# Introduction

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## Contents

# 1 Background

*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 [16]. 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 [1, 2, 4, 5, 3, 6, 7] about TGD and eight online books about TGD inspired theory of consciousness and of quantum biology [10, 8, 9, 13, 11, 12, 14, 15].

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 [1, 2, 4, 5, 3, 6, 7] about TGD and eight online books about TGD inspired theory of consciousness and of quantum biology [10, 8, 9, 13, 11, 12, 14, 15] are warmly recommended to the interested reader.

# 2 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.

## 2.1 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 [17, 18, 19, 20]. The identification of the space-time as a submanifold [21, 22] 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 $X^4$.

### 2.2 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.

### 2.3 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 nonconservation of energy in GRT corresponds to the transfer of energy between the topological condensate and vapor phase.

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

### 3.1 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 [23, 24, 25]. For instance, the decay of a 3-surface to two 3-surfaces corresponds to the decay $A \rightarrow B + C$. 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.

## 3.2 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.

## 3.3 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 [10, 8, 9, 13, 11, 12, 14, 15].

### 3.3.1 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

$$\Psi_i \rightarrow U\Psi_i \rightarrow \Psi_f \quad ,$$

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'.

### 3.3.2 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.

### 3.3.3 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 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).

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).

### 3.3.4 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.

### 3.3.5 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 simulation 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.

### 3.3.6 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.

## 3.4 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.

## 3.5 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.

### 3.5.1 Dark matter as large $\hbar$ phase

D. Da Rocha and Laurent Nottale [35] 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 $n = 4 \rightarrow 3$ 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].

### 3.5.2 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.

### 3.5.3 p-Adic and dark matter hierarchies and hierarchy of moments of consciousness

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

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 $\lambda$ 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 $\lambda$ 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.

*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.

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.

*3. 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 $\tau$ 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 $\tau_p$ 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 $\tau$ [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.

# 4 Bird's eye of view about the topics of the book

The book is devoted to the applications of p-adic length scale hypothesis and dark matter hierarchy.

p-Adic length scale hypothesis states that primes $p \simeq 2^k$, $k$ integer, in particular prime, define preferred p-adic length scales. Physical arguments supporting this hypothesis based on the generalization of Hawking's area law for blackhole entropy so that it applies in case of elementary particles are discussed in [E5].

A much deeper number theory based justification for this hypothesis is based on the generalization of the number concept fusing real number fields and p-adic number fields among common rationals or numbers in their non-trivial algebraic extensions [E1]. This approach also justifies the notion of multi-p-fractality and allows to understand scaling law in terms of simultaneous $p \simeq 2^k$- and 2-fractality.

The levels of dark matter hierarchy are identified as being labelled by the values of dynamical quantized Planck constant (also other labels can be considered). The justification for the hypothesis provided by quantum classical correspondence and the fact the sizes of space-time sheets identifiable as quantum coherence regions can be arbitrarily large.

The first part of the book is devoted to the description of elementary particle massivation in terms of p-adic thermodynamics for which mathematical justification is discussed in [E6]. In the first two chapters general theory is represented and the remaining three chapters are devoted to the detailed calculation of masses of elementary particles and hadrons, and to various new physics suggested or predicted by the resulting scenario.

Second part of the book is devoted to the application of p-adic length scale hypothesis above elementary particle length scales. The notions of topological condensation and evaporation are formulated precisely. The so called leptohadron physics, originally developed on basis of experimental anomalies, is discussed as a particular instance of an infinite fractal hierarchy of copies of standard model physics, predicted by TGD and consistent with what is known about ordinary elementary particle physics. TGD based view about nuclear physics involves light exotic quarks as a essential element, and dark nuclear physics could have implications also at the level of condensed matter physics and biology. TGD based view about high $T_c$ superconductors involves also in an essential manner dark matter and is summarized in the closing chapter.

The seven online books about TGD [1, 2, 4, 5, 3, 6, 7] and eight online books about TGD inspired theory of consciousness and quantum biology [10, 8, 9, 13, 11, 12, 14, 15] are warmly recommended for the reader willing to get overall view about what is involved.

# 5 The contents of the book

## 5.1 ParT I: p-Adic description of particle massivation

In this part of the book a p-adic description of particle massivation using p-adic thermodynamics and TGD variant of Higgs mechanism is developed.

### 5.1.1 Elementary particle vacuum functionals

Genus-generation correspondence is one of the basic ideas of TGD approach. In order to answer various questions concerning the plausibility of the idea, one should know something about the dependence of the elementary particle vacuum functionals on the vibrational degrees of freedom for the boundary component. The construction of the elementary particle vacuum functionals based on Diff invariance, 2-dimensional conformal symmetry, modular invariance plus natural stability requirements indeed leads to an essentially unique form of the vacuum functionals and one can understand why $g > 2$ bosonic families are experimentally absent and why lepton numbers are conserved separately.

An argument suggesting that the number of the light fermion families is three, is developed. The argument goes as follows. Elementary particle vacuum functionals represent bound states of $g$ handles and vanish identically for hyper-elliptic surfaces having $g > 2$. Since all $g \leq 2$ surfaces are hyper-elliptic, $g \leq 2$ and $g > 2$ elementary particles cannot appear in same non-vanishing vertex and therefore decouple. The $g > 2$ vacuum functionals not vanishing for hyper-elliptic surfaces represent many particle states of $g \leq 2$ elementary particle states being thus unstable against the decay to $g \leq 2$ states. The failure of $Z_2$ conformal symmetry for $g > 2$ elementary particle vacuum functionals would in turn explain why they are heavy: this however not absolutely necessary since these particles would behave like dark matter in any case.

### 5.1.2 Massless states and particle massivation

The massless sector of the TGD and particle massivation is studied in this chapter. The identification of the spectrum of light particles reduces to two tasks: the construction of massless states and the identification of the states which remain light in p-adic thermodynamics.

*1. Physical states as representations of super-canonical and Super Kac-Moody algebras*

Physical states belong to the representation of super-canonical algebra and Super Kac-Moody algebra of $SO(2) \times E^2 \times SU(3) \times U(2)_{ew}$ associated with the 2-D surfaces $X^2$ defined by the intersections of 3-D light like causal determinants (CDs) with 7-D CDs $X^7 = X_l^3 \times CP_2$, where $X_l^3$ is boundary of future or past directed light cone. These 2-surfaces have interpretation as partons, and the effective 2-dimensionality means that the machinery of 2-D conformal field theories can be applied in the state construction.

The recipe is simple. Construct first a null state with a non-positive conformal weight using super-canonical generators, and then apply Super-Kac Moody generators to compensate this conformal weight to get a state with vanishing conformal weight and zero mass. Pose also the conditions that the commutator of super-canonical and super Kac-Moody algebras and corresponding commutator of Virasoro algebras annihilates physical states.

The conformal weights of super-canonical algebra generators are complex and in a well-defined sense expressible in terms of zeros of Riemann Zeta although the connection is much more subtle as thought originally [C1] and conformal weight cannot be regarded as quantum number in the standard sense of the word. More precisely, the arguments of [C1] suggest that radial conformal weight $\Delta$ for super-canonical algebra in fact depends on the point of geodesic sphere $S^2$ in $CP_2$ and is given in terms of the inverse $\zeta^{-1}(z)$ of Riemann $\zeta$ having the natural complex coordinate $z$ of $S^2$ as argument. This implies a mapping of the radial conformal weights to the points of the geodesic sphere $CP_2$ serving in the role of "conformal heavenly sphere".

Linear combinations of zeros correspond to algebraic points in the intersections of real and p-adic partonic 2-surfaces and are thus in a unique role from the point of view of p-adicization. They can be also identified as conformal weights associated with parton as an n-particle state in the algebraic sense (these points correspond to arguments of n-point functions of conformal field theory in the construction of S-matrix). This discrete set of points defines in a natural manner number theoretic braid and a connection with braiding S-matrices emerges. This if one believes the basic conjecture that the numbers $p^s$, $p$ prime and $s$ zero of Riemann Zeta are algebraic numbers.

The original hypothesis was that the conformal weights of physical states are real. This would imply conformal confinement to which color confinement might reduce: what would happen that partons can have complex super-canonical conformal weights but particles have real conformal weights. It has however turned out that there is actually no strong reason for the reality of the conformal weights.

The waves $x^s$ with conformal weights $s = 1/2+i\sum_k n_k y_k$, where $s_k = 1/2+iy_k$ is a zero of Zeta, define an orthogonal basis with respect to the inner product defined by the integration measure $dx/x$. These conformal weights can be assigned to both the eigenvalues of the modified Dirac operator and to radial logarithmic waves multiplying the Hamiltonians at $\delta M^4_\pm \times CP_2$ appearing in the construction of the configuration space geometry.

The imaginary part of the complex weight would allow to distinguish between particle and its phase conjugate (phase conjugate photons obey time reversed dynamics) by assigning to a particle inherent time orientation allowing to distinguish between positive energy particle propagating to the geometric future from a negative energy particle propagating to the geometric past. Obviously a strong correlation with second law of thermodynamics would emerge. It has turned out that the conformal weights $s = 1/2 + iy_k$ correspond to systems critical against transition changing the value of Planck constant.

One can also introduce the notion of bound state conformal weight in terms of Riemann polyzetas, and it turns out that number theoretic constraints imply that the net conformal weights in this case have the same spectrum as in single particle case and that irreducible n-particle bound states are possible only for $n = 2$ and 3. This suggests a connection with valence quark numbers of mesons and baryons [C1, E8] and perhaps also with family replication phenomenon (parton with genus $g = 0, 1, 2$ as conformally bound state of sphere and $g$ handles so that only 3 stable particle families would result). The zeros of Zeta represent essentially non-stringy aspects of TGD being due to the fact that the basic objects are effectively 2-dimensional rather than 1-dimensional.

For spinor harmonics of $CP_2$ the correlation between color and electro-weak quantum numbers is not correct. Super-canonical generators provide a natural mechanism allowing to cure the problem. Boson states are identified as bi-local bilinears of fermions and anti-fermions in $X^2$ characterized by charge matrices and conformally invariant correlation function. $BF\overline{F}$ coupling constants can be identified in terms of normalization factors of the boson states. The small value of gravitational coupling can be understood as resulting by a fractal mechanism reducing its value from the square of p-adic length $L_p$, and a concrete physical interpretation for the expression of gravitational constant in terms of $CP_2$ length derived from number theoretic arguments emerges. The presence of primes $2, 3, ...23, p$ in the expression of the gravitational constant can be interpreted in terms of multi-p p-adic fractality involving these primes.

If the primes $p = 2, 3, ...23$ are present, the question whether besides p-adic length scales $L_p \propto \sqrt{p}$ also their multiples $\sqrt{\prod_i q_i} L_p$, where $\{q_i\}$ forms a subset of $\{2, 3, ..., 23\}$ define fundamental length scales. The implication would be small-p p-adic fractality for these small primes with each p-adic length scale $L_p$ taking the role of $CP_2$ length, and there indeed is some evidence for this kind of fractality.

*2. Particle massivation*

Particle massivation can be regarded as a change of the vanishing parton conformal weights describable as a thermal mixing with higher conformal weights. The observed mass squared is not p-adic thermal expectation of mass squared but that of conformal weight so that there are no problems with Lorentz invariance.

The space-time mechanism of massivation can be articulated in several manners.

1. $CP_2$ type vacuum extremals representing elementary particles have random light-like curve as an $M^4$ projection so that the average motion correspond to that of massive particle. Lighlike randomness gives rise to classical Virasoro conditions. p-Adic thermodynamics is consistent with this picture.

2. A possible candidate for the physical mechanism causing the thermal massivation is hydrodynamical mixing by the braiding flow. One can imagine several realizations for this flow. For instance a flow defined by the normal components of energy momentum tensor of the induced Kähler field at light like 3-D CDs describing the orbits of partons. Number theoretical approach leads to a purely number theoretical identification of braids and braiding flow and it seems that this flow might be more fundamental.

3. The fundamental parton level description of TGD is based on almost topological QFT for light-like 3-surfaces. Dynamics is constrained only by the requirement that $CP_2$ projection is for extremals of Chern-Simons action 2-dimensional and for off-shell states light-likeness is the only constraint. Hence a justification for the ergodic hydrodynamic flow as a fundamental cause of massivation emerges. The symmetries respecting light-likeness property correspond gives rise to Kac-Moody type algebra and super-canonical symmetries emerge also naturally as well as $N = 4$ character of super-conformal invariance. Four-momentum appears as non-conserved Noether charge (mass squared is however conserved) and has identification as gravitational four-momentum. Inertial momentum corresponds to the statistical average of gravitational four-momentum and p-adic thermodynamics is thus a natural description.

This mechanism cannot explain the massivation of electro-weak gauge bosons, which could be caused either by TGD variant of Higgs mechanism or by the fact that the charge matrices of $W$ boson and left handed component of $Z^0$ are not covariantly constant, which together with the hydrodynamical mixing could lead to a loss of correlations. TGD indeed predicts a candidate for Higgs as a wormhole contact whose throats are identified as lightlike 3-surfaces and carry quantum numbers of fermion and antifermion and it is now clear that this is the correct option.

The underlying philosophy is that real number based TGD can be algebraically continued to various p-adic number fields. This gives justification for the use of p-adic thermodynamics although the mapping of p-adic thermal expectations to real counterparts is not completely unique. Instead of energy, the Super Kac-Moody Virasoro generator $L_0$ (essentially mass squared) is thermalized in p-adic thermodynamics. This guarantees Lorentz invariance. It is important to notice that four-momentum does not appear in the definition of super Virasoro generators. The reason is simply that four-momentum does not appear in the expression of super Virasoro generators as Noether charges associated with the modified Dirac action. The dependence of Virasoro generators on four-momentum would be in conflict with Lorentz invariance.

p-Adic thermodynamics forces to conclude that $CP_2$ radius is essentially the p-adic length scale $R \sim L$ and thus of order $R \simeq 10^4\sqrt{G}$ and therefore $10^4$ times larger than the naive guess. Hence p-adic thermodynamics describes the mixing of states with vanishing conformal weights with their Super Kac-Moody Virasoro excitations having masses of order $10^{-4}$ Planck mass.

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 $L_0$!)).

There is also modular contribution to the mass squared which can be estimated using elementary particle vacuum functionals in the conformal modular degrees of freedom of the partonic 2-surface. This contribution can be identified as a contribution coming from a thermodynamics in super-canonical Virasoro algebra which generates excitations of the ground states with negative conformal weight.

The predictions of the general theory are consistent with the earlier mass calculations, and the earlier ad hoc parameters disappear. In particular, optimal lowest order predictions for the charged lepton masses are obtained and photon, gluon and graviton appear as essentially massless particles. The negative conformal weight created by super-canonical generators can have arbitrarily large magnitude (ground state corresponds to a null state of super-conformal algebra annihilated by $L_n$, $n < 0$) so that an infinite hierarchy of exotic massless states is in principle possible. These states receive mass by the proposed mechanism and they are expected to be unstable but it remains to be shown that they do not appear in the spectrum of light particles. Since $X^2$ can have an arbitrarily large size and can even correspond to black hole horizon, the emergence of this complex structure of states is completely natural.

### 5.1.3 p-Adic particle massivation: elementary particle masses

The calculation of elementary fermion and boson masses using p-adic thermodynamics is carried out. Leptons and quarks are obey almost identical mass formulas. Charged lepton mass ratios are predicted with relative errors of order one cent and QED renormalization corrections provide a plausible explanation for the discrepancies. Neutrino masses and neutrino mixing matrix can be predicted highly uniquely if the existing experimental inputs are taken seriously: the best fit of the mass squared differences requires $k = 13^2 = 169$ so that extended form of the p-adic length scale hypothesis is needed.

The prediction or quark masses is more difficult since even the deduction of even the p-adic length scale determining the masses of u, d, and s is a non-trivial task. Second difficulty is related to the topological mixing of quarks. Somewhat surprisingly, the model for U and D matrices constructed for a decade ago predicts realistic quark mass spectrum although the new mass formula is based on different assumptions and different identification of p-adic mass scales. Current quark masses and constituent quark masses can be understood if the p-adic length scale of quark is different for free and bound quarks. The analog of Gell-Mann-Okubo type mass formula results if the p-adic length scale depends on hadron. The Higgs contribution to the fermionic mass is of second order and can be even vanishing and there is an argument implying that Higgs field cannot develop vacuum expectation at fermionic space-time sheets. Top quark mass fixes highly uniquely the $CP_2$ mass scale since second order correction to electron mass must be very small in order to reproduce the top quark mass in the allowed range of values. Also top quark can correspond to several p-adic mass scales and there is direct experimental evidence for this in mass distribution of top quark.

p-Adic thermodynamics cannot explain $Z^0$ and $W$ boson masses: thermal masses are completely negligible for the p-adic temperature $T = 1/2$ whereas for $T = 1$ they are 20-30 per cent too high. There is a general argument implying that $T = 1/26$ holds true for bosons so that the masses would be completely negligible. TGD allows a candidate for a Higgs field with the same quantum numbers as its standard model counterpart and having wormhole contacts as space-time correlates just as ordinary gauge bosons have. Thus p-adic thermodynamics *resp.* Higgs mechanism would predict in excellent accuracy fermion *resp.* boson masses and allow the Higgs production rate to be about one per cent of the rate predicted by the standard model (the dominating fermionic couplings are now small).

The possibility of exotic states poses a serious problem for the proposed scenario. If elementary particles correspond to $CP_2$ type extremals, all exotic massless particles can be constructed using colored generators and by color confinement cannot induce macroscopic long range interactions. The essential assumption is that the fermionic quantization for the space-time sheets having $CP_2$ projection of dimension $D(CP_2) < 4$ is non-conventional. This has also direct relevance for the understanding of the matter antimatter asymmetry.

### 5.1.4 p-Adic particle massivation: hadron masses

In this chapter the results of the calculation of elementary particle masses will be used to construct a model predicting hadron masses.

1. *Topological mixing of quarks*

In TGD framework CKM mixing is induced by topological mixing of quarks (that is 2-dimensional topologies characterized by genus). Number theoretical constraints on topological mixing can be realized by assuming that topological mixing leads to a thermodynamical equilibrium. This gives an upper bound of 1200 for the number of different $U$ and $D$ matrices and the input from top quark mass and $\pi^+ - \pi^0$ mass difference implies that physical $U$ and $D$ matrices can be constructed as small perturbations of matrices expressible as direct sum of essentially unique $2 \times 2$ and $1 \times 1$ matrices. The maximally entropic solutions can be found numerically by using the fact that only the probabilities $p_{11}$ and $p_{21}$ can be varied freely. The solutions are unique in the accuracy used, which suggests that the system allows only single thermodynamical phase.

The matrices $U$ and $D$ associated with the probability matrices can be deduced straightforwardly in the standard gauge. The $U$ and $D$ matrices derived from the probabilities determined by the entropy maximization turn out to be unitary for most values of $n_1$ and $n_2$. This is a highly non-trivial result and means that mass and probability constraints together with entropy maximization define a sub-manifold of $SU(3)$ regarded as a sub-manifold in 9-D complex space. The choice $(n(u), n(c)) = (4, n)$, $n < 9$, does not allow unitary $U$ whereas $(n(u), n(c)) = (5, 6)$ does. This choice is still consistent with top quark mass and together with $n(d) = n(s) = 5$ it leads to a rather reasonable CKM matrix with a value of CP breaking invariant within experimental limits. The elements $V_{i3}$ and $V_{3i}$, $i = 1, 2$ are however roughly twice larger than their experimental values deduced assuming standard model. $V_{31}$ is too large by a factor 1.6. The possibility of scaled up variants of light quarks could lead to too small experimental estimates for these matrix elements. The whole parameter space has not been scanned so that better candidates for CKM matrices might well exist.

2. *Higgs contribution to fermion masses is negligible*

There are good reasons to believe that Higgs expectation for the fermionic space-time sheets is vanishing although fermions couple to Higgs. Thus p-adic thermodynamics would explain fermion masses completely. This together with the fact that the prediction of the model for the top quark mass is consistent with the most recent limits on it, fixes the $CP_2$ mass scale with a high accuracy to the maximal one obtained if second order contribution to electron's p-adic mass squared vanishes. This is very strong constraint on the model.

3. *The p-adic length scale of quark is dynamical*

The assumption about the presence of scaled up variants of light quarks in light hadrons leads to a surprisingly successful model for pseudo scalar meson masses using only quark masses and the assumption mass squared is additive for quarks with same p-adic length scale and mass for quarks labelled by different primes $p$. This conforms with the idea that pseudo scalar mesons are Goldstone bosons in the sense that color Coulombic and magnetic contributions to the mass cancel each other. Also the mass differences between hadrons containing different numbers of strange and heavy quarks can be understood if $s, b$ and $c$ quarks appear as several scaled up versions.

This hypothesis yields surprisingly good fit for meson masses but for some mesons the predicted mass is slightly too high. The reduction of $CP_2$ mass scale to cure the situation is not possible since top quark mass would become too low. In case of diagonal mesons for which quarks correspond to same p-adic prime, quark contribution to mass squared can be reduced by ordinary color interactions and in the case of non-diagonal mesons one can require that quark contribution is not larger than meson mass.

*4. Super-canonical bosons at hadronic space-time sheet can explain the constant contribution to baryonic masses*

Quarks explain only a small fraction of the baryon mass and that there is an additional contribution which in a good approximation does not depend on baryon. This contribution should correspond to the non-perturbative aspects of QCD.

A possible identification of this contribution is in terms of super-canonical gluons predicted by TGD. Baryonic space-time sheet with $k = 107$ would contain a many-particle state of super-canonical gluons with net conformal weight of 16 units. This leads to a model of baryons masses in which masses are predicted with an accuracy better than 1 per cent. Super-canonical gluons also provide a possible solution to the spin puzzle of proton.

Hadronic string model provides a phenomenological description of non-perturbative aspects of QCD and a connection with the hadronic string model indeed emerges. Hadronic string tension is predicted correctly from the additivity of mass squared for $J = 2$ bound states of super-canonical quanta. If the topological mixing for super-canonical bosons is equal to that for $U$ type quarks then a 3-particle state formed by 2 super-canonical quanta from the first generation and 1 quantum from the second generation would define baryonic ground state with 16 units of conformal weight.

In the case of mesons pion could contain super-canonical boson of first generation preventing the large negative contribution of the color magnetic spin-spin interaction to make pion a tachyon. For heavier bosons super-canonical boson need not to be assumed. The preferred role of pion would relate to the fact that its mass scale is below QCD $\Lambda$.

*5. Description of color magnetic spin-spin splitting in terms of conformal weight*

What remains to be understood are the contributions of color Coulombic and magnetic interactions to the mass squared. There are contributions coming from both ordinary gluons and super-canonical gluons and the latter is expected to dominate by the large value of color coupling strength.

Conformal weight replaces energy as the basic variable but group theoretical structure of color magnetic contribution to the conformal weight associated with hadronic space-time sheet ($k = 107$) is same as in case of energy. The predictions for the masses of mesons are not so good than for baryons, and one might criticize the application of the format of perturbative QCD in an essentially non-perturbative situation.

The comparison of the super-canonical conformal weights associated with spin 0 and spin 1 states and spin 1/2 and spin 3/2 states shows that the different masses of these states could be understood in terms of the super-canonical particle contents of the state correlating with the total quark spin. The resulting model allows excellent predictions also for the meson masses and implies that only pion and kaon can be regarded as Goldstone boson like states. The model based on spin-spin splittings is consistent with the model.

To sum up, the model provides an excellent understanding of baryon and meson masses. This success is highly non-trivial since the fit involves only the integers characterizing the p-adic length scales of quarks and the integers characterizing color magnetic spin-spin splitting plus p-adic thermodynamics and topological mixing for super-canonical gluons. The next challenge would be to predict the correlation of hadron spin with super-canonical particle content in the case of long-lived hadrons.

### 5.1.5 p-Adic Particle Massivation: New Physics

TGD certainly predicts a lot of new physics, actually infinite hierarchies of fractal copies of standard model physics, but the precise characterization of predictions has varied as the interpretation of the theory has evolved during years. No attempt to discuss systematically the spectrum of various exotic bosons and fermions, basically due to the ground states created by color super-canonical and Kac-Moody generators, will be made. Rather, the attempt is to summarize the new physics expected on basis of recent interpretation of quantum TGD.

*1. Basic new physics predictions*

Concerning new physics the basic predictions are following. TGD predicts a rich spectrum of massless states for which ground states of negative super-canonical conformal weight are created by colored super-generators. By color confinement these states do not however give rise to macroscopic long range forces. A hierarchy color and weak physics is predicted. Also dark matter hierarchy corresponding to a hierarchy of Planck constants brings in a hierarchy of variants of standard model physics labelled by the values of Planck constant. Thus in TGD the question is not about about predicting some exotic particle but entire fractal hierarchies of copies of standard model physics.

The family replication for fermions correspond in case of gauge bosons prediction of bosons labelled by genera of the two lightlike wormhole throats associated with the wormhole contact representing boson. There are very general arguments predicting that the number of fermionic genera is three and this means that gauge bosons can be arranged into genus-SU(3) singlet and octet. Octet corresponds to exotic gauge bosons and its members should develop Higgs expectation value. Completely symmetric coupling between Higgs octet and boson octet allows also the bosons with vanishing genus-SU(3) quantum numbers to develop mass.

Higgs field is predicted and its vacuum expectation value explains boson masses. By a general argument p-adic temperature for bosons is low and this means that Higgs contribution to the gauge boson mass dominates. Only p-adic thermodynamics is needed to explain fermion masses and the masses of super-canonical bosons and their super counterparts. There is an argument suggesting that vacuum expectation value of Higgs at fermion space-time sheets is not possible. Almost universality of the topological mixing inducing also CKM mixing allows to predict mass spectrum of these states.

*2. A general vision about coupling constant evolution*

The vision about coupling constant evolution has developed slowly and especially important developments have occurred during last few years. Therefore an overall view about recent understanding is in order.

Also QCD coupling constant evolution is discussed and it is found that asymptotic freedom could be lost making possible existence of several scaled up versions of QCD existing only in a finite length scale range. The basic counter arguments against lepto-hadron hypothesis are considered and it is found that the loss of asymptotic freedom could allow lepto-hadron physics. One can also consider the possibility that the copies of say electro-weak characterized by Mersenne primes do not couple directly to each other so that the objections are circumvented.

The discovery of dark matter hierarchy about fifteen years after these argument were developed resolves the problems in much more elegant manner. TGD predicts an infinite hierarchy of electro-weak and color physics physics for which particles couple directly only via gravitons. De-coherence phase transitions can however induce processes allowing the decay of particles of a given physics to particles of another physics.

*3. Summary of new physics effects*

Various new physics effects are discussed.

1. There is a brief discussion of family replication phenomenon in the case of gauge bosons based on the identification of gauge bosons as wormhole contacts. Also an argument forcing the identification of partonic vertices as branchings of partonic 2-surfaces is developed.
2. ALEPH anomaly is interpreted in terms of a fractal copy of b-quark corresponding to k=197.
3. The possible signatures of $M_{89}$ hadron physics in $e^+e^-$ annihilation experiments are discussed using a naive scaling of ordinary hadron physics.
4. It is found that the newly born concept of Pomeron of Regge theory could be identified as the sea of perturbative QCD.
5. In p-adic context exotic representations of Super Virasoro with $M^2 \propto p^k$, $k = 1, 2, ..$m are possible. For $k = 1$ the states of these representations have same mass scale as elementary particles although in real context the masses would be gigantic. This inspires the question whether non-perturbative aspects of hadron physics could be assigned to the presence of these representations. The prospects for this are promising. Pion mass is almost exactly equal to the mass of lowest state of the exotic representation for $k = 107$ and Regge slope for rotational excitations of hadrons is predicted with three per cent accuracy assuming that they correspond to the states of $k = 101$ exotic Super Virasoro representations. This leads to the idea that hadronization and fragmentation correspond to phase transitions between ordinary and exotic Super Virasoro representations and that there is entire fractal hierarchy of hadrons inside hadrons and QCD:s inside QCD:s corresponding to p-adic length scales $L(k)$, $k = 107, 103, 101, 97, ....$

*4. Cosmic primes and Mersenne primes*

p-Adic length scale hypothesis suggests the existence of a scaled up copy of hadron physics associated with each Mersenne prime $M_n = 2^n - 1$,$n$ prime: $M_{107}$ corresponds to ordinary hadron physics. There is some evidence for exotic hadrons. Centauro events and the peculiar events associated with $E > 10^5\ GeV$ radiation from Cygnus X-3 could be understood as due to the decay of gamma rays to $M_{89}$ hadron pair in the atmosphere. The decay $\pi_n \rightarrow \gamma\gamma$ produces a peak in the spectrum of the cosmic gamma rays at energy $\frac{m(\pi_n)}{2}$ and there is evidence for the peaks at energies $E_{89} \simeq 34\ GeV$ and $E_{31} \simeq 3.5 \cdot 10^{10}\ GeV$. The absence of the peak at $E_{61} \simeq 1.5 \cdot 10^6\ GeV$ can be understood as due to the strong absorption caused by the $e^+e^-$ pair creation with photons of the cosmic microwave background. Cosmic string decays *cosmic string* $\rightarrow M_2$ *hadrons* $\rightarrow M_3$ *hadrons* $.. \rightarrow M_{107}$ *hadrons* is a new source of cosmic rays. The mechanism could explain the change of the slope in the hadronic cosmic ray spectrum at $M_{61}$ pion rest energy $3 \cdot 10^6\ GeV$. The cosmic ray radiation at energies near $10^9\ GeV$ apparently consisting of protons and nuclei not lighter than Fe might be actually dominated by gamma rays: at these energies $\gamma$ and $p$ induced showers have same muon content and the decays of gamma rays to $M_{89}$ and $M_{61}$ hadrons in the atmosphere can mimic the presence of heavy nuclei in the cosmic radiation.

*5. Anomalously large direct CP breaking in $K - \overline{K}$ system and exotic gluons*

The recently observed anomalously large direct CP breaking in $K_L \rightarrow \pi\pi$ decays is explained in terms of loop corrections due to the predicted 2 exotic gluons having masses around 33.6 GeV. It will be also found that the TGD version of the chiral field theory believed to provide a phenomenological low energy description of QCD differs from its standard model version in that quark masses are replaced in TGD framework with shifts of quark masses induced by the vacuum expectation values of the scalar meson fields. This conforms with the TGD view about Higgs mechanism as causing only small mass shifts. It must be however emphasized that there is an argument suggesting that the vacuum expectation value of Higgs in fermionic case does not even make sense.

## 5.2 Part II: Applications of p-adic length scale hypothesis and dark matter hierarchy

### 5.2.1 Theory of topological condensation and evaporation

This chapter is devoted to the development of the TGD based concept of the gauge charge, of a model for coupling constant evolution at space-time level, to a proper interpretation of long ranged electro-weak and color gauge fields as classical correlates for dark gauge bosons, to a QFT model of topological condensation and evaporation, and to the application of this theory in elementary particle physics context.

*1. Basic concepts*

Quantum classical correspondence suggests that gauge charges and p-adic coupling constant should have space-time counterparts. The first problem is to define precisely the concepts like classical gauge charge, gauge flux, topological condensation and evaporation. The crucial ingredients in the model are so called $CP_2$ type extremals. The realization that # contacts (topological sum contacts and $\#_B$ contacts (join along boundaries bonds) are accompanied by causal horizons which carry quantum numbers and allow identification as partons leads to a solution of this problem.

The partons associated with topologically condensed $CP_2$ type extremals carry elementary particle vacuum numbers whereas the parton pairs associated with # contacts connecting two space-time sheets with Minkowskian signature of induced metric define parton pairs. These parton pairs do not correspond to ordinary elementary particles. Gauge fluxes through # contacts can be identified as gauge charges of the partons. Gauge fluxes between space-time sheets can be transferred through # and $\#_B$ contacts concentrated near the boundaries of the smaller space-time sheet.

Number theoretical vision allows to sharpen the quantitative picture and leads to a vision in which elementary particles correspond to infinite primes, integers, or even rationals which in turn can be mapped to finite rationals. To infinite primes, integers, and rationals it is possible to associate a finite rational $q = m/n$ by a homomorphism. $q$ defines an effective q-adic topology of space-time sheet consistent with p-adic topologies defined by the primes dividing $m$ and $n$ ($1/p$-adic topology is homeomorphic to p-adic topology). The largest prime dividing $m$ determines the mass scale of the space-time sheet in p-adic thermodynamics. $m$ and $n$ are exchanged by supersymmetry and the primes dividing $m$ ($n$) correspond to space-time sheets with positive (negative) time orientation. Two space-time sheets characterized by rationals having common prime factors can be connected by a $\#_B$ contact and can interact by exchange of particles characterized by divisors of $m$ or $n$.

Number theoretic vision suggests also a much refined interpretation for topological condensation in terms of infinite primes and inclusion hierarchy of hyper-finite factors of type $II_1$ of von Neumann algebra defined naturally by the configuration space spinors. These inclusion hierarchies have interpretation in terms of dark matter hierarchies and also in terms of cognitive hierarchies and are something completely new from the point of view of standard physics.

*2. Renormalization group equations at space-time level*

Renormalization group evolution equations for gauge couplings at given space-time sheet are discussed using quantum classical correspondence. For known extremals of Kähler action gauge couplings are RG invariants inside single space-time sheet, which supports the view that discrete p-adic coupling constant evolution replaces the ordinary coupling constant evolution.

*3. Identification of dark matter*

Number theoretical considerations led to the idea that dark matter corresponds to ordinary elementary particles having a large value of $\hbar$ implying scaled up Compton length and carrying complex conformal weights such that net conformal weights of dark matter blobs are real. These dark variants of elementary particles would have same masses as ordinary elementary particles.

It has however become clear that an infinite hierarchy of dark matters is predicted corresponding to various quantized values of $\hbar$, to the spectrum of complex conformal weights of dark particles, and to the collection of primes determining the p-adic length scales associated with the particle. The largest prime in this collection determines the mass scale of the particle and the remaining the mass scales of the the gauge bosons with which particle interacts. Particle can thus be characterized by an integer whose prime factors characterize the mass scale of particle and the mass scales of the gauge bosons that particle can exchange. Also the possibility of algebraic extensions of p-adic numbers brings in additional complexity.

The existence of a hierarchy of copies of electro-weak physics and color physics is an unavoidable prediction. A naive objection against this picture are the decay widths of intermediate gauge bosons excluding new light particles. This objection fails in many-sheeted space-time even if one allows the QCD:s in question to be asymptotically free. The reason is that each copy of weak bosons and gluons couples only to a subset of particles characterized by the integer characterizing the particle.

*4. The interpretation of long range weak and color gauge fields*

In TGD gravitational fields are accompanied by long ranged electro-weak and color gauge fields and there are three alternative options to consider.

Option I: The electro-weak charges of elementary particles are screened by vacuum gauge charges (possible in TGD) in a region of size $L_W$ of order intermediate boson length scale. This option does not explain the presence of long range electro-weak gauge fields unavoidably present if the dimension of $CP_2$ projection of space-time sheet is higher than 2 nor classical color gauge fields present for non-vacuum extremals.

Option II: Electro-weak gauge charges are not screened in the length scale $L_W$ and the gauge fluxes of elementary particles flow to larger space-time sheets via # throats within region of size $L_W$ and elementary particles have the quantized values of em $Z^0$ charges. The problem for this option are anomalously large Rutherford cross sections in condensed matter and large parity breaking effects in hadronic, nuclear, and atomic length scales.

Option III: There is a p-adic hierarchy of color and electro-weak physics such that weak bosons are massless below the p-adic length scale determining the mass scale of weak bosons. By quantum classical correspondence classical long ranged gauge fields serve as space-time correlates for gauge bosons below the p-adic length scale in question.

The unavoidable long ranged electro-weak and color gauge fields are created by dark matter and dark particles can screen dark nuclear electro-weak charges below the weak scale. Above this scale vacuum screening occurs as for ordinary weak interactions. Dark gauge bosons are massless below the appropriate p-adic length scale but massive above it and $U(2)_{ew}$ is broken only in the fermionic sector. For dark copies of ordinary fermions masses are essentially identical with those of ordinary fermions.

This option is consistent with the standard elementary particle physics for visible matter apart from predictions such as the possibility of p-adically scaled up versions of ordinary quarks predicted to appear already in ordinary low energy hadron physics. The most interesting implications are seen in longer length scales. Dark variants of ordinary valence quarks and gluons and a scaled up copy of ordinary quarks and gluons are predicted to emerge already in ordinary nuclear physics. Chiral selection in living matter suggests that dark matter is an essential component of living systems so that non-broken $U(2)_{ew}$ symmetry and 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. Simple model for rates of topological condensation and evaporation*

Order of magnitude estimates for the condensation and evaporation energies are derived and condensation and evaporation rates are estimated using simple field theoretic model. A quantitative model for the generation of matter antimatter antisymmetry is constructed with correct order or magnitude estimate for baryon to photon ratio. A special case of the model corresponds to antimatter which is dark. An explanation of Pomeron is proposed.

### 5.2.2 Recent Status of Leptohadron hypothesis

TGD suggests strongly the existence of leptohadron physics. Leptohadrons are bound states of color excited leptons and the anomalous production of $e^+e^-$ pairs in heavy ion collisions finds a nice explanation as resulting from the decays of leptohadrons with basic condensate level $k = 127$ and having typical mass scale of one $MeV$. The recent indications on the existence of a new fermion with quantum numbers of muon neutrino and the anomaly observed in the decay of ortopositronium give further support for the leptohadron hypothesis. There is also evidence for anomalous production of low energy photons and $e^+e^-$ pairs in hadronic collisions.

The identification of leptohadrons as a particular instance in the predicted hierarchy of dark matters interacting directly only via graviton exchange allows to circumvent the lethal counter arguments against the leptohadron hypothesis ($Z^0$ decay width and production of colored lepton jets in $e^+e^-$ annihilation) even without assumption about the loss of asymptotic freedom.

PCAC hypothesis and its sigma model realization lead to a model containing only the coupling of the leptopion to the axial vector current as a free parameter. The prediction for $e^+e^-$ production cross section is of correct order of magnitude only provided one assumes that leptopions decay to leptonucleon pair $e^+_{ex}e^-_{ex}$ first and that leptonucleons, having quantum numbers of electron and having mass only slightly larger than electron mass, decay to lepton and photon. The peculiar production characteristics are correctly predicted. There is some evidence that the resonances decay to a final state containing $n > 2$ particle and the experimental demonstration that leptonucleon pairs are indeed in question, would be a breakthrough for TGD.

During 18 years after the first published version of the model also evidence for colored $\mu$ has emerged. Towards the end of 2008 CDF anomaly gave a strong support for the colored excitation of $\tau$. The lifetime of the light long lived state identified as a charged $\tau$-pion comes out correctly and the identification of the reported 3 new particles as p-adically scaled up variants of neutral $\tau$-pion predicts their masses correctly. The observed muon jets can be understood in terms of the special reaction kinematics for the decays of neutral $\tau$-pion to 3 $\tau$-pions with mass scale smaller by a factor 1/2 and therefore almost at rest. A spectrum of new particles is predicted. The discussion of CDF anomaly led to a modification and generalization of the original model for lepto-pion production and the predicted production cross section is consistent with the experimental estimate.

### 5.2.3 TGD and Nuclear Physics

This chapter is devoted to the possible implications of TGD for nuclear physics. In the original version of the chapter the focus was in the attempt to resolve the problems caused by the incorrect interpretation of the predicted long ranged weak gauge fields. What seems to be a breakthrough in this respect came only quite recently (2005), more than a decade after the first version of this chapter, and is based on TGD based view about dark matter inspired by the developments in the mathematical understanding of quantum TGD. In this approach condensed matter nuclei can be either ordinary, that is behave essentially like standard model nuclei, or be in dark matter phase in which case they generate long ranged dark weak gauge fields responsible for the large parity breaking effects in living matter. This approach resolves trivially the objections against long range classical weak fields.

The basic criterion for the transition to dark matter phase having by definition large value of $\hbar$ is that the condition $\alpha Q_1 Q_2 \simeq 1$ for appropriate gauge interactions expressing the fact that the perturbation series does not converge. The increase of $\hbar$ makes perturbation series converging since the value of $\alpha$ is reduced but leaves lowest order classical predictions invariant.

This criterion can be applied to color force and inspires the hypothesis that valence quarks inside nucleons correspond to large $\hbar$ phase whereas sea quark space-time sheets correspond to the ordinary value of $\hbar$. This hypothesis is combined with the earlier model of strong nuclear force based on the assumption that long color bonds with p-adically scaled down quarks with mass of order MeV at their ends are responsible for the nuclear strong force.

*1. Is strong force due to color bonds between exotic quark pairs?*

The basic assumptions are following.

1. Valence quarks correspond to large $\hbar$ phase with p-adic length scale $L(k_{eff} = 129) = L(107)/v_0 \simeq 2^{11}L(107) \simeq 5 \times 10^{-12}$ m whereas sea quarks correspond to ordinary $\hbar$ and define the standard size of nucleons.

2. Color bonds with length of order $L(127) \simeq\simeq 2.5 \times 10^{-12}$ m and having quarks with ordinary $\hbar$ and p-adically scaled down masses $m_q(dark) \simeq v_0 m_q$ at their ends define kind of rubber bands connecting nucleons. The p-adic length scale of exotic quarks differs by a factor 2 from that of dark valence quarks so that the length scales in question can couple naturally. This large length scale as also other p-adic length scales correspond to the size of the topologically quantized field body associated with system, be it quark, nucleon, or nucleus.

   Valence quarks and even exotic quarks can be dark with respect to both color and weak interactions but not with respect to electromagnetic interactions. The model for binding energies suggests darkness with respect to weak interactions with weak boson masses scaled down by a factor $v_0$. Weak interactions remain still weak. Quarks and nucleons as defined by their $k = 107$ sea quark portions condense at scaled up weak space-time sheet with $k_{eff} = 111$ having p-adic size $10^{-14}$ meters. The estimate for the atomic number of the heaviest possible nucleus comes out correctly.

   The wave functions of the nucleons fix the boundary values of the wave functionals of the color magnetic flux tubes idealizable as strings. In the terminology of M-theory nucleons correspond to small branes and color magnetic flux tubes to strings connecting them.

*2. General features of strong interactions*

This picture allows to understand the general features of strong interactions.

1. Quantum classical correspondence and the assumption that the relevant space-time surfaces have 2-dimensional $CP_2$ projection implies Abelianization. Strong isospin group can be identified as the SU(2) subgroup of color group acting as isotropies of space-time surfaces. and the U(1) holonomy of color gauge potential defines a preferred direction of strong isospin. Dark color isospin corresponds to strong isospin. The correlation of dark color with weak isospin of the nucleon is strongly suggested by quantum classical correspondence.

2. Both color singlet spin 0 pion type bonds and colored spin 1 bonds are allowed and the color magnetic spin-spin interaction between the exotic quark and anti-quark is negative in this case. p-p and n-n bonds correspond to oppositely colored spin 1 bonds and p-n bonds to colorless spin 0 bonds for which the binding energy is free times higher. The presence of colored bonds forces the presence of neutralizing dark gluon condensate favoring states with $N - P > 0$.

3. Shell model based on harmonic oscillator potential follows naturally from this picture in which the magnetic flux tubes connecting nucleons take the role of springs. Spin-orbit interaction can be understood in terms of the color force in the same way as it is understood in atomic physics.

*3. Nuclear binding energies*

1. The binding energies per nucleon for $A \leq 4$ nuclei can be understood if they form closed string like structures, nuclear strings, so that only two color bonds per nucleon are possible. This could be understood if ordinary quarks and exotic quarks possessing much smaller mass behave as if they were identical fermions. p-Adic mass calculations support this assumption. Also the average behavior of binding energy for heavier nuclei is predicted correctly.

2. For nuclei with $P = N$ all color bonds can be pion type bonds and have thus largest color magnetic spin-spin interaction energy. The increase of color Coulombic binding energy between colored exotic quark pairs and dark gluons however favors $N > P$ and explains also the formation of neutron halo outside $k = 111$ space-time sheet.

3. Spin-orbit interaction provides the standard explanation for magic numbers. If the maximum of the binding energy per nucleon is taken as a criterion for magic, also Z=N=4,6,12 are magic. The alternative TGD based explanation for magic numbers $Z = N = 4, 6, 8, 12, 20$ would be in terms of regular Platonic solids. Experimentally also other magic numbers are known for neutrons. The linking of nuclear strings provides a possible mechanism producing new magic nuclei from lighter magic nuclei.

*4. Stringy description of nuclear reactions*

The view about nucleus as a collection of linked nuclear strings suggests stringy description of nuclear reactions. Microscopically the nuclear reactions would correspond to re-distribution of exotic quarks between the nucleons in reacting nuclei.

*5. Anomalies and new nuclear physics*

The TGD based explanation of neutron halo has been already mentioned. The recently observed tetra-neutron states are difficult to understand in the standard nuclear physics framework since Fermi statistics does not allow this kind of state. The identification of tetra-neutron as an alpha particle containing two negatively charged color bonds allows to circumvent the problem. A large variety of exotic nuclei containing charged color bonds is predicted.

The proposed model explains the anomaly associated with the tritium beta decay. What has been observed is that the spectrum intensity of electrons has a narrow bump near the endpoint energy. Also the maximum energy $E_0$ of electrons is shifted downwards. I have considered two explanations for the anomaly. The original models are based on TGD variants of original models involving belt of dark neutrinos or antineutrinos along the orbit of Earth. Only recently (towards the end of year 2008) I realized that nuclear string model provides much more elegant explanation of the anomaly and has also the potential to explain much more general anomalies.

Cold fusion has not been taken seriously by the physics community but the situation has begun to change gradually. There is an increasing evidence for the occurrence of nuclear transmutations of heavier elements besides the production of $^4He$ and $^3H$ whereas the production rate of $^3He$ and neutrons is very low. These characteristics are not consistent with the standard nuclear physics predictions. Also Coulomb wall and the absence of gamma rays and the lack of a mechanism transferring nuclear energy to the electrolyte have been used as an argument against cold fusion. TGD based model relying on the notion of charged color bonds explains the anomalous characteristics of cold fusion.

#### 5.2.4 Nuclear String Hypothesis

Nuclear string hypothesis is one of the most dramatic almost-predictions of TGD. The hypothesis in its original form assumes that nucleons inside nucleus form closed nuclear strings with neighboring nuclei of the string connected by exotic meson bonds consisting of color magnetic flux tube with quark and anti-quark at its ends. The lengths of flux tubes correspond to the p-adic length scale of electron and therefore the mass scale of the exotic mesons is around 1 MeV in accordance with the general scale of nuclear binding energies. The long lengths of em flux tubes increase the distance between nucleons and reduce Coulomb repulsion. A fractally scaled up variant of ordinary QCD with respect to p-adic length scale would be in question and the usual wisdom about ordinary pions and other mesons as the origin of nuclear force would be simply wrong in TGD framework as the large mass scale of ordinary pion indeed suggests.

*1. $A > 4$ nuclei as nuclear strings consisting of $A \leq 4$ nuclei*

In this article a more refined version of nuclear string hypothesis is developed.

1. It is assumed $^4He$ nuclei and $A < 4$ nuclei and possibly also nucleons appear as basic building blocks of nuclear strings. $A \leq 4$ nuclei in turn can be regarded as strings of nucleons. Large number of stable lightest isotopes of form $A = 4n$ supports the hypothesis that the number of $^4He$ nuclei is maximal. Even the weak decay characteristics might be reduced to those for $A < 4$ nuclei using this hypothesis.
2. One can understand the behavior of nuclear binding energies surprisingly well from the assumptions that total *strong* binding energy associated with $A \leq 4$ building blocks is *additive* for nuclear strings.
3. In TGD framework tetra-neutron is interpreted as a variant of alpha particle obtained by replacing two meson-like stringy bonds connecting neighboring nucleons of the nuclear string with their negatively charged variants. For heavier nuclei tetra-neutron is needed as an additional building brick.

*2. Bose-Einstein condensation of color bonds as a mechanism of nuclear binding*

The attempt to understand the variation of the nuclear binding energy and its maximum for $Fe$ leads to a quantitative model of nuclei lighter than $Fe$ as color bound Bose-Einstein condensates of pion like colored states associated with color flux tubes connecting $^4He$ nuclei. The color contribution to the total binding energy is proportional to $n^2$, where $n$ is the number of color bonds. Fermi statistics explains the reduction of $E_B$ for the nuclei heavier than $Fe$. Detailed estimate favors harmonic oscillator model over free nucleon model with oscillator strength having interpretation in terms of string tension.

Fractal scaling argument allows to understand $^4He$ and lighter nuclei as strings of nucleons with nucleons bound together by color bonds. Three fractally scaled variants of QCD corresponding $A > 4$ , $A = 4$, and $A < 4$ nuclei are involved. The binding energies of also $A \leq 4$ are predicted surprisingly accurately by applying simple p-adic scaling to the model of binding energies of heavier nuclei.

*3. Giant dipole resonance as de-coherence of Bose-Einstein condensate of color bonds*

Giant resonances and so called pygmy resonances are interpreted in terms of de-coherence of the Bose-Einstein condensates associated with $A \leq 4$ nuclei and with the nuclear string formed from $A \leq 4$ nuclei. The splitting of the Bose-Einstein condensate to pieces costs a precisely defined energy. For $^4He$ de-coherence the model predicts singlet line at 12.74 MeV and triplet at $\sim 27$ MeV spanning 4 MeV wide range.

The de-coherence at the level of nuclear string predicts 1 MeV wide bands 1.4 MeV above the basic lines. Bands decompose to lines with precisely predicted energies. Also these contribute to the width. The predictions are in rather good agreement with experimental values. The so called pygmy resonance appearing in neutron rich nuclei can be understood as a de-coherence for $A = 3$ nuclei. A doublet at $\sim 8$ MeV and MeV spacing is predicted. The prediction for the position is correct.

*4. Dark nuclear strings as analogs of as analogs of DNA-, RNA- and amino-acid sequences and baryonic realization of genetic code*

A speculative picture proposing a connection between homeopathy, water memory, and phantom DNA effect is discussed and on basis of this connection a vision about how the tqc hardware represented by the genome is actively developed by subjecting it to evolutionary pressures represented by a virtual world representation of the physical environment. The speculation inspired by this vision is that genetic code as well as DNA-, RNA- and amino-acid sequences should have representation in terms of nuclear strings. The model for dark baryons indeed leads to an identification of these analogs and the basic numbers of genetic code including also the numbers of aminoacids coded by a given number of codons are predicted correctly. Hence it seems that genetic code is universal rather than being an accidental outcome of the biological evolution.

### 5.2.5 Dark Nuclear Physics and Condensed Matter

The unavoidable presence of classical long ranged weak (and also color) gauge fields in TGD Universe has been a continual source of worries for more than two decades. The basic question has been whether $Z^0$ charges of elementary particles are screened in electro-weak length scale or not. For a long time the hypothesis was that the charges are feeded to larger space-time sheets in this length scale rather than screened by vacuum charges so that an effective screening results in electro-weak length scale.

A more promising approach inspired by the TGD based view about dark matter assumes that weak charges are indeed screened for ordinary matter in electro-weak length scale but that dark electro-weak bosons correspond to much longer symmetry breaking length scale.

*1. What darkness means?*

It is not at all obvious what darkness means and one can consider two variants.

1. The weak form of darkness states that only some field bodies of the particle consisting of flux quanta mediating bound state interactions between particles become dark. One can assign to each interaction a field body (em, $Z^0$, $W$, gluonic, gravitational) and p-adic prime and the value of Planck constant characterize the size of the particular field body. One might even think that particle mass can be assigned with its em field body and that Compton length of particle corresponds to the size scale of em field body.

2. The strong form of the hypothesis states that particle space-time sheet is distinguishable from em field body and can become dark. The space-time sheet of the particle would be associated

with the covering $H = M^4 \times CP_2 \to H/G_a \times G_b$, where $G_a$ and $G_b$ are subgroups of $SU(2)$ characterizing Jones inclusions, and would be analogous to a many-sheeted Riemann surface. The large value of $\hbar$ in dark matter phase would mean that Compton lengths and -times are scaled up. A model of dark atom based on this view about darkness leads to the notion of $N$-atom (each sheet of the multiple covering can carry electron so that Fermi statistics apparently fails).

Nuclear string model suggests that the sizes of color flux tubes and weak flux quanta associated with nuclei can become dark in this sense and have size of order atomic radius so that dark nuclear physics would have a direct relevance for condensed matter physics. If this happens, it becomes impossible to make a reductionistic separation between nuclear physics and condensed matter physics and chemistry anymore.

*2. What dark nucleons are?*

The basic hypothesis is that nuclei can make a phase transition to dark phase in which the size of both quarks and nuclei is measured in Angstroms. For the less radical option this transition could happen only for the color, weak, and em field bodies. Proton connected by dark color bonds super-nuclei with inter-nucleon distance of order atomic radius might be crucial for understanding the properties of water and perhaps even the properties of ordinary condensed matter. Large $\hbar$ phase for weak field body of $D$ and $Pd$ nuclei with size scale of atom would explain selection rules of cold fusion.

*3. Anomalous properties of water and dark nuclear physics*

A direct support for partial darkness of water comes from the $H_{1.5}O$ chemical formula supported by neutron and electron diffraction in attosecond time scale. The explanation would be that one fourth of protons combine to form super-nuclei with protons connected by color bonds and having distance sufficiently larger than atomic radius.

The crucial property of water is the presence of molecular clusters. Tedrahedral clusters allow an interpretation in terms of magic Z=8 protonic dark nuclei. The icosahedral clusters consisting of 20 tedrahedral clusters in turn have interpretation as magic dark dark nuclei: the presence of the dark dark matter explains large portion of the anomalies associated with water and explains the unique role of water in biology. In living matter also higher levels of dark matter hierarchy are predicted to be present. The observed nuclear transmutation suggest that also light weak bosons are present.

*4. Implications of the partial darkness of condensed matter*

The model for partially dark condensed matter inspired by nuclear string model and the model of cold fusion inspired by it allows to understand the low compressibility of the condensed matter as being due to the repulsive weak force between exotic quarks, explains large parity breaking effects in living matter, and suggests a profound modification of the notion of chemical bond having most important implications for bio-chemistry and understanding of bio-chemical evolution.

### 5.2.6 Super-Conductivity in Many-Sheeted Space-Time

In this chapter a model for high $T_c$ super-conductivity as quantum critical phenomenon is developed.

*1. Quantum criticality, hierarchy of dark matters, and dynamical $\hbar$*

Quantum criticality is the basic characteristic of TGD Universe and quantum critical superconductors provide an excellent test bed to develop the ideas related to quantum criticality into a more concrete form.

The hypothesis that Planck constants in $M^4$ and $CP_2$ degrees of freedom are dynamical possessing quantized spectrum given as integer multiples of minimum value of Planck constant adds further content to the notion of quantum criticality. Number theoretic considerations favor the hypothesis that the integers corresponding to Fermat polygons constructible using only ruler and compass and given as products $n_F = 2^k \prod_s F_s$, where $F_s = 2^{2^s} + 1$ are distinct Fermat primes, are favored. The reason would be that quantum phase $q = exp(i\pi/n)$ is in this case expressible using only iterated square root operation by starting from rationals. The known Fermat primes correspond to $s = 0, 1, 2, 3, 4$ so that the hypothesis is very strong and predicts that p-adic length scales have satellite length scales given as multiples of $n_F$ of fundamental p-adic length scale. $n_F = 2^{11}$ corresponds in TGD framework to a fundamental constant expressible as a combination of Kähler coupling strength, $CP_2$ radius and Planck length appearing in the expression for the tension of cosmic strings, and seems to be especially favored in living matter.

Phases with different values of $M^4$ and $CP_2$ Planck constants behave like dark matter with respect to each other in the sense that they do not have direct interactions except at criticality corresponding to a leakage between different sectors of imbedding space glued together along $M^4$ or $CP_2$ factors. In large $\hbar(M^4)$ phases various quantum time and length scales are scaled up which means macroscopic and macro-temporal quantum coherence.

The only coupling constant strength of theory is Kähler coupling constant $g_K^2$ which appears in the definition of the Kähler function $K$ characterizing the geometry of the configuration space of 3-surfaces (the "world of classical worlds"). The exponent of $K$ defines vacuum functional analogous to the exponent of Hamiltonian in thermodynamics. The allowed value(s) of $g_K^2$, which is (are) analogous to critical temperature(s), is (are) determined by quantum criticality requirement. Contrary to the original hypothesis inspired by the requirement that gravitational coupling is renormalization group invariant, $\alpha_K$ does not seem to depend on p-adic prime whereas gravitational constant is proportional to $L_p^2$. The situation is saved by the assumption that gravitons correspond to the largest non-super-astrophysical Mersenne prime $M_{127}$ so that gravitational coupling is effectively RG invariant in p-adic coupling constant evolution.

$\hbar(M^4)$ and $\hbar(CP_2)$ appear in the commutation and anticommutation relations of various superconformal algebras. Only the ratio of $M^4$ and $CP_2$ Planck constants appears in Kähler action and is due to the fact that the $M^4$ and $CP_2$ metrics of the imbedding space sector with given values of Planck constants are proportional to the corresponding Planck constants. This implies that Kähler function codes for radiative corrections to the classical action, which makes possible to consider the possibility that higher order radiative corrections to functional integral vanish as one might expect at quantum criticality. For a given p-adic length scale space-time sheets with all allowed values of Planck constants are possible. Hence the spectrum of quantum critical fluctuations could in the ideal case correspond to the spectrum of $\hbar$ coding for the scaled up values of Compton lengths and other quantal lengths and times. If so, large $\hbar$ phases could be crucial for understanding of quantum critical superconductors, in particular high $T_c$ superconductors.

A further great idea is that the transition to large $\hbar$ phase occurs when perturbation theory based on the expansion in terms of gauge coupling constant ceases to converge: Mother Nature would take care of the problems of theoretician. The transition to large $\hbar$ phase obviously reduces gauge coupling strength $\alpha$ so that higher orders in perturbation theory are reduced whereas the lowest order "classical" predictions remain unchanged. A possible quantitative formulation of the criterion is that maximal 2-particle gauge interaction strength parameterized as $Q_1Q_2\alpha$ satisfies the condition $Q_1Q_2\alpha \simeq 1$.

TGD actually predicts an infinite hierarchy of phases behaving like dark or partially dark matter with respect to the ordinary matter and the value of $\hbar$ is only one characterizer of these phases. These phases, especially so large $\hbar$ phase, seem to be essential for the understanding of even ordinary hadronic, nuclear and condensed matter physics. This strengthens the motivations for finding whether dark matter might be involved with quantum critical super-conductivity.

Cusp catastrophe serves as a metaphor for criticality. In the recent case temperature and doping are control variables and the tip of cusp is at maximum value of $T_c$. Critical region correspond to the cusp catastrophe. Quantum criticality suggests the generalization of the cusp to a fractal cusp. Inside the critical lines of cusp there are further cusps which corresponds to higher levels in the hierarchy of dark matters labelled by increasing values of $\hbar$ and they correspond to a hierarchy of subtle quantum coherent dark matter phases in increasing length scales. The proposed model for high $T_c$ super-conductivity involves only single value of Planck constant but it might be that the full description involves very many values of them.

*2. Many-sheeted space-time concept and ideas about macroscopic quantum phases*

Many-sheeted space-time leads to obvious ideas concerning the realization of macroscopic quantum phases.

1. The dropping of particles to larger space-time sheets is a highly attractive mechanism of super-conductivity. If space-time sheets are thermally isolated, the larger space-time sheets could be at extremely low temperature and super-conducting.

2. The possibility of large $\hbar$ phases allows to give up the assumption that space-time sheets characterized by different p-adic length scales are thermally isolated. The scaled up versions of a given space-time sheet corresponding to a hierarchy of values of $\hbar$ are possible such that the scale of kinetic energy and magnetic interaction energy remain same for all these space-time sheets. For instance, for scaled up variants of space-time sheet having size scale characterized by $L(151) = 10$ nm (cell membrane thickness) the critical temperature for superconductivity could be higher than room temperature.

3. The existence of wormhole contacts have been one of the most exotic predictions of TGD. The realization that wormhole contacts can be regarded as parton-antiparton pairs with parton and antiparton assignable to the light-like causal horizons accompanying wormhole contacts, and that Higgs particle corresponds to wormhole contact, opens the doors for more concrete models of also super-conductivity involving massivation of photons.

   The formation of a coherent state of wormhole contacts would be the counterpart for the vacuum expectation value of Higgs. The notions of coherent states of Cooper pairs and of charged Higgs challenge the conservation of electromagnetic charge. The following argument however suggests that coherent states of wormhole contacts form only a part of the description of ordinary super-conductivity. The basic observation is that wormhole contacts with vanishing fermion number define space-time correlates for Higgs type particle with fermion and antifermion numbers at light-like throats of the contact.

   The ideas that a genuine Higgs type photon massivation is involved with super-conductivity and that coherent states of Cooper pairs really make sense are somewhat questionable since the conservation of charge and fermion number is lost. A further questionable feature is that a quantum superposition of many-particle states with widely different masses would be in question. The interpretational problems could be resolved elegantly in zero energy ontology in which the total conserved quantum numbers of quantum state are vanishing. In this picture the energy, fermion number, and total charge of any positive energy state are compensated by opposite quantum numbers of the negative energy state in geometric future. This makes possible to speak about superpositions of Cooper pairs and charged Higgs bosons separately in positive energy sector.

   Rather remarkably, if this picture is taken seriously, super-conductivity can be seen as providing a direct support for both the hierarchy of scaled variants of standard model physics and for the zero energy ontology.

4. Quantum classical correspondence has turned out be a very powerful idea generator. For instance, one can ask what are the space-time correlates for various notions of condensed matter such as phonons, BCS Cooper pairs, holes, etc... For instance, TGD predicts the existence of negative energy space-time sheets so that ordinary particles can and must exist in negative energy states (in cosmological scales the density of inertial energy is predicted to vanish. The question is whether holes could have quite concrete representation as negative energy space-time sheets carrying negative energy particles and whether the notion of Cooper pair of holes could have this kind of space-time correlate.

*3. Model for high $T_c$ superconductivity*

The model for high $T_c$ super-conductivity relies on the notions of quantum criticality, dynamical Planck constant, and many-sheeted space-time.

These ideas lead to a concrete model for high $\mathrm{T}_c$ superconductors as quantum critical superconductors allowing to understand the characteristic spectral lines as characteristics of interior and boundary Cooper pairs bound together by phonon and color interaction respectively. The model for quantum critical electronic Cooper pairs generalizes to Cooper pairs of fermionic ions and for sufficiently large $\hbar$ stability criteria, in particular thermal stability conditions, can be satisfied in a given length scale. Also high $T_c$ superfluidity based on dropping of bosonic atoms to Cooper pair space-time sheets where they form Bose-Einstein condensate is possible.

At qualitative level the model explains various strange features of high $T_c$ superconductors. One can understand the high value of $T_c$ and ambivalent character of high $T_c$ super conductors suggesting both BCS type Cooper pairs and exotic Cooper pairs with non-vanishing spin, the existence of pseudogap and scalings laws for observables above $T_c$, the role of stripes and doping and the existence of a critical doping, etc... An unexpected prediction is that coherence length is actually $\hbar/\hbar_0 = 2^{11}$ times longer than the coherence length predicted by conventional theory so that type I super-conductor would be in question with stripes serving as duals for the defects of type I super-conductor in nearly critical magnetic field replaced now by ferromagnetic phase.

At quantitative level the model predicts correctly the four poorly understood photon absorption lines and the critical doping ratio from basic principles. The current carrying structures have structure locally similar to that of axon including the double layered structure of cell membrane and also the size scales are predicted to be same so that the idea that axons are high $T_c$ superconductors is highly suggestive.

### 5.2.7 Quantum Hall effect and Hierarchy of Planck Constants

I have already earlier proposed the explanation of FQHE, anyons, and fractionization of quantum numbers in terms of hierarchy of Planck constants realized as a generalization of the imbedding space $H = M^4 \times CP_2$ to a book like structure. The book like structure applies separately to $CP_2$ and to causal diamonds ($CD \subset M^4$) defined as intersections of future and past directed light-cones. The pages of the Big Book correspond to singular coverings and factor spaces of $CD$ ($CP_2$) glued along 2-D subspace of $CD$ ($CP_2$) and are labeled by the values of Planck constants assignable to $CD$ and $CP_2$ and appearing in Lie algebra commutation relations. The observed Planck constant $\hbar$, whose square defines the scale of $M^4$ metric corresponds to the ratio of these Planck constants. The key observation is that fractional filling factor results if $\hbar$ is scaled up by a rational number.

In this chapter I try to formulate more precisely this idea. The outcome is a rather detailed view about anyons on one hand, and about the Kähler structure of the generalized imbedding space on the other hand.

1. Fundamental role is played by the assumption that the Kähler gauge potential of $CP_2$ contains a gauge part with no physical implications in the context of gauge theories but contributing to physics in TGD framework since $U(1)$ gauge transformations are representations

of symplectic transformations of $CP_2$. Also in the case of $CD$ it makes also sense to speak about Kähler gauge potential. The gauge part codes for Planck constants of $CD$ and $CP_2$ and leads to the identification of anyons as states associated with partonic 2-surfaces surrounding the tip of $CD$ and fractionization of quantum numbers. Explicit formulas relating fractionized charges to the coefficients characterizing the gauge parts of Kähler gauge potentials of $CD$ and $CP_2$ are proposed based on some empirical input.

2. One important implication is that Poincare and Lorentz invariance are broken inside given $CD$ although they remain exact symmetries at the level of the geometry of world of classical worlds (WCW). The interpretation is as a breaking of symmetries forced by the selection of quantization axis.

3. Anyons would basically correspond to matter at 2-dimensional "partonic" surfaces of macroscopic size surrounding the tip of the light-cone boundary of $CD$ and could be regarded as gigantic elementary particle states with very large quantum numbers and by charge fractionization confined around the tip of $CD$. Charge fractionization and anyons would be basic characteristic of dark matter (dark only in relative sense). Hence it is not surprising that anyons would have applications going far beyond condensed matter physics. Anyonic dark matter concentrated at 2-dimensional surfaces would play key key role in the the physics of stars and black holes, and also in the formation of planetary system via the condensation of the ordinary matter around dark matter. This assumption was the basic starting point leading to the discovery of the hierarchy of Planck constants. In living matter membrane like structures would represent a key example of anyonic systems as the model of DNA as topological quantum computer indeed assumes.

4. One of the basic questions has been whether TGD forces the hierarchy of Planck constants realized in terms of generalized imbedding space or not. The condition that the choice of quantization axes has a geometric correlate at the imbedding space level motivated by quantum classical correspondence of course forces the hierarchy: this has been clear from the beginning. It is now clear that first principle description of anyons requires the hierarchy in TGD Universe. The hierarchy reveals also new light to the huge vacuum degeneracy of TGD and reduces it dramatically at pages for which $CD$ corresponds to a non-trivial covering or factor space, which suggests that mathematical existence of the theory necessitates the hierarchy of Planck constants. Also the proposed manifestation of Equivalence Principle at the level of symplectic fusion algebras as a duality between descriptions relying on the symplectic structures of $CD$ and $CP_2$ forces the hierarchy of Planck constants.

# References

## Online books about TGD


[1] M. Pitkänen (2006), *Topological Geometrodynamics: Overview.* http://www.helsinki.fi/~matpitka/tgdview/tgdview.html.

[2] M. Pitkänen (2006), *Quantum Physics as Infinite-Dimensional Geometry.* http://www.helsinki.fi/~matpitka/tgdgeom/tgdgeom.html.

[3] M. Pitkänen (2006), *Physics in Many-Sheeted Space-Time.* http://www.helsinki.fi/~matpitka/tgdclass/tgdclass.html.

[4] M. Pitkänen (2006), *Quantum TGD.* http://www.helsinki.fi/~matpitka/tgdquant/tgdquant.html.

[5] M. Pitkänen (2006), *TGD as a Generalized Number Theory.*
http://www.helsinki.fi/~matpitka/tgdnumber/tgdnumber.html.

[6] M. Pitkänen (2006), *p-Adic length Scale Hypothesis and Dark Matter Hierarchy.*
http://www.helsinki.fi/~matpitka/paddark/paddark.html.

[7] M. Pitkänen (2006), *TGD and Fringe Physics.*
http://www.helsinki.fi/~matpitka/freenergy/freenergy.html.

## Online books about TGD inspired theory of consciousness and quantum biology

[8] M. Pitkänen (2006), *Bio-Systems as Self-Organizing Quantum Systems.*
http://www.helsinki.fi/~matpitka/bioselforg/bioselforg.html.

[9] M. Pitkänen (2006), *Quantum Hardware of Living Matter.*
http://www.helsinki.fi/~matpitka/bioware/bioware.html.

[10] M. Pitkänen (2006), *TGD Inspired Theory of Consciousness.*
http://www.helsinki.fi/~matpitka/tgdconsc/tgdconsc.html.

[11] M. Pitkänen (2006), *Mathematical Aspects of Consciousness Theory.*
http://www.helsinki.fi/~matpitka/genememe/genememe.html.

[12] M. Pitkänen (2006), *TGD and EEG.*
http://www.helsinki.fi/~matpitka/tgdeeg/tgdeeg/tgdeeg.html.

[13] M. Pitkänen (2006), *Bio-Systems as Conscious Holograms.*
http://www.helsinki.fi/~matpitka/hologram/hologram.html.

[14] M. Pitkänen (2006), *Magnetospheric Consciousness.*
http://www.helsinki.fi/~matpitka/magnconsc/magnconsc.html.

[15] M. Pitkänen (2006), *Mathematical Aspects of Consciousness Theory.*
http://www.helsinki.fi/~matpitka/magnconsc/mathconsc.html.

## References to the chapters of books

[B3] The chapter *Construction of Configuration Space Kähler Geometry from Symmetry Principles: Part II* of [2].
http://www.helsinki.fi/~matpitka/tgdgeom/tgdgeom.html#compl2.

[B4] The chapter *Configuration Space Spinor Structure* of [2].
http://www.helsinki.fi/~matpitka/tgdgeom/tgdgeom.html#cspin.

[C1] The chapter *Construction of Quantum Theory: Symmetries* of [4].
http://www.helsinki.fi/~matpitka/tgdquant/tgdquant.html#quthe.

[C6] The chapter *Was von Neumann Right After All* of [4].
http://www.helsinki.fi/~matpitka/tgdquant/tgdquant.html#vNeumann.

[D6] The chapter *TGD and Astrophysics* of [3].
http://www.helsinki.fi/∼matpitka/tgdclass/tgdclass.html#astro.

[E1] The chapter *TGD as a Generalized Number Theory: p-Adicization Program* of [5].
http://www.helsinki.fi/∼matpitka/tgdnumber/tgdnumber.html#visiona.

[E2] The chapter *TGD as a Generalized Number Theory: Quaternions, Octonions, and their Hyper Counterparts* of [5].
http://www.helsinki.fi/∼matpitka/tgdnumber/tgdnumber.html#visionb.

[E3] The chapter *TGD as a Generalized Number Theory: Infinite Primes* of [5].
http://www.helsinki.fi/∼matpitka/tgdnumber/tgdnumber.html#visionc.

[E5] The chapter *p-Adic Physics: Physical Ideas* of [5].
http://www.helsinki.fi/∼matpitka/tgdnumber/tgdnumber.html#phblocks.

[E6] The chapter *Fusion of p-Adic and Real Variants of Quantum TGD to a More General Theory* of [5].
http://www.helsinki.fi/∼matpitka/tgdnumber/tgdnumber.html#mblocks.

[E8] The chapter *Riemann Hypothesis and Physics* of [5].
http://www.helsinki.fi/∼matpitka/tgdnumber/tgdnumber.html#riema.

[E9] The chapter *Topological Quantum Computation in TGD Universe* of [5].
http://www.helsinki.fi/∼matpitka/tgdnumber/tgdnumber.html#tqc.

[I1] The chapter *Quantum Theory of Self-Organization* of [8].
http://www.helsinki.fi/∼matpitka/bioselforg/bioselforg.html#selforgac.

[J6] The chapter *Coherent Dark Matter and Bio-Systems as Macroscopic Quantum Systems* of [9].
http://www.helsinki.fi/∼matpitka/bioware/bioware.html#darkbio.

[L1] The chapter *Genes and Memes* of [11].
http://www.helsinki.fi/∼matpitka/genememe/genememe.html#genememec.

[L2] The chapter *Many-Sheeted DNA* of [11].
http://www.helsinki.fi/∼matpitka/genememe/genememe.html#genecodec.

[M3] The chapter *Dark Matter Hierarchy and Hierarchy of EEGs* of [12].
http://www.helsinki.fi/∼matpitka/tgdeeg/tgdeeg/tgdeeg.html#eegdark.

## Articles related to TGD

[16] Pitkänen, M. (1983) International Journal of Theor. Phys. ,22, 575.

## Mathematics related references

[17] Eguchi, T., Gilkey, B., Hanson, J. (1980): Phys. Rep. 66, 6.

[18] Hawking, S.,W. and Pope, C., N. (1978): *Generalized Spin Structures in Quantum Gravity.* Physics Letters Vol 73 B, no 1.

[19] Gibbons, G., W., Pope, C., N. (1977): *$CP_2$ as gravitational instanton.* Commun. Math. Phys. 55, 53.

[20] Pope, C., N. (1980): *Eigenfunctions and $Spin^c$ Structures on $CP_2$* D.A.M.T.P. preprint.

[21] Eisenhart (1964): *Riemannian Geometry.* Princeton University Press.

[22] Spivak, M. (1970): *Differential Geometry I,II,III,IV.* Publish or Perish. Boston.

[23] Milnor, J. (1965): *Topology from Differential Point of View.* The University Press of Virginia.

[24] Thom, R. (1954): Commentarii Math. Helvet., 28, 17.

[25] Wallace (1968): *Differential Topology.* W. A. Benjamin, New York.

[26] Freed, D., S. (1985): *The Geometry of Loop Groups* (Thesis). Berkeley: University of California.

[27] Helgason, S. (1962): *Differential Geometry and Symmetric Spaces.* Academic Press, New York.

[28] Mickelson, J. (1989): *Current Algebras and Groups.* Plenum Press, New York.

[29] Jackiw, R. (1983): in *Gauge Theories of Eighties*, Conference Proceedings, Äkäslompolo, Finland (1982) Lecture Notes in Physics, Springer Verlag.

[30] Manes, J., L. (1986): *Anomalies in Quantum Field Theory and Differential Geometry* Ph.D. Thesis LBL-22304.

[31] Faddeev, L., D. (1984): *Operator Anomaly for Gauss Law.* Phys. Lett. Vol 145 B, no 1, 2.

[32] J. Esmonde and M. Ram Murty (1991), *Problems in Algebraic Number Theory*, Springer-Verlag, New York.

[33] A. Robinson (1974), *Non-standard Analysis*, North-Holland, Amsterdam.

## Physics related references

[34] H. Mueller, *Global Scaling*,
http://www.dr-nawrocki.de/globalscalingengl2.html .

[35] D. Da Roacha and L. Nottale (2003), *Gravitational Structure Formation in Scale Relativity*, astro-ph/0310036.