Topological Geometrodynamics: Applications

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Abstract

Some applications of Topological Geometrodynamics (TGD) are reviewed. The new view about spacetime implies new physics in all length scales and p-adic length scale hypothesis makes it possible to make quantitative predictions. Two representative examples are microscopic mechanism of particle massivation allowing to predict elementary particle masses with a surprising accuracy and fractal cosmology resolving the difficulties of the inflationary cosmology. Perhaps the most fascinating applications can be found biology where many-sheeted spacetime concept allows to understand how biosystems manage to be macroscopic quantum systems and explains also phenomena like chiral selection. TGD inspired quantum measurement theory can be regarded also as quantum theory of consciousness and leads to visions about consciousness as a universal phenomenon as well as a concrete model for brain consciousness. The interpretation of the p-adic spacetime regions as cognitive representations leads to a general theory of cognition. TGD encourages to view physics as a number theory in a very general sense and a sharpening of the Riemann hypothesis and detailed strategies for its proof emerge as an outcome of this philosophy.

Contents

1 Introduction

The notion of many-sheeted spacetime has nontrivial implications in all length scales and p-adic length scale hypothesis allows to quantify these implications. For instance, p-adic thermodynamics provides microscopic model for particle massivation predicting elementary particle masses with surprising accuracy and also new branches of physics. Exotic representations of the p-adic Super algebra in turn suggest completely new approach to the nonperturbative aspects of hadron physics.

Especially interesting are the implications of new spacetime picture in biological length scales. For instance, quantum criticality predicts the existence of macroscopic quantum systems in all length scales. This motivated the systematic development of TGD inspired theory of consciousness [15] (for about six years ago). This work has led to dramatic increase of understanding also at the level of basic quantum TGD and allowed to develop quantum measurement theory in which conscious observer is not anymore Cartesian outsider but an essential part of quantum physics. The need to understand the mechanism making biosystems macroscopic quantum systems has led to a dramatic progress in the understanding of the new physics implied by the notion of the many-sheeted spacetime. A profound change in views about the relation between the subjectively experienced time and the geometric time of physicist emerges, and leads to the solution of the basic paradoxes of the quantum physics. It became also clear that p-adic numbers are indeed an absolutely essential element of the mathematical formulation of quantum TGD proper, and that the general properties of quantum TGD force the introduction of the p-adic numbers. One can say that physics involves both real and p-adic number fields with real numbers describing the topology of the real world and various p-adic number fields describing the topology of conscious perception with the prime p labelling the p-adic topology serving as kind of intelligence quotient.

There are also deep connections with number theory. Quantum TGD inspired originally a sharpening and p-adicization of the Riemann hypothesis, provides two different strategies for its proof, and suggests that the superconformally invariant quantum critical system behind Rieman Zeta provides a toy model for quantum TGD. p-Adic length scale hypothesis at the level of the entire Universe forces the notion of infinite primes, the construction of which can be regarded as a repeated second quantization of an arithmetic quantum field theory. This in turn implies a generalization of the concepts of integer and real number (Ch. "Quaternions, Octonions and Infinite Primes" of [14]). The possibility to represent quaternionic infinite primes at the n:th level of the hierarchy as $4n$-dimensional surfaces in $8n$-dimensional imbedding space led in turn to the formulation of quantum TGD as a generalized number theory.

In this article various physical applications of the many-sheeted spacetime concept ranging from elementary particle mass calculations to cosmology are reviewed. Also the basic ideas of TGD inspired theory of consciousness and the

TGD based ideas related to the Riemann hypothesis are briefly summarized.

2 Many-sheeted spacetime concept

All spacetimes in the final state of quantum jump have same values of zero modes and are thus macrocopically equivalent so that the notion of macrosopic spacetime makes sense as a precise concept in TGD. The TGD based spacetime concept means a radical generalization of standard views already in the real context. Many-sheetedness means a hierarchy of spacetime sheets of increasing size making possible to understand the emergence of structures in terms of the macroscopic spacetime topology.

The classical non-determinism of the Kähler action forces the notion of the *association sequence* defined as a union of spacelike 3-surfaces with timelike separations. In fact, without the classical non-determinism Quantum TGD would by general coordinate invariance reduce to a theory defined in the space of 3-surfaces in $\delta M^4_+ \times CP_2$ and time would be totally lost as it is lost in the canonical quantization of General Relativity. A possible identification for the selection between branches of the multifurcation of the spacetime surface is as the the geometric counterpart of volition (Ch. "Matter, Mind, Quantum" of [15]) Topological field quantization means that spacetime topology provides classical correlates for the basic notions of the quantum field theory. p-Adicization gives a quantitative content for the idea about topological condensate as a many-sheeted spacetime surface.

One must distinguish between classical non-determinism and p-adic non-determinism characterizing all p-adic field equations and providing an excellent candidate for the geometric correlate of imagination. p-Adic non-determinism forces also the notion of *cognitive spacetime sheet* identified as a p-adic spacetime sheet having finite temporal duration, which is an attractive candidate for the geometric correlate of 'self' defined as a subsystem able to stay p-adically unentangled (Ch. "Matter, Mind, Quantum" of [15]).

Second general implication of the many-sheetedness is the possibility of *macroscopic quantum phases* (Chs. "Biological Realization of Self-Hierarchy", "Biosystems as Superconductors" of [15]). Many-sheeted spacetime concept provides a very general mechanism of superconductivity based on the 'dropping' of charged particles from atomic spacetime sheets to larger spacetime sheets. At larger spacetime sheets the temperature is expected to be much lower than on the atomic spacetime sheets so that the necessary conditions for the formation of high T_c macroscopic quantum phases are met. At larger spacetime sheet the interactions of the charged particles with the classical em fields generated by various wormholes with size of order CP_2 size feeding gauge fluxes to and from the spacetime sheet in question could give rise to the necessary gap energy.

This mechanism is fundamental in TGD inspired theory of brain consciousness (Ch. "Matter, Mind, Quantum" of [15]). It has been found already at sixties [3] that ELF em fields at EEG frequencies have anomalous effects on brain tissue at certain frequency and amplitude windows. Frequency windows correspond to multiples of cyclotron frequencies of biologically important ions in Earth's magnetic field and there are selection rules suggesting very strongly that magnetic quantum transitions are involved. The extremely low energy scale of order 10^{-14} eV implies that the temperature is below 10^{-10} Kelvin. Also the size of these quantum states is of order cell size so that there is no hope to understand these effects as quantum effects in standard physics. TGD however provides a beautiful explanation of the observations in terms of the quantum transitions of ions or their Cooper pairs in one-dimensional superconductors in Earth's magnetic field (Chs "Biological Realization of Self-Hierarchy" and "Quantum Model of EEG and Nervepulse" of [15]).

Many-sheetedness suggests new *gravitational effects*. For instance, system feeds its gravitational flux to several parallel spacetime sheets and it might be possible to change this distribution. This would affect the gravitational mass of the system at the sheets where external gravitational force is strongest. For instance, antigravity machines could be based on this phenomenon (Ch. "Anomalies Explainable by TGD Based Spacetime Concept" of [14]). These effects might also explain the relatively large variation in the measured value of Newton's constant [11].

1. Topological field quantization

Topological field quantization (Ch. "Macroscopic Quantum Phenomena and CP_2 Geometry" of [13]) implies that various notions of quantum field theory have rather precise classical analogies. Topological field quantization provides the correspondence between the abstract Fock space description of elementary particles and the description of the elementary particles as concrete geometric objects detected in the laboratory. In standard quantum field theory this kind of correspondence is lacking since classical fields are regarded as a phenomenological concept only. Topological field quanta define regions of coherence for the classical fields and classical coherence is the prequisite of the quantum coherence. The loss of coherence can be regarded as decomposition of a spacetime sheet representing superposition of classical fields to separate spacetime sheets carrying the component fields separately. Thus one can say that spacetime surfaces perform topological Fourier analysis (Ch. "Biological Realization of Self Hierarchy" of [15]).

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

The virtual particles of quantum field theory have also classical counterparts.

In particular, the virtual particles can have negative energies: this holds true also for their TGD counterparts. The fundamental difference between TGD and GRT is that in TGD the sign of energy depends on the time orientation of the spacetime sheet: this is due to the fact that in TGD energy current is vector field rather than part of a tensor field. Therefore spacetime sheets with negative energies are possible. This could have quite dramatic technological consequences: consider only the possibility of generating energy from vacuum and classical signalling backwards in time along negative energy spacetime sheets (Ch. "Anomalies Explainable by TGD Based Spacetime Concept" of [14]). Also bioystems might have invented negative energy spacetime sheets: in fact, MEs provide an ideal manner to generate coherent motions as recoil effects caused by the creation of negative energy massless extremals (Chs "Biological Realization of Self Hierarchy" and "Quantum Antenna Hypothesis" of [15]). An interesting possibility is that quantum entanglement has the formation of the join along boundaries bonds as its geometric correlate.

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

2. Basic extremals of Kähler action

Classical physics defined by spacetime geometry is exact part of quantum physics in TGD. Therefore the study of the extremals of Kähler action has played decisive role in the development of quantum TGD. Kähler action allows four kinds of basic extremals. These surfaces need not be absolute minima of Kähler action as such but very probably are building blocks from which absolute minima can be constructed. Furthermore, self-organization process by quantum jumps between quantum histories is expected to lead to asymptotic states in which spacetime surface consists of the basic extremals just like dissipation selects highly symmetric final state configurations in ordinary dissipative dynamics.

a) The so called CP_2 type extremals which are vacua and behave non-deterministically correspond to elementary particles: CP_2 extremals are isometric with CP_2 and have random lightlike curve as M^4_+ projection (Ch. "Basic Extremals of the Kähler Action" of [13]). The semiclassical quantization of the lightlikeness condition leads to the superconformal algebra of string models: it was this observation which stimulated the idea that super conformal invariance is a symmetry of quantum TGD (Ch. "p-Adic Particle Massivation: General Theory" of [14]). It was however quaternion-conformal invariance and related Super-Kac-Moody algebras rather than the superconformal and supercanonical symmetries of the lightcone boundary, which turned out to correspond to the superconformal invariance associated with CP_2 type extremals. It is possible to formulate Feynmann rules in the approximation that only CP_2 type extremals are relevant for particle physics (Ch. "Construction of S-matrix" of [13]).

b) Cosmic strings correspond to the surfaces of form $X^2 \times S^2 \in M^4_+ \times CP_2$, where S^2 is minimal surface (orbit of string) and S^2 is homologically nontrivial geodesic sphere of CP_2 (Ch. "Cosmic Strings" of [13]). Cosmic strings are unstable (they have huge positive Kähler action) and have turned out to be the 'ur -matter' whose decay to elementary particles gives rise to the visible matter: topologically condensed cosmic strings correspond to the dark matter and cosmic strings outside the spacetime sheets to the 'vacuum energy density' of the inflationary scenarios. Galaxies result when split cosmic strings burn like fire crackers to elementary particles. Gamma ray bursters result from jets of elementary particles emerging from the ends of the split strings (Chs "TGD Inspired Cosmology" and "Cosmic Strings" of [13]).

c) Vacuum extremals (VEs) are a breath-takingly general solution set. When one restricts spacetime surfaces to certain infinite family of 6-dimensional submanifolds of 8 -D imbedding space, one obtains only VEs. Canonical transformations of CP_2 combined with diffeomorphisms of M^4_+ produce new vacuum extremals. The small deformations induced by the interaction of VEs with nonvacuum spacetime sheets deforms them to nonvacuum extremals. This suggests that biomatter and its non-determinism are related to VEs and that the interaction of VEs with matter give rise to cognitive spacetime sheets having by definition a finite temporal duration.

d) 'Massless extremals' (MEs) are an extremely general solution set representing various gauge fields and gravitational fields (Chs "Quantum antenna hypothesis" and "Quantum Model for EEG and Nervepulse" of [15]). Being scale invariant, they come in all size scales. MEs allow the canonical transformations localized with respect to M^4_+ coordinates as symmetries and also hypercomplex variant of conformal algebra as dynamical symmetries. MEs contain waves propagating with velocity of light in single direction so that there is no dispersion: preservation of pulse shape and its arbitrariness as function of time at given point makes them ideal for classical communications. The presence of the light like vacuum currents is however a purely TGD based feature and implies generation of coherent light and gravitons.

World should be full of MEs with all possible sizes since they have a vanishing action: addition of ME with a finite time duration yields new absolute minimum of the Kähler action since the value of the Kähler action does not change in this operation. Since MEs have vanishing action, the natural guess is that in the interaction with matter VEs become structures consisting of MEs with a finite time duration and having interpretation as representing classical communications between two systems. Thus MEs could provide an important instance of a cognitive spacetime sheet. It is even possible to have pairs of positive and negative energy MEs with a vanishing total energy: these pairs are ideal candidates for the geometrical correlates mind, 'the mind stuff', and make the Cartesian view about mind a reasonable approximation.

M^4_+ projection of ME is 4-dimensional and this implies that the vacuum conformal weight of corresponding Super Virasoro representations is $h_{vac} = 0$. Thus one can say that various supersymmetries are unbroken. In particular MEs allow exotic Super Virasoro representations (Ch. "General Theory of Qualia" of [15]) for which the mass squared eigenvalue is

$$m^2 \propto L_0 = n = 0 \ \ mod \ \ p^k \ \ , \ \ k > 0 \ \ .$$

The real counterparts of these masses are extremely small being proportional to p^{-k}. Quite generally, the Super Algebra generators $O_n \ , \ n \ mod \ p^k = 0 \ , \ k > 0$ span an infinite fractal hierarchy of sub-algebras of the entire super algebra so that these representations are expected to be very important physically. The degeneracies of states for given $n = O(p^k)$ are astrophysical for physically interesting primes so that these systems have enormous information storage capacities. The hypothesis is that exotic p-adic Super Algebra representations define an infinite hierarchy of lifeforms interacting with the classical gauge fields associated with MEs (Ch. "Biological Realization of Self-Hierarchy" of [15]).

This leads to a model of qualia (Ch. "General Theory of Qualia" of [15]) and one can identify the most important resonance frequencies of EEG as harmonics of the fundamental transition frequencies associated with the relevant exotic Super Virasoro representations. This prediction can be regarded as victory of p-adic TGD and TGD inspired theory of consciousness since the frequencies in question are constants of Nature if p-adic length scale hypothesis holds true.

3. The new physics implied by the notion of induced gauge field

The fact that classical fields are expressible in terms of CP_2 coordinates implies strong constraints between them. Classical color gauge fields are unavoidable and interact with the exotic Super Virasoro representations and could thus be important for our conscious experience (Ch. "Spectroscopy of Consciousness" of [15]).

Classical em fields are accompanied almost always by classical and Z^0 fields and also W fields are unavoidable. The requirement that parity breaking effects caused by classical Z^0 fields are small in nuclear and atomic length scales and that neutrinos screen the classical Z^0 fields generated by atomic nuclei, fixes to very high degree the structure of the many-sheeted spacetime in condensed matter length scales (Ch. "TGD and Condensed Matter" of [14]). The new electroweak physics is especially important in the biologically interesting length scales since neutrino Compton length corresponds to the cell length scale. For instance, chiral selection has an explanation in terms of a spontaneous symmetry breaking induced by the classical Z^0 fields (Ch. "TGD and Condensed Matter" of [14]). Exotic electroweak physics is also a key element in the TGD based model of the conscious brain. Classical W fields can induce exotic nuclear transmutations by $p \leftrightarrow n$ process conserving the net charge and long range charge entanglement becomes possible in principle (Ch. "Spectroscopy of Consciousness" of [15]).

Classical Z^0 fields cause other exotic effects.

i) Classical Z^0 fields could explain the anomalous acceleration of spacecrafts in

outer space emerges [1] (Ch. "TGD and Astrophysics" of [14]).
ii) Classical Z^0 magnetic fields of Sun and Earth provide a possible explanation for solar neutrino deficit: neutrino beam from the solar core simply disperses in the Z^0 magnetic fields of Sun and Earth (Ch. "TGD and Astrophysics" of [14]).
iii) There are claims for exotic effects related to rotating macroscopic bodies [7]: the Z^0 magnetic fields generated by these bodies could provide a natural explanation for these effects (Ch. "Anomalies Explainable by TGD Based Spacetime Concept" of [14]).
iv) Classical Z^0 magnetic fields could prevent the gravitational collapse of Super Nova to black-hole (Ch. "TGD and GRT" of [13]).
v) Classical Z^0 fields are also essentially involved with the explanation of the anomalous tritium beta decays [9] (Ch. "TGD and Nuclear Physics" of [14]).

4. TGD and GRT

The relationship between TGD and GRT is discussed in (Ch. "TGD and GRT" of [13]). The requirement that classical four-momentum is a conserved exactly seems to be in conflict with the fact that GRT based spacetime is an experimentally well established concept. The transfer of energy momentum between different spacetime sheets of the many-sheeted spacetime can however explain the apparent energy nonconservation even in the cosmological length scales since by quantum criticality there is no upper bound for the size of the spacetime sheets present in the topological condensate.

Concerning the description of the condensate, the basic idea is that the spacetime of GRT is idealization obtained by smoothing out all topological details (in particular particles) of size smaller than a given length scale L and by describing their presence using various current densities such as YM currents and energy momentum tensor. Einstein's equations correspond to special solutions to the field equations but are not true generally. Note that spacetime surfaces are also absolute minima of Kähler action: this gives very strong constraints on the model.

For the spacetimes satisfying Einstein's equations, the equations governing the energy transfer between the condensate and vapour phase are derived in Ch. "TGD and GRT" of [13] and it is found that Schwartshild metric corresponds to a stationary situation for which the energy-momentum transfer between the two phases vanishes. A feature characteristic for TGD is that any electromagnetically neutral mass distribution is accompanied by a long range Kähler electric and therefore also by a classical Z^0 electric gauge field. The requirement that Z^0 force is weaker than the gravitational force gives strong constraints on the values of the vacuum quantum numbers: the space time at astrophysical scales must correspond to a large vacuum quantum number limit of TGD.

The basic objection against this picture is that only very few metrics can be represented as an induced metric: the dimension of the flat space allowing imbedding of an arbitrary spacetime metric is of order few hundred. The absolute minima of Kähler action carry however vacuum Einstein tensor which generates a coherent state of gravitons: the order parameter associated with the coherent state gives an additional contribution to the quantum expectation value of the metric tensor and thus much more general variety of effective metrics becomes possible.

5. TGD inspired cosmology

TGD Universe is quantum counterpart of a statistical system at critical temperature. As a consequence, topological condensate is expected to possess hierarchical, fractal like structure containing topologically condensed 3-surfaces with all possible sizes. Both Kähler magnetized and Kähler electric 3-surfaces ought to be important and string like objects indeed provide a good example of Kähler magnetic structures important in TGD inspired cosmology (Ch. "Cosmic Strings" of [13]). In particular, spacetime is expected to be many-sheeted even at cosmological scales and ordinary cosmology must be replaced with a many-sheeted cosmology. The presence of the 'vapour phase' consisting of free cosmic strings and possibly also of elementary particles is second crucial aspect of the TGD inspired cosmology.

Quantum criticality of the TGD Universe supports the view that the many-sheeted cosmology is in some sense critical and possesses a fractal structure. Phase transitions, in particular the topological phase transitions giving rise to new spacetime sheets, are (quantum) critical phenomena involving no scales. If the curvature of the 3-space does not vanish, it defines scale: hence the flatness of the cosmic time=constant section of the cosmology implied by the criticality is consistent with the scale invariance of the critical phenomena. This motivates the assumption that the new spacetime sheets created in topological phase transitions are in good approximation modellable as critical Robertson-Walker cosmologies for some period of time at least: therefore a connection with inflationary cosmologies results.

The requirement of imbeddability shows its predictive power in TGD inspired cosmology (Ch. "TGD and Cosmology" of [13]). TGD allows global imbedding of subcritical cosmologies but neither inflationary cosmologies nor overcritical cosmologies are possible in TGD. TGD however allows the imbedding of a one-parameter family of critical cosmologies with flat cosmic time = constant sections. The infinite size of the horizon for the imbeddable critical cosmologies is in accordance with the presence of arbitrarily long range fluctuations at criticality and guarantees the average isotropy of the cosmology. Imbedding is possible for some critical duration of time. The parameter labelling these cosmologies is a scale factor characterizing the duration of the critical period. The mass density at the limit of very small values of cosmic time a behaves as $1/a^2$ so that mass per comoving volume approaches zero. Therefore critical cosmology can be regarded as a 'Silent Whisper amplified to Big Bang' and transformed to hyperbolic cosmology before its imbedding fails. Split strings decay to elementary particles in this transition and give rise to seeds of galaxies (Ch. "Cosmic Strings" of [13]). In some later stage the hyperbolic cosmology can decompose to disjoint 3-surfaces. Thus each sub-cosmology is analogous to biological growth process leading eventually to death. An important constraint to TGD inspired cosmology is the requirement that Hagedorn temperature $T_H \sim 1/R$, where R is CP_2 size, is the limiting temperature of the radiation dominated phase.

The critical cosmologies can be used as a building blocks of a fractal cosmology containing cosmologies containing ... cosmologies. p-Adic length scale hypothesis allows a quantitative formulation of the fractality. Fractal cosmology predicts cosmos to have essentially the same experimentally verified [16] optic properties as inflationary scenario but avoids the prediction of an vacuum energy density of unkown origin. Fractal cosmology explains the paradoxal result that the observed density of the matter is much lower than the critical density associated with the largest spacetime sheet of the fractal cosmology. Also the observation that some astrophysical objects seem to be older than the Universe, finds a nice explanation.

A longstanding puzzle of TGD inspired cosmology has been the apparent conflict with the conservation of energy implied by Poincare invariance. The energy densities of both critical cosmology and radiation dominated cosmology near Hagedorn temperature are huge as compared to the energy density of the cosmic strings in 'vapour phase'. The solution of the paradox relies on the possibility of negative energy virtual gravitons represented by topological quanta having negative time orientation and hence also negative energy condensed on the larger spacetime sheets. The absorption of negative energy gravitons by photons implies gradual redshifting of the microwave background radiation. Negative energy virtual gravitons give rise to a negative gravitational potential energy. Quite generally, negative energy virtual bosons build up the negative interaction potential energy so that TGD provides concrete topologization for the age old notion of potential energy.

3 p-Adic aspects of TGD

The hunch that p-adic numbers might be of relevance for TGD led rather rapidly to p-adic mass calculations and to other applications of p-adic numbers. The understanding about how p-adic numbers should be imbedded in the basic mathematical structure of TGD has developed with a much slower pace and the theory is still in a rather speculative stage. A longheld working hypothesis has been that the spin glass analogy implied by the huge vacuum degeneracy of the Kähler action could force p-adic topology as an effective spacetime topology. TGD inspired theory of consciousness however suggests p-adic topology is genuine rather than effective topology and that both p-adic and real physics are needed in order to have complete description of reality. Real topology is the topology of reality and various p-adic topologies are topologies of possible experiences about reality. More precisely, p-adic spacetime regions provide cognitive representations about real regions representing material regions: this view is also supported by TGD as a generalized number theory vision to be discussed in the next section.

1. p-Adic numbers

Like real numbers, p-adic number number fields R_p, p prime, can be regarded as completions of the rational numbers to a larger number field allowing the generalization of differential calculus. p-Adic topology is ultrametric, which means that the distance function $d(x,y)$ satisfies the inequality $d(x,z) \leq Max\{d(x,y), d(y,z)\}$ (here $(Max(a,b)$ denotes maximum of a and b) rather than the usual triangle inequality $d(x,z) \leq d(x,y) + d(y,z)$.

p-Adic numbers have pinary expansion in powers of p analogous to the decimal expansion $x = \sum_{n\geq 0} x_n p^n$ and the number of terms in the expansion can be infinite so that p-adic number need not be finite as a real number. The norm of the p-adic number (counterpart of $|x|$ for real numbers) is defined as $N_p(x = \sum_{n\geq 0} x_n p^n) = p^{-n_0}$ and depends only very weakly on p-adic number. The ultrametric distance function can be defined as $d_p(x,y) = N_p(x-y)$.

p-Adic numbers allow the generalization of the differential calculus and of the concept of analytic function $f(x) = \sum f_n x^n$. The set of the functions having vanishing p-adic derivative consists of so called pseudo constants, which depend on a finite number of positive pinary digits of x only so that one has $f_N(x = \sum_n x_n p^n) = f(x_N = \sum_{n<N} x_n p^n)$. This implies that p-adic differential equations are non-deterministic.

It seems that p-adic numbers alone do not lead to an interesting physical theory. There must be map from p-adics to reals mapping the predictions of the p-adic theory to real numbers. In TGD a crucial role in played by the map of the p-adic numbers to the positive real numbers by the so called canonical identification I:

$$I : \sum x_n p^n \in R_p \rightarrow \sum_n x_n p^{-n} \in R \ . \qquad (1)$$

Canonical identification has inverse, which is single valued for the real numbers having infinite number of pinary digits but two-valued for real numbers having finite number of pinary digits (the reason is that real number with finite number or pinary digits has two equivalent pinary expansions: $(x = 1 = .999999...$ in case of decimal expansion and $x = 1 = 0yyyy...$, $y = p-1$, in case of pinary expansion). Canonical identification is an absolutely essential element of the p-adic mass calculations.

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

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

Integral function $F(x)$ is obtained using the inverse of the derivation just as in the real context and is unique if p-adic pseudo constants required to reduce to ordinary constants. p-Adic integration defined in this manner makes it possible to define p-adic variational principles. One can consider also other possibilities to define p-adic integral, in particular the definition based on a generalization of Fourier analysis, but these will not be discussed here (Ch. "p-Adicization of Quantum TGD" of [14]).

2. Vacuum degeneracy of the Kähler action and spin glass analogy

The space of minima of free energy for spin glass is known to have ultrametric topology. p-Adic topology is also ultrametric and this motivates the hypothesis that quantum average spacetime, 'topological condensate', defined as maximum of Kähler function can be obtained by gluing together p-adic regions with various values of the p-adic prime p.

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

Spin glass consists of magnetized regions such that the direction of the magnetization varies randomly in the spatial degrees of freedom but is frozen in time. What is peculiar that, although there are large gradients on the boundaries of the regions with a definite direction of magnetization, no large surface energies are generated. An obvious p-adic explanation suggests itself: p-adic magnetization could be pseudo constant and hence piecewise constant with a vanishing derivative on the boundaries of the magnetized regions so that no p-adic surface energy would be generated.

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

The TGD counterpart of the energy landscape can be constructed as follows. The configuration space of TGD (the space of 3-surfaces in H) has fiber-space like structure deriving from the decomposition $CH = \cup_{zeromodes} G/H$. The fiber is the coset space G/H such that G is the group of the canonical transformation of the light cone boundary- In particular, the canonical transformations of CP_2 act in the fiber as isometries. The base space is the infinite-dimensional space of the zero modes characterizing the size and shape as well as the classical Kähler field at the 3-surface. The set of the maxima of the Kähler function as function of both fiber degrees of freedom and zero modes defines reduced configuration space CH_{red} as the TGD counterpart of the energy landscape possessing ultrametric topology possibly induced from a p-adic norm. Spin-glass analogy alone would suggest that p-adic topology is only an effective topology of CH_{red} and possibly also of spacetime surfaces. TGD inspired theory of consciousness and TGD as a generalized number theory visions however suggest that p-adic topology is a genuine topology at the spacetime level. The dynamical nature of the spacetime topology in small conforms with the vision about spacetime as a Cantorian fractal [10].

3. p-Adic length scale hypothesis

p-Adic length scale hypothesis provides precise quantitative formulation for the notion of the many-sheeted fractal spacetime and is responsible for much of the predictive power of TGD. p-Adic length scale hypothesis states the existence of a p-adic length scale hierarchy with p-adic length scales given by

$$L_p = \sqrt{p}l \ ,$$

where l is the fundamental p-adic length scale of order CP_2 size R. The prediction of the p-adic mass calculations for electron mass[1] fixes the value of this parameter to be $l \simeq 10^4\sqrt{G}$. The same prediction results from the requirement that cosmic strings have correct string tension to explain the density of the galactic dark matter (Ch. "Cosmic Strings" of [13]). Also secondary and higher length scales $L_{p,n} \simeq \sqrt{p^n}L_p$ and corresponding time scales resulting from p-adic fractality are important, in particular in TGD inspired theory of consciousness [15]. The possibility to assign L_p with a given prime p can be understood. p-Adic thermodynamics predicts that light particles possess mass squared of order $M^2 \sim 1/p$ and Uncertainty Principle leads directly to the p-adic length scale hypothesis.

The second, nontrivial, part of the p-adic length scale hypothesis is that the physically interesting p-adic primes correspond to primes near prime powers of 2, $p \simeq 2^k$, k prime. The possibility that k is a power of prime is not excluded and there is some support for this. There are rather few p-adic primes near prime powers of two and Mersenne primes $M_n = 2^n - 1$ (where n is prime) are especially interesting physically. The hypothesis is also interesting above the elementary particle length scales $p > M_{127}$ and has testable implications in nuclear, atomic and condensed matter length scales. p-Adic length scale hypothesis is of crucial importance in TGD based model of biosystems (Ch. "Biological Realization of

[1]Electron must correspond to M_{127} from the requirement that the ratios of the p-adic mass scales associated with intermediate gauge bosos, hadrons and electron come out correctly.

Self-Hierarchy" of [15]). Important resonance frequencies of EEG correspond to the fundamental transition frequencies of the exotic Super Virasoro representations determined by the corresponding p-adic time scales (Chs "General Theory of Qualia" and "Spectroscopy of Consciousness" of [15]. p-Adic length scale hypothesis seems to make sense in cosmological length scales (Ch. "TGD Inspired Cosmology" of [13]).

One can deduce the dependence of the Kähler coupling strength α_K on the p-adic length scale L_p from the approximation that gravitational constant is same in all p-adic length scales plus the relationship

$$G = L_p^2 exp(-S_K(CP_2)) \ , \quad S_K(CP_2) = \frac{\pi}{8\alpha_K} \ , \quad L_p = \sqrt{p} l \ , \tag{2}$$

where $S_K(CP_2)$ is Kähler action for CP_2 type extremal representing elementary particle. This hypothesis is inspired by dimensional considerations. The evolution is logarithmic and the predicted low energy value of α_K in electron length scale is

$$\alpha_K(M_{127}) = 136.3496143 \ ,$$

which is surprisingly near to the fine structure constant

$$\frac{1}{\alpha_{em}(m_e)} = 137.0360211$$

at m_e: the deviation is only .5 per cent. It must be however emphasized that the coupling constant evolution of α_K is much faster than that of α_{em} so that near equality might be more or less a coincidence.

Here a brief comparison of the predictions for the fundamental parameters of physics with those of other theories is in order. The Cantorian $\mathcal{E}^\infty$ theory of Mohammed El Naschie predicts the value of the fine structure constant to be $1/\alpha_{em} = 137 + \phi^5(1-\phi^5) = 137.082039325$, where $\phi = (\sqrt{5}-1)/2$ is Golden Mean. Also the values of other coupling parameters of the Standard Model, as well as coupling constants and dimension type parameters related to the heterotic string theory are predicted. By using topological arguments, author predicts the average Hausdorff dimension of the Cantorian fractal spacetime to be $4+\phi^3$. The average number of the fermion generations is predicted to be $n_g \simeq 3.09$. In TGD framework the existence of the configuration space geometry fixes spacetime and imbedding space-dimensions. Family replication phenonenon has a topological explanation in terms of the genus of the boundary component of the three-surface carrying elementary particle quantum numbers. The argument predicting that there are only three light particle generations relies on the observation that 2-surfaces with genus $g < 3$, as opposed to those with genus $g \geq 3$, are always hyperelliptic (Ch. "Elementary Particle Vacuum Functionals" of [13]). The success of the p-adic mass calculations provides strong support for the genus-generation correspondence.

p-Adic length scale hypothesis can be understood by using a generalization of Hawking-Bekenstein law to relate the value of elementary particle mass squared to the area of elementary particle horizon defined as the surface at which Euclidian metric signature of topologically condensed CP_2 type extremal changes to Minkowskian metric signature of the background spacetime. If one requires that the radius of the horizon itself corresponds to the p-adic length scale $L(k)$, generalized Hawking-Bekenstein law relating to each other the p-adic entropy of the elementary particle and horizon radius implies p-adic length scale hypothesis (Ch. "p-Adic Particle Massivation: General Theory" of [14]).

The hypothesis that the transformation of thought to action and sensory input to cognition correspond to phase transitions transforming real regions to p-adic regions and vice versa even at elementary particle length scales, leads to an explanation for why p-adic length scale hypothesis applies also to real regions and explains the selection of the preferred p-adic topologies as due to the exceptionally high cognitive degeneracy implied by the p-adic non-determinism (the presence of the p-adic regions corresponding to *both* p and $k!$). Elementary particles with preferred p-adic primes would be winners in the fight for survival because their p-adic counterparts are winners.

4. p-Adic elementary particle physics

p-Adic physics provides first principle microscopic description of particle massivation. p-Adic description of Higgs mechanism is based on three assumptions having justification in terms of the QFT limit of TGD (Ch. "Low Energy Field Theory Limit of TGD" of [14]).

a) Primes $p \simeq 2^k$, k power of prime, in particular Mersenne primes, correspond to the physically most interesting p-adic primes determining the primary condensation level of the elementary particle and the mass scale of the elementary particle. Mersenne primes M_n, $n = 89, 107, 127$ correspond to intermediate gauge bosons, hadrons and electron respectively and the observation that the ratios of the corresponding mass scales correspond to the ratios of the square roots of these primes was the original observation stimulating the idea that number theory could explain elementary particle mass scales.

b) The massivation follows from the small mixing of the massless states with super heavy states and from the coupling to the recently identified TGD counterpart of the Higgs field. Longitudinal components of the intermediate gauge bosons result automatically from the fact that mixed particle states by Poincare invariance have same energy momentum and are thus off-mass-shell particles. The mixing is described by p-adic thermodynamics for Super Virasoro generator L_0. A purely p-adic feature is the quantization of temperature to $T = 1/n$ at low temperature limit by the requirement that p-adic Boltzmann weights $p^{L_0/T}$ exist as p-adic numbers. Note that extremely strong constraints on the Hamiltonian are also posed: the spectrum must be essentially integer valued. All elementary fermions turn out to have minimum p-adic temperature $T = 1$ whereas bosons must correspond to $T = 1/2$ for which thermal masses are negligibly small. In case of fermions thermal masses dominate over Higgs contribution whereas bosonic masses in practice result from the coupling to the Higgs field.

c) Super-conformal invariance, originally suggested by the zitterbewegung property of the CP_2 type extremals, is realized as quaternion-conformal invariance and the corresponding Super-Kac-Moody algebra corresponds to the group $P \times SU(3) \times U(2)_{ew}$ (P denotes Poincare group).

In Ch. "p-Adic Particle Massivation: Elementary Particle Masses" of [14], the calculation of elementary fermion and boson masses using p-adic thermodynamics is carried out. Leptons and quarks 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. Contrary to the earlier erraneous calculation, Z^0 and W boson masses come out 20-30 percent too high for $T = 1$ and the only possible option is $T = 1/2$ with negligibly small thermal masses and TGD version of Higgs mechanism. A large number of exotics is predicted. All particles have $N = 1$ super partners obeying identical mass formulas, also bosons have family replication and ordinary fermions and bosons have color excitations. The succces of the calculations means a triumph for the genus-generation hypothesis predicting the dependence of the masses on the genus of the boundary component associated with the elementary particle (Ch. "Elementary Particle Vacuum Functionals" of [13] and Ch. "p-Adic Particle Massivation: Elementary Particle Masses" of [14]).

In Ch. "p-Adic Particle Massivation: Hadron Massess" of [14], the main emphasis is in the understanding of the hadron masses using as inputs quark masses and a model for the CKM mixing of quarks based on the mixing of boundary topologies. Number theory gives strong constraints on CKM matrix and one ends up with a mixing scenario fixing quark masses essentially uniquely. Number theoretical constraints (mixing matrices are proportional to rational unitary matrices) might fix CKM matrix uniquely. As a by product one obtains a possible solution of proton spin crisis. By taking phenomenologically into account spin-spin and isospin-isospin interactions between quarks one obtains excellent fit of hadron masses. Top quark is an exception: in the simplest scenario top mass is predicted to be either about 3 times smaller (55 GeV) or about 5 times larger than the mass of the observed top candidate. A possible explanation is based on the identification of the observed top as u/d quark of M_{89} hadron physics. The general mass scale for light quarks as predicted by TGD is much higher than predicted by standard model and in TGD context one must identify quark mass parameters appearing in chiral perturbation theory as quark mass shifts rather than quark masses.

TGD predicts large number of exotic states but leaves open the p-adic length scales associated with them. Mersenne primes are especially interesting candidates for length scales associated with new physics.

a) The existence of M_{127} leptohadron physics (Ch. "Leptohadron Hypothesis" of [14]) was suggested for years ago to explain the anomalous production of e^+e^- pairs in low energy heavy ion collisions. Leptohadrons are bound states of color excited leptons. The strongest counter argument against leptohadron physics are the decays of Z^0 to exotic leptons not allowed by Z^0 decay width. The predicted loss of asymptotic freedom however solves this problem and it is possible to have an arbitrary number of exotic QCD:s, each of them existing only in a finite energy interval.

b) TGD predicts also the existence of higher boson generations and $N = 1$ super symmetry. The recently observed anomalously large direct CP breaking in $K \rightarrow \pi\pi$ decays has TGD based explanation in terms of higher gluon generations (Ch. "p-Adic Particle Massivation: New Physics" of [14]). Sparticles obey the same mass formulas as particles but are characterized by different p-adic prime.

c) In p-adic context exotic representations of Super Virasoro with $M^2 = O(p^k)$, $k = 1, 2, ..$ are possible. For $k = 1$ the states of these representations have same mass scale as elementary particles. 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 very promising (Ch. "p-Adic Particle Massivation: New Physics" of [14]). Pion mass is almost exactly equal to the mass of the 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 TGD inspired theory of consciousness as a generalization of quantum measurement theory

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 [15] and leads to a quantitative understanding of the relationship between sensory qualia and EEG (Chs "General Theory of Qualia" and "Spectroscopy of Consciousness" of [15]). The basic elements of the theory are following.

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. U is however only formally analogous to Schrödinger time evolution of infinite duration since there is no real time evolution involved since S-matrix represents Glebch-Gordan coefficients for free and interacting Super Algebra representations. 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 parametrize 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. Localization in zero mode degrees of freedom implies that a localization to a definite sector D_P of the configuration space labelled by infinite prime P occurs: D_P has infinite-p p-adic topology, which is essentially equivalent with the real topology with respect to the canonical identification. The localization in zero modes implies that the final states of quantum jump correspond to quantum superpositions of spacetime surfaces which are macroscopically equivalent. Hence the world of conscious experience looks classical. Quantum jump can be interpreted also as quantum computation.

The concept of self is absolutely essential for the understanding of the macroscopic and macrotemporal aspects of consciousness. Self corresponds to a subsystem able to remain p-adically un-entangled under the sequential informational time evolutions U. In real context this means that self generates subcritical entanglement, criticality being defined by the unique pinary cutoff involved with reals-to-p-adics mapping. It is assumed that the experiences of the self after the last 'wake-up' sum 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 a mental image: 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 spacetime 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.

The so called Negentropy Maximization Principle (Ch. "Negentropy Maximization Principle" of [15]) defines the dynamics of the subjective time evolution. NMP states that each quantum jump leads to an eigenstate of the density matrix of some subsystem of self. This assumption reproduces the standard measurement theory with the density matrix appearing in the role of a universal quantum observable. NMP also states that the subsystem of self giving rise to maximum negentropy gain in quantum jump is quantum measured in given quantum jump. Entanglement entropy in minimized in the quantum jump and the identification of the quantum entanglement as the physical correlate for attentiveness or alertness is natural although not necessary. The generalization of quantum measurement theory, already described, makes it possible to understand the objectivity of sensory experience as resulting from quantum statistical determinism in temporal domain. It seems that the only logical manner to define subsystem is as quantum sub-history.

The fourth basic element is quantum theory of self-organization based on the identification of quantum jump as the basic step of self-organization (Ch. "Quantum Theory of Self-Organization" of [15]). 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 prequisite for quantum self-organization. Zero modes represent fundamental order parameters and the 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.

The fifth basic element are the concepts of association sequence and cognitive spacetime sheet. The huge vacuum degeneracy of the Kähler action suggests strongly that the absolute minimum spacetime is not always unique. For instance, a sequence of bifurcations can occur so that a given spacetime branch can be fixed only by selecting a finite number of 3-surfaces with timelike(!) separations on the orbit of 3-surface. In case that non-determinism is located to a finite time interval and is microscopic, this sequence of 3-surfaces has interpretation as a geometric correlate for a volitional non-determinism associated with our choices. p-Adic non-determinism in turn corresponds to the non-determinism associated with free imanigation essential for cognitive modelling. Genuine cognitive spacetime sheets (as opposed to 'sensory' spacetime sheets made possible by classical nondeterminism) can be identified as p-adic spacetime sheets having finite temporal duration and psychological time can be identified as a temporal center of mass coordinate of the cognitive spacetime sheet. The gradual drift of the cognitive spacetime sheets to the direction of future force by the geometry of the future lightcone explains the arrow of psychological time. Simplest

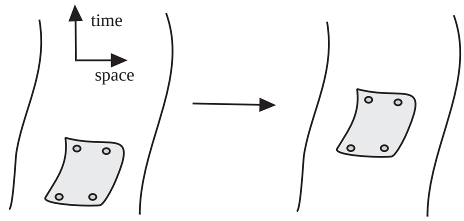

Figure 1: The mechanism giving rise to the arrow of psychological time

dimensional estimate gives for the average increment τ of geometric time in quantum jump $\tau \sim 10^4$ CP_2 times so that $2^{127}-1 \sim 10^{38}$ quantum jumps are experienced during secondary p-adic time scale $T_2(k=127) \simeq 0.1$ seconds which is the duration of physiological moment and predicted to be fundamental time scale of human consciousness (Ch. "Genes and Memes" of [15]).

The sixth basic element adds a physical theory of cognition to this vision. TGD spacetime decomposes into regions obeying real and p-adic topologies labelled by primes $p = 2, 3, 5, ...$ p-Adic regions obeys 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 spacetime regions are obtained by glueing 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. The transformation of a thought into an action and of sensory input to cognition can be identified as phase transitions in which p-adic spacetime regions are transformed to real ones and vice versa. This process is predicted to occur in all length scales and the success of p-adic mass calculations and p-adic length scale hypothesis can be interpreted as a direct evidence for its occurrence in elementary particle length scales.

5 TGD and Riemann hypothesis

Riemann hypothesis states that the nontrivial zeros of Riemann Zeta function lie on the axis $x = 1/2$. Since Riemann zeta function allows an interpretation as a thermodynamical partition function for a quantum field theoretical system consisting of bosons labelled by primes, it is interesting to look Riemann hypothesis from the perspective of physics. There is strong evidence for the connection between Riemann Zeta and quantum critical chaotic systems and suggestions for proof of Riemann hypothesis along these lines have been proposed [2]. Quantum TGD provides an additional view point to the hypothesis and suggests sharpening of Riemann hypothesis, detailed strategies of proof of the sharpened hypothesis, and heuristic arguments for why the hypothesis is true Hypothesis" of [13]).

One very promising strategy is based on, what I call, Universality Principle. The function, that I refer to as $\hat{\zeta}$, is defined by the product formula for ζ and exists in the infinite-dimensional algebraic extension Q_∞ of rationals containing all roots of primes. $\hat{\zeta}$ is defined for all values of s for which the partition functions $1/(1-p^{-z})$ appearing in the product formula have value in Q_∞. Universality Principle states that $|\hat{\zeta}|^2$, defined as the product of the p-adic norms of $|\hat{\zeta}|^2$ by reversing the order of producting in the adelic formula, equals to $|\zeta|^2$ and, being an infinite dimensional vector in Q_∞, vanishes only if it contains a rational factor which vanishes. This factor is present only provided an infinite number of partition functions appearing in the product formula of $\hat{\zeta}$ have rational valued norm squared: this locates the plausible candidates for the zeros on the lines $Re[s] = n/2$.

Universality Principle implies the original sharpened form of the Riemann hypothesis in a generalized form: the real part of the phase p^{-iy} is rational for an infinite number of primes for zeros of ζ. Universality Principle, even if proven, does not however yield a proof of the Riemann hypothesis. The failure of the Riemann hypothesis becomes however extremely implausible. An important outcome of this approach is the realization that superconformal invariance is a natural symmetry associated with ζ (not surprisingly, since the symmetry group of complex analysis is in question!).

Superconformal invariance inspires a strategy for proving (not a proof of, as was the first over-optimistic belief) the Riemann hypothesis. The vanishing of the Riemann Zeta reduces to an orthogonality condition for the eigenfunctions of a non-Hermitian operator D^+ having the zeros of Riemann Zeta as its eigenvalues. The construction of D^+ is inspired by the conviction that Riemann Zeta is associated with a physical system allowing superconformal transformations as its symmetries and second quantization in terms of the representations of superconformal algebra. The eigenfunctions of D^+ are analogous to coherent states of a harmonic oscillator and in general not orthogonal to each other. The states orthogonal to a vacuum state (having a negative norm squared) correspond to the zeros of Riemann Zeta. The physical states having a positive norm squared correspond to the zeros of Riemann Zeta at the critical line. Riemann hypothesis follows by reductio ad absurdum from the hypothesis that ordinary superconformal algebra acts as gauge symmetries for all coherent states orthogonal to the vacuum state, including also the non-physical might-exist coherent states off from the critical line.

Although these approaches to the Riemann hypothesis do not yield its proof, they concretize the vision about TGD based physics as a generalized number theory. Two new realizations of the superconformal algebra result and the second realization has direct application to the modelling of $1/f$ noise (Ch. "Quantum Control and Coordination in Biosystems" of [15]).

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