absence of desires is also reported to be a characteristic feature of that-which-is and Zen type experiences. Ego separates itself from external world in quantum jump by state function reduction leading to an uncorrelated product state. Ego disappears when the self fuses with external world negentropically. Perhaps also desires could be equated with the tendency to preserve ego.

5.7.4 Extended states of consciousness

Extended states of consciousness seem to be the exact opposite of that-which-experiences. Psi experiments concern subtle connections between subjects removed in space, and occasionally also in time. These experiments are reviewed in [J8] and the following representation follows this review closely. The pioneering work related with card and dice-guessing was done by J. B. Rhine in 1930s.

The formation of negentropic entanglement gives a natural general explanation of these experiences. Negentropic sharing and fusion of mental images would be part of the mechanism for extended states of consciousness.

The notions of geometric memory and electromagnetic self allow also to understand basic features of these experiences. For instance, the notion of geometric memory allows to understand

memories about previous lives and prenatal experiences in which the contents of consciousness is time shifted. The model for sensory representations leads to the conclusion that the topological field quanta of ELF fields, having frequencies in EEG range and by Uncertainty Principle having size of Earth, are crucial element of our sensory experience. The formation of flux tubes between topological field quanta associated with different selves could explain a large variety of paranormal experiences.

1. *The experiments of Russel Targ and Harold Puthoff*

The experiments of Russel Targ and Harold Puthoff [J21] were carried in the 1970's some of the best known experiments on subtle connections among distant subjects in regard to the transference of thoughts and images. Both sender and receiver were closed in a sealed, opaque, electrically shielded chamber so that no sensory communication was possible. Sender was subjected to light flashes at regular intervals. This caused a characteristic pattern in the EEG of the sender. In some cases also the receiver exhibited these rhythms.

In remote vision experiments sender served as a beacon. Receiver tried to describe verbally or by sketches what the beacon saw. Independent judges matched on the average 66 per cent of time with what was actually seen by the beacon. There are also remote viewing experiments from other laboratories. The distances between sender and receiver vary from miles to thousands of miles and it seems that distance does not matter.

Distance independence supports the interpretation of both experiments in terms of fusion and sharing of mental images.

2. *The experiments of Stanley Krippner*

In the experiments of Stanley Krippner [J23] image transmission was studied while receiver was asleep. Experimenter, sender and volunteer met each other in the beginning of the experiment. Sender spent the night concentrating on an art print, which he/she had received in the beginning of the experiment in a closed envelope. The brain waves and eye movements of the volunteer were recorded. The experimenter woke the volunteer at the end of the REM period by intercom and the volunteer described the dream.

A correlation between the contents of the dream and of the art print was observed. The score was higher on nights, when there were few or no electric storms in the area and sunspot activity was lowest.

The simplest interpretation is again in terms of fusion of mental images of the subject persons. These mental images are perhaps represented at the personal magnetic sensory canvas. Electric storms and sunspot activity affect directly Earth's magnetic field and should affect the communication mechanism since the experiments of Blackman and other suggest that em selves could correspond to magnetic transition frequencies associated with magnetic field of 2 Gauss which is near to the nominal value 5 Gauss of the Earth's magnetic field. In fact, there exists independent evidence for a general correlation of geomagnetic activity with psi experiences [J15].

3. *The experiments of J. Grinberg-Zylverbaum*

In the experiments of J. Grinberg-Zylverbaum [J9] the transfer of EEG potentials was studied. Two subject persons were involved. They were closed in Faraday cages. The sender was meditating. Another subject person was subject to a stimulus in random intervals; not even the experimenter knew, when they were applied. Non-stimulated subject person was in a relaxed state. Stimulus was sudden, short light or sound or short electric shock to index and ring fingers of the right hand causing a characteristic pattern in the EEG of the stimulated person.

The EEG's of the subject persons were synchronized. The possible presence of transferred potentials in the EEG of nonstimulated subject was studied. Transferred potentials were detected in 25 percent of all cases *provided* persons had met before the experiment. A dramatic example was young couple, deeply in love, whose EEGs remained synchronized throughout the experiment.

The fusion of ELF selves means synchronization of ELF em fields and since ELF selves correspond directly to EEG frequencies, synchronization of EEGs is an immediate consequence and can transfer the synchronous firing in brain circuit of the sender to corresponding brain circuit of the receiver. The personal contact before the experiment certainly exchanges the probability for the fusion of ELF selves. Also quantum entanglement between sub-selves of subject persons might be involved.

It is known that the EEGs of right and left brain are synchronized in deep meditation. There are also experiments of synchronization of EEGs for different subjects in group meditation [J17]. The explanation is same as in above case. Also quantum entanglement might be involved. For instance, quantum entanglement is crucial for the fusion of left and right perceptive fields to single perceptive field.

4. Telesomatic effects

Also the transfer of actual bodily effects from subject person to another has been studied: references to these experiments can be found in [J8]. Physiological changes are found to be triggered in the targeted person by the mental process of another. Distance makes little or no difference. Thus the interpretation in terms of quantum entanglement suggests itself.

There are also reports of the transference of pain between persons having very close mutual relationship. Identical twins, mothers and their sons or daughters, couples in love, etc. . Also the relationship between psychiatrist and patient provides example of this kind and is known as projective identification. The general rule seems to be that the relationship between individuals is always involved with psi effects. This is in accordance with the hypothesis about sharing of mental images having ELF em fields and field bodies as physical correlates. For instance, the field bodies of persons in an intimate relationship might develop gradually direct contacts (say magnetic flux tubes connecting physical bodies).

5. Grof's experience with altered states of consciousness

Findings of modern psychotherapists, especially the work of Stanislav Grof [J8, J19] suggest that besides the ordinary "biographic-recollective" domain of psyche also perinatal and transpersonal domains of psyche exist. Transpersonal domain can mediate connection between our mind and practically any part or aspect of the phenomenal world. Grof studied for several decades altered states of consciousness induced by psychedelic drugs or holotropic breathing.

In the experience of "*dual unity*", loosening and melting of the boundaries of the body ego happens but in the merging with another person, own identity is not lost. In the *identification* with another person loss of own identity occurs. Body image, physical sensations, emotional reactions and attitudes, thought processes, memories, facial expressions, typical gestures and mannerisms, postures, movement and even the inflection of the voice become those of the second person. The other can be someone in the presence or absent. Identification involving time shift is also possible. Part of an experience can come from subject's childhood, his or her ancestry or even of a previous lifetime.

Also group identification and group consciousness is possible. Person can identify with an entire group of people having some racial, cultural, national, ideological, religious, political or professional characteristics. People may experience the totality of suffering of all the soldiers or tenderness of all lovers and dedication of all mothers in regard to their babies.

Identification with animals is possible. This involves body image, specific physiological sensations, instinctual drives, unique perceptions of the environment, emotional reactions, etc.. Person can identify with plants and botanical processes. Also identification with inorganic world can occur. People can identify with rivers, storms, tornadoes, mountains, Or stones, quartz crystals, minerals.... Even the identification with structures of atomic and sub-atomic world is claimed to be possible. At the second end of spectrum are racial and collective experiences and identification with entire human species and the experiences in which one identifies with the whole Earth or even entire cosmos. Also out of body experiences, clairvoyance, clairaudience and telepathy are common. Displacement in time is possible. Patient can have embryonal and fetal experiences and even ancestral experiences as well as past incarnation experiences.

Identification experiences can be generally understood as sharing and fusion of mental images. The fusion of mental images can occur between very many individuals, say members of a species and would give rise to kind of stereo consciousness analogous to the stereo vision resulting in the fusion of left and right visual fields. We could also share this stereo consciousness: for instance, shamanist could share the mental images of animal species.

Perinatal experiences and memories extending beyond the lifetime of individual could be explained in terms of geometric memory and the notion of 4-dimensional body: actually these experiences do not in any significant manner differ from ordinary memories. The content of the conscious experience is multilocal both in subjective and geometric time in the sense that the

experience contains contributions from several moments of geometric time simultaneously.

Our personal self hierarchy could actually contain higher levels than the levels represented by ELF emf fields associated with EEG. This hypothesis makes sense if the contribution of the higher levels of our self hierarchy to our conscious experience under normal circumstances is only some kind of general awareness (“silent observer”). These higher levels could actually explain the experienced continuity of self. For instance, during sleep there would be some kind of basic awareness present: the lack of memories about sleep state would lead to, in this framework, erroneous conclusion that sleep state is unconscious.

6 Boolean Mind And Cognition

6.1 Fermions And Boolean Cognition

Fermionic Fock state basis defines naturally a quantum version of Boolean algebra. In zero energy ontology predicting that physical states have vanishing net quantum numbers, positive and negative energy components of zero energy states with opposite fermion numbers define realizations of Boolean functions via time-like quantum entanglement. One can also consider an interpretation of zero energy states in terms of rules of form $A \rightarrow B$ with the instances of A and B represented as elements Fock state basis fixed by the diagonalization of the density matrix defined by M -matrix. Hence Boolean consciousness would be basic aspect of zero energy states. Physical states would be more like memes than matter. Note also that the fundamental super-symmetric duality between bosonic degrees of freedom (size and shape of the 3-surface) and fermionic degrees of freedom would correspond to the sensory-cognitive duality.

This would explain why Boolean and temporal causalities are so closely related. Note that zero energy ontology is certainly consistent with the usual positive energy ontology if unitary process U associated with the quantum jump is more or less trivial in the degrees of freedom usually assigned with the material world. There are arguments suggesting that U is tensor product of factoring S -matrices associated with 2-D integrable QFT theories [K6]: these are indeed almost trivial in momentum degrees of freedom. This would also imply that our geometric past is rather stable so that quantum jump of geometric past does not suddenly change your profession from that of musician to that of physicist.

6.2 Fuzzy Logic, Quantum Groups, And Jones Inclusions

Matrix logic [A2] emerges naturally when one calculates expectation values of logical functions defined by the zero energy states with positive energy fermionic Fock states interpreted as inputs and corresponding negative energy states interpreted as outputs. Also the non-commutative version of the quantum logic, with spinor components representing amplitudes for truth values replaced with non-commutative operators, emerges naturally. The finite resolution of quantum measurement generalizes to a finite resolution of Boolean cognition and allows description in terms of Jones inclusions $\mathcal{N} \subset \mathcal{M}$ of infinite-dimensional Clifford algebras of the world of classical worlds (WCW) identifiable in terms of fermionic oscillator algebras. \mathcal{N} defines the resolution in the sense that quantum measurement and conscious experience does not distinguish between states differing from each other by the action of \mathcal{N} .

The finite-dimensional quantum Clifford algebra \mathcal{M}/\mathcal{N} creates the physical states modulo the resolution. This algebra is non-commutative which means that corresponding quantum spinors have non-commutative components. The non-commutativity codes for the that the spinor components are correlated: the quantized fractal dimension for quantum counterparts of 2-spinors satisfying $d = 2\cos(\pi/n) \leq 2$ expresses this correlation as a reduction of effective dimension.

The moduli of spinor components however commute and have interpretation as eigenvalues of truth and false operators or probabilities that the statement is true/false. They have quantized spectrum having also interpretation as probabilities for truth values and this spectrum differs from the spectrum $\{1, 0\}$ for the ordinary logic so that fuzzy logic results from the finite resolution of Boolean cognition [K39].

6.3 P-Adic Physics As Physics Of Cognition

p-Adic physics as physics of cognition and intentionality provides a further element of TGD inspired theory of consciousness. At the fundamental level light-like 3-surfaces are basic dynamical objects in TGD Universe and have interpretation as orbits of partonic 2-surfaces. The generalization of the notion of number concept by fusing real numbers and various p-adic numbers to a more general structure makes possible to assign to real parton a p-adic prime p and corresponding p-adic partonic 3-surface obeying same algebraic equations. The almost topological QFT property of quantum TGD is an essential prerequisite for this. The intersection of real and p-adic 3-surfaces would consist of a discrete set of points with coordinates which are algebraic numbers. p-Adic partons would relate to both intentionality and cognition.

Real fermion and its p-adic counterpart forming a pair would represent matter and its cognitive representation being analogous to a fermion-hole pair resulting when fermion is kicked out from Dirac sea. The larger the number of points in the intersection of real and p-adic surfaces, the better the resolution of the cognitive representation would be. This would explain why cognitive representations in the real world are always discrete (discreteness of numerical calculations represent the basic example about this fundamental limitation).

All transcendental p-adic integers are infinite as real numbers and one can say that most points of p-adic space-time sheets are at spatial and temporal infinity in the real sense so that intentionality and cognition would be literally cosmic phenomena. If the intersection of real and p-adic space-time sheet contains large number of points, the continuity and smoothness of p-adic physics should directly reflect itself as long range correlations of real physics realized as p-adic fractality. It would be possible to measure the correlates of cognition and intention and in the framework of zero energy ontology [K6] the success of p-adic mass calculations can be seen as a direct evidence for the role of intentionality and cognition even at elementary particle level: all matter would be basically created by intentional action as zero energy states.

6.4 Infinite Primes And Cognition

Somehow it is obvious that infinite primes must have some very deep role to play in quantum TGD and TGD inspired theory of consciousness. What this role precisely is has remained an enigma although I have considered several detailed interpretations, one of them above.

In the following an interpretation allowing to unify the views about fermionic Fock states as a representation of Boolean cognition and p-adic space-time sheets as correlates of cognition is discussed. Very briefly, real and p-adic partonic 3-surfaces serve as space-time correlates for the bosonic super algebra generators, and pairs of real partonic 3-surfaces and their algebraically continued p-adic variants as space-time correlates for the fermionic super generators. Intentions/actions are represented by p-adic/real bosonic partons and cognitions by pairs of real partons and their p-adic variants and the geometric form of Fermi statistics guarantees the stability of cognitions against intentional action. It must be emphasized that this interpretation is not identical with the one discussed above since it introduces different identification of the space-time correlates of infinite primes.

6.4.1 Infinite primes very briefly

Infinite primes have a decomposition to infinite and finite parts allowing an interpretation as a many-particle state of a super-symmetric arithmetic quantum field theory for which fermions and bosons are labelled by primes. There is actually an infinite hierarchy for which infinite primes of a given level define the building blocks of the infinite primes of the next level. One can map infinite primes to polynomials and these polynomials in turn could define space-time surfaces or at least light-like partonic 3-surfaces appearing as solutions of Chern-Simons action so that the classical dynamics would not pose too strong constraints.

The simplest infinite primes at the lowest level are of form $m_B X/s_F + n_B s_F$, $X = \prod_i p_i$ (product of all finite primes). The simplest interpretation is that X represents Dirac sea with all states filled and $X/s_F + s_F$ represents a state obtained by creating holes in the Dirac sea. m_B , n_B , and s_F are defined as $m_B = \prod_i p_i^{m_i}$, $n_B = \prod_i q_i^{n_i}$, and $s_F = \prod_i q_i$, m_B and n_B have no common prime factors. The integers m_B and n_B characterize the occupation numbers of bosons in

modes labelled by p_i and q_i and $s_F = \prod_i q_i$ characterizes the non-vanishing occupation numbers of fermions.

The simplest infinite primes at all levels of the hierarchy have this form. The notion of infinite prime generalizes to hyper-quaternionic and even hyper-octonionic context and one can consider the possibility that the quaternionic components represent some quantum numbers at least in the sense that one can map these quantum numbers to the quaternionic primes.

The obvious question is whether WCW degrees of freedom and WCW spinor (Fock state) of the quantum state could somehow correspond to the bosonic and fermionic parts of the hyper-quaternionic generalization of the infinite prime. That hyper-quaternionic (or possibly hyper-octonionic) primes would define as such the quantum numbers of fermionic super generators does not make sense. It is however possible to have a map from the quantum numbers labelling super-generators to the finite primes. One must also remember that the infinite primes considered are only the simplest ones at the given level of the hierarchy and that the number of levels is infinite.

6.4.2 Algebraic Brahman=Atman identity

The proposed view about cognition emerges from the notion of infinite primes [K34], which was actually the first genuinely new mathematical idea inspired by TGD inspired consciousness theorizing. Infinite primes, integers, and rationals have a precise number theoretic anatomy. For instance, the simplest infinite primes correspond to the numbers $P_{\pm} = X \pm 1$, where $X = \prod_k p_k$ is the product of all finite primes. Indeed, $P_{\pm} \bmod p = 1$ holds true for all finite primes. The construction of infinite primes at the first level of the hierarchy is structurally analogous to the quantization of super-symmetric arithmetic quantum field theory with finite primes playing the role of momenta associated with fermions and bosons. Also the counterparts of bound states emerge. This process can be iterated: at the second level the product of infinite primes constructed at the first level replaces X and so on.

The structural similarity with repeatedly second quantized quantum field theory strongly suggests that physics might in some sense reduce to a number theory for infinite rationals M/N and that second quantization could be followed by further quantizations. As a matter of fact, the hierarchy of space-time sheets could realize this endless second quantization geometrically and have also a direct connection with the hierarchy of logics labeled by their order. This could have rather breathtaking implications.

1. One is forced to ask whether this hierarchy corresponds to a hierarchy of realities for which level below corresponds in a literal sense infinitesimals and the level next above to infinity.
2. Second implication is that there is an infinite number of infinite rationals behaving like real units ($M/N \equiv 1$ in real sense) so that space-time points could have infinitely rich number theoretic anatomy not detectable at the level of real physics. Infinite integers would correspond to positive energy many particle states and their inverses (infinitesimals with number theoretic structure) to negative energy many particle states and $M/N \equiv 1$ would be a counterpart for zero energy ontology to which oneness and emptiness are assigned in mysticism.
3. Single space-time point, which is usually regarded as the most primitive and completely irreducible structure of mathematics, would take the role of Platonian mathematical ideas being able to represent in its number theoretic structure even the quantum state of entire Universe. Algebraic Brahman=Atman identity and algebraic holography would be realized in a rather literal sense.

This number theoretic anatomy should relate to mathematical consciousness in some manner. For instance, one can ask whether it makes sense to speak about quantum jumps changing the number theoretic anatomy of space-time points and whether these quantum jumps give rise to mathematical ideas. In fact, the identifications of Platonian mathematical ideas as spinor fields in WCW on one hand and as the set number theoretic anatomies of point of imbedding space force the conclusion that WCW spinor fields (recall also the identification as correlates for logical mind) can be realized in terms of the space for number theoretic anatomies of imbedding space points. Therefore quantum

jumps would be correspond to changes in anatomy of the space-time points. Imbedding space would be experiencing genuine number theoretical evolution. The whole physics would reduce to the anatomy of numbers. All mathematical notions which are more than mere human inventions would be imbeddable to the Platonia realized as the number theoretical anatomies of single imbedding space point.

In [K7, K34] a concrete realization of this vision is discussed by assuming hyper-octonionic infinite primes as a starting point. The simplest realization of infinite octonionic/quaternionic primes as products of infinite primes and octonions avoids the problems related to non-associativity and commutativity. Quantum states are required to be associative in the sense that they correspond to quantum super-positions of all possible associations for the products of finite primes (say $|A(BC)\rangle + |(AB)C\rangle$). The ground states of super conformal representations would correspond to infinite primes mappable to space-time surfaces (quantum classical correspondence). The excited states of super-conformal representations would be represented as quantum entangled states in the tensor product of state spaces \mathcal{H}_{h_k} formed from Schrödinger amplitudes in discrete subsets of the space of 8 real units associated with imbedding space 8 coordinates at point h_k : the interpretation is in terms of a 8-fold tensor power of basic super-conformal representation. Although the representations are not completely local at the level of imbedding space, they involve only a discrete set of points identifiable as arguments of n-point function. The basic symmetries of the standard model reduce to number theory if hyper-octonionic infinite rationals are allowed. Color confinement reduces to rationality of infinite integers representing many particle states.

7 Quantum Correlates Of Qualia

The basic theoretical ingredients described above lead to the following general vision about qualia described in detail in [K13]. In the following the latest view about theory is summarized. The notion of quale is understood in an extremely general sense: “primary attribute of conscious experience” might serve as a synonym for “quale” in the sense as it is used in the following.

7.1 Development Of Ideas

To achieve something which would deserve to be called a general theory of qualia required almost a decade. During the first years, and in lack of any general theory of qualia, I could only make educated guesses, which were doomed to be wrong.

1. A connection between qualia and EEG MEs emerged, when I learned about the effects of classical electromagnetic fields on brain at frequencies which are cyclotron frequencies or amplitude modulated by cyclotron frequencies [J6].
2. The discovery that p-adic physics is physics of cognition (or at least imagination, one should be very cautious in order to avoid over generalizations!) clarified the views about the relationship between cognition and sensory experience [K21].
3. The notion of the many-sheeted ionic flow equilibrium was a further important breakthrough [K3, K4]. It allowed to realize that MEs, superconducting magnetic flux tubes, and ordinary biomatter at atomic space-time sheets form a three-levelled master-slave hierarchy.
4. The realization that MEs carrying super-symplectic representations at their light-like boundaries are excellent candidates for the carriers of at least some of our qualia, gave a totally new perspective to the problem of qualia [K23]. It seems however that MEs are not all that is needed: our qualia involve both super-symplectic and magnetic quantum phase transitions.
5. The work with the problems related to the precise formulation of Negentropy Maximization Principle led to the realization that each quantum jump defines a quantum measurement followed by a state preparation leading to an unentangled product state. This means the reduction of the quantum measurement theory to basic quantum TGD. The next realization was that the quantum jump sequence defining self defines a statistical ensemble of prepared states. One can identify the fundamental statistical ensembles of statistical physics as selves and implied a deep and precise connection between thermodynamics and the theory of qualia

allowing a general classification of qualia and an identification of their thermodynamical correlates.

6. The last breakthrough in development, which is still continuing, was the realization that very general arguments lead to the view that ultimate (conscious-to-us) sensory representations are realized outside the body on the magnetic canvas provided by the magnetic flux tube structures associated with brain and having most plausibly size for which Earth size as a natural unit. One can see cortex as a collection of standard features some of which are associated to the objects of the perceptive field represented as magnetic sub-selves. Frequency place coding (MEs generate magnetic quantum phase transitions) plays a key role in this association.

7.1.1 Music metaphor at axonal level

Music metaphor has been one philosophical guide line behind the identification of the quantum correlates of the sensory qualia.

1. Axons are like strings of a music instrument. What this metaphor means is however not obvious. Frequency coding relates only the intensity of the sensory quale. Nerve pulses induce dropping of various ions to magnetic flux tubes and this generates EEG MEs at EEG frequencies serving as entanglers to the sensory magnetic canvas and the variation of these frequencies could code for the distance to the object of the perceptive field.

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.

A stronger interpretation of the metaphor is that sensory pathways are like strings of a musical instrument such that the sound produced by the string corresponds to a sensory modality associated with the sensory pathway. Nerve pulse patterns determine the experience as chords from from the notes of various instruments in the same sense as the musician produces the music. This leads to a generalization of the idea about brain as an associative net.

More concretely, postsynaptic receptors act as neuronal sensory receptors and transmitters emitted and MEs generated by the presynaptic neuron induce neuronal sensory experiences in the postsynaptic neuron. The specialization of the neuronal receptors would be same for the entire sensory pathway and determine the qualia associated with it.

2. Resonance is an essential aspect of music instrument as is resonant frequency modulation which can involve several levels. The frequencies characterizing the hierarchical modulation provides a partial characterization of the sensory representations. Quantum mechanically resonance corresponds to a harmonic perturbation with frequency which is difference of energies for the states of some sub-system. In this kind of situation quantum jumps can be amplified to quantum phase transitions and sub-self representing mental image wakes up.

Unfortunately, music metaphor is only a metaphor and has led to a plethora of various models for qualia.

7.1.2 ME's and qualia

The identification of MEs as building blocks of sensory and cognitive structures leads to a rather concrete model for long term memory and forces the hypothesis that MEs define an infinite hierarchy of electromagnetic life forms living in symbiosis with each other, magnetic flux tube structures, and the matter at atomic space-time sheets. The realization that MEs serve as quantum holograms and the properties of the super-symplectic stats gave the final justification for this identification. The model allows to understand EEG as a direct physical correlate of mind-like space-times sheets

(MEs) associated with ELF selves and provides a general vision about the electromagnetic organization of brain as sensory and motor organ of higher level self. Also what might be called RF (radio frequency) and MW (microwave) MEs representing our mental images are crucial for the model.

The model of qualia leads to rather detailed view about the sizes of the hierarchy of various MEs defining what might be called our radiation body. Also the notion of magnetic body is needed. It took a long time to answer the question whether we should identify ourselves with the self associated with brain; with the entire body; with ELF ME having size at least of order Earth circumference; or with self having literally infinite size. The last two options seems to be more plausible than the first two: the illusion that we are nothing but our physical bodies is created by the fact that during wake-up state sensory input is about the region surrounding our body. The simplest option is that the relevant magnetic flux tube structures have same sizes as ELF MEs. During sleep our attention might be directed to transpersonal levels of consciousness.

7.1.3 MEs, magnetic superconductors, and many-sheeted ionic flow equilibrium

The lack of clearcut empirical evidence for the predicted supra phases has been a stumbling block for the quantitative development of the theory for a long time. The situation changed dramatically when I learned about the effects of ELF em fields on living matter¹. This article provided the ingredients making possible a general quantitative model of quantum control and coordination in which self hierarchy has as its dynamical correlate hierarchy of weakly coupled super conductors and massless extremals (MEs) interacting with the ordinary matter at atomic space-time sheets. MEs indeed provide a model of Josephson junction and an explanation for the amplitude windows observed in the experiments of Blackman and others [J16].

Later the experimental findings challenging the notions of ionic channels and pumps [I5] led to the identification of homeostasis as many-sheeted ionic flow equilibrium in which the ionic concentrations at atomic space-time sheets are controlled by much smaller ionic concentrations at superconducting magnetic flux tubes. MEs control superconducting magnetic flux tubes via magnetic induction, by inducing magnetic phase transitions and by acting as Josephson junctions between magnetic flux tubes.

Magnetic transitions at superconducting magnetic flux tubes serve as seeds for phase transitions in quantum critical quantum spin glass type phase of macroscopic super conductor leading to generation of a region of new kind of phase whose quantum numbers differ from old one by the quantum numbers associated with magnetic transition frequency. Thus quantum transitions are amplified to macroscopic quantum transitions and Bose-Einstein condensation (analogous to induced emission) is the basic mechanism behind the process.

The first natural guess was that magnetic quantum phase transitions correspond to our qualia. That transition frequencies are involved is indeed in nice accordance with quantum jumps between histories as moment of consciousness identification. However, the fact that magnetic states correspond to a lower level of abstraction than super-symplectic states associated with MEs, suggests that magnetic qualia do not correspond to our qualia directly. Rather primitive chemical qualia experienced by cell level selves might be in question.

7.1.4 The role of super-symplectic algebra

An important step in the development of the theory of qualia was the realization of the importance of super-symplectic symmetries. The answer to this question might have been guessed by taking quantum measurement theory as a starting point.

1. Basic geometric objects is the configuration space of all possible three-surfaces in $M_+^4 \times CP_2$. In absence of non-determinism of Kähler action everything would reduce to the boundary of the future light-cone ($\delta M_+^4 \times CP_2$) carrying representations of super-symplectic and super-conformal algebra localized with respect to the light-like radial coordinate of the light-cone boundary. These symmetries are obviously cosmological. Also quaternion conformal symmetries are possible and these can be identified as the TGD counterparts of string model conformal symmetries responsible for elementary particle quantum numbers.

¹I am grateful for Gene Johnson for sending me the popular article of Yarrow [J6] about bio-electromagnetism.

2. The non-determinism of Kähler action forces to introduce super-symplectic representations at the light-like boundaries X^3 of MEs acting as quantum holograms. Thus superconformal and super-symplectic symmetries become macroscopic symmetries and must be crucial for consciousness.
3. There are two kinds of WCW degrees of freedom: quantum fluctuating non-zero modes and zero modes which can be regarded as classical, non-quantum fluctuating degrees of freedom in complete consistency with the reduction of standard quantum measurement theory to the localization in zero modes occurring in each quantum jump. Zero mode algebra contains the generators of super-symplectic algebra with even conformal weight. In particular, zero modes contain the points of an infinite-dimensional flag-manifold extended to contain the radial Virasoro algebra of the light-like boundary of ME localized with respect to CP_2 . Radial coordinate corresponds to the light-like coordinate of the the light-like boundary of ME. This flag-manifold parametrizes all possible choices of the quantization axes for the canonical Lie-algebra.

7.2 Qualia And Thermodynamics

The connection between thermodynamics and qualia was the real breakthrough in the development of ideas. In some sense this finding is not a news: the close connection between pressure sense and temperature sense and thermodynamics is basic facts of psychophysics. In TGD framework the contents of consciousness is determined as some kind of average over the sequence of very large number of quantum jump and this suggests strongly that non-geometric qualia allow statistical description generalizing ordinary thermodynamical ensemble to the ensemble formed by the prepared states in the sequence of quantum jumps after the last “wake-up” of self. This picture allows to see the ageing of self with respect to subjective time as an approach to thermal equilibrium.

1. There are geometric qualia corresponding to zero modes expressing the result of quantum measurement in each quantum jump. All geometric information about space-time surface should reduce to geometric qualia. For instance, geometric data given by visual, auditory, and tactile senses should reduce to conscious information about zero modes or about increments of zero modes in quantum jump.
2. The sequence of the prepared states can be modelled as a statistical ensemble of Fock states, which suggests that thermodynamics is basically part of theory of consciousness. The ensemble of prepared states gives rise to a large number of statistical qualia. The relationship $dE = TdS - PdV + \mu dN + B \cdot dM...$ generalizes to TGD context: note however that in case of ME selves energy is replaced with the Super Virasoro generator L_0 associated with the light-cone boundary of ME. Each intensive-extensive variable pair in the differential should correspond to a non-geometric quale, which results only when there is gradient (flow) of the extensive variable in the direction of the subjective time. Super-symplectic thermodynamics should obviously map ordinary thermodynamics to the level of conscious experience.
3. Since subjective experience corresponds to quantum jumps, it is natural to assume that only the increments of zero modes and quantum numbers are experienced consciously. Statistical interpretation also suggests that an averaging over increments occurs. The possibility of sub-selves makes possible to have mental images of finite time duration and this makes possible structured subjective memories (for instance, it becomes possible to remember the digits of phone number). A further working hypothesis is universality: qualia associated with quantum phase transitions depend only on the quantum number increments. In particular, the increments of Poincare and color and electroweak quantum numbers define what might be called universal kinesthetic qualia.

The thermodynamical expression for dE suggests a general classification of qualia consistent with the “holy trinity” of existences implied by TGD.

1. *Emotions as order-disorder qualia*

$T - S$ pair correspond subjective existence and generalizes to disorder-order type, information theoretic qualia qualia about the state of self: hot-cold and pain-pleasure type sensations and also

more abstract experiences associated with various sub-selves of self. These qualia are strongly emotional single-pixel holistic qualia measuring whether some kind of an entropy variable is increasing or decreasing. The total entropy for the statistical ensemble defined by self determines how sharp the mental image is. Low entropy content means alertness and attentiveness. High entropy content means fuzzy mental image. Getting tired means inability to keep mental images in low entropy state.

2. Kinesthetic qualia defined by generalized forces

p-V pair corresponds to the geometric existence and is replaced with generalized force-generalized coordinate pairs in quantum fluctuating degrees of freedom. The increments of maximum number of mutually commuting Poincare, color and electroweak quantum numbers define this kind of qualia. The increments of four-momentum code for the sensation of force whereas the increments of orbital angular momentum code for the sensation of torque. Spin flip could code for something else. Tactile senses such as pressure sense and their generalizations involve kinesthetic qualia. The increment of energy or equivalently, increment of frequency, can be identified as correlate for hearing in generalized sense responsible for the dynamical nature of auditory experience (hearing is time-like version of force sense). It is not clear whether spin flip has interpretation as torque or possibly as figure background separation. In TGD based model of auditory experience hearing relates to Z^0 magnetic spin flip phase transitions for cognitive neutrino pairs.

The rate for the increase of the two diagonal color quantum numbers should code intensity type variables associated with color sensation. The rate for the increase of electric charge of sub-self should code for electric sense possessed by, say, fishes. Also $B - M$, $\phi\rho$ and $E - P$ pairs correspond to generalized forces since electromagnetic fields are reduced to space-time geometry in TGD framework.

3. Generalized chemical qualia $\mu - N$

$\mu - N$ pair corresponds to “objective existence” defined by quantum histories and N is generalized to a number of particle like excitations in the Fock state resulting in the state preparation. In this case there must be a flow of particle number in the direction of the subjective time, that is Bose-Einstein condensation type process for, say Cooper pairs. Quite generally, super-symplectic and quaternion conformal super algebras should define these qualia and the number of these qualia is very large.

i) One can assign particle numbers to phases with various magnetic quantum numbers and these could define generalized chemical qualia which could perhaps be regarded as qualia and subqualia of chemical qualia defined by a particular ion and chemical qualia could actually reduce to magnetic qualia. Since the changes of magnetic field induce these quantum phase transition, it would seem that magnetic and Z^0 magnetic quantum phase transitions at superconducting magnetic flux tubes could correspond to this kind of qualia. In principle, endogenous NMR and its generalizations induced by the interaction of magnetic and Z^0 magnetic fields of MEs with magnetic and Z^0 magnetic flux tube structures are possible. Chemical qualia would very naturally correspond to the Bose-Einstein condensation of ions to the superconducting magnetic flux tubes: these ions could be even the ions of tastant or odorant. Also secondary representations at the level of cortex in terms of superconducting light ions are possible and would give rise to classification of tastes and odours. Magnetic qualia are characterized by definite transition frequencies and this makes possible place-/time coding by magnetic transition frequencies if magnetic or Z^0 magnetic field varies along magnetic flux tube/is a function of time. The activation of a point of living map would generate some quale at that point.

ii) For super-symplectic qualia the number of Bose-Einstein condensed “WCW photons” having nontrivial dependence on WCW degrees of freedom replaces number of molecules. The condensation rates for the numbers of the WCW photons with non-vanishing color quantum numbers could be interpreted as correlates of color qualia whereas the condensation rates for color singlet WCW photons could relate to the intensity of color sensation. If the rates for the transfer of color quantum numbers define intensity type variables associated with color experience then BE condensation to color singlet states does not give rise to experienced quale so that only non-diagonal color generators correspond to visual colors. Also the BE condensation of the ordinary coherent light should give rise to some kind of quale: perhaps vibratory sense which can be developed to effective vision, could correspond to non-colored vision. WCW Hamiltonians are also labelled by

2-dimensional orbital spin quantum number and longitudinal momentum. Polarization sense and sensation about motion of the object of visual field would naturally relate to spin and longitudinal momentum.

iii) Tactile senses involve topological phase transitions involving the creation of flux tubes between object and skin whose number would thus be the relevant variable. The purely sensory aspect of physical pain could correspond to a topological phase transition involving the splitting of join-along boundaries bonds between space-time sheets (MEs could even define these bonds) so that N would be now the number of flux tubes. The simplest picture requires that the MEs associated with sensory organs are connected to the MEs responsible for our experience. Of course, splitting and generation of flux tubes could occur also at the level of sensory representations.

4. Boolean qualia

7.2.1 Boolean qualia

Boolean qualia would be naturally associated with fermion number or fermionic spin degrees of freedom. There are super-symplectic and super-Kac Moody type Boolean qualia. The spin flipping transitions associated with the fermionic generators of super-symplectic algebra might give rise to Boolean consciousness with intrinsic meaning (“This is true”) but there are many other possibilities.

A general model for abstraction process based on the Combinatorial Hierarchy [K14] not only explains the basic numbers of the genetic code but also suggests an entire hierarchy of codes in accordance with fractality of TGD Universe.

The next code after genetic code in the hierarchy of codes defined by Combinatorial Hierarchy is very attractive candidate for a “memetic code”. The hypothesis predicts correctly the .1 second time scale for the duration of “our” self (immediate short term memory, duration of psychological moment). Code-words correspond to the sequences of 126 bits with a duration of 1/1260 seconds: this is slightly below the time scale of nerve pulse so that membrane oscillations are perhaps a more natural realization for the code. The facts that the time scale of causal diamond CD associated with d quark corresponds to 1280 Hz frequency and the time scale of electron’s CD corresponds to 10 Hz frequency suggest that quark pairs allow a realization of the memetic code with single quark sub-CD representing and electron CD the code word.

7.3 Geometric Qualia And Zero Modes

The zero modes of WCW are special in the sense that in each quantum jump localization occurs in this space. Zero modes characterize the size and shape of 3-surface and are excellent candidate to represent information about the state of organism (3-surface itself) geometrically. Zero modes can be parametrized as an infinite-dimensional flag-manifold associated with the algebra of the infinitesimal canonical transformations of $E^2 \times CP_2$, where S^2 is sphere at the light-cone boundary extended by Virasoro algebra acting in radial direction of light-cone boundary. Physically this space corresponds to all possible choices of the quantization axes for generators of super-symplectic Algebra and, in accordance with the basic assumptions of quantum measurement theory, each quantum jump involves this kind of choice. Infinite-dimensional flag manifold contains as sub-flag-manifold $S^2 \times F_3$ parameterizing choices of quantization axes of spin and color ($F_3 = SU(3)/U(1) \times U(1)$). Lorentz invariance suggests the extension of S^2 to 2+2 dimensional flag-manifold $F = SO(3, 1)/SO(2) \times R$ parameterizing various choices of the quantization axes for Lorentz quantum numbers [K13].

There are continuous, geometric and kinesthetic (both geometric in four-dimensional sense) qualia like position and velocity; orientation and angular velocity, and also geometric time and experienced rate of time flow. All these pairs correspond to mutually in-compatible observables quantum mechanically. The hypothesis motivated by the work of Barbara Shipman [Shipman_{1,2,3}] is that some coordinates of F_3 parametrize positions. The generalization of this hypothesis is that the infinite-dimensional flag-manifold associated with the zero mode part super-symplectic algebra somehow gives rise to a conscious representation of continuous, classical qualia basically assignable to the choice of quantization axes. The hypothesis indeed makes sense: the entire isometry group of WCW , in particular the sub-group defined by zero modes, leaves induced Kähler form invariant

but affects magnetic and Z^0 magnetic fields and hence magnetic transition frequencies. Also color rotations act in F_3 nontrivially and, although they leave Kähler form invariant, they affect magnetic and Z^0 magnetic fields and thus the corresponding magnetic transition frequencies. This means that a curve of the infinite-dimensional flag-manifold can be mapped to a varying cyclotron frequency.

8 Solutions To Some Paradoxes

The TGD inspired theory of consciousness provides a solution to the many paradoxes related to the basic quantum physics and the philosophy of conscious mind. The solution of these paradoxes is basically due to the replacement of the dualistic and monistic world views by the tripartistic world view of TGD.

8.1 Paradoxes Related To Quantum Physics

The basic paradox is the conflict between the non-determinism of the state function reduction and the determinism of the Schrödinger equation. At a more general level this paradox is the conflict between the subjectively experienced actuality of the free will and the determinism of the objective world. The resolution of this paradox is simple in TGD context. One must give up the idea of single objective reality and replace it with a deterministic quantum history, which changes in each quantum jump, which is a genuine act of free will occurring outside the realm of the geometric space-time. Thus the objective reality, in the sense of a physical theory, is indeed deterministic, apart from the non-determinism related to the special properties of the Kähler action. In fact, a determinism of the Kähler action is achieved by replacing the ordinary concept of the 3-space with the concept of an association sequence and this naturally leads to a model for thinking systems. Volition seems to correspond to the selection between various degenerate absolute minima of the Kähler action and has thus a direct classical counterpart.

In the context of the deterministic physics, theoretician encounters two rather unpleasant paradoxes. The determinism implies that the unique objective reality corresponds to a single solution of the field equations. The first question is “What determines the initial conditions, say at the moment of the big bang?” and the attempt to answer this question leads necessarily outside the physical theory: one possibility is to postulate anthropic principle. In TGD objective reality changes at each quantum jump and the localization in zero modes and NMP imply a genuine evolution: therefore the recent objective reality is an outcome of conscious selections. The second problem encountered by a theoretician is that in principle it is not possible to test a deterministic theory since only single solution of the field equations is realized and a genuine testing would require the comparison of the time developments for various initial data. In practice this problem can be circumvented by assuming the existence of identical sub-systems having very weak interactions with the external world but in principle the problem remains unsolved.

The famous Einstein-Bohr debate was related with the question whether God plays dice or not. Amusingly, in TGD context both were correct in their own ways! Quantum histories are indeed deterministic but God can replace the old quantum history with a new one: perhaps one should not however call this act dice playing but simply an act of free will. Einstein was also an advocate of local realism: this led to Einstein-Podolski-Rosen paradox created by the possibility of quantum entanglement between distant system. In TGD framework local realism holds true at the level of the infinite-dimensional WCW but not at the level of space-time since point like particles are replaced with 3-surfaces.

The Schrödinger cat paradox has also an elegant solution in TGD context. The point is that conscious experience is associated with a quantum jump leading to a final state in which cat is either dead or alive. There is no conscious experience about the situation in which the cat is both dead and alive giving answer to the question “Dead or alive?”. More generally, this feature of consciousness also could explain why the world of our conscious experience looks classical: it simply cannot look but classical since the very moment of consciousness makes it classical. In fact, the world *is* predicted to be genuinely classical to the extent that mutual quantum entanglement between different p-adic sub-Universes seems impossible for purely mathematical reasons. The localization into zero modes occurring in quantum jumps strengthens this conclusion considerably since it

implies that the final states of quantum jumps are superpositions of macroscopically equivalent space-time surfaces: the world of conscious experience is genuinely classical.

The phenomenon of dissipation is paradoxical from the point of view of standard physics. It is generally accepted that the fundamental laws of classical physics are reversible whereas everyday reality is manifestly irreversible. Thus the situation is rather schizophrenic. Two worlds, the reversible and extremely beautiful world of the fundamental physics and the irreversible and mathematically rather ugly “real” world, seem to exist simultaneously. The quantum jumps between quantum histories concept solves the paradox and one can understand the dissipative world as an effective description forming an “almost” -envelope for the sequence of reversible worlds (time developments).

The standard physics is based on positive energy ontology and leads to the paradox caused by conservation laws. Quantum jumps preserve the values of conserved quantum numbers so that the question about initial values of the quantum numbers arises and leads to the necessity to postulate some meta level principle selecting the quantum states of entire universe having the preferred values of total quantum numbers. Of course, the problems are also caused by the fact that one must be able to compare the infinite values of total conserved quantum numbers- at least in the case of energy. Zero energy ontology provides an elegant solution of the problem and implies that any zero energy state is in principle creatable from vacuum.

8.2 Paradoxes Related To The Theories Of Consciousness

Chalmers describes in his book “Conscious Mind” [J5] several paradoxes related to the materialistic and dualistic theories of mind. A common denominator for these problems is the assumption that consciousness is a property of a physical state: hence these paradoxes disappear in TGD context. These paradoxes are encountered also in the quantum theories of consciousness identifying consciousness as a property of a macroscopic quantum state, say Bose Einstein condensate.

In the materialistic theories of mind, postulating a unique objective reality, consciousness is an epiphenomenon and free will is necessarily a peculiar illusion and one can always ask why the consciousness is needed at all: nothing changes in the physical reality if consciousness is dropped away. It is also very difficult to understand how the contents of consciousness are determined by the state of the material world.

In the dualistic theories postulating a unique objective reality (say the theory of Chalmers [J5]), the problems are related to the coupling between matter and mind. The basic problem of the dualistic theories is what Chalmers calls hard problem: how the physical processes in the brain give rise to conscious experience? If the laws of the physics determine the behaviour of the system completely then one ends up immediately either with a complete separation of the mind and matter so that our conscious experience tells nothing about the material world or with materialism and epiphenomenalism. One can also consider a non-trivial coupling between matter and “mind like” fields but assuming a deterministic physics one ends up with a situation in which the mind fields are effectively just additional physical fields and consciousness is again redundant.

An exotic example of this kind of a paradox is the following one described in [J5]. In the dualistic theories in which the physical laws determine the objective reality, all psychological (third person) aspects of the mind are in principle purely physical. The book written by Chalmers about consciousness is obviously an example of a completely physical phenomenon. Therefore the contents of the book need not have anything to do with Chalmers’s ideas about consciousness! More generally, the reports about the states of consciousness need not have anything to do with the states of consciousness in the dualistic theories of this kind. The only manner to save the day (and the uniqueness of the objective reality) is to accept materialism and epiphenomenalism.

In TGD framework, which could be called tripartistic, hard problem and other problems of the dualistic theories disappear since there is no need to assign consciousness to quantum history. Moment of consciousness as quantum jump between quantum histories hypothesis allows even to define measures for the information contents of the conscious experience despite the fact that one cannot write explicit formulas for the contents of conscious experience.

8.3 Logical Paradoxes And Concept Of Time

Many logical paradoxes could be resolved if one assumes that there are two times: geometric and subjective and that the space-time surface providing linguistic representations changes quantum jump by quantum jump. In particular, during the conscious argument leading to the logical paradox!

The objections of Uri Fidelman [J22] against the Platonic vision about reality involve the paradoxes of the cyclic cosmology (one might think that Turing machine in cyclic cosmology might be able to “know” whether it has halted immediately after starting and thus be much more powerful than ordinary Turing machine). Basic paradox is that in cyclic cosmology allowing time travel one can imagine a son who murders his mother.

It is interesting to consider this paradox as resulting from identification of the identification of subjective time with geometric time, which I see only as an approximation. In TGD the counterpart of time travel would be sequence of quantum jumps changing the entire classical history quantum jump by quantum jump and inducing the shift of the space-time region, where the contents of consciousness of time traveller are concentrated, to the geometric past. No paradoxes result since space-time is not a fixed arena of dynamics but changes in each quantum jump.

As a second example one can take the second objection of Uri Fidelman [J22] against Penrose’s program known as Berry’s paradox. *Non-formalizable theory cannot provide a model of the physical world which includes the brain’s cognitive function, since such a model must be lingual, written or spoken. However, such a model implies the following paradox of Berry: Let n be the smallest number which cannot be defined by an English sentence having less than, say, a hundred letters. This number exists, since the number of all possible combinations of a hundred letters is finite. Nevertheless, it has just now been defined by a sentence comprising less than a hundred letters.*

Berry’s paradox could be understood when the piece of text is seen as inducing a sequence of quantum jumps in which the space-time region at which the argument is represented symbolically changes. For the initial space-time region representing my cognitive state there is indeed smallest number n which cannot be defined by using less than one hundred words (using the English in that space-time!). After reading the statement quantum history is replaced by a new, more complex one in which this this number can be defined by using less than one hundred words since a new reflective level of cognitive consciousness has emerged and is represented at space-time level.

This example encourages to think the possibility of replacing the idea of a fixed axiomatic system with a living and dynamically evolving system becoming conscious of new axioms from which new theorems can grow. Mathematician would not be anymore an outsider but and active participator affecting the mathematical system he is studying. For instance, when paradoxal statement represented symbolically becomes conscious in quantum jump sequence, also the context in which it was originally stated changes. This dynamical view about mathematical system could allow to solve antinomies.

REFERENCES

Mathematics

- [A1] Super Virasoro algebra. Available at: http://en.wikipedia.org/wiki/Super_Virasoro_algebra.
- [A2] Stern A. *Matrix Logic*. North-Holland, 1988.
- [A3] Freund PG Brekke L. p-Adic Numbers in Physics. *Phys Rep*, 233(1), 1993.

Condensed Matter Physics

- [D1] Burning salt water. Available at: <http://www.youtube.com/watch?v=aGgOATfoBgo>.
- [D2] Fractional quantum Hall Effect. Available at: http://en.wikipedia.org/wiki/Fractional_quantum_Hall_effect.

[D3] Gamma itoni L et al. Stochastic Resonance. *Rev Mod Phys* ., 70, January 1998.

[D4] Ho M-W. Can Water burn. Available at: <http://www.i-sis.org.uk/canWaterBurn.php>, 2009.

Physics of Earth

Biology

[I1] Chirality (chemistry). Available at: [http://en.wikipedia.org/wiki/Chirality_\(chemistry\)](http://en.wikipedia.org/wiki/Chirality_(chemistry)).

[I2] High energy phosphate. Available at: http://en.wikipedia.org/wiki/High-energy_phosphate.

[I3] Quantum Mechanics Boosts Photosynthesis. Available at: <http://physicsworld.com/cws/article/news/41632>.

[I4] Popp F-A et al. Emission of Visible and Ultraviolet Radiation by Active Biological Systems. *Collective Phenomena*, 3, 1981.

[I5] Pollack G. *Cells, Gels and the Engines of Life*. Ebner and Sons, 2000.

[I6] Turberfield J A Green SJ, Lubrich D. DNA Hairpins: Fuel for Autonomous DNA Devices. *Biophys J*, October 2006.

[I7] Merali Z. Water gave life on Earth a guiding hand. *New Scientist*, (2540), February 2006.

Neuroscience and Consciousness

[J1] Libet B. Readiness potentials preceding unrestricted spontaneous and preplanned voluntary acts. Available at: <http://tinyurl.com/jqp1>, 1982.

[J2] Baars BJ. Understanding Subjectivity: Global Workspace Theory and the Resurrection of the Observing Self. *J Conscious Stud*, 3(3):211–16, 1996.

[J3] Pert CB. *Molecules of Emotion*. Simon & Schuster Inc., 1997.

[J4] Blackman CF. *Effect of Electrical and Magnetic Fields on the Nervous System*, pages 331–355. Plenum, New York, 1994.

[J5] Chalmers D. *The conscious mind: in search of a fundamental theory*. Oxford University Press, New York, 1996.

[J6] Yarrow D. Spin the tale of the dragon. Available at: <http://www.ratical.org/reatvllle/RofD2.html>, 1990.

[J7] Ackerman E. *Biophysical Science*. Prentice Hall, 1962.

[J8] Laszlo E. Psi, Grof, Jung and the Quantum Vacuum. Available at: <http://godel.psy.uwa.edu.au/dynapsych/1996/subtle.html>, 1996.

[J9] Grinberg-Zylverbaum J et al. Human communication and the electrophysiological activity of the brain. *Subtle Energies*, 3, 1993.

[J10] Libet B et al. Subjective referral of the timing for a conscious sensory experience. *Brain*, 102, 1979.

[J11] Phillips H. Perchange to learn. *New Scientist*, 163:2205, 1999.

- [J12] Henkel J. How life learns: an epistemological basis for consciousness. Available at: <http://www.tiac.net/users/knowweb/liflern2.htm>, 1998.
- [J13] Miller JP. Brain Waves Deciphered. *Nature*, November 1996.
- [J14] Persinger M. The tectonic strain theory as an explanation for UFO phenomena. Available at: <http://www.laurentian.ca/www/neurosci/tectonicedit.htm>, 1999.
- [J15] Persinger M. The tectonic strain theory as an explanation for UFO phenomena. Available at: <http://www.laurentian.ca/www/neurosci/tectonicedit.htm>, 1999.
- [J16] Cherry N. Conference report on effects of ELF fields on brain. Available at: <http://www.tassie.net.au/emfacts/icnirp.txt>, 2000.
- [J17] Reissman SS Nevandee DA. Measurement of the electroencephalogram (EEG) coherence in group meditation. 1996.
- [J18] Lavallee F C Persinger MA. Theoretical and Experimental Evidence of Macroscopic Entanglement between Human Brain Activity and Photon Emissions: Implications for Quantum Consciousness and Future Applications. *J Consc Expl & Res*, 1(7):785–807, October 2010.
- [J19] Grof S. *The Adventure of Self-discovery*. State University of New York Press, Albany, 1988.
- [J20] Blackmore SJ. *The Meme Machine*. Oxford University Press, Oxford, 1999.
- [J21] Puthoff H Targ R. Information transmission under conditions of sensory shielding. *Nature*, 251, 1974.
- [J22] Fidelman U. Cerebral asymmetry implies that a total theory of the universe and of the mind is impossible. *Science*, 2002.
- [J23] Krippner S Ullman M. *Dream Studies and Telepathy: An Experimental Approach*, 1970.

Books related to TGD

- [K1] Pitkänen M. About Nature of Time. In *TGD Inspired Theory of Consciousness*. Online book. Available at: http://tgdtheory.fi/public_html/tgdconsc/tgdconsc.html#timenature, 2006.
- [K2] Pitkänen M. About the New Physics Behind Qualia. In *Quantum Hardware of Living Matter*. Online book. Available at: http://tgdtheory.fi/public_html/bioware/bioware.html#newphys, 2006.
- [K3] Pitkänen M. Bio-Systems as Super-Conductors: part I. In *Quantum Hardware of Living Matter*. Online book. Available at: http://tgdtheory.fi/public_html/bioware/bioware.html#superc1, 2006.
- [K4] Pitkänen M. Bio-Systems as Super-Conductors: part II. In *Quantum Hardware of Living Matter*. Online book. Available at: http://tgdtheory.fi/public_html/bioware/bioware.html#superc2, 2006.
- [K5] Pitkänen M. Conscious Information and Intelligence. In *TGD Inspired Theory of Consciousness*. Online book. Available at: http://tgdtheory.fi/public_html/tgdconsc/tgdconsc.html#intsysc, 2006.
- [K6] Pitkänen M. Construction of Quantum Theory: M-matrix. In *Towards M-Matrix*. Online book. Available at: http://tgdtheory.fi/public_html/tgdquantum/tgdquantum.html#towards, 2006.
- [K7] Pitkänen M. Construction of Quantum Theory: Symmetries. In *Towards M-Matrix*. Online book. Available at: http://tgdtheory.fi/public_html/tgdquantum/tgdquantum.html#quthe, 2006.

- [K8] Pitkänen M. Dark Forces and Living Matter. In *Hyper-finite Factors and Dark Matter Hierarchy*. Online book. Available at: http://tgdtheory.fi/public_html/neuplanck/neuplanck.html#darkforces, 2006.
- [K9] Pitkänen M. Dark Matter Hierarchy and Hierarchy of EEGs. In *TGD and EEG*. Online book. Available at: http://tgdtheory.fi/public_html/tgdeeg/tgdeeg.html#eegdark, 2006.
- [K10] Pitkänen M. DNA as Topological Quantum Computer. In *Genes and Memes*. Online book. Available at: http://tgdtheory.fi/public_html/genememe/genememe.html#dnatqc, 2006.
- [K11] Pitkänen M. Does TGD Predict the Spectrum of Planck Constants? In *Hyper-finite Factors and Dark Matter Hierarchy*. Online book. Available at: http://tgdtheory.fi/public_html/neuplanck/neuplanck.html#Planck, 2006.
- [K12] Pitkänen M. Evolution in Many-Sheeted Space-Time. In *Genes and Memes*. Online book. Available at: http://tgdtheory.fi/public_html/genememe/genememe.html#prebio, 2006.
- [K13] Pitkänen M. General Theory of Qualia. In *Bio-Systems as Conscious Holograms*. Online book. Available at: http://tgdtheory.fi/public_html/hologram/hologram.html#qualia, 2006.
- [K14] Pitkänen M. Genes and Memes. In *Genes and Memes*. Online book. Available at: http://tgdtheory.fi/public_html/genememe/genememe.html#genememec, 2006.
- [K15] Pitkänen M. Macroscopic Quantum Coherence and Quantum Metabolism as Different Sides of the Same Coin: Part I. In *Bio-Systems as Conscious Holograms*. Online book. Available at: http://tgdtheory.fi/public_html/hologram/hologram.html#metab, 2006.
- [K16] Pitkänen M. Magnetic Sensory Canvas Hypothesis. In *TGD and EEG*. Online book. Available at: http://tgdtheory.fi/public_html/tgdeeg/tgdeeg.html#mec, 2006.
- [K17] Pitkänen M. Many-Sheeted DNA. In *Genes and Memes*. Online book. Available at: http://tgdtheory.fi/public_html/genememe/genememe.html#genecodec, 2006.
- [K18] Pitkänen M. Matter, Mind, Quantum. In *TGD Inspired Theory of Consciousness*. Online book. Available at: http://tgdtheory.fi/public_html/tgdconsc/tgdconsc.html#conscic, 2006.
- [K19] Pitkänen M. Negentropy Maximization Principle. In *TGD Inspired Theory of Consciousness*. Online book. Available at: http://tgdtheory.fi/public_html/tgdconsc/tgdconsc.html#nmpr, 2006.
- [K20] Pitkänen M. *p-Adic length Scale Hypothesis and Dark Matter Hierarchy*. Online book. Available at: http://tgdtheory.fi/public_html/paddark/paddark.html, 2006.
- [K21] Pitkänen M. p-Adic Physics as Physics of Cognition and Intention. In *TGD Inspired Theory of Consciousness*. Online book. Available at: http://tgdtheory.fi/public_html/tgdconsc/tgdconsc.html#cognic, 2006.
- [K22] Pitkänen M. *Physics in Many-Sheeted Space-Time*. Online book. Available at: http://tgdtheory.fi/public_html/tgdclass/tgdclass.html, 2006.
- [K23] Pitkänen M. Quantum Antenna Hypothesis. In *Quantum Hardware of Living Matter*. Online book. Available at: http://tgdtheory.fi/public_html/bioware/bioware.html#tubuc, 2006.
- [K24] Pitkänen M. Quantum Astrophysics. In *Physics in Many-Sheeted Space-Time*. Online book. Available at: http://tgdtheory.fi/public_html/tgdclass/tgdclass.html#gastro, 2006.

- [K25] Pitkänen M. Quantum Model for Nerve Pulse. In *TGD and EEG*. Online book. Available at: http://tgdtheory.fi/public_html/tgdeeg/tgdeeg.html#pulse, 2006.
- [K26] Pitkänen M. Quantum Model of EEG. In *TGD and EEG*. Online book. Available at: http://tgdtheory.fi/public_html/tgdeeg/tgdeeg.html#eegII, 2006.
- [K27] Pitkänen M. *Quantum Physics as Infinite-Dimensional Geometry*. Online book. Available at: http://tgdtheory.fi/public_html/tgdgeom/tgdgeom.html, 2006.
- [K28] Pitkänen M. *Quantum TGD*. Online book. Available at: http://tgdtheory.fi/public_html/tgdquant/tgdquant.html, 2006.
- [K29] Pitkänen M. Quantum Theory of Self-Organization. In *Bio-Systems as Self-Organizing Quantum Systems*. Online book. Available at: http://tgdtheory.fi/public_html/bioselforg/bioselforg.html#selforgac, 2006.
- [K30] Pitkänen M. Self and Binding. In *TGD Inspired Theory of Consciousness*. Online book. Available at: http://tgdtheory.fi/public_html/tgdconsc/tgdconsc.html#selfbindc, 2006.
- [K31] Pitkänen M. TGD and Astrophysics. In *Physics in Many-Sheeted Space-Time*. Online book. Available at: http://tgdtheory.fi/public_html/tgdclass/tgdclass.html#astro, 2006.
- [K32] Pitkänen M. *TGD and Fringe Physics*. Online book. Available at: http://tgdtheory.fi/public_html/freenergy/freenergy.html, 2006.
- [K33] Pitkänen M. *TGD as a Generalized Number Theory*. Online book. Available at: http://tgdtheory.fi/public_html/tgdnumber/tgdnumber.html, 2006.
- [K34] Pitkänen M. TGD as a Generalized Number Theory: Infinite Primes. In *TGD as a Generalized Number Theory*. Online book. Available at: http://tgdtheory.fi/public_html/tgdnumber/tgdnumber.html#visionc, 2006.
- [K35] Pitkänen M. TGD as a Generalized Number Theory: Quaternions, Octonions, and their Hyper Counterparts. In *TGD as a Generalized Number Theory*. Online book. Available at: http://tgdtheory.fi/public_html/tgdnumber/tgdnumber.html#visionb, 2006.
- [K36] Pitkänen M. Time and Consciousness. In *TGD Inspired Theory of Consciousness*. Online book. Available at: http://tgdtheory.fi/public_html/tgdconsc/tgdconsc.html#timesc, 2006.
- [K37] Pitkänen M. Time, Spacetime and Consciousness. In *Bio-Systems as Conscious Holograms*. Online book. Available at: http://tgdtheory.fi/public_html/hologram/hologram.html#time, 2006.
- [K38] Pitkänen M. *Topological Geometrodynamics: an Overview*. Online book. Available at: http://tgdtheory.fi/public_html/tgdview/tgdview.html, 2006.
- [K39] Pitkänen M. Was von Neumann Right After All? In *Hyper-finite Factors and Dark Matter Hierarchy*. Online book. Available at: http://tgdtheory.fi/public_html/neuplanck/neuplanck.html#vNeumann, 2006.
- [K40] Pitkänen M. *p-Adic length Scale Hypothesis*. Online book. Available at: http://tgdtheory.fi/public_html/padphys/padphys.html, 2013.