TGD Inspired Quantum Theory of Consciousness and of Bio-systems: an Overall View

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Abstract

The purpose of this chapter is to represent a bird eye's of view about the basic ideas of TGD inspired consciousness and its applications to living matter. The notions of classical and quantum TGD are introduced in more detail. The identification of p-adic physics as physics of cognition motivates a brief summary of the basic p-adic aspects of quantum TGD. TGD inspired theory of consciousness and the basic vision about bio-systems as macroscopic quantum systems are summarized.

1 Introduction

T(opological) G(eometro)D(ynamics) is one of the many attempts to find a unified description of basic interactions. The development of the basic ideas of TGD to a relatively stable form took time of about half decade [1]. The great challenge is to construct a mathematical theory around these physically very attractive ideas and I have devoted the last twenty-three years for the realization of this dream and this has resulted in seven online books [TGD, TGDgeom, TGDquant, TGDnumber, TGDclass, TGDpad, TGDfree] about TGD and eight online books about TGD inspired theory of consciousness and of quantum biology [TGDconsc, TGDselforg, TGDware, TGDholo, TGDgeme, TGDeeg, TGDmagn, TGDmath].

Quantum T(opological)D(ynamics) as a classical spinor geometry for infinite-dimensional configuration space, p-adic numbers and quantum TGD, and TGD inspired theory of consciousness have been for last decade of the second millenium the basic three strongly interacting threads in the tapestry of quantum TGD.

For few yeas ago the discussions with Tony Smith generated a fourth thread which deserves the name 'TGD as a generalized number theory'. The work with Riemann hypothesis made time ripe for realization that the notion of infinite primes could provide, not only a reformulation, but a deep generalization of quantum TGD. This led to a thorough and extremely fruitful revision of the basic views about what the final form and physical content of quantum TGD might be.

The fifth thread came with the realization that by quantum classical correspondence TGD predicts an infinite hierarchy of macroscopic quantum systems with increasing sizes, that it is not at all clear whether standard quantum mechanics can accommodate this hierarchy, and that a dynamical quantized Planck constant might be necessary and certainly possible in TGD framework. The identification of hierarchy of Planck constants whose values

TGD "predicts" in terms of dark matter hierarchy would be natural. This also led to a solution of a long standing puzzle: what is the proper interpretation of the predicted fractal hierarchy of long ranged classical electro-weak and color gauge fields. Quantum classical correspondences allows only single answer: there is infinite hierarchy of p-adically scaled up variants of standard model physics and for each of them also dark hierarchy. Thus TGD Universe would be fractal in very abstract and deep sense.

TGD forces the generalization of physics to a quantum theory of consciousness, and represent TGD as a generalized number theory vision leads naturally to the emergence of p-adic physics as physics of cognitive representations. The seven online books [TGD, TGDgeom, TGDquant, TGDnumber, TGDclass, TGDpad, TGDfree] about TGD and eight online books about TGD inspired theory of consciousness and of quantum biology [TGDconsc, TGDselforg, TGDware, TGDholo, TGDgeme, TGDeeg, TGDmagn, TGDmath] are warmly recommended to the interested reader.

1.1 Basic Ideas of TGD

The basic physical picture behind TGD was formed as a fusion of two rather disparate approaches: namely TGD is as a Poincare invariant theory of gravitation and TGD as a generalization of the old-fashioned string model.

1.1.1 TGD as a Poincare invariant theory of gravitation

The first approach was born as an attempt to construct a Poincare invariant theory of gravitation. Space-time, rather than being an abstract manifold endowed with a pseudo-Riemannian structure, is regarded as a surface in the 8-dimensional space $H = M^4_+ \times CP_2$, where M^4_+ denotes the interior of the future light cone of the Minkowski space (to be referred as light cone in the sequel) and $CP_2 = SU(3)/U(2)$ is the complex projective space of two complex dimensions [2, 3, 4, 5]. The identification of the space-time as a submanifold [6, 7] of $M^4 \times CP_2$ leads to an exact Poincare invariance and solves the conceptual difficulties related to the definition of the energy-momentum in General Relativity [Misner-Thorne-Wheeler, Logunov *et al*]. The actual choice $H = M^4_+ \times CP_2$ implies the breaking of the Poincare invariance in the cosmological scales but only at the quantum level. It soon however turned out that submanifold geometry, being considerably richer in structure than the abstract manifold geometry, leads to a geometrization of all basic interactions. First, the geometrization of the elementary particle quantum numbers is achieved. The geometry of CP_2 explains electro-weak and color

quantum numbers. The different H-chiralities of H-spinors correspond to the conserved baryon and lepton numbers. Secondly, the geometrization of the field concept results. The projections of the CP_2 spinor connection, Killing vector fields of CP_2 and of H-metric to four-surface define classical electro-weak, color gauge fields and metric in X^4.

1.1.2 TGD as a generalization of the hadronic string model

The second approach was based on the generalization of the mesonic string model describing mesons as strings with quarks attached to the ends of the string. In the 3-dimensional generalization 3-surfaces correspond to free particles and the boundaries of the 3- surface correspond to partons in the sense that the quantum numbers of the elementary particles reside on the boundaries. Various boundary topologies (number of handles) correspond to various fermion families so that one obtains an explanation for the known elementary particle quantum numbers. This approach leads also to a natural topological description of the particle reactions as topology changes: for instance, two-particle decay corresponds to a decay of a 3-surface to two disjoint 3-surfaces.

1.1.3 Fusion of the two approaches via a generalization of the space-time concept

The problem is that the two approaches seem to be mutually exclusive since the orbit of a particle like 3-surface defines 4-dimensional surface, which differs drastically from the topologically trivial macroscopic space-time of General Relativity. The unification of these approaches forces a considerable generalization of the conventional space-time concept. First, the topologically trivial 3-space of General Relativity is replaced with a "topological condensate" containing matter as particle like 3-surfaces "glued" to the topologically trivial background 3-space by connected sum operation. Secondly, the assumption about connectedness of the 3-space is given up. Besides the "topological condensate" there is "vapor phase" that is a "gas" of particle like 3-surfaces (counterpart of the "baby universies" of GRT) and the non-conservation of energy in GRT corresponds to the transfer of energy between the topological condensate and vapor phase.

1.2 The five threads in the development of quantum TGD

The development of TGD has involved four strongly interacting threads: physics as infinite-dimensional geometry; p-adic physics; TGD inspired the-

ory of consciousness and TGD as a generalized number theory. In the following these five threads are briefly described.

1.2.1 Quantum TGD as configuration space spinor geometry

A turning point in the attempts to formulate a mathematical theory was reached after seven years from the birth of TGD. The great insight was "Do not quantize". The basic ingredients to the new approach have served as the basic philosophy for the attempt to construct Quantum TGD since then and are the following ones:

a) Quantum theory for extended particles is free(!), classical(!) field theory for a generalized Schrödinger amplitude in the configuration space CH consisting of all possible 3-surfaces in H. "All possible" means that surfaces with arbitrary many disjoint components and with arbitrary internal topology and also singular surfaces topologically intermediate between two different manifold topologies are included. Particle reactions are identified as topology changes [8, 9, 10]. For instance, the decay of a 3-surface to two 3-surfaces corresponds to the decay $A \to B+C$. Classically this corresponds to a path of configuration space leading from 1-particle sector to 2-particle sector. At quantum level this corresponds to the dispersion of the generalized Schrödinger amplitude localized to 1-particle sector to two-particle sector. All coupling constants should result as predictions of the theory since no nonlinearities are introduced.

b) Configuration space is endowed with the metric and spinor structure so that one can define various metric related differential operators, say Dirac operator, appearing in the field equations of the theory.

1.2.2 p-Adic TGD

The p-adic thread emerged for roughly ten years ago as a dim hunch that p-adic numbers might be important for TGD. Experimentation with p-adic numbers led to the notion of canonical identification mapping reals to p-adics and vice versa. The breakthrough came with the successful p-adic mass calculations using p-adic thermodynamics for Super-Virasoro representations with the super-Kac-Moody algebra associated with a Lie-group containing standard model gauge group. Although the details of the calculations have varied from year to year, it was clear that p-adic physics reduces not only the ratio of proton and Planck mass, the great mystery number of physics, but all elementary particle mass scales, to number theory if one assumes that primes near prime powers of two are in a physically favored

position. Why this is the case, became one of the key puzzless and led to a number of arguments with a common gist: evolution is present already at the elementary particle level and the primes allowed by the p-adic length scale hypothesis are the fittest ones.

It became very soon clear that p-adic topology is not something emerging in Planck length scale as often believed, but that there is an infinite hierarchy of p-adic physics characterized by p-adic length scales varying to even cosmological length scales. The idea about the connection of p-adics with cognition motivated already the first attempts to understand the role of the p-adics and inspired 'Universe as Computer' vision but time was not ripe to develop this idea to anything concrete (p-adic numbers are however in a central role in TGD inspired theory of consciousness). It became however obvious that the p-adic length scale hierarchy somehow corresponds to a hierarchy of intelligences and that p-adic prime serves as a kind of intelligence quotient. Ironically, the almost obvious idea about p-adic regions as cognitive regions of space-time providing cognitive representations for real regions had to wait for almost a decade for the access into my consciousness.

There were many interpretational and technical questions crying for a definite answer. What is the relationship of p-adic non-determinism to the classical non-determinism of the basic field equations of TGD? Are the p-adic space-time region genuinely p-adic or does p-adic topology only serve as an effective topology? If p-adic physics is direct image of real physics, how the mapping relating them is constructed so that it respects various symmetries? Is the basic physics p-adic or real (also real TGD seems to be free of divergences) or both? If it is both, how should one glue the physics in different number field together to get *The Physics*? Should one perform p-adicization also at the level of the configuration space of 3-surfaces? Certainly the p-adicization at the level of super-conformal representation is necessary for the p-adic mass calculations. Perhaps the most basic and most irritating technical problem was how to precisely define p-adic definite integral which is a crucial element of any variational principle based formulation of the field equations. Here the frustration was not due to the lack of solution but due to the too large number of solutions to the problem, a clear symptom for the sad fact that clever inventions rather than real discoveries might be in question.

Despite these frustrating uncertainties, the number of the applications of the poorly defined p-adic physics growed steadily and the applications turned out to be relatively stable so that it was clear that the solution to these problems must exist. It became only gradually clear that the solution of the problems might require going down to a deeper level than that represented

by reals and p-adics.

1.2.3 TGD as a generalization of physics to a theory consciousness

General coordinate invariance forces the identification of quantum jump as quantum jump between entire deterministic quantum histories rather than time=constant snapshots of single history. The new view about quantum jump forces a generalization of quantum measurement theory such that observer becomes part of the physical system. Thus a general theory of consciousness is unavoidable outcome. This theory is developed in detail in the books [TGDconsc, TGDselforg, TGDware, TGDholo, TGDgeme, TGDeeg, TGDmagn, TGDmath].

1. Quantum jump as a moment of consciousness

The identification of quantum jump between deterministic quantum histories (configuration space spinor fields) as a moment of consciousness defines microscopic theory of consciousness. Quantum jump involves the steps

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

where U is informational "time development" operator, which is unitary like the S-matrix characterizing the unitary time evolution of quantum mechanics. U is however only formally analogous to Schrödinger time evolution of infinite duration although there is *no* real time evolution involved. It is not however clear whether one should regard U-matrix and S-matrix as two different things or not: U-matrix is a completely universal object characterizing the dynamics of evolution by self-organization whereas S-matrix is a highly context dependent concept in wave mechanics and in quantum field theories where it at least formally represents unitary time translation operator at the limit of an infinitely long interaction time. The S-matrix understood in the spirit of superstring models is however something very different and could correspond to U-matrix.

The requirement that quantum jump corresponds to a measurement in the sense of quantum field theories implies that each quantum jump involves localization in zero modes which parameterize also the possible choices of the quantization axes. Thus the selection of the quantization axes performed by the Cartesian outsider becomes now a part of quantum theory. Together these requirements imply that the final states of quantum jump correspond to quantum superpositions of space-time surfaces which are macroscopically equivalent. Hence the world of conscious experience looks classical. At least

formally quantum jump can be interpreted also as a quantum computation in which matrix U represents unitary quantum computation which is however not identifiable as unitary translation in time direction and cannot be 'engineered'.

2. The notion of self

The concept of self is absolutely essential for the understanding of the macroscopic and macro-temporal aspects of consciousness. Self corresponds to a subsystem able to remain un-entangled under the sequential informational 'time evolutions' U. Exactly vanishing entanglement is practically impossible in ordinary quantum mechanics and it might be that 'vanishing entanglement' in the condition for self-property should be replaced with 'subcritical entanglement'. On the other hand, if space-time decomposes into p-adic and real regions, and if entanglement between regions representing physics in different number fields vanishes, space-time indeed decomposes into selves in a natural manner.

It is assumed that the experiences of the self after the last 'wake-up' sum up to single average experience. This means that subjective memory is identifiable as conscious, immediate short term memory. Selves form an infinite hierarchy with the entire Universe at the top. Self can be also interpreted as mental images: our mental images are selves having mental images and also we represent mental images of a higher level self. A natural hypothesis is that self S experiences the experiences of its subselves as kind of abstracted experience: the experiences of subselves S_i are not experienced as such but represent kind of averages $\langle S_{ij} \rangle$ of sub-subselves S_{ij}. Entanglement between selves, most naturally realized by the formation of join along boundaries bonds between cognitive or material space-time sheets, provides a possible a mechanism for the fusion of selves to larger selves (for instance, the fusion of the mental images representing separate right and left visual fields to single visual field) and forms wholes from parts at the level of mental images.

3. Relationship to quantum measurement theory

The third basic element relates TGD inspired theory of consciousness to quantum measurement theory. The assumption that localization occurs in zero modes in each quantum jump implies that the world of conscious experience looks classical. It also implies the state function reduction of the standard quantum measurement theory as the following arguments demonstrate (it took incredibly long time to realize this almost obvious fact!).

a) The standard quantum measurement theory a la von Neumann involves the interaction of brain with the measurement apparatus. If this inter-

action corresponds to entanglement between microscopic degrees of freedom m with the macroscopic effectively classical degrees of freedom M characterizing the reading of the measurement apparatus coded to brain state, then the reduction of this entanglement in quantum jump reproduces standard quantum measurement theory provide the unitary time evolution operator U acts as flow in zero mode degrees of freedom and correlates completely some orthonormal basis of configuration space spinor fields in non-zero modes with the values of the zero modes. The flow property guarantees that the localization is consistent with unitarity: it also means 1-1 mapping of quantum state basis to classical variables (say, spin direction of the electron to its orbit in the external magnetic field).

b) Since zero modes represent classical information about the geometry of space-time surface (shape, size, classical Kähler field,...), they have interpretation as effectively classical degrees of freedom and are the TGD counterpart of the degrees of freedom M representing the reading of the measurement apparatus. The entanglement between quantum fluctuating non-zero modes and zero modes is the TGD counterpart for the $m - M$ entanglement. Therefore the localization in zero modes is equivalent with a quantum jump leading to a final state where the measurement apparatus gives a definite reading.

This simple prediction is of utmost theoretical importance since the black box of the quantum measurement theory is reduced to a fundamental quantum theory. This reduction is implied by the replacement of the notion of a point like particle with particle as a 3-surface. Also the infinite-dimensionality of the zero mode sector of the configuration space of 3-surfaces is absolutely essential. Therefore the reduction is a triumph for quantum TGD and favors TGD against string models.

Standard quantum measurement theory involves also the notion of state preparation which reduces to the notion of self measurement. Each localization in zero modes is followed by a cascade of self measurements leading to a product state. This process is obviously equivalent with the state preparation process. Self measurement is governed by the so called Negentropy Maximization Principle (NMP) stating that the information content of conscious experience is maximized. In the self measurement the density matrix of some subsystem of a given self localized in zero modes (after ordinary quantum measurement) is measured. The self measurement takes place for that subsystem of self for which the reduction of the entanglement entropy is maximal in the measurement. In p-adic context NMP can be regarded as the variational principle defining the dynamics of cognition. In real context self measurement could be seen as a repair mechanism allowing the system

to fight against quantum thermalization by reducing the entanglement for the subsystem for which it is largest (fill the largest hole first in a leaking boat).

4. Selves self-organize

The fourth basic element is quantum theory of self-organization based on the identification of quantum jump as the basic step of self-organization [I1]. Quantum entanglement gives rise to the generation of long range order and the emergence of longer p-adic length scales corresponds to the emergence of larger and larger coherent dynamical units and generation of a slaving hierarchy. Energy (and quantum entanglement) feed implying entropy feed is a necessary prerequisite for quantum self-organization. Zero modes represent fundamental order parameters and localization in zero modes implies that the sequence of quantum jumps can be regarded as hopping in the zero modes so that Haken's classical theory of self organization applies almost as such. Spin glass analogy is a further important element: self-organization of self leads to some characteristic pattern selected by dissipation as some valley of the "energy" landscape.

Dissipation can be regarded as the ultimate Darwinian selector of both memes and genes. The mathematically ugly irreversible dissipative dynamics obtained by adding phenomenological dissipation terms to the reversible fundamental dynamical equations derivable from an action principle can be understood as a phenomenological description replacing in a well defined sense the series of reversible quantum histories with its envelope.

5. Classical non-determinism of Kähler action

The fifth basic element are the concepts of association sequence and cognitive space-time sheet. The huge vacuum degeneracy of the Kähler action suggests strongly that the absolute minimum space-time is not always unique. For instance, a sequence of bifurcations can occur so that a given space-time branch can be fixed only by selecting a finite number of 3-surfaces with time like(!) separations on the orbit of 3-surface. Quantum classical correspondence suggest an alternative formulation. Space-time surface decomposes into maximal deterministic regions and their temporal sequences have interpretation a space-time correlate for a sequence of quantum states defined by the initial (or final) states of quantum jumps. This is consistent with the fact that the variational principle selects preferred extremals of Kähler action as generalized Bohr orbits.

In the case that non-determinism is located to a finite time interval and is microscopic, this sequence of 3-surfaces has interpretation as a simula-

tion of a classical history, a geometric correlate for contents of consciousness. When non-determinism has long lasting and macroscopic effect one can identify it as volitional non-determinism associated with our choices. Association sequences relate closely with the cognitive space-time sheets defined as space-time sheets having finite time duration and psychological time can be identified as a temporal center of mass coordinate of the cognitive space-time sheet. The gradual drift of the cognitive space-time sheets to the direction of future force by the geometry of the future light cone explains the arrow of psychological time.

6. p-Adic physics as physics of cognition and intentionality

The sixth basic element adds a physical theory of cognition to this vision. TGD space-time decomposes into regions obeying real and p-adic topologies labelled by primes $p = 2, 3, 5, ...$ p-Adic regions obey the same field equations as the real regions but are characterized by p-adic non-determinism since the functions having vanishing p-adic derivative are pseudo constants which are piecewise constant functions. Pseudo constants depend on a finite number of positive pinary digits of arguments just like numerical predictions of any theory always involve decimal cutoff. This means that p-adic space-time regions are obtained by gluing together regions for which integration constants are genuine constants. The natural interpretation of the p-adic regions is as cognitive representations of real physics. The freedom of imagination is due to the p-adic non-determinism. p-Adic regions perform mimicry and make possible for the Universe to form cognitive representations about itself. p-Adic physics space-time sheets serve also as correlates for intentional action.

A more more precise formulation of this vision requires a generalization of the number concept obtained by fusing reals and p-adic number fields along common rationals (in the case of algebraic extensions among common algebraic numbers). This picture is discussed in [E1]. The application this notion at the level of the imbedding space implies that imbedding space has a book like structure with various variants of the imbedding space glued together along common rationals (algebraics). The implication is that genuinely p-adic numbers (non-rationals) are strictly infinite as real numbers so that most points of p-adic space-time sheets are at real infinity, outside the cosmos, and that the projection to the real imbedding space is discrete set of rationals (algebraics). Hence cognition and intentionality are almost completely outside the real cosmos and touch it at a discrete set of points only.

This view implies also that purely local p-adic physics codes for the

p-adic fractality characterizing long range real physics and provides an explanation for p-adic length scale hypothesis stating that the primes $p \simeq 2^k$, k integer are especially interesting. It also explains the long range correlations and short term chaos characterizing intentional behavior and explains why the physical realizations of cognition are always discrete (say in the case of numerical computations). Furthermore, a concrete quantum model for how intentions are transformed to actions emerges.

The discrete real projections of p-adic space-time sheets serve also space-time correlate for a logical thought. It is very natural to assign to p-adic pinary digits a p-valued logic but as such this kind of logic does not have any reasonable identification. p-Adic length scale hypothesis suggest that the $p = 2^k - n$ pinary digits represent a Boolean logic B^k with k elementary statements (the points of the k-element set in the set theoretic realization) with n taboos which are constrained to be identically true.

1.2.4 TGD as a generalized number theory

Quantum T(opological)D(ynamics) as a classical spinor geometry for infinite-dimensional configuration space, p-adic numbers and quantum TGD, and TGD inspired theory of consciousness, have been for last ten years the basic three strongly interacting threads in the tapestry of quantum TGD. For few yeas ago the discussions with Tony Smith generated a fourth thread which deserves the name 'TGD as a generalized number theory'. It relies on the notion of number theoretic compactifiction stating that space-time surfaces can be regarded either as hyper-quaternionic, and thus maximally associative, 4-surfaces in M^8 identifiable as space of hyper-octonions or as surfaces in $M^4 \times CP_2$ [E2].

The discovery of the hierarchy of infinite primes and their correspondence with a hierarchy defined by a repeatedly second quantized arithmetic quantum field theory gave a further boost for the speculations about TGD as a generalized number theory. The work with Riemann hypothesis led to further ideas.

After the realization that infinite primes can be mapped to polynomials representable as surfaces geometrically, it was clear how TGD might be formulated as a generalized number theory with infinite primes forming the bridge between classical and quantum such that real numbers, p-adic numbers, and various generalizations of p-adics emerge dynamically from algebraic physics as various completions of the algebraic extensions of rational (hyper-)quaternions and (hyper-)octonions. Complete algebraic, topological and dimensional democracy would characterize the theory.

What is especially satisfying is that p-adic and real regions of the space-time surface could emerge automatically as solutions of the field equations. In the space-time regions where the solutions of field equations give rise to in-admissible complex values of the imbedding space coordinates, p-adic solution can exist for some values of the p-adic prime. The characteristic non-determinism of the p-adic differential equations suggests strongly that p-adic regions correspond to 'mind stuff', the regions of space-time where cognitive representations reside. This interpretation implies that p-adic physics is physics of cognition. Since Nature is probably extremely brilliant simulator of Nature, the natural idea is to study the p-adic physics of the cognitive representations to derive information about the real physics. This view encouraged by TGD inspired theory of consciousness clarifies difficult interpretational issues and provides a clear interpretation for the predictions of p-adic physics.

1.2.5 Dynamical quantized Planck constant and dark matter hierarchy

By quantum classical correspondence space-time sheets can be identified as quantum coherence regions. Hence the fact that they have all possible size scales more or less unavoidably implies that Planck constant must be quantized and have arbitrarily large values. If one accepts this then also the idea about dark matter as a macroscopic quantum phase characterized by an arbitrarily large value of Planck constant emerges naturally as does also the interpretation for the long ranged classical electro-weak and color fields predicted by TGD. Rather seldom the evolution of ideas follows simple linear logic, and this was the case also now. In any case, this vision represents the fifth, relatively new thread in the evolution of TGD and the ideas involved are still evolving.

1. Dark matter as large $\hbar$ phase

D. Da Rocha and Laurent Nottale [17] have proposed that Schrödinger equation with Planck constant $\hbar$ replaced with what might be called gravitational Planck constant $\hbar_{gr} = \frac{GmM}{v_0}$ ($\hbar = c = 1$). v_0 is a velocity parameter having the value $v_0 = 144.7 \pm .7$ km/s giving $v_0/c = 4.6 \times 10^{-4}$. This is rather near to the peak orbital velocity of stars in galactic halos. Also subharmonics and harmonics of v_0 seem to appear. The support for the hypothesis coming from empirical data is impressive.

Nottale and Da Rocha believe that their Schrödinger equation results from a fractal hydrodynamics. Many-sheeted space-time however suggests

astrophysical systems are not only quantum systems at larger space-time sheets but correspond to a gigantic value of gravitational Planck constant. The gravitational (ordinary) Schrödinger equation would provide a solution of the black hole collapse (IR catastrophe) problem encountered at the classical level. The resolution of the problem inspired by TGD inspired theory of living matter is that it is the dark matter at larger space-time sheets which is quantum coherent in the required time scale [D6].

Already before learning about Nottale's paper I had proposed the possibility that Planck constant is quantized [E9] and the spectrum is given in terms of logarithms of Beraha numbers: the lowest Beraha number B_3 is completely exceptional in that it predicts infinite value of Planck constant. The inverse of the gravitational Planck constant could correspond a gravitational perturbation of this as $1/\hbar_{gr} = v_0/GMm$. The general philosophy would be that when the quantum system would become non-perturbative, a phase transition increasing the value of $\hbar$ occurs to preserve the perturbative character and at the transition $n = 4 \to 3$ only the small perturbative correction to $1/\hbar(3) = 0$ remains. This would apply to QCD and to atoms with $Z > 137$ as well.

TGD predicts correctly the value of the parameter v_0 assuming that cosmic strings and their decay remnants are responsible for the dark matter. The harmonics of v_0 can be understood as corresponding to perturbations replacing cosmic strings with their n-branched coverings so that tension becomes n^2-fold: much like the replacement of a closed orbit with an orbit closing only after n turns. $1/n$-sub-harmonic would result when a magnetic flux tube split into n disjoint magnetic flux tubes. Also a model for the formation of planetary system as a condensation of ordinary matter around quantum coherent dark matter emerges [D6].

2. Dark matter as a source of long ranged weak and color fields

Long ranged classical electro-weak and color gauge fields are unavoidable in TGD framework. The smallness of the parity breaking effects in hadronic, nuclear, and atomic length scales does not however seem to allow long ranged electro-weak gauge fields. The problem disappears if long range classical electro-weak gauge fields are identified as space-time correlates for massless gauge fields created by dark matter. Also scaled up variants of ordinary electro-weak particle spectra are possible. The identification explains chiral selection in living matter and unbroken $U(2)_{ew}$ invariance and free color in bio length scales become characteristics of living matter and of bio-chemistry and bio-nuclear physics. An attractive solution of the matter antimatter asymmetry is based on the identification of also antimatter as dark matter.

3. p-Adic and dark matter hierarchies

Dark matter hierarchy assigned to a spectrum of Planck constant having arbitrarily large values brings additional elements to the TGD inspired theory of consciousness and of living matter.

a) Macroscopic quantum coherence can be understood since a particle with a given mass can in principle appear as arbitrarily large scaled up copies (Compton length scales as $\hbar$). The phase transition to this kind of phase implies that space-time sheets of particles overlap and this makes possible macroscopic quantum coherence.

b) The space-time sheets with large Planck constant can be in thermal equilibrium with ordinary ones without the loss of quantum coherence. For instance, the cyclotron energy scale associated with EEG turns out to be above thermal energy at room temperature for the level of dark matter hierarchy corresponding to magnetic flux quanta of the Earth's magnetic field with the size scale of Earth and a successful quantitative model for EEG results [M3].

Dark matter hierarchy leads to detailed quantitative view about quantum biology with several testable predictions [M3]. The applications to living matter suggests that the basic hierarchy corresponds to a hierarchy of Planck constants coming as $\hbar(k) = \lambda^k(p)\hbar_0$, $\lambda \simeq 2^{11}$ for $p = 2^{127-1}$, $k = 0, 1, 2, ...$ [M3]. Also integer valued sub-harmonics and integer valued sub-harmonics of λ might be possible. Each p-adic length scale corresponds to this kind of hierarchy and number theoretical arguments suggest a general formula for the allowed values of Planck constant λ depending logarithmically on p-adic prime [C6]. Also the value of $\hbar_0$ has spectrum characterized by Beraha numbers $B_n = 4cos^2(\pi/n)$, $n \geq 3$, varying by a factor in the range $n > 3$ [C6]. It must be however emphasized that the relation of this picture to the model of quantized gravitational Planck constant h_{gr} appearing in Nottale's model is not yet completely understood.

The general prediction is that Universe is a kind of inverted Mandelbrot fractal for which each bird's eye of view reveals new structures in long length and time scales representing scaled down copies of standard physics and their dark variants. These structures would correspond to higher levels in self hierarchy. This prediction is consistent with the belief that 75 per cent of matter in the universe is dark.

4. Living matter and dark matter

Living matter as ordinary matter quantum controlled by the dark matter hierarchy has turned out to be a particularly successful idea. The hypoth-

esis has led to models for EEG predicting correctly the band structure and even individual resonance bands and also generalizing the notion of EEG [M3]. Also a generalization of the notion of genetic code emerges resolving the paradoxes related to the standard dogma [L2, M3]. A particularly fascinating implication is the possibility to identify great leaps in evolution as phase transitions in which new higher level of dark matter emerges [M3].

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

5. Dark matter hierarchy and the notion of self

The vision about dark matter hierarchy leads to a more refined view about self hierarchy and hierarchy of moments of consciousness [J6, M3]. The larger the value of Planck constant, the longer the subjectively experienced duration and the average geometric duration $T(k) \propto \lambda^k$ of the quantum jump.

Quantum jumps form also a hierarchy with respect to p-adic and dark hierarchies and the geometric durations of quantum jumps scale like $\hbar$. Dark matter hierarchy suggests also a slight modification of the notion of self. Each self involves a hierarchy of dark matter levels, and one is led to ask whether the highest level in this hierarchy corresponds to single quantum jump rather than a sequence of quantum jumps. The averaging of conscious experience over quantum jumps would occur only for sub-selves at lower levels of dark matter hierarchy and these mental images would be ordered, and single moment of consciousness would be experienced as a history of events. The quantum parallel dissipation at the lower levels would give rise to the experience of flow of time. For instance, hadron as a macro-temporal quantum system in the characteristic time scale of hadron is a dissipating system at quark and gluon level corresponding to shorter p-adic time scales. One can ask whether even entire life cycle could be regarded as

a single quantum jump at the highest level so that consciousness would not be completely lost even during deep sleep. This would allow to understand why we seem to know directly that this biological body of mine existed yesterday.

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

6. The time span of long term memories as signature for the level of dark matter hierarchy

The simplest dimensional estimate gives for the average increment τ of geometric time in quantum jump $\tau \sim 10^4\ CP_2$ times so that $2^{127} - 1 \sim 10^{38}$ quantum jumps are experienced during secondary p-adic time scale $T_2(k = 127) \simeq 0.1$ seconds which is the duration of physiological moment and predicted to be fundamental time scale of human consciousness [L1]. A more refined guess is that $\tau_p = \sqrt{p}\tau$ gives the dependence of the duration of quantum jump on p-adic prime p. By multi-p-fractality predicted by TGD and explaining p-adic length scale hypothesis, one expects that at least $p = 2$-adic level is also always present. For the higher levels of dark matter hierarchy τ_p is scaled up by $\hbar/\hbar_0$. One can understand evolutionary leaps as the emergence of higher levels at the level of individual organism making possible intentionality and memory in the time scale defined τ [L2].

Higher levels of dark matter hierarchy provide a neat quantitative view about self hierarchy and its evolution. For instance, EEG time scales corresponds to $k = 4$ level of hierarchy and a time scale of .1 seconds [J6], and EEG frequencies correspond at this level dark photon energies above the thermal threshold so that thermal noise is not a problem anymore. Various levels of dark matter hierarchy would naturally correspond to higher levels in the hierarchy of consciousness and the typical duration of life cycle would give an idea about the level in question.

The level would determine also the time span of long term memories as discussed in [M3]. $k = 7$ would correspond to a duration of moment of conscious of order human lifetime which suggests that $k = 7$ corresponds to the highest dark matter level relevant to our consciousness whereas higher

levels would in general correspond to transpersonal consciousness. $k = 5$ would correspond to time scale of short term memories measured in minutes and $k = 6$ to a time scale of memories measured in days.

The emergence of these levels must have meant evolutionary leap since long term memory is also accompanied by ability to anticipate future in the same time scale. This picture would suggest that the basic difference between us and our cousins is not at the level of genome as it is usually understood but at the level of the hierarchy of magnetic bodies [L2, M3]. In fact, higher levels of dark matter hierarchy motivate the introduction of the notions of super-genome and hyper-genome. The genomes of entire organ can join to form super-genome expressing genes coherently. Hyper-genomes would result from the fusion of genomes of different organisms and collective levels of consciousness would express themselves via hyper-genome and make possible social rules and moral.

2 Basics of classical and quantum TGD

2.1 The notion of many-sheeted space-time

Quantum classical correspondences states that all quantum phenomena should have space-time correlates. Not only quantum states but also quantum jump sequences should have space-time correlates and the facts that space-time surfaces are indeed analogous to Bohr orbits and the failure of the classical non-determinism of the basic variational principle in standard sense make this possible. This correspondence cannot be of course one-to-one. In a well-defined sense classical TGD defined as the dynamics of space-time surface determining them as kind of generalized Bohr orbits can be regarded as an exact part of quantum theory and assuming quantum classical correspondence has served as an extremely valuable guideline in the attempts to interpret TGD, to form a view about what TGD really predicts, and to to guess what the underlying quantum theory could be and how it deviates from standard quantum theory.

2.1.1 Basic extremals of the Kähler action

In this chapter the classical field equations associated with the Kähler action are studied. The study of the extremals of the Kähler action has turned out to be extremely useful for the development of TGD. Towards the end of year 2003 quite dramatic progress occurred in the understanding of field

equations and it seems that field equations might be in well-defined sense exactly solvable.

1. General considerations

The vanishing of Lorentz 4-force for the induced Kähler field means that the vacuum 4-currents are in a mechanical equilibrium. Lorentz 4-force vanishes for all known solutions of field equations which inspires the hypothesis that all extremals or at least the absolute minima of Kähler action satisfy the condition. The vanishing of the Lorentz 4-force in turn implies local conservation of the ordinary energy momentum tensor. The corresponding condition is implied by Einstein's equations in General Relativity. The hypothesis would mean that the solutions of field equations are what might be called generalized Beltrami fields. The condition implies that vacuum currents can be non-vanishing only provided the dimension D_{CP_2} of the CP_2 projection of the space-time surface is less than four so that in the regions with $D_{CP_2} = 4$, Maxwell's vacuum equations are satisfied.

The hypothesis that Kähler current is proportional to a product of an arbitrary function ψ of CP_2 coordinates and of the instanton current generalizes Beltrami condition and reduces to it when electric field vanishes. Kähler current has vanishing divergence for $D_{CP_2} < 4$, and Lorentz 4-force indeed vanishes. The remaining task would be the explicit construction of the imbeddings of these fields and the demonstration that field equations can be satisfied.

Under additional conditions magnetic field reduces to what is known as Beltrami field. Beltrami fields are known to be extremely complex but highly organized structures. The natural conjecture is that topologically quantized many-sheeted magnetic and Z^0 magnetic Beltrami fields and their generalizations serve as templates for the helical molecules populating living matter, and explain both chirality selection, the complex linking and knotting of DNA and protein molecules, and even the extremely complex and self-organized dynamics of biological systems at the molecular level.

Field equations can be reduced to algebraic conditions stating that energy momentum tensor and second fundamental form have no common components (this occurs also for minimal surfaces in string models) and only the conditions stating that Kähler current vanishes, is light-like, or proportional to instanton current, remain and define the remaining field equations. The conditions guaranteing topologization to instanton current can be solved explicitly. Solutions can be found also in the more general case when Kähler current is not proportional to instanton current. On basis of these findings there are strong reasons to believe that classical TGD is exactly solvable.

2. Does TGD define a a generalized topological quantum field theory?

A long standing assumption has been that the principle selecting the unique space-time going through given 3-surface (not reducing to single space-like component however) is absolute minimization of Kähler action. The number theoretical considerations suggest a more refined and more local principle, in which maximization or minimization of the value occurs for regions where the sign of action density is definite [E2] and that these two variational principles define dual pairs of 4-surfaces. This variational principle allows to interpret space-time surfaces generalized calibrations for which Kähler action density defines a four-form worm the physical extremals so that theory can be said to be topologized.

In fact already the generalized Bohr orbit property leads one to suspect that classical TGD defines a topological field theory generalized in such a manner that various conserved Noether charges can be regarded as topological invariants as extrema of these invariants for a given topology of 3-surface. There are of course zero modes characterizing the shape and size of the four-surface involved. Perhaps the maxima of Kähler function with respect to the zero modes define genuine topological invariants.

3. Generalized Bohr orbit property and second law of thermodynamics?

By quantum classical correspondence the non-deterministic space-time dynamics should mimic the dissipative dynamics of the quantum jump sequence. Beltrami fields appear in physical applications as asymptotic self organization patterns for which Lorentz force and dissipation vanish. This suggests that the preferred extrema defining the Bohr orbits, be they absolute minima of Kähler action or something more general, correspond to space-time sheets which asymptotically satisfy generalized Beltrami conditions so that one can indeed assign to the final (rather than initial!) 3-surface a unique 4-surface apart from effects related to non-determinism. Absolute minimization makes sense p-adically only if abstracted to purely algebraic generalized Beltrami conditions. The notion of Kähler calibration is purely algebraic local notion and certainly makes sense also p-adically. Also the equivalence of Bohr orbit property with the second law strongly suggests itself.

4. The dimension of CP_2 projection as classifier for the fundamental phases of matter

The dimension D_{CP_2} of CP_2 projection of the space-time sheet encountered already in p-adic mass calculations classifies the fundamental phases

of matter. For $D_{CP_2} = 4$ empty space Maxwell equations hold true. This phase is chaotic and analogous to de-magnetized phase. $D_{CP_2} = 2$ phase is analogous to ferromagnetic phase: highly ordered and relatively simple. $D_{CP_2} = 3$ is the analog of spin glass and liquid crystal phases, extremely complex but highly organized by the properties of the generalized Beltrami fields. This phase is the boundary between chaos and order and corresponds to life emerging in the interaction of magnetic bodies with bio-matter. It is possible only in a finite temperature interval (note however the p-adic hierarchy of critical temperatures) and characterized by chirality just like life.

5. Specific extremals of Kähler action

The study of extremals of Kähler action represents more than decade old layer in the development of TGD.

a) The huge vacuum degeneracy is the most characteristic feature of Kähler action (any 4-surface having CP_2 projection which is Legendre sub-manifold is vacuum extremal, Legendre sub-manifolds of CP_2 are in general 2-dimensional). This vacuum degeneracy is behind the spin glass analogy and leads to the p-adic TGD. As found in the second part of the book, various particle like vacuum extremals also play an important role in the understanding of the quantum TGD.

b) The so called CP_2 type vacuum extremals have finite, negative action and are therefore an excellent candidate for real particles whereas vacuum extremals with vanishing Kähler action are candidates for the virtual particles. These extremals have one dimensional M^4 projection, which is light like curve but not necessarily geodesic and locally the metric of the extremal is that of CP_2: the quantization of this motion leads to Virasoro algebra. Space-times with topology $CP_2\#CP_2\#...CP_2$ are identified as the generalized Feynmann diagrams with lines thickened to 4-manifolds of "thickness" of the order of CP_2 radius. The quantization of the random motion with light velocity associated with the CP_2 type extremals in fact led to the discovery of Super Virasoro invariance, which through the construction of the configuration space geometry, becomes a basic symmetry of quantum TGD.

c) There are also various non-vacuum extremals.

i) String like objects, with string tension of same order of magnitude as possessed by the cosmic strings of GUTs, have a crucial role in TGD inspired model for the galaxy formation and in the TGD based cosmology.

ii) The so called massless extremals describe non-linear plane waves propagating with the velocity of light such that the polarization is fixed in given point of the space-time surface. The purely TGD:eish feature is the light

like Kähler current: in the ordinary Maxwell theory vacuum gauge currents are not possible. This current serves as a source of coherent photons, which might play an important role in the quantum model of bio-system as a macroscopic quantum system.
iii) In the so called Maxwell's phase, ordinary Maxwell equations for the induced Kähler field are satisfied in an excellent approximation. A special case is provided by a radially symmetric extremal having an interpretation as the space-time exterior to a topologically condensed particle. The sign of the gravitational mass correlates with that of the Kähler charge and one can understand the generation of the matter antimatter asymmetry from the basic properties of this extremal. The possibility to understand the generation of the matter antimatter asymmetry directly from the basic equations of the theory gives strong support in favor of TGD in comparison to the ordinary EYM theories, where the generation of the matter antimatter asymmetry is still poorly understood.

2.1.2 The notion of many-sheeted space-time

The notions of many-sheeted space-time, and topological condensation and evaporation represent the basic new concepts of TGD.

a) Renormalization group invariance of the Kähler function implies that 3-surfaces with all possible sizes are important in the functional integral. The compactness of CP_2 in turn implies that 3-surfaces representable as maps $M^4 \to CP_2$ have an outer boundary and that so called topological field quantization occurs: space-time surface decomposes into disjoint regions characterized by a handful of vacuum quantum numbers, space-time sheets. Also classical fields decompose to topological light rays, flux quanta of magnetic and electric fields, etc. These results suggest that 3-space or topological condensate, as we call it, is many-sheeted, consisting of topological field quanta glued on each other. The resulting many-sheeted space-time has a hierarchical, fractal like structure: 3-surfaces with boundary condensed on 3-surfaces with boundary condensed on... .

b) Of utmost importance is that topological field quanta allow discrete scalings as dynamical symmetries and this symmetry corresponds naturally to the p-adic scalings by the powers of $\sqrt{p}$, where p is the p-adic prime. The interpretation is in terms of effective p-adic topology and p-adic fractality implying long range correlations. These real long range correlations can be understand in terms of purely local p-adic continuity and smoothness so that p-adically infinitesimal physics would code for long length scale real physics [E1]. Both p-adic mass calculations and various other appli-

cations [TGDpad] and theoretical considerations [E1] favor p-adic length scale hypothesis stating that the values $p \simeq 2^k$, k integer with prime values preferred.

A further refinement of the picture comes from the dark matter hierarchy whose levels correspond to increasing values of Planck constant $\hbar = \lambda^k \hbar_0$, where λ is integer for which TGD provides a prediction [C6], and for which a favored value in living matter is $\lambda \simeq 2^{11}$. Considerations related to the Poincare invariance lead to the prediction that dark matter space-time sheets should define λ^k-fold coverings of M^4 in H so that the difference between dark and ordinary matter would be purely topological.

b) At the the first level of the condensation hierarchy quarks condensate to hadrons, hadrons to nuclei, nuclei and electrons to atoms, atoms to molecules, etc., each of these systems being a 3-surface with boundary. Also macroscopic bodies (!) are identified as 3-surfaces with boundaries (their outer surface): this means a completely new manner to understand the visible every day world with matter as a manifestion of 3-topology: 3-space with topology replaces 3-space with matter!

c) The formation of join along boundaries bonds is a new fundamental interaction, which plays a key role as a phenomenological interaction in chemistry, especially in biochemistry, and at macroscopic level (macroscopic bodies just touch each other). This interaction provides a topological mechanism for the generation of coherent quantum systems from smaller units and also dissipation (loss of quantum coherence) can be understood topologically. A complex parameter measuring quantum coherence is identified and the connection with super conductivity and super fluidity is pointed out.

d) In the length scales much larger than CP_2 size, gauge charges are identified as classical gauge charges defined as gauge fluxes and a classical quantization of the electromagnetic and Z^0 gauge charges supported by the absolute minimization of the Kähler action is assumed. The absolute minimization of the Kähler action forces the generation of long range Z^0 fields in macroscopic length scales. The observed extreme smallness of the parity breaking effects in nuclear and atomic length scales requires that elementary particles feed their Z^0 gauge charges to the space-time sheets having typical size of order cell size, where it is screened by the topologically condensed neutrinos. The large parity breaking caused by the classical Z^0 force provides a possible explanation for the chirality selection in the biosystems. The solar neutrino puzzle provides a second potential applications of the classical Z^0 force.

e) The requirement of the classical gauge charge conservation requires that gauge fluxes are feeded from the boundary of a given space-time sheet

to a larger space-time sheet through tiny wormholes called # throats in the sequel. These # particle like objects effectively carry opposite classical gauge charges on the two space-time sheets but quantum mechanically they behave as extremely tiny dipoles. The inertial masses of these particles must be small, of the order $1/L(n)$, where $L(n)$ corresponds a typical size of the 3-surface in the length scale hierarchy. This makes possible the formation of Bose Einstein condensates of # throats near the boundaries of space-time sheets. These BE condensates might have fundamental role in biology and biochemistry of the living matter.

f) TGD based space-time concept is applied to construct a simple model of color confinement. The condensation takes place at two levels. Quarks and gluons (represented by CP_2 type extremals) condense on small M^4 type 3-surfaces and these surfaces secondarily condense on the hadronic 3-surface. Valence quarks (at least) are assumed to be connected by Kähler electric flux tubes (join along boundaries bonds) so that they combine to form color singlets. Since the classical gluon field is proportional to the Kähler field, the flux tubes (analogous to hadronic strings) can be regarded as color electric flux tubes and the picture of a confinement analogous to that provided by QCD results. Spin glass degeneracy allows to understand the generation of macro-temporal quantum coherence and the same mechanism allows also to understand more quantitatively color confinement by applying unitarity conditions.

2.2 Construction of quantum theory

The vision about TGD as a generalized number theory allows to concretize considerably the previous views about quantum TGD and get rid of internal inconsistencies. The superconformal invariance associated with the light cone boundary and quaternion-conformal invariance are quite different things: the first one can be regarded as cosmological symmetry whereas the latter is the symmetry crucial for elementary particle physics. Accordingly, configuration space Dirac equation and super-Virasoro conditions associated with the quaternion-conformal super-Kac-Moody algebra are separate conditions: this realization allows to get rid of some earlier ad hoc constructs forced by the physically intuition yielded by the p-adic mass calculations and replacing the strictly geometric approach. Unless one is doing quantum cosmology, one can safely forget supercanonical symmetries associated with the lightcone boundary and concentrate on $M^4 \times SO(3,1) \times SU(3) \times U(2)_{ew}$ Super-Kac-Moody algebra acting as gauge symmetries of gravitational, color and electroweak interactions and forming the backbone of p-adic mass cal-

culations.

In cosmological scales the state construction involves the construction of super-canonical representations fixing the state basis at the boundary of configuration space defined by the boundary $\delta M_+^4 \times CP_2$ of the imbedding space. A natural manner to fix the basis for the configuration space spinor fields S in $C(\delta M_+^4 \times CP_2)$ is to require that the basis forms a representation for some Abelian extension of the isometry group of the configuration space.

a) A symplectic $U(1)$ extension of the isometry group induced from the Poisson brackets is constructed.

b) The spinor representations of the symplectic extension are assumed to be constructable in terms of configuration space Dirac opertora. The properties of the CH geometry suggest that configuration space Dirac equation should reduce to Super Virasoro conditions. These conditions say nothing about mass spectrum of elementary particles since cm degrees of freedom represent zero modes not contributing to configuration space metric and Dirac equation.

In practice all that is need is the construction of local physical states as representations of quaternion-conformal super algebra. The only new element is that supergenerators carry fermion number. This means a slight modification of the standard super-algebra structure. In this way one circumvents the Majorana condition forcing the dimension of the imbedding space to $d = 2 \ mod \ 8$. The algebra contains N-S type super generators carrying quark number and Ramond type super generators carrying lepton number. The construction of states as representations of this algebra leads to SKMD equations and yields universal mass formula. SKMD operator contains Kac-Moody central charge as parameter but the requirement that mass squared spectrum is integer valued in natural units, fixes the value of this parameter. Ramond and NS algebras are parts of a larger algebra obtained by combining the two algebras and allowing conformal generators with half odd integer conformal weight: these generators do not however act as geometric transformations and possess quantum numbers of leptoquark. One must pose either NS or Ramond type gauge conditions on the physical states.

One can assign to a particle like 3-surface also cm degrees of freedom. This means that particles are characterized by partial waves in $H = M_+^4 \times CP_2$ so that in the point like limit Kaluza-Klein theory in H results. Color compensation mechanism allows the compensation of the anomalous color associated with color partial waves by the color associated with the monomials of $n = 0$ leptonic and $n = 1/2$ quark like generators of the dynamical Super Virasoro algebras.

In TGD the basic object is U-matrix and it is not clear how closely it corresponds to S-matrix of quantum field theories defined as a unitary time translation operator. U-matrix can be seen at the general level as Glebsch-Gordan coefficients relating free and interacting representations of the quaternion-conformal algebra and superconformal algebra associated with lightcone boundary. Free representation corresponds to the tensor product of super-algebras associated with $\cup_i X^4(Y_i^3)$, Y_i^3 are the space-time surfaces associated with the infinite primes labelling the incoming particles whereas interacting representations corresponds to the superalgebras associated with $X^4(\cup_i Y_i^3)$ defined by the infinite integer defined as the product of infinite primes characterizing incoming states. This hypothesis reduces interactions to generalized number theory and gives hopes of making practical calculations someday.

At practical level the construction reduces to the construction of local S-matrix and quaternion-conformal invariance together with the fact that effective one-dimensionality reduces the situation algebraically to that encountered in string models gives good hopes that stringy S-matrix provides an excellent approximation. An open question is whether this S-matrix is approximation to U-matrix or not.

2.3 Construction of S-matrix at high energy limit

It is possible to write Feynmann rules for S-matrix in the approximation that only CP_2 type extremals appear as virtual and real particles. All CP_2 type extremals are locally isometric with CP_2 itself and only the random lightlike curve is dynamical. The classical dynamics is actually isomorphic with stringy dynamics since classical Virasoro conditions are satisfied. Fermions belong to representations of Super-Kac-Moody algebra of $M^4 \times SO(3,1) \times SU(3) \times U(2)_{ew}$. The classical non-determinism of the dynamics implies that Feynmann graph expansion is topologized. This saves from fermionic divergences since the exponent of the momentum generator effecting translation along the lines of Feynmann graph corresponds to that associated with the modified Dirac action and thus to free quantum theory for fermions.

Vertex operators $V(a,b,c)$ are generalizations of the vertex operators of string theory: instead of strings 3-surface inside CP_2 type extremal fuse together. Propagator factors are products of the exponent of Kähler action for CP_2 type extremal proportional to the volume of the CP_2 type extremal, the 'stringy' $1/(L_0 + i\epsilon)$ factor, which in fact comes from the vertices, and translation operator along the geodesic representing cm motion.

The theory has some features characteristic for quantum TGD.

a) One can assume that each quantum jump involves localization in zitterbewegung degrees of freedom. The resulting S-matrix is independent of the choise of the representative for the zitterbewegung orbit as long as the cm motion connects the lines of the vertices. The predictions depend however on an arbitrary function of U of CP_2 coordinates giving rise to a decomposition of CP_2 to 'time slices'. The dependence of the propagator is only through the volume of CP_2 type extremal determined by U whereas coupling constants have more complicated, but presumably very mild dependence on U. The dependence on the function U means that one must average the scattering rates over the allowed spectrum of functions U. This dependence of the fundamental coupling constants on U is in accordance with spin glass analogy and means that fundamental coupling constants are not strictly speaking constants.

b) The volume of the internal line, which is fraction of CP_2 volume determines the value of the exponent of Kähler action and provides thus a supression factor serving as an infrared cutoff. A constraint to the allowed functions U results from the topological condensation of CP_2 in particle like space-time sheet (for instance massless extremal), which implies that CP_2 type extremals cannot extend outside the region with size of order p-adic length scale L_p. The only interpretation is that the information about infrared cutoff length scale is coded into the structure of particle: particle in the box is quite not the same as free particle. This suggests new view about color confinement: quarks and gluons correspond to CP_2 type extremals which cannot exist too long time as free particles and therefore cannot leave hadron. The result also means that even elementary particles are to some degree adaptive systems.

c) The classical non-determinism of the Kähler action, not only makes possible the geometrization of the Feynmann rules, but also allows the interpretation of the S-matrix elements as transition amplitudes from a given vacuum to a new vacuum differing by an addition of a space-time sheet containing zero-energy state with incoming/outgoing states having positive/negative energies. By crossing symmetry this amplitude is indeed equal to S-matrix element. This means that zero energy states represent scattering events as physical states and obviously correspond to a higher, self-referential level of the physical existence. Entire hierarchy of higher level physical states coding in their structure physical laws at the lower levels of the hierachy is predicted. Thus classical non-determinism makes possible self-referential Universe whereas p-adic non-determinism makes possible cognitive representations.

3 p-Adic aspects of quantum TGD

It took quite a long time to end up with the recent picture how p-adic numbers emerge as a basic aspect of quantum TGD and what p-adicization of TGD might mean. Of course, recent picture need not be the final yet and there are several unsolved problems. In the following the basic properties of the p-adic numbers are described shortly and then it is demonstrated how p-adic numbers might emerge from TGD and how one should formulate p-adic version of quantum TGD formalism.

3.1 p-Adic numbers

Like real numbers, p-adic numbers can be regarded as completions of the rational numbers to a larger number field allowing the generalization of differential calculus. Each prime p defines a p-adic number field allowing the counterparts of the usual arithmetic operations. The basic difference between real and p-adic numbers is that p-adic topology is ultrametric. This means that the distance function $d(x,y)$ (the counterpart of $|x-y|$ in the real context) satisfies the inequality

$$d(x,z) \leq Max\{d(x,y), d(y,z)\} \ ,$$

(Max(a,b) denotes maximum of a and b) rather than the usual triangle inequality

$$d(x,z) \leq d(x,y) + d(y,z) \ .$$

p-Adic numbers have expansion in powers of p analogous to the decimal expansion

$$x = \sum_{n \geq 0} x_n p^n \ ,$$

and the number of terms in the expansion can be infinite so that p-adic number need not be finite as a real number. The norm of the p-adic number (counterpart of $|x|$ for real numbers) is defined as

$$N_p(x = \sum_{n \geq 0} x_n p^n) = p^{-n_0} \ ,$$

and depends only very weakly on p-adic number. The ultrametric distance function can be defined as $d_p(x,y) = N_p(x-y)$.

p-Adic numbers allow the generalization of the differential calculus and of the concept of analytic function $f(x) = \sum f_n x^n$. The basic rules of the

p-adic differential calculus are the same as those of the ordinary differential calculus. There is however one important new element: the set of the functions having vanishing p-adic derivative consists of so called pseudo constants, which depend on a finite number of positive pinary digits of x only so that one has

$$f_N(x = \sum_n x_n p^n) = f(x_N = \sum_{n<N} x_n p^n) \ .$$

In the real case only constant functions have vanishing derivative. This implies that p-adic differential equations are non-deterministic.

An essential element is the map of the p-adic numbers to the positive real numbers by the so called canonical identification I:

$$I : \sum x_n p^n \in R_p \rightarrow \sum_n x_n p^{-n} \in R \ .$$

Canonical identification makes it possible to map the predictions of the p-adic physics to real numbers. Canonical identification has inverse, which is single valued for the real numbers having infinite number of pinary digits but two-valued for real numbers having finite number of pinary digits (the reason is that real number with finite number or pinary digits has two equivalent pinary expansions: ($x = 1 = .999999...$ in case of decimal expansion and $x = 1 = 0yyyy...$, $y = p - 1$, in case of pinary expansion).

The definition of a definite integral for p-adic numbers is not a trivial problem. The first problem is that p-adic numbers are not well ordered and one cannot define what ordered integration interval $[a, b]$ means p-adically. Canonical identification solves this problem: a is smaller than b if the real counterpart of a under canonical identification is smaller than the real counterpart of b. The second problem is that Riemann sum gives identically vanishing p-adic integral if coordinate increments approach zero at the limit. One can however define the definite integral in terms of the integral function:

$$\int_a^b f(x)dx = F(b) - F(a) \ \ ; \ \ f(x) = \frac{dF(x)}{dx} \ .$$

Integral function $F(x)$ is obtained using the inverse of the derivation just as in the real context and is unique if p-adic pseudo constants required to reduce to ordinary constants.

One can consider also other possibilities to define p-adic integral. This is not so alarming as it sounds since the idea that p-adic physics is physics of cognitive representations might allow several nonequivalent definitions of definite integral.

a) Especially interesting, and perhaps also practical definition, is based on p-adic Fourier analysis relying on discretization and on the use of Pythagorean phases as counterparts of planewaves. In this case planewaves form a complete and orthogonal set and satisfy the natural physical constraints. For Pythagorean planewaves integral reduces to a sum and ultrametricity implies that the p-adic integral is finite for bounded functions. This property could guarantee UV finiteness of the p-adic QFT limit of TGD.

b) In case of canonical images of real functions, which are not p-adically differentiable, canonical identification makes it possible to induce the division of the p-adic integration interval to subintervals from the corresponding real division and p-adic integral can be calculated from the generalized Riemann sum obtained in this manner. The crucial property of the generalized Riemann sum making possible finite valued integral, is that the p-adic norms of the coordinate increments do not necessarily approach zero even when real coordinate increments do so. This integral need not be equivalent with the direct generalization of real integral and need not work for p-adically differentiable functions, whose real images are not continuous.

c) The so called adelic integration formula defines a promising approach to configuration space integration and might make sense also p-adically.

p-Adic integration makes it possible to define p-adic variational principles: the p-adic counterpart of the action is mapped by the canonical identification to real number and is minimized. The field equations are same as in real case and absolute minimization conditions are interpreted as algebraic conditions on the initial values of configuration space coordinates on lightcone boundary. The solutions of Euler-Lagrange equations are non-deterministic by the existence of the p-adic pseudo constants.

p-Adic fractals are functions $R \to R$ obtained from p-adically analytic functions $f : R_p \to R_p$ as composite functions $f_R = I \circ f \circ I^{-1}$. The last link in the long chain was the realization that the emergence of p-adic fractals in basic quantum TGD is what makes p-adic number fields a basic structural element of quantum TGD.

3.2 How p-adic numbers emerge from quantum TGD?

During last ten years I have developed several arguments suggesting how and why p-adic numbers are an essential part of TGD. Many of the arguments have looked rather convincing but as it seems now, wrong. In the following I represent only the arguments which seem to make sense when one accepts 'TGD as a generalized number theory' vision.

3.2.1 p-Adic physics as physics of cognitive representations

TGD as a generalized number theory vision forces to interpret p-Adic physics as the physics of cognitive representations. This assumption is rather radical since it means that cognition is present already in p-adic length scales in the sense that the p-adic versions of CP_2 type extremals provide cognitive representations for elementary particles. This vision obviously means a concrete realization of the Universe as a Computer idea which was one of the basic sources of inspiration durig the initial states of p-adic TGD.

3.2.2 Vacuum degeneracy of the Kähler action and spin glass analogy

The space of minima of free energy for spin glass is known to have ultrametric topology. p-Adic topology is also ultrametric and this motivated the hypothesis that quantum average space-time, 'topological condensate', defined as a maximum of Kähler function can be obtained by gluing together regions characterized by various values of the p-adic prime p. It must be emphasized that this hypothesis is just a guess and not even correct as such, and it seems that TGD as a generalized number theory vision gives the real justification for the p-adics. A good guess is however that the ultrametric topology of the reduced configuration space consisting of the maxima of the Kähler function is induced from the p-adic norm and that there is a close connection between the two p-adicities. The following arguments tries to make this idea more precise.

The unique feature of the Kähler action is its enormous vacuum degeneracy: any space-time surface, whose CP_2 projection is a so called Legendre manifold (having dimension $D \leq 2$) is vacuum extremal. This is expected to imply a large degeneracy of the absolute minimum space-times: for instance, several absolute minima with the same action are possible for single 3-surface (this forces to a generalization of space-time concept obtained by introducing 'association sequences'). The degeneracy means an obvious analogy with the spin glass phase characterized by 'frustration' implying a large number of degenerate ground states. In the construction of the configuration space geometry the analogy between quantum TGD and spin glass becomes precise.

Spin glass consists of magnetized regions such that the direction of the magnetization varies randomly in the spatial degrees of freedom but is frozen in time. What is peculiar that, although there are large gradients on the boundaries of the regions with a definite direction of magnetization, no large

surface energies are generated. An obvious p-adic explanation suggests itself: p-adic magnetization could be pseudo constant and hence piecewise constant with a vanishing derivative on the boundaries of the magnetized regions so that no p-adic surface energy would be generated.

In the description of the spin glass phase also ultrametricity, which is the basic property of the p-adic topology, emerges in a natural manner. The energy landscape describing the free energy of spin glass as a function of various parameters characterizing spin glass, is fractal like function and there are infinite number of energy minima. In this case there is a standard manner to endow the space of the free energy minima with an ultrametric topology [11].

The counterpart of the energy landscape in TGD can be constructed as follows. The configuration space of TGD (the space of 3-surfaces in H) has fiber-space like structure deriving from the decomposition $CH = \cup_{zeromodes} G/H$. The fiber is the coset space G/H such that G is the group of the canonical transformation of the light cone boundary. In particular, the canonical transformations of CP_2 act in the fiber as isometries. The base space is the infinite-dimensional space of the zero modes characterizing the size and shape as well as the classical Kähler field at the 3-surface.

To calculate S-matrix element, one must form Fock space inner product as a functional of 3-surface X^3 multiplied with the vacuum functional $exp(K)$ and integrate it over the entire configuration space:

$$S_{i\to f} = \int \langle \Psi_f, \Psi_i \rangle (X^3) exp(K(X^3)\sqrt{G} DX^3 \ .$$

The integration over the fiber degrees of freedom reduces to a Gaussian integration around the maxima of the Kähler function with respect to the fiber coordinates. The equally poorly defined Gaussian and metric determinants cancel each other in this integration and one obtains a well defined end result. Canonical transformations are 'almost gauge symmetries' since only classical gravitational fields destroy canonical symmetries acting as $U(1)$ gauge transformations. This means that the action for several canonically related configurations can be degenerate and several maxima are expected for given values of the zero modes. This means that the subset CH_0 of the configuration space consisting of the maxima of the Kähler function has many sheets parametrized by the zero modes and that generalized catastrophe theory is obtained.

If a localization in the zero modes occurs in the quantum jump, one can circumvent the integration over the zero modes in practice. The exponent for the maximum of the Kähler action is expected to have maxima as a

function of the zero modes too. The maxima of $exp(K_{max})$ as function of zero modes define the counterpart of the energy landscape and $exp(K_{max})$ is the counterpart of the energy serving as a height function of the energy landscape. It could quite well be that this height function can be induced from a p-adic norm. If so, the allowed values of p define a decomposition of the space of zero modes to sectors D_p. For 'full' CP_2 type extremals representing virtual gravitons the exponent is indeed proportional to $1/p$ if one takes seriously the argument determining the possible values of the Kähler coupling strength. Thus cognitive p-adicity and spin glass p-adicity would be related to each other. The connection with gravitons is especially interesting since also classical gravitation is closely related to the spin glass degeneracy.

3.3 Various cognitive maps

3.3.1 Canonical identification

The canonical identification $x = \sum_m x_m p^n \in R_p \rightarrow \sum x_n p^{-n} \equiv x_R \in R$ mapping p-adics to reals is the cornerstone of p-adic TGD. The construction of p-adic QFT forces to fix precisely the definition for the inverse of the canonical identification map. The suggested formula for $I : R_p \rightarrow R$ applies, when one maps the predictions of p-adic QFT (probabilities, values of the mass squared, etc...) to reals: in this case the real counterpart of a p-adic number is automatically non-negative.

When real space-time surfaces (absolute minima of Kähler action) are mapped by I^{-1} to their p-adic counterparts, one encounters several problems.

a) The inverse of the canonical identification is two-valued.

b) Canonical identification map is not defined for negative real numbers.

c) Canonical identification is not manifestly General Coordinate Invariant concept

d) The direct canonical image of the space-time surface is not p-adically differentiable. What is needed is smooth surface perhaps satisfying the p-adic counterparts of the field equations associated with the absolute minimization of the Kähler action.

The correct solution of these problems is provided by the interpretation of p-adic space-time regions as cognitive regions so that canonical identification between real and space-time regions can be regarded as a map defining cognitive representation rather than as two different manners to interpret the same space-time sheet. Thus the map involves always pinary cutoff

defining the precision of the representation. Pinary cutoff comes from the requirement that the canonical image with a pinary cutoff can be completed to a p-adic space-time surface which is solution of field equations. Obviously the optimal representation is obtained when pseudoconstants reduce to ordinary constants.

3.3.2 Phase preserving canonical identification

Before the emergence of new view about p-adic physics, the above listed problems forced to consider a modification of the canonical identification map and several options have been considered. The requirement of General Coordinate Invariance finally led to what seemed to be a unique solution to these problems. One must define canonical identification in preferred imbedding space coordinates: if preferred coordinates are not unique, the transformations between the preferred coordinates systems must commute with the modified canonical identification. Although this mapping is not relevant for the definition of fundamental theory, it might make sense if taken as a map defining cognitive representations at the level of Schröndinger amplitudes. In particular, the beautiful mathematical properties of this map and the direct connection with quantum measurement theory, suggest that one should not not keep mind open for possible applications of this map in some future theory of cognition!

The preferred coordinates are Minkowski coordinates $(m^0, m^3, m^1, m^2))$ and complex coordinates of CP_2 transforming linearly under certain Cartan sugroup $U(1) \times U(1)$ determined by the surface Y^3: these coordinates are determined modulo rotations of subgroup $SO(2) \times U(1) \times U(1)$ of Cartan subgroup of $SO(3,1) \times SU(3)$ acting as multiplication by a phase factor in case of $m^1 + im^2$ and CP_2 complex coordinates. Lorentz boosts in Cartan subgroup of $SO(3,1)$ act as multiplication by hyperbolic 'phase factor' in case of the coordinate pair $(m^0, m^3) \equiv a(cosh(\eta), sinh(\eta))$. The mapping commutes with these transformations if the phase factors are mapped as such to their p-adic counterparts, that is without canonical identification. The mapping is only possible for rational complex phase factors: they correspond to Pythagorean triangles. The coordinate $a = \sqrt{(m^0)^2 - (m^3)^2}$ and moduli of the complex coordinates are mapped using canonical identification.

Since phase preserving canonical identification is discontinuous in phase degrees of freedom, the image of the space-time surface induced by the mapping of H is in the generic case discrete and does not form a subset of any p-adic 4-surface. One can however require that p-adic space-time surface is a smooth completion of a minimal pinary cutoff of the image fixed by

the requirement that p-adic counterparts of the field equations guaranteing absolute minimization of the Kähler action are satisfied. The phenomenon of p-adic pseudo constants and non-determinism of Kähler action give good hopes of achieving this. There is a direct connection with quantum measurement theory since the transformations of Cartan algebra commuting with the canonical identification map corresponds to a maximal set of commuting observables in the algebra of the isometry charges.

Although it seems that phase preserving canonical identification might not be useful at the level of imbdeding space, it can be applied to map real spinor fields to their p-adic counterparts. The natural requirement is that the modulus squared is mapped continuously in the cognitive map so that canonical identification is the natural possibility. The phases of eigenstate basis represent typically quantum numbers such as momentum components and spin. Therefore Pythagorean phases are a natural representation of the phase factors and must be mapped as such to their p-adic counterparts. Thus phase preserving canonical identification is natural for spinor fields and Schödinger amplitudes.

3.3.3 How large p-adic space-time sheets can be?

During the development of p-adic TGD two seemingly mutually inconsistent competing identifications of reals and p-adics have caused a lot of painful tension. Canonical identification provides one possible identification map respecting continuity whereas the identification of rationals as points common to p-adics and reals respects algebra of rationals. The resolution of tension comes from the realization that canonical identification is a cognitive representation of external world whereas the identification by common rationals is self-representation.

Canonical identification maps inside out and viceversa. Space-time region having finite size in the real sense can have arbitrarily large size in p-adic sense and vice versa. This raises a rather thought provoking questions. Could the p-adic space-time sheets have cosmological or even infinite size with respect to the real metric but have be p-adically finite? How large space-time surface is responsible for the p-adic representation of my body? Could the large or even infinite size of the cognitive space-time sheets explain why creatures of a finite physical size can invent the notion of infinity and construct cosmological theories? Could it be that pinary cutoff $O(p^n)$ defining the resolution of a p-adic cognitive representation would define the size of the space-time region needed to realize the cognitive representation? The idea about astrophysical size of the p-adic cognitive space-time sheets

providing representation of body and brain is consistent with TGD inspired theory of consciousness, which forces to take very seriously the idea that even human consciousness involves astrophysical length scales.

If canonical identification mediates the connection between the predictions of the p-adic and real physics as the success of the p-adic mass calculations suggest, one can also ask whether there is a kind of a duality between short real length scales and long p-adic length scales and vice versa. The progress of physics to shorter real length scales would be accompanied by the creation of cognitive space-time sheets having progressively larger sizes meaning evolution of consciousness.

3.4 p-Adic length scale hypothesis

p-Adic length scale hypothesis states the existence of a p-adic length scale hierarchy with p-adic length scales given by $L(p) = \sqrt{p}l$, where l is the fundamental p-adic length scale of order CP_2 size R: $l \sim 10^4\sqrt{G}$. The possibility to associate $L(p)$ with a given p can be understood. p-Adic thermodynamics predicts that light particles possess mass squared of order $M^2 \sim 1/p$ and Uncertainty Principle leads directly to the p-adic length scale hypothesis. The second, nontrivial, part of the p-adic length scale hypothesis is that the physically interesting p-adic primes correspond to primes near prime powers of 2, $p \simeq 2^k$, k prime. The possibility that k is a power of prime is not excluded and there is some support for this. There are rather few p-adic primes near prime powers of two and Mersenne primes $M_n = 2^n - 1$ (where n is prime) are especially interesting physically.

The hypothesis is especially interesting above the elementary particle length scales pM_{127} and has testable implications in nuclear physics, atomic physics and condensed matter length scales. The most convincing support for this hypothesis are provided by the elementary particle mass calculations: if one assumes that the p-adic primes associated with elementary particles are primes near prime powers of two, one can predict lepton and gauge boson masses with accuracy better than one per cent. Also quark masses can be predicted but the calculation of the hadron masses requires some modelling (CKM matrix, color force, etc...). The existing empirical information about neutrino mass squared differences suggests that the allowed values of k are indeed *powers* of prime rather than primes.

3.5 CP_2 type extremals and elementary particle blackhole analogy

CP_2 type extremals are vacuum extremals having a finite negative action so that one can lower the action of the ordinary vacuum extremals by gluing CP_2 type extremals to them. CP_2 type extremals have one-dimensional M^4_+ projection which is light like random curve. Lightlikeness condition leads to classical Virasoro algebra constraints. For modified Dirac action quaternion-conformal spinors represent the solutions of field equations and contrary to the vacuum extremals, these solutions represent non-vacuum solutions. $M^4 \times SO(3,1) \times SU(3) \times SU(2)_{ew}$ Super-Kac-Moody algebra acts as symmetries and the spectrum of elementary particles is precisely known. The obvious interpretation of the CP_2 type extremals is as a model of elementary particle.

CP_2 extremals are much like blackholes in the sense that they possess elementary particle horizon: this is the surface at which the Euclidian signature of the metric of the CP_2 type extremal changes to the Minkowskian signature of the bacground space-time. One can indeed generalize Bekenstein-Hawking law to a statement saying that the real counterpart of the p-adic entropy predicted by the p-adic thermodynamics is proportional to the surface area of the elementary particle horizon. In particular, for primes $p \sim 2^k$, where k is power of prime, the radius of the elementary particle horizon is itself a p-adic length scale. This suggests a double p-adicization associated with p and k and an additional cognitive degeneracy due to the k-adic non-determinism, and hence also the dominance of the final states of quantum jump for which $p \simeq 2^k$ holds true: there would be simply very many physically equivalent physical states for these values of p.

3.6 p-Adic thermodynamics and particle massivation

The underlying idea of TGD based description of particle massivation is following. Due to the interaction of a topologically condensed 3-surface describing elementary particle with the background space-time, massless ground states are thermally mixed with the excitations with mass of order $m_0 \sim 1/R$ (R is CP_2 length scale, $1/R$ of order 10^{-4} Planck masses) created by the Super Virasoro generators. Instead of energy, the Virasoro generator L_0 (essentially mass squared) is thermalized. This guarantees Lorentz invariance automatically. p-Adic temperature is quantized by purely number theoretical constraints (Boltzmann weight $exp(-E/kT)$ is replaced with p^{L_0/T_p}, $1/T_p$ integer) and fermions correspond to $T_p = 1$ whereas $T_p = 1/2$

seems to be the only reasonable choice for bosons. That mass squared, rather than energy, is a fundamental quantity at CP_2 length scale is also suggested by a simple dimensional argument (Planck mass squared is proportional to $\hbar$ so that it should correspond to a generator of some Lie-algebra (Virasoro generator L_0!)).

Optimal lowest order predictions for the charged lepton masses are obtained and photon, gluon and graviton appear as essentially massless particles. The calculations support the existence of massless gluons and Z^0 quanta associated with so called massless extremals (MEs). One important prediction is that p-adic thermodynamics cannot explain the masses of the intermediate gauge bosons although the predictions for the fermion masses are excellent. This observation led to the identification of the TGD counterpart of Higgs field whose vacuum expectation provides the dominating contribution to the bosonic masses and only shifts bosonic masses.

3.7 Localization in zero modes and evolution

TGD as a generalized number theory visions suggests that configuration space decomposes into regions D_P characterized by infinite primes P, which are essentially equivalent with reals under canonical identification. Each infinite prime P decomposes in a well-defined sense to finite p-adic primes and an attractive hypothesis is that these primes serve as labels for space-time regions. If U-matrix is rational valued one can interpret U-matrix elements as elements of any p-adic number field or of reals.

If U-matrix is not rational and if sub-U-matrix for the transitions leading to D_P has values in some algebraic extension of R_P, one must generalize the notion of unitarity by allowing U-matrix to be a 'sum' of sub-U-matrices belonging to algebraic extensions of different infinite-p p-adic number fields R_P. This is possible if one assumes that localization in D_P occurs in each quantum jump. In fact, the localization in zero modes hypothesis implies localization into D_P. The localization in zero modes is forced by the requirement that quantum jump corresponds to a quantum measurement in the QFT sense of the word.

This picture suggest that the subjective time development is a sequence of quantum jumps such that single quantum jump decomposes to the following steps.

a) Unitary transformation U, acts on the initial state localized in some sector D_{P_1} of CH and leads to dispersion in CH.

b) Quantum jump implying a localization to some sector D_{P_2} occurs. Thus time development corresponds to a sequence .... $\rightarrow P_1 \rightarrow P_2$... of

infinite primes and simple geometric argument suggests that P increases in the long run. One can interpret the increase of P as evolution inducing the increase of finite p-adic primes which in well-defined sense compose P.

4 TGD inspired theory of consciousness very briefly

For reader's benefit the basic concepts and ideas of TGD inspired theory of consciousness are summarized briefly below.

4.1 Moment of consciousness as quantum jump between quantum histories

The identification of quantum jump as a moment of consciousness defines what might be called microscopic theory of consciousness. To grow flesh around this skeleton, one must formulate precisely what happens in quantum jump and the development of the theory has been largely due to the increased understanding of the quantum jump concept. The basic assumption is that any quantum jump corresponds to a quantum measurements for the density matrix of some subsystem (possibly decomposing to unetangled subsystems). It is however far from obvious what the notion of quantum measurement means when quantum states are quantum histories: in particular, the precise definition of the subsystem concept has turned out to be a difficult challenge. The requirement that allowed quantum measurements are local operations in zero modes, forces localization in zero modes in each quantum jump. This in turn implies that the world of conscious experience looks classical.

To sum-up the recent picture about quantum jump: TGD Universe is quantum computer in extremely general sense of the word. Every quantum jump involves unitary informational "time development" U (quantum computation) and quantum jump involving localization in zero modes (halting of the computation). Quantum computation lasts infinitely long time but this time has nothing to do with the subjectively experienced time, which is basically measured by the number of quantum jumps occurred after the wake-up of self. Besides informational and subjective time developments, there is geometric time development of the space-time surface determined by the absolute minimization of Kähler action. These three time developments fuse to single "holy trinity" of informational, subjective and geometric time evolutions. This "holy trinity" corresponds to the "holy trinity" of matter in the sense of res extensa identified as 3-surfaces, ideas identified as quantum histories/objective realities (logos=cosmos) and to the world of subjective experiences defined by the quantum jump sequences for selves.

4.2 Information gain of conscious experience

One cannot write any formula for the contents of conscious experience. This does not make impossible to assign well-defined information measures for the contents of conscious experience associated with single quantum jump. The idea is simple: interpret conscious systems as "information eaters" in the sense that information gain in conscious experience is difference for the information measures for the initial and final states $U\Psi_i$ and Ψ_f respectively. Since one can write formula for the quantum histories, it is possible to assign well defined information measures to them.

In real context these information measures would be however typically infinite. A crucial role is played by the unique pinary cutoff associated with any mapping of a real geometric object to its p-adic counterpart and the fact that the real counterpart of p-adic integer n is finite even in the case that n is infinite as ordinary integer. p-Adicization and pinary cutoff suggest a universal manner to characterize the finite mental abilities of self caused by its finite size (information gains are bounded by $p \times log(p)$). One could perhaps call the p-adic image of reality with pinary cutoff as "personal p-adicity" of self characterized by p-adic prime p. The assumption that information measures are local with respect to configuration space together with the fact that configuration space spinors are analogous to ordinary single particle Schrödinger amplitudes, makes it possible to assign unique measure to a given type of information.

4.3 TGD predicts standard quantum measurement theory

TGD inspired theory of conciousness and standard quantum measurement theory are closely related. The assumption that localization occurs in zero modes in each quantum jump implies that the world of conscious experience looks classical. It also implies standard quantum measurement theory as the following arguments demonstrate (it took incredibly long time to realize this almost obvious fact!).

i) The standard quantum measurement theory a la von Neumann involves the interaction of brain with the measurement apparatus. If this interaction corresponds to entanglement between microscopic degrees of freedom m with the macroscopic effectively classical degrees of freedom M characterizing the reading of the measurement apparatus coded to brain state, then the reduction of this entanglement in quantum jump reproduces standard quantum measurement theory provide the unitary time evolution operator U acts as flow in zero mode degrees of freedom and correlates completely some

orthonormal basis of configuration space spinor fields in non-zero modes with the values of the zero modes. The flow property guarantees that the localization is consistent with unitarity: it also means 1-1 mapping of quantum state basis to classical variables (say, spin direction of the electron to its orbit in the external magnetic field).

ii) Since zero modes represent classical information about the geometry of space-time surface (shape, size, classical Kähler field,...), they have interpretation as effectively classical degrees of freedom and are the TGD counterpart of the degrees of freedom M representing the reading of the measurement apparatus. The entanglement between quantum fluctuating non-zero modes and zero modes is the TGD counterpart for the $m - M$ entanglement. Therefore the localization in zero modes is equivalent with a quantum jump leading to a final state where the measurement apparatus gives a definite reading.

This simple prediction is of utmost theoretical importance since the black box of the quantum measurement theory is reduced to a fundamental quantum theory. This reduction is implied by the replacement of the notion of a point like particle with particle as a 3-surface. Also the infinite-dimensionality of the zero mode sector of the configuration space of 3-surfaces is absolutely essential. Therefore the reduction is a triumph for quantum TGD and favors TGD against string models.

4.4 Negentropy Maximization Principle

Standard quantum measurement theory follow from the hypothesis that localization in zero modes occurs in each quantum jump and that the 'time development' operator U acts effectively as flow in zero modes in preferred basis for incoming states. TGD inspired theory of consciousness however encourages the generalization of quantum measurement theory by introducing the notion of self measurement occurring in quantum fluctuating degrees of freedom and following ordinary quantum measurement and meaning the measurement of the density matrix for some subsystem of self. Self measurement occurs again and again until the resulting state is a completely unentangled state. Obviously the cascade of self measurements is equivalent with state preparation process.

The so called Negentropy Maximization Principle in principle tells which kind of pair of unentangled subsystem defines the self measurement. The conscious experience itself is associated with the entire unentangled subsystem (self). NMP says is that the entanglement entropy reduction associated with the conscious experience is as large as it can be in a given quantum

state: in this sense we live in the best possible world. Self measurement provides a fundamental self repair mechanism and allows quantum system to fight against thermalization according to the principle 'If you are in a leaking boat it is best to fill in the largest hole first'. NMP is the basic variational principle of cognition in p-adic context.

It must be emphasized that self measurement reduces entropy and thus corresponds to a tendency opposite to that described by second law or thermodynamics which in turn reflects directly the non-determinism of Kähler action.

The precise formulation NMP involves delicate issues. In the standard physics context NMP does not make sense whereas in the TGD context an elegant formulation with sensical predictions is possible. In particular, NMP reduces to a local principle since universe decomposes to unentangled subsystems corresponding to space-time sheets in different number fields: in standard physics context the only self would be entire Universe. The definition of the negentropy concept in the p-adic framework involves quite interesting delicacies: for instance, entanglement with a vanishing entanglement entropy is possible. The definition of the notion of subsystem is highly nontrivial in TGD context. The principle of quantum holography comes in rescue here and suggest strongly that the lightlike boundaries of massless extremals (MEs) are universal candidates for geometric correlates of subsystems.

4.5 The notions of self and subjective memory

Self is identified as a subsystem able to remain p-adically unentangled during informational time evolutions U associated with the sequential quantum jumps. Or putting it differently: self is a subsystem behaving like its own sub-Universe p-adically (with respect to NMP). This concept of self makes sense in quantum TGD framework since the map mapping real system to its p-adic counterpart is characterized by a unique pinary cutoff and maps subcritical real entanglement to a vanishing p-adic entanglement. Note that the requirement that U does not generate real entanglement does not make sense. The hypothesis that the experiences of self associated with the quantum jumps occurred after the wake-up sum up to single experience, implies that self can have memories about earlier moments of consciousness. Therefore self becomes extended object with respect to subjective time and has a well defined "personal history". If the temporal binding of experiences involves kind of averaging (possible weighted such that the most recent experience has largest weight), quantum statistical determinism makes the total

experience defined by the heap of the experiences associated with individual quantum jumps reliable. Subjective memory has natural identification as short term memory, which is fraction of second for sensory experiences.

There are two kinds of selves: irreducible selves having no subselves and reducible selves possessing subselves. Irreducible self has no mental images and the identification of the irreducibility as "whole-body" consciousness or pure awareness is attractive. Reducible selves correspond to ordinary consciousness. New self can "wake-up" in two manners.

a) In a given quantum jump irreducible self generates two mutually unentangled subsystems providing two new candidates for subselves. The subsystem giving rise to a new subself candidate must generate so large an entanglement that NMP allows the quantum jump reducing p-adic entanglement to zero. Whether a new subself is actually created depends on whether the self candidate is able to remain p-adically unentangled in the next step $\Psi_i \to U\Psi_i$.

b) The alternative possibility is that self wakes up spontaneously, when informational "time development" operator U generates vanishing p-adic entanglement. Sufficiently intelligent self could hence apply two strategies to wake-up sub-selves.

4.6 Summation hypothesis and binding of experiences

Subsystem X possessing self behaves essentially as a separate p-adic sub-Universe with respect to NMP. If one postulates that the conscious experiences of subsystems X_i of an unentangled subsystem X integrate with the self experience of X to single experience, one obtains filtered hierarchy of conscious experiences with increasingly richer contents and at the top of the hierarchy is entire universe, God, enjoying eternal self-consciousness since it cannot get entangled with any larger system.

An attractive hypothesis is that the experience of self is abstraction in the sense that the experiences of subselves X_{ij} of X_i are abstracted to average experiences $\langle X_{ij} \rangle$ experienced as mental images. This implies that the experiences of sub-sub-...selves of X are effectively unconcious to X. This hierarchy obviously has extremely far-reaching consequences. The averaging involved with the temporal binding implies that experiences of individual selves are reliable and abstraction brings in the possibility of quantum statistical determinism at the level of ensembles.

4.7 Binding of experiencers by entanglement

The binding of experiencers is also possible. The binding of selves by quantum entanglement however destroys the component selves. This process naturally corresponds to the formation of wholes from their parts at the level of mental images, say the formation of word from letters represented as subselves. Entanglement mechanism could also provide also a a mechanism of "enlightment". This mechanism might make possible communication between selves belonging to different levels of the self hierarchy (this kind of communication could occur during sleep). "Ontogeny recapitulates phylogeny" metaphor suggests that the generation of entanglement corresponds geometrically to the formation of join along boundaries bonds between space-time sheets associated with the two entangled selves.

4.8 Mindlike and material space-time sheets

In TGD space-time surfaces decompose into real and p-adic regions. p-Adic regions are identified as cognitive representations for real regions. The basic motivation for this identification is the inherent non-determinism of the p-adic field equations making possible imagination and simulation.

The classical non-determinism of Kähler action makes possible also real space-time sheets of finite temporal duration. These space-time sheets are identified as mindlike space-time sheets serving as geometric correlates of sensory experience. Thus matter-mind duality is realized geometrically although space-time as such is not conscious. The notion of mindlike space-time sheets (referred to as cognitive space-time sheets in earlier writings) has turned out to be crucial for the understanding of cognition and sensory experience.

Mindlike space-time sheets provide a simulation of geometric history and explain the intentional aspects of consciousness (planning, expectations, desires,...), the localization of contents to finite time interval, and give rise to what might be called "geometric memory". Each quantum jump involves naturally comparison of the expected time development provided by "geometric memory" and the actual subjective time development stored in subjective memory. This comparison should give rise to those emotions involving comparison of some kind.

One can understand the arrow of psychological time very simply. The center of mass time coordinate for a given mindlike space-time sheet is zero mode so that each quantum jump involves localization to a superposition of space-time surfaces for which the values of the psychological time for all

mindlike space-time sheets involved are identical. Since there is much more room in the future of a given point of the future lightcone than in its past, mindlike space-time sheets are expected to gradually drift in the direction of future so that the arrow of psychological time results.

4.9 The notion of association sequence

The notion of association sequence is closely related to the notion of mindlike space-time sheet. The origin of association sequence concept is the enormous vacuum degeneracy of the Kähler action, which implies classical non-determinism in the sense that the absolute minimum for a given spacelike 3-surface is not unique. In order to get rid of this non-determinism one must generalize the concept of 3-surface. Also association sequences, that is 3-surfaces consisting of sequences of disjoint 3-surfaces with timelike(!) separations, must be allowed. In the p-adic quantum field theory limit this phenomenon has a nice description: the integration constants appearing in the absolute minima of the p-adic effective action are piecewise constant functions depending on a finite number of pinary digits: system behaves like a spin glass also in the time direction.

It is useful to distinguish between volitional non-determiminism for which the effects are macroscopic and long lasting and the non-determinism with microscopic and shortlasting consequences. The contents of the conscious experience (locus of the non-determinism of the quantum jump) are located around a more or less unique value of the geometric time (or several values in case of geometric memories!). A working hypothesis worth of studying is that sensory experiences correspond to real and cognition to p-adic association sequences.

Association sequences of association sequences are also possible and average spatial and temporal distances ΔL and ΔT between fundamental building blocks of the association sequence give measures for the temporal and spatial resolutions of the cognitive or sensory representation provided by the association sequence. For volitional non-determinism various degenerate absolute minima can be identified as various alternatives of macroscopic volitional acts and quantum entanglement between particle like states and the branches of the classical multifurcation makes possible volitional acts.

4.10 p-Adic–real phase transitions as a transformation of thought to action and of sensory input to cognition

Basic hypothesis is that sensory experiences resp. thoughts have real resp. p-adic space-time sheets as their geometric correlates. A fundamental model for the transformation of thought into action is as a p-adic-to-real phase transition for the topology of a mindlike space-time sheet induced by quantum jump. TGD as a generalized number theory vision suggests that this kind of phase transition can be induced by a variation of the parameters in the polynomial $P(p, q)$ of two quaternionic imbedding space coordinates defining the space-time surface changing a p-adic root to a real one or viceversa. The reverse of this phase transition corresponds to the transformation of sensory experiences to cognition.

In principle it is enough that very simple and possibly standardized p-adic–real transformations occur at some level, say neuronal level or at the level of topological field quanta of em field ("massless extremals"). The reason is that simple transformations can serve as symbols inducing macrocopic action in an initial value sensitive system (single push of button can induce nuclear war). The commands given using written or spoken language are typical examples of the emergence of this kind symbol function.

4.11 Fermions and Boolean 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, leads to the idea that many fermion states give representation for what might be called Boolean maind.

Combining the concept of association sequence with the fermionic realization of Boolean algebra and requiring that fermionic states exist in finite time interval defined by the duration of mindlike space-time sheets and that time like entanglement is possible for many-fermion states, one ends up with a rather concrete model for Boolean consciousness at the level of brain. The model relies on the unique properties of condensed matter neutrinos: the energy of condensed matter neutrinos is negative so that cognitive neutrino pairs have can have nearly vanishing net energy so that their generation is energetically easy. Antineutrino temporal sequences of varying Z^0 magnetization for antineutrinos at the cell membrane space-time sheet are ideal for represesenting 126 bit memetic codons.

The so called Combinatorial Hierarchy provides a simple model for abstraction process explaining basic numbers of the genetic code and predicting

an entire hierarchy of 'genetic codes'. The identification of the next level of the hierarchy as a 'memetic code' when combined with the p-adic length scale hypothesis leads to the prediction that the duration of the memetic codeword should be .1 seconds, often taken to be the duration of psychological moment. The number of binary digits in the memetic codeword is 126, which means that single bit corresponds to a time scale of one millisecond: this is slightly below the time scale of nerve pulse and it might be that cell membrane oscillations induced by Z^0 oscillations correspond to memetic codons.

4.12 Quantum theory of self-organization

The hypothesis that configuration space decomposes into sectors D_p such that the effective topology in D_p is p-adic, is crucial for the understanding of the p-adic aspects of quantum TGD. Mathematical consistency requires that each quantum jump involves localization in some sector D_p: this is also implied by the localization in zero modes. Evolution as can be regarded as a gradual statistical increase of the p-adic prime characterizing D_p. Simple arguments suggest that one must allow also infinite primes. Infinite primes decompose into finite primes in a well defined sense and "Ontogeny recapitulates phylogeny" metaphor suggests that this decomposition corresponds to the decomposition of the space-time surface to cognitive and matter like space-time sheets both of which are characterized by finite p-adic primes. This decomposition makes evolution local: the increase of the finite prime characterizing finite space-time regions favors the increase of the infinite prime.

Conscious self is the basic concept of TGD inspired theory of consciousness and the concept of self-organization gets quite new meaning in TGD framework. Inside each self NMP dictates to which kind of subsystem-complement decomposition given quantum jump gives rise and thus dictates what kind of state preparation occurs during the cascade of self measurements.

Quantum jump is the basic step of self-organization. The requirement that quantum jump corresponds to quantum measurement, implies that quantum jump involves localization in so called zero modes identifiable as the order parameters characterizing the shape and size and Kähler field structure of the space-time surface. This means that the evolution in zero modes is effectively classical and modellable using dissipative classical dynamics, and Haken"s classical theory of self organization generalizes almost as such: also TGD version of spontaneous symmetry breaking follows automatically. One

can also understand why the world of conscious experience is classical.

Self-organization of selves in the "energy" landscape of quantum spin glass throws considerable insight to the basic mysteries of the living matter. Darwinian selection of both genes and memes can be understood as resulting from dissipation allowing very few asymptotic self-organization patterns located near the bottoms of the deep valleys of spin glass "energy" landscape. For instance, protein folding can be understood as resulting from the self-organization of protein self leading to the bottom of a deep valley of spin glass landscape. Also the formation of long term memories can be understood using this paradigm.

In case of bound states quantum entanglement makes possible the formation of long range quantum correlations and the emergence of longer and longer p-adic length scales can be regarded as the counterpart for the emergence of dynamical units of increasing size. The feed of quantum entanglement (entropy) is the necessary prequisite of self-organization replacing self-organized units (selves) with larger ones. Both the passive (sensory experiences) and active aspects of consciousness (reaction to sensory perception) are in essential role in biological self-organization.

5 Bio-systems as macroscopic quantum systems

TGD Universe [TGD] can be regarded as a quantum counterpart of a critical thermodynamical system: the so called Kähler coupling strength is the only a priori free parameter of quantum TGD and is mathematically completely analogous to temperature. The requirement that Kähler coupling strength is analogous to critical temperature, makes the theory unique. Criticality implies long range quantum correlations in all length scales and could provide a first principle explanation for the ability of the bio-systems to act as macroscopic quantum systems. The task is to identify the mechanisms realizing the predicted long range quantum correlations.

5.1 Topological field quantization

Topological field quantization [TGD] is one of the basic differences between TGD and ordinary quantum field theories. In TGD space-time is regarded as a surface of the 8-dimensional space $H = M^4_+ \times CP_2$ and classical gauge fields are induced from the curvature of the CP_2 spinors connection. The compactness of CP_2 implies that the imbedding of a given gauge field typically fails on 3-dimensional surfaces and this implies many-sheeted space-time structure with different sheets having finite M^4_+-projection and outer

boundary. At the boundaries the gauge fluxes flow from the smaller sheet to a larger one via tiny wormholes with size determined by CP_2 size.

A lower bound for the size of the topological field quantum is given by the p-adic length scale. p-Adic length scale hypothesis leads to a prediction of a series of preferred length scales: the length scales should correspond to primes $p \simeq 2^m$, m prime or possibly a power of prime and it seems possible to identify these length scales in bio-systems. This gives for the many-sheeted space-time concept a status of a quantitative hypothesis.

Topological field quantization [D7] implies that various notions of quantum field theory have rather precise classical analogies. Topological field quantization provides the correspondence between the abstract Fock space description of elementary particles and the description of the elementary particles as concrete geometric objects detected in the laboratory. In standard quantum field theory this kind of correspondence is lacking since classical fields are regarded as a phenomenological concept only. Topological field quanta define regions of coherence for the classical fields and classical coherence is the prequisite of the quantum coherence.

The energies and other classical charges of the topological field quanta are quantized by the absolute minimization of the Kähler action making classical space-time surfaces the counterparts of the Bohr orbits. Feynmann diagrams become classical space-time surfaces with lines thickened to 4-manifolds. For instance, "massless extremals" representing topologically quantized classical radiation fields are the classical counterparts of gravitinos and photons. Topologically quantized non-radiative nearby fields give rise to various geometric structures such as magnetic and electric flux tubes.

The virtual particles of quantum field theory have also classical counterparts. In particular, the virtual particles of quantum field theory can have negative energies: this is true also for the TGD counterparts of the virtual particles. The fundamental difference between TGD and GRT is that in TGD the sign of energy depends on the time orientation of the space-time sheet: this is due to the fact that in TGD energy current is vector field rather than part of tensor field. Therefore space-time sheets with negative energies are possible. This could have quite dramatic technological consequences: consider only the possibility of generating energy from vacuum and classical signalling backwards in time along negative energy space-time sheets [G3]. Also bio-systems might have invented negative energy space-time sheets: in fact, so called "massless extremals" provide an manner to generate coherent motions as recoil effects caused by the creation of negative energy massless extremals [I4, I5]. An interesting possibility is that quantum entanglement has the formation of the join along boundaries bonds as its geometric cor-

relate.

Topological field quanta could serve as templates for the formation of the bio-structures. Thus topologically quantized classical electromagnetic fields could be equally important for the functioning of the living systems as the structures formed by the visible bio-matter and the visible part of bio-system might represent only a dip of an ice berg.

The hierarchical structure of the many-sheeted space-time has very concrete implications for the understanding of bio-systems and one ends up with a rather concrete picture for how energy, electromagnetic fields and information are transferred from one space-time sheet to another. Almost empty space-time sheets, containing only classical electromagnetic fields at their interior and wormholes on their boundaries, could provide an excellent physical realization for the cognitive and sensory representations of the external world: various space-time sheets would be mimicking each other's behaviour!

5.2 Formation of the join along boundaries bonds

In many critical systems criticality can be understood purely geometrically in terms of the concept of bond. The crucial factor is the probability for a bond to exist between subsystems. If the probability is larger than the critical probability, the system freezes by forming a single connected structure. Below criticality very few bonds exist and the system is in a liquid like state. At criticality arbitrarily large connected subsystems can exist and the shape and size of subystem becomes dynamical. This phase is obviously the most interesting one biologically.

Join along boundaries bonds connecting the outer boundaries of the topological field quanta provide a geometric realization of the quantum criticality in quantum TGD in the sense that the formation of join along boundaries bonds is a necessary condition for the formation of larger quantum systems from smaller topological field quanta. Geometrically it corresponds simply to the touching of the two 3-surfaces. Join along boundaries bonds appear in all length scales. Non-biological examples are the color flux tubes connecting the 3-surfaces with subhadronic size connecting valence quarks, the bonds connecting nucleons in nuclei to form clusters and the chemical bonds between atoms.

In biological length scales the proteins connecting different lipid layers of the cell membrane and cell interior and exterior, the MAPs (micotubule associated proteins) joining microtubules, the gap junctions connecting coherently firing groups of neurons and cells belonging to the epithelial cell

sheets, are good examples of join along boundaries bonds. The dynamical nature of the join along boundaries condensates at criticality could provide a quantum level explanation for the ability of the bio-systems to change their size, shape and topology.

Join along boundaries bonds serve also as Josephson junctions connecting space-time sheets representing different levels of the self-hierarchy. Josephson currents in turn provide a means of quantum control.

5.3 Wormhole Bose Einstein condensates

5.3.1 How wormholes emerge?

The gauge and gravitational fluxes at the boundary of a given space-time sheet must go somewhere by gauge flux conservation. This forces the existence of a larger space-time sheet and of tiny wormholes connecting the two space-time sheets and feeding the gauge fluxes from the smaller sheet to the larger one. Wormholes (# contacts) are elementary particle like objects (actually deformed pieces of so called CP_2 type extremals) having size of order CP_2 size about 10^4 Planck lengths and, being sources and sinks of gauge field lines, wormhole throats effectively like classical charges, the charges of throats at the two space-time sheets being of opposite sign. Hence wormholes look like dipoles and couple to the difference of the classical gauge potentials associated with the two space-time sheets. Also the coupling to the difference of the gauge potentials serving as order parameters for the coherent states of photons is possible.

5.3.2 Wormhole BE condensate

Since wormholes can be regarded as very light particles, with the inertial mass determined by the p-adic length scale associated with the space-time sheet in question, they suffer BE condensation, and the resulting structure is a macroscopic quantum system. Since wormholes mediate an interaction between subsystem and the external world (the two space-time sheets in question), wormhole super conductivity is an excellent candidate for a universal model of a nervous system. The coupling of the wormhole BE condensate to the geometry of the boundary of the space-time sheet in turn could make possible the quantum control of the size and shape of 3-surface. The usual master-slave relationship between background space-time and fields could be reversed in bio-systems. This is expected to happen in macromolecular and microtubular length scales as well as during the growth of multicellular organism. Furthermore, the transfer of energy and classical electromagnetic

between different space-time sheets can take place only via the coupling of ordinary matter with the wormhole BE condensates, which in turn couple to the geometry of the boundary of space-time sheet in a unique manner. Thus wormhole BE condensates should provide a royal road to the understanding of energy and information transfer in bio-systems if TGD is a correct theory.

5.3.3 Possible applications of wormhole concept

Wormhole concept has several potential applications.

a) An interesting possibility is that various bio-structures act as weakly coupled wormhole super conductors. For instance, the lipid layers of the cell membrane are identified as coupled wormhole super conductors. Join along boundaries bonds connecting the lipid layers/cell interior and exterior could serve as Josephson junctions. Also the boundaries of the interior and exterior of the cell and microtubule could form weakly coupled wormhole super conductors connected by Josephson junctions.

b) Wormholes could be important also in DNA and molecular length scales and perhaps provide even DNA with a rudimentary nervous system. This idea gets support from the successful model of the so called Comorosan effect [J5]. What happens in Comorosan effect is that for certain frequencies and irradiation times quantized in multiples of 5 seconds, the interaction of a laser light with the bio-matter enhances the entzyme substrate interaction. There are many peculiar selection rules involved, which can be explained if substrate and entzyme molecules form a pair of wormhole super conductors coupled by Josephson junctions. The wormhole super currents flowing in the coupled molecular wormhole super conductors affect the reaction rates and the interaction with the laser laser light affects these currents.

c) The transfer of a chemical energy and charge over macroscopic distances is a mystery from the view point of standard physics. One possibility is that the energy of the liberated photons could be absorbed by the charged wormholes and generate propagating soliton like deformations on the boundary of the protein space-time sheet. The electrons dropped from the atomic space-time sheet to the protein space-time sheet could be trapped in the regions of enhanced positive wormhole charge density associated with the propagating deformation and this would make possible the charge transfer.

d) The transfer of the classical electromagnetic fields from a larger space-time sheet to a smaller one must involve the rearrangement of the wormhole charge densities or even creation of wormhole pairs serving as sources of the electric field at the smaller space-time sheet. It might be that this process can occur only through a quantum jump replacing the old quantum average

effective space-time with a new one and giving to a net increase of the wormhole density. According to TGD inspired theory of consciousness this would mean that a moment of consciousness is involved with this quantum jump. From this it is clear that the presence of the external electromagnetic fields can generate or destroy wormhole BE condensates and have a profound influence on living systems. This is in accordance with the ideas of [Fröhlich] about the fundamental importance of electric dipoles in bio-systems: it however seems that macroscopic quantum systems would be created, not by the dipoles, but by the charged wormholes serving as sources of the dipole fields.

e) Wormholes are characterized by a complex order parameter and since 3-space according to TGD is very complicated topologically, the phase increments of the order parameter around closed loops (integer multiples of 2π) can carry important biological information. For instance, the conservation of these integers along a cylindrical structure, which branches, gives important selection rules for growth. The book of Winfree [Winfree] contains a rather interesting example about these selection rules (left and right hand leg have opposite winding numbers and if one tries implant a left handed leg in place of a lost right handed leg, two additional right handed legs grow!).

5.4 Coherent light and gravitons

The concept of the induced gauge field differs from the ordinary gauge field concept in that even in the absence of the matter purely classical field configurations having non-vanishing gauge currents as their sources are possible. Also Einstein tensor can be nontrivial in the absence of the ordinary matter and its negative plays the role of energy momentum tensor of vacuum. Each Fourier component of the gauge current/Einstein tensor serves as a source of coherent photons/gravitons. The mechanism has no counterpart in ordinary QED.

The so called massless extremals describing nonlinear waves propagating with light velocity and carrying non-vanishing gauge currents and Einstein tensor are especially interesting candidates for the sources of coherent light and gravitons. The direction of the propagation of the wave defines a preferred direction in case of the massless extremals and makes linear geometric structures especially interesting as possible candidates for sources of coherent photons: in fact, the lightlikeness of the vacuum current maximizes the efficiency of these quantum antennae since the photon emission occurs in a resonant like manner. There is a natural interaction between coherent light and photons, which should be important in bio-systems (making possible the absorption of coherent photons in efficient manner).

Linear structures are indeed frequently encountered in bio-systems. Examples are DNA, proteins, microtubules and various filamentary structures. Microtubules provide an attractive candidate for a source of coherent photons and coherent photons could give a means for the intercellular communication [Albrecht-Buehler]. The identification of bio-photons [Popp] as coherent light generated by DNA:s is suggestive.

5.5 Ionic super conductors and many-sheeted ionic flow equilibrium

The observations about the special effects of ELF em fields on brain at cyclotron frequencies of ions Na^+, Cl^-, K^+, Ca^{++} and electron in Earth's magnetic field to brain were made already at 1983 [12]. These experiments suggest strongly that these ions/their Cooper pairs form are confined in the magnetic field of Earth and form bound states with macroscopic size of order cell size and extremely small binding energy corresponding to frequency of order 10 Hz. This is certainly not possible in the standard physics framework but can be understood as resulting from the dropping of ions and electrons from the atomic space-time sheet to the space-time sheet of the cell where the density of the matter is very low. The extremely low rate of energy transfer between various space-time sheets and self measurements governed by Negentropy Maximization Principle allowing the system to fight against thermalization, should allow non-atomic space-time sheets to stay in a superconducting state.

The fact that multiples of the cyclotron frequencies correspond directly to the most important frequencies of EEG suggests very stronly that these frequencies are crucial for the understanding of the sensory representations. Furthermore, the $n = 3$ multiple of proton cyclotron frequency in Eath's magnetic field is 900 Hz and corresponds to the millisecond time scale of the nerve pulse, perhaps not an accident. There is very cold, dry and silent in the cellular space-time sheets and this makes possible macroscopic quantum phases formed by Cooper pairs of Na^+, Cl^-, K^+ ions, proton and electron as well as well as Ca^{++} ions. Also other ions, even molecular ions, are possible but these ions are especially important for the generation of EEG.

Also electron Cooper pairs of high T_c electronic super conductor as well as Cooper pairs of neutrino super conductor are important. Besides magnetic cyclotron frequencies Z^0 magnetic cyclotron frequencies and wormhole cyclotron frequencies make sense: Z^0 currents for ions indeed induce automatically also ionic currents. Also neutrino Cooper pairs are possible and wormhole super conductivity is possible for wormholes located on the

boundaries of the space-time sheets. These macroscopic quantum phases characterized by cyclotron frequencies provide the hardware for consciousness in TGD framework.

The dynamical hierarchy of Josephson currents and supracurrents flowing between the space-time sheets belonging to different levels of the self hierarchy, leads to a general quantitative model of quantum control and quantum realization of master-slave hierarchy. Many-sheeted ionic flow equilibrium allows the amplification of extremely low ionic densities at superconducting magnetic flux tube structures to get amplified to much higher ionic densities at atomic space-time sheets. Massless extremals (MEs) interact with superconducing ions at magnetic flux tubes via magnetic induction changing supra currents, by acting as Josephson junctions, by inducing supra current leakage betweent space-time sheets at different levels of the hierarchy, by inducing magnetic phase transitions, etc...

Some outcomes are a model of EEG and nerve pulse predicting correctly the important EEG frequencies and time scale of nerve pulse, quantum mechanism of synchronous firing, and quantum model of comparison circuits. Perhaps the most important prediction is that our magnetic body serves as the sensory magnetic canvas where sensory representations are realized and by Uncertainty Principle having the size of order Earth. We are much more than our neurons if TGD is correct!

5.6 Identification of mindlike space-time sheets as massless extremals

The so called 'massless extremals' (MEs) are basic solutions of field equations associated with Kähler action (see chapter "Quantum antenna hypothesis"). MEs describe propagation of one-dimensional nondispersive wave with light velocity and are accompanied by lightlike vacuum current generating coherent photons and gravitons. Since the vacuum current behaves in a non-deterministic manner at given point of ME, it is ideal for the coding of classical information. MEs can appear also as pairs of space-time sheets such that the two space-time sheets have opposite time orientations and hence also energies so that the net energy of ME pair vanishes. MEs define a fractal hierarchy starting from elementary particle length scales and extending up to cosmic length scales. MEs have lightlike boundaries carrying supercanonical

One can assign to the lightlike boundaries of MEs representations of superconformal and supercanonical algebras. Supercanonical symmetry is thus transformed from a cosmological symmetry to an ordinary macroscopic

symmetry. Apart from small gravitational effects, supercanonical degrees of freedom commute with the translational degrees of freedom. Physical states associated with MEs correspond to Bose-Einstein condensates of collinear photons and gravitons (these degrees of freedom correspond to quaternion conformal degrees of freedom explaining elementary particle quantum numbers) having an additional supercanonical degeneracy. Supercanonical states can be interpreted as quantum holograms storing quantum information to the lightlike boundary of ME, which is thus analogous to the moment of big bang at the cosmological level.

The energies of BE condensed photons and gravitons come as multiples of $E = \pi/L$, where L is the length L of ME. p-Adic length scales $L_p(n) = p^{n/2}L_p$ for $p \simeq 2^k$, k power of prime, define a preferred set of lengths for MEs, and this means quantization of the fundamental transition frequencies involved with the transitions of photonic and gravitonic BE condensates as multiples of $f(p,n) = \pi/L_p(n)$. Rather amazingly, in ELF range these frequencies correspond to resonant EEG frequencies!

The supercanonical degrees of freedom commute with Poincare algebra apart from gravitational effects which means a gigantic almost-degeneracy of states. This means that supercanonical states can provide huge entanglement negentropy resources crucial for quantum computation and communication type operations as well as for cognitive representations. Thus supercanonical representations can be interpreted as quantum level articulation for the statement that TGD Universe is quantum critical quantum spin glass. Supercanonical representations clearly provide an excellent candidate for an infinite hierarchy of life forms. These lifeforms are labelled by three integers (k,m,n): physically interesting primes correspond to $p \simeq 2^{k^m}$, whereas k prime and m and n are integers. Perhaps it is these lifeforms which make mindlike space-time sheets living creatures and these lifeforms emerge already in elementary particle length scales and become increasingly complex when the p-adic length scale increases. If so, life could be regarded as a symbiosis of these lifeforms with lower level lifeforms associated with superconducting magnetic flux tubes.

These lifeforms ('mind') interact with each other, superconducting magnetic flux tubes and ordinary matter via coherent light and gravitons and the classical gauge fields associated with MEs. MEs indeed act as receiving and sending quantum antennae and the lightlike classical vacuum currents associated with MEs allow to understand the classical aspects of dynamical quantum holograms and of quantum communications made possible by MEs.

MEs can act as junctions inducing the leakage of supra currents between

space-time sheets belonging to different levels of the p-adic hierarchy. MEs can also serve as Josephson junctions between magnetic flux tubes. MEs interact with superconducting magnetic flux tube circuitry also by magnetic induction analogous to the interaction of brain's magnetic fields with SQUIDs. MEs can induce also magnetic quantum transitions. These interaction mechanisms could explain the observed intensity windows in the interaction of ELF em fields with bio-matter [13].

The natural identification of MEs as building blocks of 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 and bio-matter. The model allows to understand EEG as a direct physical correlate of mindlike 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. MEs corresponding to entire frequency spectrum from UV to ULF are involved. In particular, RF (radiofrequency) and MW (microwave) MEs representing our mental images are crucial for the model. MEs are also crucial in the model of qualia. MEs are present also below cellular length scales and even at molecular level.

The model of qualia [K3] leads to a rather detailed view about the sizes of the hierarchy of various MEs defining what might be called our electromagnetic body. It took 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; with ULF ME having size of order order light years from the fact that we have long term memories in time scale of lifetime; or with self having literally infinite size. In light of the fact that the supercanonical representations associated with MEs correspond to higher abstraction level than ordinary quantum states, the last two options seem to be more plausible than the first three: 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.

5.7 Quantized Planck constant and dark matter hierarchy

By quantum classical correspondence space-time sheets can be identified as quantum coherence regions. Hence the fact that they have all possible size scales more or less unavoidably implies that Planck constant must be quantized and have arbitrarily large values. If one accepts this then also the idea about dark matter as a macroscopic quantum phase characterized by

an arbitrarily large value of Planck constant emerges naturally as does also the interpretation for the long ranged classical electro-weak and color fields predicted by TGD. Rather seldom the evolution of ideas follows simple linear logic, and this was the case also now. In any case, this vision represents the fifth, relatively new thread in the evolution of TGD and the ideas involved are still evolving.

5.7.1 Dark matter as large $\hbar$ phase

D. Da Rocha and Laurent Nottale have proposed that Schrödinger equation with Planck constant $\hbar$ replaced with what might be called gravitational Planck constant $\hbar_{gr} = \frac{GmM}{v_0}$ ($\hbar = c = 1$). v_0 is a velocity parameter having the value $v_0 = 144.7 \pm .7$ km/s giving $v_0/c = 4.6 \times 10^{-4}$. This is rather near to the peak orbital velocity of stars in galactic halos. Also subharmonics and harmonics of v_0 seem to appear. The support for the hypothesis coming from empirical data is impressive.

Nottale and Da Rocha believe that their Schrödinger equation results from a fractal hydrodynamics. Many-sheeted space-time however suggests astrophysical systems are not only quantum systems at larger space-time sheets but correspond to a gigantic value of gravitational Planck constant. The gravitational (ordinary) Schrödinger equation would provide a solution of the black hole collapse (IR catastrophe) problem encountered at the classical level. The resolution of the problem inspired by TGD inspired theory of living matter is that it is the dark matter at larger space-time sheets which is quantum coherent in the required time scale [D6].

I have proposed already earlier the possibility that Planck constant is quantized and the spectrum is given in terms of logarithms of Beraha numbers: the lowest Beraha number B_3 is completely exceptional in that it predicts infinite value of Planck constant. The inverse of the gravitational Planck constant could correspond a gravitational perturbation of this as $1/\hbar_{gr} = v_0/GMm$. The general philosophy would be that when the quantum system would become non-perturbative, a phase transition increasing the value of $\hbar$ occurs to preserve the perturbative character and at the transition $n = 4 \to 3$ only the small perturbative correction to $1/\hbar(3) = 0$ remains. This would apply to QCD and to atoms with $Z137$ as well.

TGD predicts correctly the value of the parameter v_0 assuming that cosmic strings and their decay remnants are responsible for the dark matter. The harmonics of v_0 can be understood as corresponding to perturbations replacing cosmic strings with their n-branched coverings so that tension becomes n^2-fold: much like the replacement of a closed orbit with an orbit

closing only after n turns. $1/n$-sub-harmonic would result when a magnetic flux tube split into n disjoint magnetic flux tubes.

The study of inclinations (tilt angles with respect to the Earth's orbital plane) leads to a concrete model for the quantum evolution of the planetary system. Only a stepwise breaking of the rotational symmetry and angular momentum Bohr rules plus Newton's equation (or geodesic equation) are needed, and gravitational Shrödinger equation holds true only inside flux quanta for the dark matter.

a) During pre-planetary period dark matter formed a quantum coherent state on the (Z^0) magnetic flux quanta (spherical cells or flux tubes). This made the flux quantum effectively a single rigid body with rotational degrees of freedom corresponding to a sphere or circle (full SO(3) or SO(2) symmetry).

b) In the case of spherical shells associated with inner planets the $SO(3) \to SO(2)$ symmetry breaking led to the generation of a flux tube with the inclination determined by m and j and a further symmetry breaking, kind of an astral traffic jam inside the flux tube, generated a planet moving inside flux tube. The semiclassical interpretation of the angular momentum algebra predicts the inclinations of the inner planets. The predicted (real) inclinations are 6 (7) resp. 2.6 (3.4) degrees for Mercury resp. Venus). The predicted (real) inclination of the Earth's spin axis is 24 (23.5) degrees.

c) The $v_0 \to v_0/5$ transition allowing to understand the radii of the outer planets in the model of Da Rocha and Nottale can be understood as resulting from the splitting of (Z^0) magnetic flux tube to five flux tubes representing Earth and outer planets except Pluto, whose orbital parameters indeed differ dramatically from those of other planets. The flux tube has a shape of a disk with a hole glued to the Earth's spherical flux shell.

It is important to notice that effectively a multiplication $n \to 5n$ of the principal quantum number is in question. This allows to consider also alternative explanations. Perhaps external gravitational perturbations have kicked dark matter from the orbit or Earth to $n = 5k$, $k = 2, 3, ..., 7$ orbits: the fact that the tilt angles for Earth and all outer planets except Pluto are nearly the same, supports this explanation. Or perhaps there exist at least small amounts of dark matter at all orbits but visible matter is concentrated only around orbits containing some critical amount of dark matter and these orbits satisfy $n \; mod \; 5 = 0$ for some reason.

d) A remnant of the dark matter is still in a macroscopic quantum state at the flux quanta. It couples to photons as a quantum coherent state but the coupling is extremely small due to the gigantic value of $\hbar_{gr}$ scaling alpha by $\hbar/\hbar_{gr}$: hence the darkness.

The rather amazing coincidences between basic bio-rhythms and the periods associated with the states of orbits in solar system suggest that the frequencies defined by the energy levels of the gravitational Schrödinger equation might entrain with various biological frequencies such as the cyclotron frequencies associated with the magnetic flux tubes. For instance, the period associated with $n = 1$ orbit in the case of Sun is 24 hours within experimental accuracy for v_0.

5.7.2 Dark matter as a source of long ranged weak and color fields

Long ranged classical electro-weak and color gauge fields are unavoidable in TGD framework. The smallness of the parity breaking effects in hadronic, nuclear, and atomic length scales does not however seem to allow long ranged electro-weak gauge fields. The problem disappears if long range classical electro-weak gauge fields are identified as space-time correlates for massless gauge fields created by dark matter. Also scaled up variants of ordinary electro-weak particle spectra are possible. The identification explains chiral selection in living matter and unbroken $U(2)_{ew}$ invariance and free color in bio length scales become characteristics of living matter and of bio-chemistry and bio-nuclear physics. An attractive solution of the matter antimatter asymmetry is based on the identification of also antimatter as dark matter.

5.7.3 Dark matter hierarchy and consciousness

The emergence of the vision about dark matter hierarchy has meant a revolution in TGD inspired theory of consciousness. Dark matter hierarchy means also a hierarchy of long term memories with the span of the memory identifiable as a typical geometric duration of moment of consciousness at the highest level of dark matter hierarchy associated with given self so that even human life cycle represents at this highest level single moment of consciousness.

Dark matter hierarchy leads to detailed quantitative view about quantum biology with several testable predictions [M3]. The applications to living matter suggests that the basic hierarchy corresponds to a hierarchy of Planck constants coming as $\hbar(k) = \lambda^k(p)\hbar_0$, $\lambda \simeq 2^{11}$ for $p = 2^{127-1}$, $k = 0, 1, 2, ...$ [M3]. Also integer valued sub-harmonics and integer valued sub-harmonics of λ might be possible. Each p-adic length scale corresponds to this kind of hierarchy and number theoretical arguments suggest a general formula for the allowed values of Planck constant λ depending logarithmi-

cally on p-adic prime [C6]. Also the value of $\hbar_0$ has spectrum characterized by Beraha numbers $B_n = 4cos^2(\pi/n)$, $n \geq 3$, varying by a factor in the range $n3$ [C6].

The general prediction is that Universe is a kind of inverted Mandelbrot fractal for which each bird's eye of view reveals new structures in long length and time scales representing scaled down copies of standard physics and their dark variants. These structures would correspond to higher levels in self hierarchy. This prediction is consistent with the belief that 75 per cent of matter in the universe is dark.

1. Living matter and dark matter

Living matter as ordinary matter quantum controlled by the dark matter hierarchy has turned out to be a particularly successful idea. The hypothesis has led to models for EEG predicting correctly the band structure and even individual resonance bands and also generalizing the notion of EEG [M3]. Also a generalization of the notion of genetic code emerges resolving the paradoxes related to the standard dogma [L2, M3]. A particularly fascinating implication is the possibility to identify great leaps in evolution as phase transitions in which new higher level of dark matter emerges [M3].

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

2. Dark matter hierarchy and the notion of self

The vision about dark matter hierarchy leads to a more refined view about self hierarchy and hierarchy of moments of consciousness [J6, M3]. The larger the value of Planck constant, the longer the subjectively experienced duration and the average geometric duration $T(k) \propto \lambda^k$ of the quantum jump.

Dark matter hierarchy suggests also a slight modification of the notion of

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

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

3. The time span of long term memories as signature for the level of dark matter hierarchy

Higher levels of dark matter hierarchy provide neat quantitative view about self hierarchy and its evolution. For instance, EEG time scales corresponds to $k = 4$ level of hierarchy and a time scale of .1 seconds [J6], and EEG frequencies correspond at this level dark photon energies above the thermal threshold so that thermal noise is not a problem anymore. Various levels of dark matter hierarchy would naturally correspond to higher levels in hierarchy of consciousness and the typical duration of life cycle would give an idea about the level in question.

The level would determine also the time span of long term memories as discussed in [M3]. $k = 7$ would correspond to a duration of moment of conscious of order human lifetime which suggests that $k = 7$ corresponds to the highest dark matter level relevant to our consciousness whereas higher levels would in general correspond to transpersonal consciousness. $k = 5$ would correspond to time scale of short term memories measured in minutes and $k = 6$ to a time scale of memories measured in days.

The emergence of these levels must have meant evolutionary leap since long term memory is also accompanied by ability to anticipate future in the same time scale. This picture would suggest that the basic difference

between us and our cousins is not at the level of genome as it is usually understood but at the level of the hierarchy of magnetic bodies [L2, M3]. In fact, higher levels of dark matter hierarchy motivate the introduction of the notions of super-genome and hyper-genome. The genomes of entire organ can join to form super-genome expressing genes coherently. Hyper-genomes would result from the fusion of genomes of different organisms and collective levels of consciousness would express themselves via hyper-genome and make possible social rules and moral.

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