Topological Condensation and Evaporation

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Abstract

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 super-symmetry 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. The only possible interpretation is that there exists 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 anti-matter which is dark. An explanation of Pomeron is proposed.

1 Introduction

The concept of 3-space in TGD is considerably more general than in the conventional theories. 3-space is not any more connected but can have arbitrary many disjoint components. Even macroscopic boundaries are allowed: macroscopic bodies are interpreted as 3-surfaces having outer boundary. There are strong indications that 3-space has a hierarchical fractal structure: 3-surfaces topologically condensed on 3-surfaces condensed on..., where topological condensation means that 'small' 3-surface is 'glued' to a larger 3-surface by connected sum operation. Topological evaporation and condensation concepts can be applied to the TGD inspired cosmology. For example, the generation of matter antimatter asymmetry could be understood as caused by a small difference between topological evaporation rates for fermions and anti-fermions so that anti-fermion number evaporates into vapor phase or matter and antimatter reside at different space-time sheets. Antimatter could be also in dark matter phase.

The fundamental feature of topological condensation is the generation of Kähler electric fields implied by the minimization of Kähler action: the condensed particle develops Kähler charge (and as a consequence electromagnetic and/or Z^0 charge), which at astrophysical scales is apart from a numerical factor equal the mass of particle using Planck mass as unit. In shorter length scales the Kähler charge can be larger and reflects the development of long range Z^0 fields. The previous work has been based on implicit assumption that the anomalous Z^0 charge is proportional to mass even at elementary level. In the recent approach it is assumed that the proportionality holds true for many-particle systems and that electromagnetic gauge charges have their quantized values at elementary particle length scales.

The unavoidable presence of long ranged classical electro-weak fields for space-time surfaces having CP_2 projection of dimension $D > 2$ and the smallness of the parity breaking effects in hadronic, nuclear and atomic length scales, poses strong interpretational problems. Similarly, the presence of classical long ranged color fields for non-vacuum extremals poses a deep interpretational problem.

Topological field quantization is completely new notion distinguishing classical TGD from Maxwellian electrodynamics. The presence of Kähler charge implies that 3-surface has outer boundary: the larger the charge the smaller the size of the 3-surface. This makes it possible to relate the size of the 3-surface (topological field quantum) to the Kähler charge of a typical particle in the condensate. The formation of macroscopic quantum systems, such as super conductors, corresponds to the formation of bonds between boundaries of the neighboring topological field quanta.

The huge vacuum degeneracy of the Kähler action implies analogy with spin glass phase and this leads to the idea that the effective quantum average space-time, topological condensate, determined as the absolute minimum of the effective action, can be naturally endowed with ultra-metric topology and consists of p-adic regions with different values of p glued together along their boundaries. A useful working hypothesis that various p-adic levels of the topological condensate form p-adic hierarchy ($p_1 \leq p_2$ can condense on p_2 and the typical size scale for surface at level p is given by L_p). According to the p-adic length scale hypothesis physically interesting length scales should come as square roots of powers of 2: $L(n) \simeq 2^{\frac{n}{2}} L_0$, $L_0 = k10^4\sqrt{G}$, $k \simeq 1.288$, n prime or power of prime. For condensed matter applications the interesting values of n are: $n = 127$ (Mersenne prime, electron Compton length), $n = 127, 131, 137, 139, 149,\ 151, 157, 167, 169...$ and it is of considerable interest to find whether these length scales correspond to quantum coherence lengths or other physically interesting length scales.

Finding a proper interpretation of classical gauge fields has turned to be the key interpretational problem and it many jumps outside of system has been required to end up with the recent view based on the application of quantum classical correspondence and the interpretation of the troublesome classical electro-weak and color gauge fields in terms of dark matter.

1.1 How to understand classical gauge charges and gauge coupling evolution at space-time level?

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. One cannot exclude the possibility that classical vectorial gauge charges are equal to their quantized counterparts. Gauge fluxes between space-time sheets can be transferred through # throats (as opposed to # contacts!) 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 is 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 super-symmetry 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 more 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.

The second question is whether it is possible to understand gauge coupling evolution at space-time level. Quantum criticality suggests that Kähler coupling strength and thus also other gauge couplings are renormalization group invariants for a given space-time sheet characterized by a p-adic prime p. Coupling constant evolution would thus be replaced with a discrete p-adic coupling constant evolution. This picture has turned out to have a precise space-time counterpart.

1.2 How long ranged classical electro-weak and color gauge fields can be consistent with the smallness of parity breaking effects and color confinement?

Long ranged electro-weak gauge fields are unavoidably present when the dimension D of the CP_2 projection of the space-time sheet is larger than 2. Classical color gauge fields are non-vanishing for all non-vacuum extremals. This poses deep interpretational problems. During years I have discussed several solutions to these problems.

Option I: The trivial solution of the constraints is that Z^0 charges are neutralized at electro-weak length scale. The problem is that this option leaves open the interpretation of classical long ranged electro-weak gauge fields unavoidably present in all length scales when the dimension for the CP_2 projection of the space-time surface satisfies $D > 2$.

Option II: Second option involves several variants but the basic assumption is that nuclei or even quarks feed their Z^0 charges to a space-time sheet with size of order neutrino Compton length. The smallness of parity breaking effects in hadronic, atomic, and nuclear length scales is not the only difficulty. The scattering of electrons, neutrons and protons in the classical long range Z^0 force contributes to the Rutherford cross section and it is very difficult to see how neutrino screening could make these effects small enough. Strong isotopic effects in condensed matter due to the classical Z^0 interaction energy are expected. It is far from clear whether all these constraints can be satisfied by any assumptions about the structure of topological condensate.

Option III: During 2005 (27 years after the birth of TGD!) third option solving the problems emerged based on the progress in the understanding of the basic mathematics behind TGD. In ordinary phase the Z^0 charges of elementary particles are indeed neutralized in intermediate boson length scale so that the problems related to the parity breaking trivialize. Besides this an infinite number of p-adic copies of ordinary QCD and electro-weak physics are predicted and can be assigned to dark matter defined in a very general sense.

Classical electro-weak gauge fields in macroscopic length scales are identified as space-time correlates for the gauge fields created by dark matter, which corresponds to a macroscopically quantum coherent phase for which elementary particles possibly possess complex conformal weights such that the net conformal weight of the system is real.

In this phase $U(2)_{ew}$ symmetry is not broken except for fermions so that gauge bosons are massless whereas fermion masses are essentially the same as for ordinary matter. By charge screening gauge bosons look massive in length scales much longer than the relevant p-adic length scale. The large parity breaking effects in living matter (chiral selection for bio-molecules) support the view that dark matter is what makes living matter living.

Classical long ranged color gauge fields always present for non-vacuum extremals are interpreted as space-time correlates of gluon fields associated with dark copies of hadron physics. It seems that this picture is indeed what TGD predicts.

1.3 Topological condensation and evaporation

Topological condensation and evaporation, interpreted rather naively, have been present from beginning in p-adic TGD but the proposed simple field theoretical model for these processes has not yielded any concrete applications. The realization that $\#$ ($\#_B$) contacts can be regarded as particles (string like objects) allows to develop a microscopic model for topological evaporation and condensation such that the basic new elements are splitting of $\#$ contact and fusion of topologically condensed CP_2 type extremals to $\#$ contact. The earlier quantum field theoretical model has only phenomenological value.

1.4 Organization of the chapter

The organization of this chapter is as follows:

1. A thorough consideration of notions of gauge charge, gauge flux, $\#$ and $\#_B$ contacts, etc. has turned out to be necessary for the formulation of theory of topological condensation and evaporation. The essential New Physics element is that $\#$ and $\#_B$ contacts involve parton pairs which do not correspond to ordinary elementary particles. The general theory theory of system in external fields is considered. Number theoretical ideas are applied to deduce a more quantitative view about how p-adic aspects of fundamental interactions.

2. It is demonstrated that the vision about p-adic coupling constant evolution has space-time counterpart in the sense that gauge charges for a given space-time sheet are RG invariants. Also an argument that they depend only only on the p-adic length scale characterizing the space-time sheet is developed. Also space-time view about the connection between electro-weak charge screening and effective massivation is developed.

3. The vision about dark matter as a new kind of phase of matter with elementary particles possessing complex super-canonical conformal weights and forming blocks with real conformal weights is discussed. This vision leads to the identification of long ranged classical electro-weak and color gauge fields as space-time correlates for massless dark gauge bosons associated with dark matter. Also matter antimatter asymmetry can be understood if antimatter is actually in negative energy dark matter phase.

4. A model for topological condensation and evaporation is discussed. The model is applied in elementary particle physics length scales. The identification of Pomeron as 'sea' is proposed. The small difference in the topological evaporation rates for particle and particle is discussed as an explanation for the generation of matter antimatter asymmetry. The proposed model reproduces correctly photon- baryon ratio. A variant of the model is based on the hypothesis that anti-matter is in dark matter phase.

2 Basic conceptual framework

The notions of topological condensate and p-adic length scale hierarchy are in a central role in TGD and for a long time it seemed that the physical interpretation of these notions is relatively straightforward. The evolution of number theoretical ideas however forced to suspect that the implications for physics might be much deeper and involve not only a solution to the mysteries of dark matter but also force to bring basic notions of TGD inspired theory of consciousness. At this moment the proper interpretation of the mathematical structures involving typically infinite hierarchies generalizing considerably the mathematical framework of standard physics is far from established so that it is better to represent just questions with some plausible looking answers.

2.1 Basic concepts

It is good to discuss the basic notions before discussing the definition of gauge charges and gauge fluxes.

2.1.1 CP_2 type vacuum extremals

CP_2 type extremals behave like elementary particles (in particular, light-likeness of M^4 projection gives rise to Virasoro conditions). CP_2 type vacuum extremals have however vanishing four-momentum although they carry classical color charges. This raises the question how they can gain elementary particle quantum numbers.

In topological condensation of CP_2 type vacuum extremal a light-like causal horizon is created. Number theoretical considerations strongly suggest that the horizon carries elementary particle numbers and can be identified as a parton. The quantum numbers or parton would serve as sources of the classical gauge fields created by the causal horizon.

In topological evaporation CP_2 type vacuum extremal carrying only classical color charges is created. This would suggest that the scattering of CP_2 type vacuum extremals defines a topological quantum field theory resulting as a limit of quantum gravitation (CP_2 is gravitational instanton) and that CP_2 type extremals define the counterparts of vacuum lines appearing in the formulation of generalized Feynman diagrams [C6].

2.1.2 # contacts as parton pairs

The earlier view about # contacts as passive mediators of classical gauge and gravitational fluxes is not quite correct. The basic modification is due to the fact that one can assign parton or parton pair to the # contact so that it becomes a particle like entity. This means that an entire p-adic hierarchy of new physics is predicted.

1. Formally # contact can be constructed by drilling small spherical holes S^2 in the 3-surfaces involved and connecting the spherical boundaries by a tube $S^2 \times D^1$. For instance, CP_2 type extremal can be glued to space-time sheet with Minkowskian signature or space-time sheets with Minkowskian signature can be connected by # contact having Euclidian signature of the induced metric. Also more general contacts are possible since S^2 can be replaced with a

2-surface of arbitrary genus and family replication phenomenon can be interpreted in terms of the genus.

The # contact connecting two space-time sheets with Minkowskian signature of metric is accompanied by two "elementary particle horizons", which are light-like 3-surfaces at which the induced 4-metric becomes degenerate. Since these surfaces are causal horizons, it is not clear whether # contacts can mediate classical gauge interactions. If there is an electric gauge flux associated with elementary particle horizon it tends to be either infinite by the degeneracy of the induced metric. It is not clear whether boundary conditions allow to have finite gauge fluxes of electric type. A similar difficulty is encountered when one tries to assign gravitational flux to the # contact: in this case even the existence of flux in non-singular case is far from obvious. Hence the naive extrapolation of Newtonian picture might not be quite correct.

2. Number theoretical considerations suggests that the two light-like horizons associated with # contacts connecting space-time sheets act as dynamical units analogous to shock waves or light fronts carrying quantum numbers so that the identification as partons is natural. Quantum holography would suggest itself in the sense that the quantum numbers associated with causal horizons would determine the long range fields inside space-time sheets involved.

3. # contacts can be modelled in terms of CP_2 type extremals topologically condensed simultaneously to the two space-time sheets involved. The topological condensation of CP_2 type extremal creates only single parton and this encourages the interpretation as elementary particle. The gauge currents for CP_2 type vacuum extremals have a vanishing covariant divergence so that there are no conserved charges besides Kähler charge. Hence electro-weak gauge charges are not conserved classically in the region between causal horizons whereas color gauge charges are. This could explain the vacuum screening of electro-weak charges at space-time level. This is required since for the known solutions of field equations other than CP_2 type extremals vacuum screening does not occur.

4. In the special case space-time sheets have opposite time orientations and the causal horizons carry opposite quantum numbers (with four-momentum included) the # contact would serve the passive role of flux mediator and one could assign to the contact generalized gauge fluxes as quantum numbers associated with the causal horizons. This is the case if the contact is created from vacuum in topological condensation so that the quantum numbers associated with the horizons define naturally generalized gauge fluxes. Kind of generalized quantum dipoles living in two space-times simultaneously would be in question. # contacts in the ground state for space-time sheets with opposite time orientation can be also seen as zero energy parton-antiparton pairs bound together by a piece of CP_2 type extremal.

5. When space-time sheets have same time orientation, the two-parton state associated with the # contact has non-vanishing energy and it is not clear whether it can be stable.

2.1.3 $\#_B$ contacts as bound parton pairs

Besides # contacts also join along boundaries bonds (JABs, $\#_B$ contacts) are possible. They can connect outer boundaries of space-time sheets or the boundaries of small holes associated with the interiors of two space-time sheets which can have Minkowskian signature of metric and can mediate classical gauge fluxes and are excellent candidates for mediators of gauge interactions between space-time sheet glued to a larger space-time sheet by topological sum contacts and join along boundaries contacts. The size scale of the causal horizons associated with parton pairs can be arbitrary whereas the size scale of # contacts is given by CP_2 radius.

The existence of the holes for real space-time surfaces is a natural consequence of the induced gauge field concept: for sufficiently strong gauge fields the imbeddability of gauge field as an induced gauge field fails and hole in space-time appears as a consequence. The holes connected by $\#_B$ contacts obey field equations, and a good guess is that they are light-like 3-surfaces and carry parton quantum numbers. This would mean that both # and $\#_B$ contacts allow a fundamental description in terms of pair of partons.

Magnetic flux tubes provide a representative example of $\#_B$ contact. Instead of $\#_B$ contact also more descriptive terms such as join along boundaries bond (JAB), color bond, and magnetic flux tube are used. $\#_B$ contacts serve also as a space-time correlate for bound state formation and one can even consider the possibility that entanglement might have braiding of bonds defined by # contacts as a space-time correlate [E9].

It seems difficult to exclude join along boundaries contacts between between holes associated with the two space-time sheets at different levels of p-adic hierarchy. If these contacts are possible, a transfer of conserved gauge fluxes would be possible between the two space-time sheets and one could speak about interaction in conventional sense.

2.1.4 Topological condensation and evaporation

Topological condensation corresponds to a formation of # or $\#_B$ contacts between space-time sheets. Topological evaporation means the splitting of # or $\#_B$ contacts. In the case of elementary particles the process changes almost nothing since the causal horizon carrying parton quantum numbers does not disappear. The evaporated CP_2 type vacuum extremal having interpretation as a gravitational instanton can carry only color quantum numbers.

As # contact splits partons are created at the two space-time sheets involved. This process can obviously generate from vacuum space-time sheets carrying particles with opposite signs of energies and other quantum numbers. Positive energy matter and negative energy anti-matter could be thus created by the formation of # contacts with zero net quantum numbers which then split to produce pair of positive and negative energy particles at different space-time sheets having opposite time orientations. This mechanism would allow a creation of positive energy matter and negative energy antimatter with an automatic separation of matter and antimatter at space-time sheets having different time orientation. This might resolve elegantly the puzzle posed by matter-antimatter asymmetry.

The creation of # contact leads to an appearance of radial gauge field in condensate and this seems to be impossible at the limit of infinitely large space-time sheet since it involves a radical instantaneous change in field line topology. The finite size of the space-time sheet can however resolve the difficulty.

If all quantum numbers of elementary particle are expressible as gauge fluxes, the quantum numbers of topologically evaporated particles should vanish. In the case of color quantum numbers and Poincare quantum numbers there is no obvious reason why this should be the case. Despite this the cancellation of the interior quantum numbers by those at boundaries or light-like causal determinants could occur and would conform with the effective 2-dimensionality stating that quantum states are characterized by partonic boundary states associated with causal determinants. This could be also seen as a holographic duality of interior and boundary degrees of freedom [A2].

2.2 Gauge charges and gauge fluxes

The concepts of mass and gauge charge in TGD has been a source of a chronic headache. There are several questions waiting for a definite answer. How to define gauge charge? What is the microscopic physics behind the gauge charges necessarily accompanying long range gravitational fields? Are these gauge charges quantized in elementary particle level? Can one associate to elementary particles classical electro-weak gauge charges equal to its quantized value or are all electro-weak charges screened at intermediate boson length scale? Is the generation of the vacuum gauge charges, allowed in principle by the induced gauge field concept, possible in macroscopic length scales? What happens to the gauge charges in topological evaporation? Should Equivalence Principle be modified in order to understand the fact that Robertson-Walker metrics are inertial but not gravitational vacua.

2.2.1 How to define the notion of gauge charge?

In TGD gauge fields are not primary dynamical variables but induced from the spinor connection of CP_2. There are two manners to define gauge charges.

1. In purely group theoretical approach one can associate non-vanishing gauge charge to a 3-surface of finite size and quantization of the gauge charge follows automatically. This definition should work at Planck length scales, when particles are described as 3-surfaces of CP_2 size and classical space-time mediating long range interactions make no sense. Gauge interactions are mediated by gauge boson exchange, which in TGD has topological description in terms of CP_2 type extremals [C4].
2. Second definition of gauge charge is as a gauge flux over a closed surface. In this case quantization is not obvious nor perhaps even possible at classical level except perhaps for Abelian charges. For a closed 3-surface gauge charge vanishes and one might well argue that this is the case for finite 3-surface with boundary since the boundary conditions might well generate gauge charge near the boundary cancelling the gauge charge created by particles condensed on 3-surface. This would mean that at low energies (photon wavelength large than size of the 3-surfaces) the 3-surfaces in vapor phase look like neutral particles. Only at high energies the evaporated particles would behave as ordinary elementary particles. Furthermore, particle leaves in topological evaporation its gauge charge in the condensate.

The alternative possibility that the long range $\frac{1}{r^2}$ gauge field associated with particle disappears in the evaporation, looks topologically impossible at the limit when larger space-time sheet has infinite size: only the simultaneous evaporation of opposite gauge charges might be possible in this manner at this limit. Topological evaporation provides a possible mechanism for the generation of vacuum gauge charges, which is one basic difference between TGD and standard gauge theories.

There is a strong temptation to draw a definite conclusion but it is better to be satisfied with a simplifying working hypothesis that gauge charges are in long length scales definable as gauge fluxes and vanish for macroscopic 3-surfaces of finite size in vapor phase. This would mean that the topological evaporation of say electron as an electromagnetically charged particle would not be possible except at CP_2 length scale: in the evaporation from secondary condensation level electron would leave its gauge charges in the condensate. Vapor phase particle still looks electromagnetically charged in length scales smaller than the size of the particle surface if the neutralizing charge density is near (or at) the boundary of the surface and gauge and gravitational interactions are mediated by the exchange of CP_2 type extremals.

2.2.2 In what sense could # contacts feed gauge fluxes?

One can associate with the # throats magnetic gauge charges $\pm Q_i$ defined as gauge flux running to or from the throat. The magnetic charges are of opposite sign and equal magnitude on the two space-time sheets involved. For Kähler form the value of magnetic flux is quantized and non-vanishing only if the the $t = constant$ section of causal horizon corresponds to a non-trivial homology equivalence class in CP_2 so that # contact can be regarded as a homological magnetic monopole. In this case # contacts can be regarded as extremely small magnetic dipoles formed by tightly bound # throats possessing opposite magnetic gauge charges. # contacts couple to the difference of the classical gauge fields associated with the two space-time sheets and matter-# contact and # contact-# contact interaction energies are in general non-vanishing.

Electric gauge fluxes through # throat evaluated at the light-like elementary particle horizon X_l^3 tend to be either zero or infinite. The reason is that without appropriate boundary conditions the normal component of electric $F^{tn}\sqrt{(g_4)}/g^2$ either diverges or is infinite since g^{tt} diverges by the effective three-dimensionality of the induced metric at X_l^3. In the gravitational case an additional difficulty is caused by the fact that it is not at all clear whether the notion of gravitational flux is well defined. It is however possible to assign gravitational mass to a given space-time sheets as will be found in the section about space-time description of charge renormalization.

The simplest conclusion would be that the notions of gauge and gravitational fluxes through # contacts do not make sense and that # contacts mediate interactions in a more subtle manner. For instance, for a space-time sheet topologically condensed at a larger space-time sheet the larger space-time sheet would characterize the basic coupling constants appearing in the S-matrix associated with the topologically condensed space-time sheets. In particular, the value of $\hbar$ would characterize the relation between the two space-time sheets. A stronger hypothesis would be that the value of $\hbar$ is coded partially by the Jones inclusion between the state spaces involved. The larger space-time sheet would correspond to dark matter from the point of view of smaller space-time sheet [C7, F9].

One can however try to find loopholes in the argument.

1. It might be possible to pose the finiteness of $F^{tn}\sqrt{g_4}/g^2$ as a boundary condition. The variation principle determining space-time surfaces implies that space-time surfaces are analogous to Bohr orbits so that there are also hopes that gauge fluxes are quantized.

2. Another way out of this difficulty could be based on the basic idea behind renormalization in TGD framework. Gauge coupling strengths are allowed to depend on space-time point so that the gauge currents are conserved. Gauge coupling strengths $g^2/4\pi$ could become infinite at causal horizon. The infinite values of gauge couplings at causal horizons might be a TGD counterpart for the infinite values of bare gauge couplings in quantum field theories. There are however several objections against this idea. The values of coupling constants should depend on space-time sheet only so that the situation is not improved by this trick in CP_2 length scale. Dependence of g^2 on space-time point means also that in the general case the definition of gauge charge as gauge flux is lost so that gauge charges do not reduce to fluxes.

It seems that the notion of a finite electric gauge flux through the causal horizon need not make sense as such. Same applies to the notion of gravitational gauge flux. The notion of gauge flux seems however to have a natural quantal generalization. The creation of a # contact between two space-time sheets creates two causal horizons identifiable as partons and carrying conserved charges assignable with the states created using the fermionic oscillator operators associated with the second quantized induced spinor field. These charges must be of opposite sign so that electric gauge fluxes through causal horizons are replaced by quantal gauge charges. For opposite time orientations also four-momenta cancel each other. The particle states can of course transform by interactions with matter at the two-space-time sheets so that the resulting contact is not a zero energy state always.

This suggests that for gauge fluxes at the horizon are identifiable as opposite quantized gauge charges of the partons involved. If the the net gauge charges of # contact do not vanish, it can be said to possess net gauge charge and does not serve as a passive flux mediator anymore. The possibly screened classical gauge fields in the region faraway from the contact define the classical correlates for gauge fluxes. A similar treatment applies to gravitational flux in the case that the time orientations are opposite and gravitational flux is identifiable as gravitational mass at the causal horizon.

Internal consistency would mildly suggest that # contacts are possible only between space-time sheets of opposite time orientation so that gauge fluxes between space-time sheets of same time orientation would flow along $\#_B$ bonds.

2.2.3 Are the gauge fluxes through # and $\#_B$ contacts quantized?

There are good reasons (the absolute minimization of the Kähler action plus maximization of the Kähler function) to expect that the gauge fluxes through # (if well-defined) and $\#_B$ contacts are quantized. The most natural guess would be that the unit of electric electromagnetic flux for $\#_B$ contact is 1/3 since this makes it possible for the electromagnetic gauge flux of quarks to flow to larger space-time sheets. Anyons could however mean more general quantization rules [E9]. The quantization of electromagnetic gauge flux could serve as a unique experimental signature for # and $\#_B$ contacts and their currents. The contacts can carry also magnetic fluxes. In the case of $\#_B$ contacts the flux quantization would be dynamical and analogous to that appearing in super conductors.

2.2.4 Hierarchy of gauge and gravitational interactions

The observed elementary particles are identified as CP_2 type extremals topologically condensed at space-time sheets with Minkowski signature of induced metric with elementary particle horizon being responsible for the parton aspect. This suggests that at CP_2 length scale gauge and gravitational interactions correspond to the exchanges of CP_2 type extremals with light-like M^4 projection with branching of CP_2 type extremal serving as the basic vertex as discussed in [C4]. The gravitational and gauge interactions between the partons assignable to the two causal horizons associated with # contact would be mediated by the # contact, which can be regarded as a gravitational instanton and the interaction with other particles at space-time sheets via classical gravitational fields.

Gauge fluxes flowing through the $\#_B$ contacts would mediate higher level gauge and interactions between space-time sheets rather than directly between CP_2 type extremals. The hierarchy of flux tubes defining string like objects strongly suggests a p-adic hierarchy of "strong gravities" with gravitational constant of order $G \sim L_p^2$, and these strong gravities might correspond to gravitational fluxes mediated by the flux tubes.

2.3 Can one regard # *resp.* $\#_B$ contacts as particles *resp.* string like objects?

#-contacts have obvious particle like aspects identifiable as either partons or parton pairs. $\#_B$ contacts in turn behave like string like objects. Using the terminology of M-theory, $\#_B$ contacts connecting the boundaries of space-time sheets could be also seen as string like objects connecting two branes. Again the ends holes at the ends of $\#_B$ contacts carry well defined gauge charges.

2.3.1 # contacts as particles and $\#_B$ contacts as string like objects?

The fact that # contacts correspond to parton pairs raises the hope that it is possible to apply p-adic thermodynamics to calculate the masses of # contact and perhaps even the masses of the partons. If this the case, one has an order of magnitude estimate for the first order contribution to the mass of the parton as $m \sim 1/L(p_i)$, $i = 1, 2$. It can of course happen that the first order contribution vanishes: in this case an additional factor $1/\sqrt{p_i}$ appears in the estimate and makes the mass extremely small.

For # contacts connecting space-time sheets with opposite time orientations the vanishing of the net four-momentum requires $p_1 = p_2$. According to the number theoretic considerations below it is possible to assign several p-adic primes to a given space-time sheet and the largest among them, call it p_{max}, determines the p-adic mass scale. The milder condition is that p_{max} is same for the two space-time sheets.

There are some motivations for the working hypothesis that # contacts and the ends of $\#_B$ contacts feeding the gauge fluxes to the lower condensate levels or vice versa tend to be located near the boundaries of space-time sheets. For gauge charges which are not screened by vacuum charges (em and color charges) the imbedding of the gauge fields created by the interior gauge charges becomes impossible near the boundaries and the only possible manner to satisfy boundary conditions is that gauge fluxes flow to the larger space-time sheet and space-time surface becomes a vacuum extremal of the Kähler action near the boundary.

For gauge bosons the density of boundary $\#_B$ contacts should be very small in length scales, where matter is essentially neutral. For gravitational $\#_B$ contacts the situation is different. One might well argue that there is some upper bound for the gravitational flux associated with single # or $\#_B$ contact (or equivalently the gravitational mass associated with causal horizon) given by Planck mass or CP_2 mass so that the number of gravitational contacts is proportional to the mass of the system.

The TGD based explanation for Podkletnov effect [26] is based on the assumption that magnetically charged # contacts are carries of gravitational flux equal to Planck mass and predicts effect with correct order of magnitude. The model generalizes also to the case of $\#_B$ contacts. The lower bound for the gravitational flux quantum must be rather small: the mass $1/L(p)$ determined by the p-adic prime associated with the larger space-time sheet is a first guess for the unit of flux.

2.3.2 Could # and $\#_B$ contacts form macroscopic quantum phases?

The description as # contact as a parton pair suggests that it is possible to assign to # contacts inertial mass, say of order $1/L(p)$, they should be describable using d'Alembert type equation for a scalar field. # contacts couple dynamically to the geometry of the space-time since the induced metric defines the d'Alembertian. There is a mass gap and hence # contacts could form a Bose-Einstein (BE) condensate to the ground state. If # contacts are located near the boundary of the space-time surface, the d'Alembert equation would be 3-dimensional. One can also ask whether # contacts define a particular form of dark matter having only gravitational interactions with the ordinary matter.

Also coherent states of # contacts are possible and as will be found, Higgs mechanism could be understood as a generation of coherent state of neutral Higgs particles identified as wormhole contacts having quantum numbers of left (right) handed fermion and right (left) handed antifermion.

Also the probability amplitudes for the positions of the ends of $\#_B$ contacts located at the boundary of the space-time sheet could be described using an order parameter satisfying d'Alembert equation with some mass parameter and whether the notion of Bose-Einstein condensate makes sense also now. The model for atomic nucleus assigns to the ends of the $\#_B$ contact realized as a color magnetic flux tube quark and anti-quark with mass scale given by $k = 127$ (MeV scale) [F8].

This inspires the question whether # and $\#_B$ contacts could be essential for understanding biosystems as macroscopic quantum systems [I3]. The BE condensates/coherent states associated with the # contacts would behave in many respects like super conductor: for instance, the concept of Josephson junction generalizes. As a matter fact, it seems that $\#_B$ contacts, join along boundaries, or magnetic flux tubes could indeed be a key element of not only living matter but even nuclear matter and condensed matter in TGD Universe.

2.4 The relationship between inertial gravitational masses

It took quite a long time to accept the obvious fact that the relationship between inertial and gravitational masses cannot be quite the same as in General Relativity.

2.4.1 Modification of the Equivalence Principle?

The findings of [D3] combined with the basic facts about imbeddings of Robertson-Walker cosmologies [D5] force the conclusion that inertial mass density vanishes in cosmological length scales. This is possible if the sign of inertial energy depends on time orientation of the space-time sheet. This forces a modification of Equivalence Principle. The modified Equivalence Principle states that gravitational energy corresponds to the absolute value of inertial energy. Since inertial energy can have both signs, this means that gravitational mass is not conserved and is non-vanishing even for vacuum extremals. This differences is dual for the two time times: the experienced time identifiable as a sequence of quantum jumps and geometric time.

More generally, all conserved (that is Noether-) charges of the Universe vanish identically and their densities vanish in cosmological length scales. The simplest generalization of the Equivalence Principle would be that gravitational four-momentum equals to the absolute value of inertial four-momentum and is thus not conserved in general. Gravitational mass density does not vanish for vacuum extremals and, as will be found, one can deduce the renormalization of gravitational constant at given space-time sheet from the requirement that gravitational mass is conserved inside given space-time sheet. The conservation law holds only true inside given space-time sheet.

An interesting question is whether inertial-gravitational duality generalizes to the case of color gauge charges so that color gauge fluxes would correspond to "gravitational" color charges and the charges defined by the conserved currents associated with color isometries would define "inertial" color charges. Since induced color fields are proportional to color Hamiltonians multiplied by Kähler form they vanish identically for vacuum extremals in accordance with "gravitational" color confinement.

2.4.2 # contacts, non-conservation of gauge charges and gravitational four-momentum, and Higgs mechanism

Gravitational # contacts are necessary and if gravitational energy can be regarded in the Newtonian limit as a gauge charge, the contacts feed the gravitational energy regarded as a gauge flux to the lower condensate levels. The non-conservation of gravitational gauge flux means that # contacts can carry gravitational four-momentum and since CP_2 type vacuum extremals are the natural candidates for # contacts, the natural hypothesis is that the non-conserved light-like gravitational four-momentum of # contacts is responsible for the non-conservation of gravitational four-momentum flux. The non-conservation of the light-like gravitational four-momentum of CP_2 type extremals would in turn be responsible for the non-conservation of the net gravitational four-momentum.

contacts could be also carriers of inertial mass which must be conserved in absence of four-momentum exchange between environment and wormhole contact. Therefore Equivalence Principle cannot hold true in a strict sense even at elementary particle level. Equivalence Principle would be satisfied in a weak sense if the inertial four-momentum is equal to the average four-momentum associated with the zitterbewegung motion and corresponds to the center of mass motion for the # contact.

The non-conservation of weak gauge currents for CP_2 type extremals implies a non-conservation of weak charges and the finite range of weak forces. If wormhole contacts correspond to pieces of CP_2 type vacuum extremal, electro-weak gauge currents are not conserved classically unlike color and Kähler current. The non-conservation of weak isospin corresponds to the presence of pairs of right/left handed fermion and left/right handed antifermion at wormhole contacts. These wormhole contacts are excellent candidates for the TGD counterpart of Higgs boson providing the most natural mechanism for the massivation of weak bosons. The dominant contribution to fermion mass would be due to p-adic thermodynamics [F3]. If weak form of Equivalence Principle holds true, inertial mass would result simply as the average of non-conserved light-like gravitational four-momentum.

There would be two contributions to the mass of the elementary particle.

1. Part of the inertial mass is generated in the topological condensation of CP_2 type extremal representing elementary particle involving only single light like elementary particle horizon, say fermion, and would correspond naturally to the contribution to the mass modellable using p-adic thermodynamics. The contribution from primary topological condensation is negligible if the radius of the zitterbewegung orbit is larger than the size of the space-time sheet containing the topologically condensed boson so that the motion is along a light-like geodesic in a good approximation. For gauge bosons this contribution should be very small or vanishing. Systems like superconductors where also photons and even gravitons can become massive [D3] might form an exception in this respect.

2. The space-time sheet representing massless state suffered secondary topological condensation at a larger space-time sheet and viewed as a particle can develop an additional contribution to the mass via Higgs mechanism since the wormhole contacts cannot be regarded as moving along light like geodesics of M^4 in the length and time scale involved. # contacts carrying a net weak isospin would have interpretation as TGD counterparts of neutral Higgs bosons and the formation of coherent state involving a superposition of states with varying number of wormhole contacts would correspond to the generation of a vacuum expectation value of Higgs field. The inertial mass of the wormhole contact must be small, presumably its order of magnitude is given by $1/L_p$, where L_p is the characteristic p-adic length scale associated with a given condensate level.

There has been considerable further progress in the understanding of Higgs mechanism.

1. The generalized complex eigenvalues λ of the modified Dirac operator which can depend on position are excellent candidates for the space-time correlate of order parameter representing the Higgs expectation value [C1]. These eigenvalues can be also regarded as a complex square roots of real conformal weights since their modulus squared has the role of mass squared. In this framework Higgs expectation can be interpreted as a thermal expectation for λ.

2. The view about fermions as wormhole throats and about gauge bosons (see section below) and Higgs as pairs of wormhole throats associated with wormhole contacts suggests strongly that fermions cannot develop vacuum expectation value of Higgs. This hypothesis is consistent with the notion of generalized Feynman diagram and with p-adic mass calculations and leads to a very stringent model of hadron masses based on the experimental value range for top quark mass [F4, F5]. There is also an argument allowing to deduce the p-adic temperature assignable to gauge bosons [C5] and the predicted value of p-adic temperature is so low ($T_p = 1/26$) that only Higgs contribution to the gauge boson mass matters. For fermions p-adic temperature equals to $T_p = 1$.

2.4.3 Gravitational mass is necessarily accompanied by non-vanishing gauge charges

The experience from the study of the extremals of the Kähler action [D1] suggests that for non-vacuum extremals at astrophysical scales Kähler charge doesn't depend on the properties of the condensate and is apart from numerical constant equal to the gravitational mass of the system using Planck mass as unit:

$$Q_K = \epsilon_1 \frac{M_{gr}}{m_{proton}} \ . \qquad (1)$$

The condition $\frac{\epsilon_1}{\sqrt{\alpha_K}} < 10^{-19}$ must hold true in astrophysical length scales since the long range gauge force implied by the Kähler charge must be weaker than gravitational interaction at astrophysical length scales. It is not clear whether the 'anomalous' Kähler charge can correspond to a mere Z^0 gauge or em charge or more general combination of weak charges.

Also for the imbedding of Schwartschild and Reissner-Nordström metrics as vacuum extremals non-vanishing gravitational mass implies that some electro-weak gauge charges are non-vanishing [D1]. For vacuum extremals with $sin^2(\theta_W) = 0$ em field indeed vanishes whereas Z^0 gauge field is non-vanishing.

If one assumes that the weak charges are screened completely in electro-weak length scale, the anomalous charge can be only electromagnetic if it corresponds to ordinary elementary particles. This however need not be consistent with field equations. Perhaps the most natural interpretation for the "anomalous" gauge charges is due to the elementary charges associated with dark matter. Since weak charges are expected to be screened in the p-adic length scale characterizing weak boson mass scale, the implication is that scaled down copies of weak bosons with arbitrarily small mass scales and arbitrarily long range of interaction are predicted. Also long ranged classical color gauge fields are unavoidable which forces to conclude that also a hierarchy of scaled down copies of gluons exists.

One can hope that photon and perhaps also Z^0 and color gauge charges in Cartan algebra could be quantized classically at elementary particle length scale ($p \leq M_{127}$, say) and electromagnetic gauge charge in all length scales apart from small renormalization effects. One of the reasons is that classical electromagnetic fields make an essential part in the description of, say, hydrogen atom.

The study of the extremals of Kähler action and of the imbeddings of spherically symmetric metrics [D3, D1] shows that the imbeddings are characterized by frequency type vacuum quantum numbers, which allow to fix these charges to pre-determined values. The minimization of Kähler action for a space-time surface containing a given 3-surface leads to the quantization of the vacuum parameters and hopefully to charge quantization. This motivates the hypothesis that the electromagnetic charges associated with the classical gauge fields of topologically condensed elementary particles are equal to their quantized counterparts. The discussion of dark matter leads to the conclusion that electro-weak and color gauge charges of dark matter can be non-vanishing [J6, F9].

2.5 TGD based description of external fields

The description of a system in external field provides a nontrivial challenge for TGD since the system corresponds now to a p-adic space-time sheet k_1 condensed on background 3-surface $k_2 > k_1$. The problem is to understand how external fields penetrate into the smaller space-time sheet and also how the gauge fluxes inside the smaller space-time sheet flow to the external space-time sheet. One should also understand how the penetrating magnetic or electric field manages to preserve its value (if it does so). A good example is provided by the description of system, such as atom or nucleus, in external magnetic or electric field. There are several mechanisms of field penetration:

2.5.1 Induction mechanism

In the case of induction fields are mediated from level k_1 to levels $k_2 \neq k_1$. The external field at given level k_1 acts on $\#$ and $\#_B$ throats (both accompanied by a pair of partons) connecting levels k_2 and k_1. The motion of $\#$ and $\#_B$ contacts, induced by the gauge and gravitational couplings of partons involved to classical gauge and gravitational fields, creates gauge currents serving as sources of classical gauge field at the space-time sheets involved. This mechanism involves "dark" partons not predicted by standard model.

A good example is provided by the rotation of charged $\#$ throats induced by a constant magnetic field, which in turn creates constant magnetic field inside a cylindrical condensate space-time sheet.

A second example is the polarization of the charge density associated with the # throats in the external electric field, which in turn creates a constant electric field inside the smaller space-time sheet.

One can in principle formulate general field equations governing the penetration of a classical gauge field from a given condensate level to other levels. The simplified description is based on the introduction of series of fields associated with various condensate levels as analogs of H and B and D and E fields in the ordinary description of the external fields. The simplest assumption is that the fields are linearly related. A general conclusion is that due to the delicacies of the induced field concept, the fields on higher levels appear in the form of flux quanta and typically the field strengths at the higher condensate levels are stronger so that the penetration of field from lower levels to the higher ones means a decomposition into separate flux tubes.

The description of magnetization in terms of the effective field theory of Weiss introduces effective field H, which is un-physically strong: a possible explanation as a field consisting of flux quanta at higher condensate levels. A general order of magnitude estimate for field strength of magnetic flux quantum at condensate level k is as $1/L^2(k)$.

2.5.2 Penetration of magnetic fluxes via # contacts

At least magnetic gauge flux can flow from level p_1 to level p_2 via # contacts. These surfaces are of the form $X^2 \times D^1$, where X^2 is a closed 2-surface. The simplest topology for X^2 is that of sphere S^2. This leads to the first nontrivial result. If a nontrivial magnetic flux flows through the contact, it is quantized. The reason is that magnetic flux is necessarily over a closed surface.

The concept of induced gauge field implies that magnetic flux is nontrivial only if the surface X^2 is homologically nontrivial: CP_2 indeed allows homologically nontrivial sphere. Ordinary magnetic field can be decomposed into co-homologically trivial term plus a term proportional to Kähler form and the flux of ordinary magnetic field comes only from the part of the magnetic field proportional to the Kähler form and the magnetic flux is an integer multiple of some basic flux.

The proposed mechanism predicts that magnetic flux can change only in multiples of basic flux quantum. In super conductors this kind of behavior has been observed. Dipole magnetic fields can be transported via several # contacts: the minimum is one for ingoing and one for return flux so that magnetic dipoles are actual finite sized dipoles on the condensed surface. Also the transfer of magnetic dipole field of, say neutron inside nucleus, to lower condensate level leads to similar magnetic dipole structure on condensate level. For this mechanism the topological condensation of elementary particle, say charged lepton space-time sheet, would involve at least two # contacts and the magnetic moment is proportional to the distance between these contacts. The requirement that the magnetic dipole formed by the # contacts gives the magnetic moment of the particle gives an estimate for the distance d between # throats: by flux quantization the general order of magnitude is given by $d \sim \frac{\alpha_{em} 2\pi}{m}$.

2.5.3 Penetration of electric gauge fluxes via # contacts

For # contact for the opposite gauge charges of partons define the value of generalized gauge electric flux between the two space-time sheets. In this case it is also possible to interpret the partons as sources of the fields at the two space-time sheets. If the # contacts are near the boundary of the smaller space-time sheet the interpretation as a flow of gauge flux to a larger space-time sheet is perfectly sensible. The partons near the boundary can be also seen as generators of a gauge field compensating the gauge fluxes from interior.

The distance between partons can be much larger than p-adic cutoff length $L(k)$ and a proper spatial distribution guarantees homogeneity of the magnetic or electric field in the interior. The distances of the magnetic monopoles are however large in this kind of situation and it is an open problem whether this kind of mechanism is consistent with experimental facts.

An estimate for the electric gauge flux Q_{em} flowing through the # contact is obtained as $n \sim \frac{E}{QL(k)}$: $Q \sim EL^2(k)$, which is of same order of magnitude as electric gauge flux over surface of are $L^2(k)$. In magnetic case the estimate gives $Q_M \sim BL^2(k)$: the quantization of Q_M is consistent with homogeneity requirement only provided the condition $B > \frac{\Phi_0}{L^2(k)}$, where Φ_0 is elementary flux quantum, holds true. This means that flux quantization effects cannot be avoided in weak magnetic fields. The second consequence is that too weak magnetic field cannot penetrate at all to the condensed surface: this is certainly the case if the total magnetic flux is smaller than elementary flux quantum. A good example is provided by the penetration of magnetic field into cylindrical super conductor through the end of the cylinder. Unless the field is strong enough the penetrating magnetic field decomposes into vortex like flux tubes or does not penetrate at all.

The penetration of flux via dipoles formed by # contacts from level to a second level in the interior of condensed surface implies phenomena analogous to the generation of polarization (magnetization) in dielectric (magnetic) materials. The conventional description in terms of fields H, B, M and D, E, P has nice topological interpretation (which does not mean that the mechanism is actually at work in condensed matter length scales). Magnetization M (polarization P) can be regarded as the density of fictitious magnetic (electric) dipoles in the conventional theory: the proposed topological picture suggests that these quantities essentially as densities for # contact pairs. The densities of M and P are of opposite sign on the condensed surface and condensate. $B = H - M$ corresponds to the magnetic field at condensing surface level reduced by the density $-M$ of # contact dipoles in the interior. H denotes the external field at condensate level outside the condensing surface, M $(-M)$ is the magnetic field created by the # contact dipoles at condensate (condensed) level. Similar interpretation can be given for D, E, P fields. The penetrating field is homogenous only above length scales larger than the distance between # throats of dipoles: p-adic cutoff scale $L(k)$ gives natural upper bound for this distance: if this is the case and the density of the contacts is at least of order $n \sim \frac{1}{L^3(k)}$ the penetrating field can be said to be constant also inside the condensed surface.

In condensed matter systems the generation of ordinary polarization and magnetization fields might be related to the permanent # contacts of atomic surfaces with, say, $k = 139$ level. The field created by the neutral atom contains only dipole and higher multipoles components and therefore at least two # contacts per atom is necessary in gas phase, where join along boundaries contacts between atoms are absent. In the absence of external field these dipoles tend to have random directions. In external field # throats behave like opposite charges and their motion in external field generates dipole field. The expression of the polarization field is proportional to the density of these static dipole pairs in static limit. # contacts make possible the penetration of external field to atom, where it generates atomic transitions and leads to the emission of dipole type radiation field, which gives rise to the frequency dependent part of dielectric constant.

2.5.4 Penetration via $\#_B$ contacts

The field can also through $\#_B$ contacts through the boundary of the condensed surface or through the small holes in its interior. The quantization of electric charge quantization would reduce to the quantization of electric gauge flux in $\#_B$ contacts. If there are partons at the ends of contact they affect the gauge gauge flux.

The penetration via $\#_B$ contacts necessitates the existence of join along boundaries bonds starting from the boundary of the condensed system and ending to the boundary component of a hole in the background surface. The field flux flows simply along the 3-dimensional stripe $X^2 \times D^1$: since X^2 has boundary no flux quantization is necessary. This mechanism guarantees automatically the homogeneity of the penetrating field inside the condensed system.

An important application for the theory of external fields is provided by bio-systems in which the penetration of classical electromagnetic fields between different space-time sheets should play central role: what makes the situation so interesting is that the order parameter describing the # and $\#_B$ Bose-Einstein condensates carries also phase information besides the information about the strength of the normal component of the penetrating field.

2.6 Number theoretical considerations

Number theoretical considerations allow to develop more quantitative vision about the how p-adic length scale hypothesis relates to the ideas just described.

2.6.1 How to define the notion of elementary particle?

p-Adic length scale hierarchy forces to reconsider carefully also the notion of elementary particle. p-Adic mass calculations led to the idea that particle can be characterized uniquely by single p-adic prime characterizing its mass squared. It however turned out that the situation is probably not so simple.

The work with modelling dark matter suggests that particle could be characterized by a collection of p-adic primes to which one can assign weak, color, em, gravitational interactions, and possibly also other interactions. It would also seem that only the space-time sheets containing common primes in this collection can interact. This leads to the notions of relative and partial darkness. An entire hierarchy of weak and color physics such that weak bosons and gluons of given physics are characterized by a given p-adic prime p and also the fermions of this physics contain space-time sheet characterized by same p-adic prime, say M_{89} as in case of weak interactions. In this picture the decay widths of weak bosons do not pose limitations on the number of light particles if weak interactions for them are characterized by p-adic prime $p \neq M_{89}$. Same applies to color interactions.

The p-adic prime characterizing the mass of the particle would perhaps correspond to the largest p-adic prime associated with the particle. Graviton which corresponds to infinitely long ranged interactions, could correspond to the same p-adic prime or collection of them common to all particles. This might apply also to photons. Infinite range might mean that the join along boundaries bonds mediating these interactions can be arbitrarily long but their transversal sizes are characterized by the p-adic length scale in question.

The natural question is what this collection of p-adic primes characterizing particle means? The hint about the correct answer comes from the number theoretical vision, which suggests that at fundamental level the branching of boundary components to two or more components, completely analogous to the branching of line in Feynman diagram, defines vertices [C4, C6, E3].

1. If space-time sheets correspond holographically to multi-p p-adic topology such that largest p determines the mass scale, the description of particle reactions in terms of branchings indeed makes sense. This picture allows also to understand the existence of different scaled up copies of QCD and weak physics. Multi-p p-adicity could number theoretically correspond to q-adic topology for $q = m/n$ a rational number consistent with p-adic topologies associated with prime factors of m and n ($1/p$-adic topology is homeomorphic with p-adic topology).

2. One could also imagine that different p-adic primes in the collection correspond to different space-time sheets condensed at a larger space-time sheet or boundary components of a given space-time sheet. If the boundary topologies for gauge bosons are completely mixed, as the model of hadrons forces to conclude, this picture is consistent with the topological explanation of the family replication phenomenon and the fact that only charged weak currents involve mixing of quark families. The problem is how to understand the existence of different copies of say QCD. The second difficult question is why the branching leads always to an emission of gauge boson characterized by a particular p-adic prime, say M_{89}, if this p-adic prime does not somehow characterize also the particle itself.

2.6.2 What effective p-adic topology really means?

The need to characterize elementary particle p-adically leads to the question what p-adic effective topology really means. p-Adic mass calculations leave actually a lot of room concerning the answer to this question.

1. The naivest option is that each space-time sheet corresponds to single p-adic prime. A more general possibility is that the boundary components of space-time sheet correspond to different p-adic primes. This view is not favored by the view that each particle corresponds to a collection of p-adic primes each characterizing one particular interaction that the particle in question participates.

2. A more abstract possibility is that a given space-time sheet or boundary component can correspond to several p-adic primes. Indeed, a power series in powers of given integer n gives rise to a well-defined power series with respect to all prime factors of n and effective multi-p-adicity could emerge at the level of field equations in this manner.

One could say that space-time sheet or boundary component corresponds to several p-adic primes through its effective p-adic topology in a hologram like manner. This option is the most flexible one as far as physical interpretation is considered. It is also supported by the number theoretical considerations predicting the value of gravitational coupling constant [E3].

An attractive hypothesis is that only space-time sheets characterized by integers n_i having common prime factors can be connected by join along boundaries bonds and can interact by particle exchanges and that each prime p in the decomposition corresponds to a particular interaction mediated by an elementary boson characterized by this prime.

The physics of quarks and hadrons provides an immediate test for this interpretation. The surprising and poorly understood conclusion from the p-adic mass calculations was that the p-adic primes characterizing light quarks u,d,s satisfy $k_q < 107$, where $k = 107$ characterizes hadronic space-time sheet [F4].

1. The interpretation of $k = 107$ space-time sheet as a hadronic space-time sheet implies that quarks topologically condense at this space-time sheet so that $k = 107$ cannot belong to the collection of primes characterizing quark.

2. Quark space-time sheets must satisfy $k_q < 107$ unless $\hbar$ is large for the hadronic space-time sheet so that one has $k_{eff} = 107+22 = 129$. This predicts two kinds of hadrons. Low energy hadrons consists of u, d, and s quarks with $k_q < 107$ so that hadronic space-time sheet must correspond to $k_{eff} = 129$ and large value of $\hbar$. One can speak of confined phase. This allows also $k = 127$ light variants of quarks appearing in the model of atomic nucleus [F8]. The hadrons consisting of c,t,b and the p-adically scaled up variants of u,d,s having $k_q > 107$, $\hbar$ has its ordinary value in accordance with the idea about asymptotic freedom and the view that the states in question correspond to short-lived resonances.

2.6.3 Do infinite primes code for q-adic effective space-time topologies?

Besides the hierarchy of space-time sheets, TGD predicts, or at least suggests, several hierarchies such as the hierarchy of infinite primes [E3], hierarchy of Jones inclusions [C7], hierarchy of dark matters with increasing values of $\hbar$ [F9, J6], the hierarchy of extensions of given p-adic number field, and the hierarchy of selves and quantum jumps with increasing duration with respect to geometric time. There are good reasons to expect that these hierarchies are closely related.

1. Some facts about infinite primes

The hierarchy of infinite primes can be interpreted in terms of an infinite hierarchy of second quantized super-symmetric arithmetic quantum field theories allowing a generalization to quaternionic or perhaps even octonionic context [E3]. Infinite primes, integers, and rationals have decomposition to primes of lower level.

Infinite prime has fermionic and bosonic parts having no common primes. Fermionic part is finite and corresponds to an integer containing and bosonic part is an integer multiplying the product of all primes with fermionic prime divided away. The infinite prime at the first level of hierarchy corresponds in a well defined sense a rational number $q = m/n$ defined by bosonic and fermionic integers m and n having no common prime factors.

2. Do infinite primes code for effective q-adic space-time topologies?

The most obvious question concerns the space-time interpretation of this rational number. Also the question arises about the possible relation with the integers characterizing space-time sheets having interpretation in terms of multi-p-adicity. On can assign to any rational number $q = m/n$ so called q-adic topology. This topology is not consistent with number field property like p-adic topologies. Hence the rational number q assignable to infinite prime could correspond to an effective q-adic topology.

If this interpretation is correct, arithmetic fermion and boson numbers could be coded into effective q-adic topology of the space-time sheets characterizing the non-determinism of Kähler action in the relevant length scale range. For instance, the power series of $q > 1$ in positive powers with integer coefficients in the range $[0, q)$ define q-adically converging series, which also converges with respect to the prime factors of m and can be regarded as a p-adic power series. The power series of q in negative powers define in similar converging series with respect to the prime factors of n.

I have proposed earlier that the integers defining infinite rationals and thus also the integers m and n characterizing finite rational could correspond at space-time level to particles with positive *resp.* negative time orientation with positive *resp.* negative energies. Phase conjugate laser beams would represent one example of negative energy states. With this interpretation super-symmetry exchanging the roles of m and n and thus the role of fermionic and bosonic lower level primes would correspond to a time reversal.

1. The first interpretation is that there is single q-adic space-time sheet and that positive and negative energy states correspond to primes associated with m and n respectively. Positive (negative) energy space-time sheets would thus correspond to p-adicity ($1/p$-adicity) for the field modes describing the states.

2. Second interpretation is that particle (in extremely general sense that entire universe can be regarded as a particle) corresponds to a pair of positive and negative energy space-time sheets labelled by m and n characterizing the p-adic topologies consistent with $m-$ and n-adicities. This looks natural since Universe has necessary vanishing net quantum numbers. Unless one allows the non-uniqueness due to $m/n = mr/nr$, positive and negative energy space-time sheets can be connected only by # contacts so that positive and negative energy space-time sheets cannot interact via the formation of $\#_B$ contacts and would be therefore dark matter with respect to each other.

Positive energy particles and negative energy antiparticles would also have different mass scales. If the rate for the creation of # contacts and their CP conjugates are slightly different, say due to the presence of electric components of gauge fields, matter antimatter asymmetry could be generated primordially.

These interpretations generalize to higher levels of the hierarchy. There is a homomorphism from infinite rationals to finite rationals. One can assign to a product of infinite primes the product of the corresponding rationals at the lower level and to a sum of products of infinite primes the sum of the corresponding rationals at the lower level and continue the process until one ends up with a finite rational. Same applies to infinite rationals. The resulting rational $q = m/n$ is finite and defines q-adic effective topology, which is consistent with all the effective p-adic topologies corresponding to the primes appearing in factorizations of m and n. This homomorphism is of course not 1-1.

If this picture is correct, effective p-adic topologies would appear at all levels but would be dictated by the infinite-p p-adic topology which itself could refine infinite-P p-adic topology [E3] coding information too subtle to be catched by ordinary physical measurements [E10].

Obviously, one could assign to each elementary particle infinite prime, integer, or even rational to this a rational number $q = m/n$. q would associate with the particle q-adic topology consistent with a collection of p-adic topologies corresponding to the prime factors of m and n and characterizing the interactions that the particle can participate directly. In a very precise sense particles would represent both infinite and finite numbers.

2.6.4 Under what conditions space-time sheets can be connected by $\#_B$ contact?

Assume that particles are characterized by a p-adic prime determining it mass scale plus p-adic primes characterizing the gauge bosons to which they couple and assume that $\#_B$ contacts mediate gauge interactions. The question is what kind of space-time sheets can be connected by $\#_B$ contacts.

1. The first working hypothesis that comes in mind is that the p-adic primes associated with the two space-time sheets connected by $\#_B$ contact must be identical. This would require that particle is many-sheeted structure with no other than gravitational interactions between various sheets. The problem of the multi-sheeted option is that the characterization of events like electron-positron annihilation to a weak boson looks rather clumsy.

2. If the notion of multi-p p-adicity is accepted, space-time sheets are characterized by integers and the largest prime dividing the integer might characterize the mass of the particle. In this case a common prime factor p for the integers characterizing the two space-time sheets could be enough for the possibility of $\#_B$ contact and this contact would be characterized by this prime. If no common prime factors exist, only $\#$ contacts could connect the space-time sheets. This option conforms with the number theoretical vision. This option would predict that the transition to large $\hbar$ phase occurs simultaneously for all interactions.

2.6.5 What about the integer characterizing graviton?

If one accepts the hypothesis that graviton couples to both visible and dark matter, graviton should be characterized by an integer dividing the integers characterizing all particles. This leaves two options.

Option I: gravitational constant characterizes graviton number theoretically

The argument leading to an expression for gravitational constant in terms of CP_2 length scale led to the proposal that the product of primes $p \leq 23$ are common to all particles and one interpretation was in terms of multi-fractality. If so, graviton would be characterized by a product of some or all primes $p \leq 23$ and would thus correspond to a very small p-adic length scale. This might be also the case for photon although it would seem that photon cannot couple to dark matter always. $p = 23$ might characterize the transversal size of the massless extremal associated with the space-time sheet of graviton.

Option II: graviton behaves as a unit with respect to multiplication

One can also argue that if the largest prime assignable to a particle characterizes the size of the particle space-time sheet it does not make sense to assign any finite prime to a massless particle like graviton. Perhaps graviton corresponds to simplest possible infinite prime $P = X \pm 1$, X the product of all primes.

As found, one can assign to any infinite prime, integer, and rational a rational number $q = m/n$ to which one can assign a q-adic topology as effective space-time topology and as a special case effective p-adic topologies corresponding to prime factors of m and n.

In the case of $P = X \pm 1$ the rational number would be equal to ± 1. Graviton could thus correspond to $p = 1$-adic effective topology. The "prime" $p = 1$ indeed appears as a factor of any integer so that graviton would couple to any particle. Formally the 1-adic norm of any number would be 1 or 0 which would suggest that a discrete topology is in question.

The following observations help in attempts to interpret this.

1. CP_2 type extremals having interpretation as gravitational instantons are non-deterministic in the sense that M^4 projection is random light-like curve. This condition implies Virasoro conditions which suggests interpretation in terms topological quantum theory limit of gravitation involving vanishing four-momenta but non-vanishing color charges. This theory would represent gravitation at the ultimate CP_2 length scale limit without the effects of topological condensation. In longer length scales a hierarchy of effective theories of gravitation corresponds to the coupling of space-time sheets by join along boundaries bonds would emerge and could give rise to "strong gravities" with strong gravitational constant proportional to L_p^2. It is quite possible that the M-theory based vision about duality between gravitation and gauge interactions applies to electro-weak interactions and in these "strong gravities".

2. p-Adic length scale hypothesis $p \simeq 2^k$, k integer, implies that $L_k \propto \sqrt{k}$ corresponds to the size scale of causal horizon associated with # contact. For $p = 1$ k would be zero and the causal horizon would contract to a point which would leave only generalized Feynman diagrams consisting of CP_2 type vacuum extremals moving along random light-like orbits and obeying Virasoro conditions so that interpretation as a kind of topological gravity suggests itself.

3. $p = 1$ effective topology can make marginally sense for vacuum extremals with vanishing Kähler form and carrying only gravitational charges. The induced Kähler form vanishes identically by the mere assumption that X^4, be it continuous or discontinuous, belongs to $M^4 \times Y^2$, Y^2 a Lagrange sub-manifold of CP_2.

Why topological graviton, or whatever the particle represented by CP_2 type vacuum extremals should be called, should correspond to the weakest possible notion of continuity? The most plausible answer is that discrete topology is *consistent* with any other topology, in particular with any p-adic topology. This would express the fact that CP_2 type extremals can couple to any p-adic prime. The vacuum property of CP_2 type extremals implies that the splitting off of CP_2 type extremal leaves the physical state invariant and means effectively multiplying integer by $p = 1$.

It seems that Option I suggested by the deduction of the value of gravitational constant looks more plausible as far as the interpretation of gravitation is considered. This does not however mean that CP_2 type vacuum extremals carrying color quantum numbers could not describe gravitational interactions in CP_2 length scale.

3 Could also gauge bosons correspond to wormhole contacts?

The developments in the formulation of quantum TGD which have taken place during the period 2005-2007 (see [C3] besides this chapter) suggest dramatic simplifications of the general picture about elementary particle spectrum. p-Adic mass calculations [F3, F4, F5] leave a lot of freedom concerning the detailed identification of elementary particles. The basic open question is whether the *theory is free at parton level* as suggested by the recent view about the construction of S-matrix and by the almost topological QFT property of quantum TGD at parton level [C3]. Or more concretely: do partonic 2-surfaces carry only free many-fermion states or can they carry also bound states of fermions and anti-fermions identifiable as bosons?

What is known that Higgs boson corresponds naturally to a wormhole contact [C5]. The wormhole contact connects two space-time sheets with induced metric having Minkowski signature. Wormhole contact itself has an Euclidian metric signature so that there are two wormhole throats which are light-like 3-surfaces and would carry fermion and anti-fermion number in the case of Higgs. Irrespective of the identification of the remaining elementary particles MEs (massless extremals, topological light rays) would serve as space-time correlates for elementary bosons. Higgs type wormhole contacts would connect MEs to the larger space-time sheet and the coherent state of neutral Higgs would generate gauge boson mass and could contribute also to fermion mass.

The basic question is whether this identification applies also to gauge bosons (certainly not to graviton). This identification would imply quite a dramatic simplification since the theory would be free at single parton level and the only stable parton states would be fermions and anti-fermions. As will be found this identification allows to understand the dramatic difference between graviton and other gauge bosons and the weakness of gravitational coupling, gives a connection with the string picture of gravitons, and predicts that stringy states are directly relevant for nuclear and condensed matter physics as has been proposed already earlier [F8, J1, J2].

3.1 Option I: Only Higgs as a wormhole contact

The only possibility considered hitherto has been that elementary bosons correspond to partonic 2-surfaces carrying fermion-anti-fermion pair such that either fermion or anti-fermion has a non-physical polarization. For this option CP_2 type extremals condensed on MEs and travelling with light velocity would serve as a model for both fermions and bosons. MEs are not absolutely necessary for this option. The couplings of fermions and gauge bosons to Higgs would be very similar topologically. Consider now the counter arguments.

1. This option fails if the theory at partonic level is free field theory so that anti-fermions and elementary bosons cannot be identified as bound states of fermion and anti-fermion with either of them having non-physical polarization.

2. Mathematically oriented mind could also argue that the asymmetry between Higgs and elementary gauge bosons is not plausible whereas asymmetry between fermions and gauge bosons is. Mathematician could continue by arguing that if wormhole contacts with net quantum numbers of Higgs boson are possible, also those with gauge boson quantum numbers are unavoidable.

3. Physics oriented thinker could argue that since gauge bosons do not exhibit family replication phenomenon (having topological explanation in TGD framework) there must be a profound difference between fermions and bosons.

3.2 Option II: All elementary bosons as wormhole contacts

The hypothesis that quantum TGD reduces to a free field theory at parton level is consistent with the almost topological QFT character of the theory at this level. Hence there are good motivations for studying explicitly the consequences of this hypothesis.

3.2.1 Elementary bosons must correspond to wormhole contacts if the theory is free at parton level

Also gauge bosons could correspond to wormhole contacts connecting MEs [D1] to larger space-time sheet and propagating with light velocity. For this option there would be no need to assume the presence of non-physical fermion or anti-fermion polarization since fermion and anti-fermion would reside at different wormhole throats. Only the definition of what it is to be non-physical would be different on the light-like 3-surfaces defining the throats.

The difference would naturally relate to the different time orientations of wormhole throats and make itself manifest via the definition of light-like operator $o = x^k\gamma_k$ appearing in the generalized eigenvalue equation for the modified Dirac operator [A6]. For the first throat o^k would correspond to a light-like tangent vector t^k of the partonic 3-surface and for the second throat to its M^4 dual $\hat{t}^k$ in a preferred rest system in M^4 (implied by the basic construction of quantum TGD). What is nice that this picture non-asks the question whether t^k or $\hat{t}^k$ should appear in the modified Dirac operator.

Rather satisfactorily, MEs (massless extremals, topological light rays) would be necessary for the propagation of wormhole contacts so that they would naturally emerge as classical correlates of bosons. The simplest model for fermions would be as CP_2 type extremals topologically condensed on MEs and for bosons as pieces of CP_2 type extremals connecting ME to the larger space-time sheet. For fermions topological condensation is possible to either space-time sheet.

3.2.2 What about light-like boundaries and macroscopic wormhole contacts?

Light-like boundaries of the space-time sheet can have macroscopic size and can carry free many-fermion states but not elementary bosons. Number theoretic braids and anyons might be assignable to these structures. Deformations of cosmic strings to magnetic flux tubes with a light-like outer boundary are especially interesting in this respect.

If the ends of a string like object move with light velocity as implied by the usual stringy boundary conditions they indeed define light-like 3-surfaces. Many-fermion states could be assigned at the ends of string. One could also connect in pairwise manner the ends of two time-like strings having opposite time orientation using two space-like strings so that the analog of boson state consisting of two wormhole contacts and analogous to graviton would result. "Wormhole throats" could have arbitrarily long distance in M^4.

Wormhole contacts can be regarded as slightly deformed CP_2 type extremals only if the size of M^4 projection is not larger than CP_2 size. The natural question is whether one can construct macroscopic wormhole contacts at all.

1. The throats of wormhole contacts cannot belong to vacuum extremals. One might however hope that small deformations of macrosopic vacuum extremals could yield non-vacuum wormhole contacts of macroscopic size.

2. A large class of macroscopic wormhole contacts which are vacuum extremals consists of surfaces of form $X^2_1 \times X^2_2 \subset (M^1 \times Y^2) \times E^3$, where Y^2 is Lagrangian manifold of CP_2 (induced Kähler form vanishes) and $M^4 = M^1 \times E^3$ represents decomposition of M^1 to time-like and space-like sub-spaces. X^2_2 is a stationary surface of E^3. Both $X^2_1 \subset M^1 \times CP_2$ and X^2_2 have an Euclidian signature of metric except at light-like boundaries $X^1_a \times X^2_2$ and $X^1_b \times X^2_2$ defined by ends of X^2_1 defining the throats of the wormhole contact.

3. This kind of vacuum extremals could define an extremely general class of macroscopic wormhole contacts as their deformations. These wormhole contacts describe an interaction of wormhole throats regarded as closed strings as is clear from the fact that X^2 can be visualized as an analog of closed string world sheet X^2_1 in $M^1 \times Y^2$ describing a reaction leading

from a state with a given number of incoming closed strings to a state with a given number of outgoing closed strings which correspond to wormhole throats at the two space-time sheets involved.

3.2.3 Phase conjugate states and matter- antimatter asymmetry

By fermion number conservation fermion-boson and boson-boson couplings must involve the fusion of partonic 3-surfaces along their ends identified as wormhole throats. Bosonic couplings would differ from fermionic couplings only in that the process would be $2 \rightarrow 4$ rather than $1 \rightarrow 3$ at the level of throats.

The decay of boson to an ordinary fermion pair with fermion and anti-fermion at the same space-time sheet would take place via the basic vertex at which the 2-dimensional ends of light-like 3-surfaces are identified. The sign of the boson energy would tell whether boson is ordinary boson or its phase conjugate (say phase conjugate photon of laser light) and also dictate the sign of the time orientation of fermion and anti-fermion resulting in the decay.

The two space-time sheets of opposite time orientation associated with bosons would naturally serve as space-time correlates for the positive and negative energy parts of the zero energy state and the sign of boson energy would tell whether it is phase conjugate or not. In the case of fermions second space-time sheet is not absolutely necessary and one can imagine that fermions in initial/final states correspond to single space-time sheet of positive/negative time orientation.

Also a candidate for a new kind interaction vertex emerges. The splitting of bosonic wormhole contact would generate fermion and time-reversed anti-fermion having interpretation as a phase conjugate fermion. This process cannot correspond to a decay of boson to ordinary fermion pair. The splitting process could generate matter-antimatter asymmetry in the sense that fermionic antimatter would consist dominantly of negative energy anti-fermions at space-time sheets having negative time orientation [D5, D6].

This vertex would define the fundamental interaction between matter and phase conjugate matter. Phase conjugate photons are in a key role in TGD based quantum model of living matter. This involves model for memory as communications in time reversed direction, mechanism of intentional action involving signalling to geometric past, and mechanism of remote metabolism involving sending of negative energy photons to the energy reservoir [K1]. The splitting of wormhole contacts has been considered as a candidate for a mechanism realizing Boolean cognition in terms of "cognitive neutrino pairs" resulting in the splitting of wormhole contacts with net quantum numbers of Z^0 boson [J3, M6].

3.3 Graviton and other stringy states

Fermion and anti-fermion can give rise to only single unit of spin since it is impossible to assign angular momentum with the relative motion of wormhole throats. Hence the identification of graviton as single wormhole contact is not possible. The only conclusion is that graviton must be a superposition of fermion-anti-fermion pairs and boson-anti-boson pairs with coefficients determined by the coupling of the parton to graviton. Graviton-graviton pairs might emerge in higher orders. Fermion and anti-fermion would reside at the same space-time sheet and would have a non-vanishing relative angular momentum. Also bosons could have non-vanishing relative angular momentum and Higgs bosons must indeed possess it.

Gravitons are stable if the throats of wormhole contacts carry non-vanishing gauge fluxes so that the throats of wormhole contacts are connected by flux tubes carrying the gauge flux. The mechanism producing gravitons would the splitting of partonic 2-surfaces via the basic vertex. A connection with string picture emerges with the counterpart of string identified as the flux tube connecting the wormhole throats. Gravitational constant would relate directly to the value of the string tension.

The TGD view about coupling constant evolution [C5] predicts $G \propto L_p^2$, where L_p is p-adic length scale, and that physical graviton corresponds to $p = M_{127} = 2^{127} - 1$. Thus graviton would have geometric size of order Compton length of electron which is something totally new from the point of view of usual Planck length scale dogmatism. In principle an entire p-adic hierarchy of gravitational forces is possible with increasing value of G.

The explanation for the small value of the gravitational coupling strength serves as a test for the proposed picture. The exchange of ordinary gauge boson involves the exchange of single CP_2 type extremal giving the exponent of Kähler action compensated by state normalization. In the case of graviton exchange two wormhole contacts are exchanged and this gives second power for the exponent of Kähler action which is not compensated. It would be this additional exponent that would give rise to the huge reduction of gravitational coupling strength from the naive estimate $G \sim L_p^2$.

Gravitons are obviously not the only stringy states. For instance, one obtains spin 1 states when the ends of string correspond to gauge boson and Higgs. Also non-vanishing electro-weak and color quantum numbers are possible and stringy states couple to elementary partons via standard couplings in this case. TGD based model for nuclei as nuclear strings having length of order $L(127)$ [F8] suggests that the strings with light M_{127} quark and anti-quark at their ends identifiable as companions of the ordinary graviton are responsible for the strong nuclear force instead of exchanges of ordinary mesons or color van der Waals forces.

Also the TGD based model of high T_c super-conductivity involves stringy states connecting the space-time sheets associated with the electrons of the exotic Cooper pair [J1, J2]. Thus stringy states would play a key role in nuclear and condensed matter physics, which means a profound departure from stringy wisdom, and breakdown of the standard reductionistic picture.

3.4 Spectrum of non-stringy states

The 1-throat character of fermions is consistent with the generation-genus correspondence. The 2-throat character of bosons predicts that bosons are characterized by the genera (g_1, g_2) of the wormhole throats. Note that the interpretation of fundamental fermions as wormhole contacts with second throat identified as a Fock vacuum is excluded.

The general bosonic wave-function would be expressible as a matrix M_{g_1,g_2} and ordinary gauge bosons would correspond to a diagonal matrix $M_{g_1,g_2} = \delta_{g_1,g_2}$ as required by the absence of neutral flavor changing currents (say gluons transforming quark genera to each other). 8 new gauge bosons are predicted if one allows all 3×3 matrices with complex entries orthonormalized with respect to trace meaning additional dynamical $SU(3)$ symmetry. Ordinary gauge bosons would be $SU(3)$ singlets in this sense. The existing bounds on flavor changing neutral currents give bounds on the masses of the boson octet. The 2-throat character of bosons should relate to the low value $T = 1/n \ll 1$ for the p-adic temperature of gauge bosons as contrasted to $T = 1$ for fermions.

If one forgets the complications due to the stringy states (including graviton), the spectrum of elementary fermions and bosons is amazingly simple and almost reduces to the spectrum of standard model. In the fermionic sector one would have fermions of standard model. By simple counting leptonic wormhole throat could carry $2^3 = 8$ states corresponding to 2 polarization states, 2 charge states, and sign of lepton number giving 8+8=16 states altogether. Taking into account phase conjugates gives 16+16=32 states.

In the non-stringy boson sector one would have bound states of fermions and phase conjugate fermions. Since only two polarization states are allowed for massless states, one obtains $(2+1)\times(3+1) = 12$ states plus phase conjugates giving 12+12=24 states. The addition of color singlet states for quarks gives 48 gauge bosons with vanishing fermion number and color quantum numbers. Besides 12 electro-weak bosons and their 12 phase conjugates there are 12 exotic bosons and their 12 phase conjugates. For the exotic bosons the couplings to quarks and leptons are determined by the orthogonality of the coupling matrices of ordinary and boson states. For exotic counterparts of W bosons and Higgs the sign of the coupling to quarks is opposite. For photon and Z^0 also the relative magnitudes of the couplings to quarks must change. Altogether this makes 48+16+16=80 states. Gluons would result as color octet states. Family replication would extend each elementary boson state into $SU(3)$ octet and singlet and elementary fermion states into $SU(3)$ triplets.

4 Is it possible to understand coupling constant evolution at space-time level?

It is not yet possible to deduce the length scale evolution gauge coupling constants from Quantum TGD proper. Quantum classical correspondence however encourages the hope that it might be possible to achieve some understanding of the coupling constant evolution by using the classical theory.

This turns out to be the case and the earlier speculative picture about gauge coupling constants associated with a given space-time sheet as RG invariants finds support. It remains an open question whether gravitational coupling constant is RG invariant inside give space-time sheet. The discrete p-adic coupling constant evolution replacing in TGD framework the ordinary RG evolution allows also formulation at space-time level as also does the evolution of $\hbar$ associated with the phase resolution.

4.1 Overview

4.1.1 The evolution of gauge couplings at single space-time sheet

The renormalization group equations of gauge coupling constants g_i follow from the following idea. The basic observation is that gauge currents have vanishing covariant divergences whereas ordinary divergence does not vanish except in the Abelian case. The classical gauge currents are however proportional to $1/g_i^2$ and if g_i^2 is allowed to depend on the space-time point, the divergences of currents can be made vanishing and the resulting flow equations are essentially renormalization group equations. The physical motivation for the hypothesis is that gauge charges are assumed to be conserved in perturbative QFT. The space-time dependence of coupling constants takes care of the conservation of charges.

A surprisingly detailed view about RG evolution emerges.

1. The UV fixed points of RG evolution correspond to CP_2 type extremals (elementary particles).

2. The Abelianity of the induced Kähler field means that Kähler coupling strength is RG invariant which has indeed been the basic postulate of quantum TGD. The only possible interpretation is that the coupling constant evolution in sense of QFT:s corresponds to the discrete p-adic coupling constant evolution.

3. IR fixed points correspond to space-time sheets with a 2-dimensional CP_2 projection for which the induced gauge fields are Abelian so that covariant divergence reduces to ordinary divergence. Examples are cosmic strings (, which could be also seen as UV fixed points), vacuum extremals, solutions of a sub-theory defined by $M^4 \times S^2$, S^2 a homologically non-trivial geodesic sphere, and "massless extremals".

4. At the light-like boundaries of the space-time sheet gauge couplings are predicted to be constant by conformal invariance and by effective two-dimensionality implying Abelianity: note that the 4-dimensionality of the space-time surface is absolutely essential here.

5. In fact, all known extremals of Kähler action correspond to RG fixed points since gauge currents are light-like so that coupling constants are constant at a given space-time sheet. This is consistent with the earlier hypothesis that gauge couplings are renormalization group invariants and coupling constant evolution reduces to a discrete p-adic evolution. As a consequence also Weinberg angle, being determined by a ratio of $SU(2)$ and $U(1)$ couplings, is predicted to be RG invariant. A natural condition fixing its value would be the requirement that the net vacuum em charge of the space-time sheet vanishes. This would state that em charge is not screened like weak charges.

6. When the flow determined by the gauge current is not integrable in the sense that flow lines are identifiable as coordinate curves, the situation changes. If gauge currents are divergenceless for all solutions of field equations, one can assume that gauge couplings are constant at a given space-time sheet and thus continuous also in this case. Otherwise a natural guess is that the coupling constants obtained by integrating the renormalization group equations are continuous in the relevant p-adic topology below the p-adic length scale. Thus the effective p-adic topology would emerge directly from the hydrodynamics defined by gauge currents.

4.1.2 RG evolution of gravitational constant at single space-time sheet

Similar considerations apply in the case of gravitational and cosmological constants.

1. In this case the conservation of gravitational mass determines the RG equation (gravitational energy and momentum are not conserved in general).

2. The assumption that coupling cosmological Λ constant is proportional to $1/L_p^2$ (L_p denotes the relevant p-adic length scale) explains the mysterious smallness of the cosmological constant and leads to a RG equation which is of the same form as in the case of gauge couplings.

3. Asymptotic cosmologies for which gravitational four momentum is conserved correspond to the fixed points of coupling constant evolution now but there are much more general solutions satisfying the constraint that gravitational mass is conserved.

4. It seems that gravitational constant cannot be RG invariant in the general case and that effective p-adicity can be avoided only by a smoothing out procedure replacing the mass current with its average over a four-volume 4-volume of size of order p-adic length scale.

4.1.3 p-Adic evolution of gauge couplings

If RG invariance at given space-time sheet holds true, the question arises whether it is possible to understand p-adic coupling constant evolution at space-time level.

1. Simple considerations lead to the idea that M^4 scalings of the intersections of 3-surfaces defined by the intersections of space-time surfaces with light-cone boundary induce transformations of space-time surface identifiable as RG transformations. If sufficiently small they leave gauge charges invariant: this seems to be the case for known extremals which form scaling invariant families. When the scaling corresponds to a ratio p_2/p_1, $p_2 > p_1$, bifurcation would become possible replacing p_1-adic effective topology with p_2-adic one.

2. Stability considerations determine whether p_2-adic topology is actually realized and could explain why primes near powers of 2 are favored. The renormalization of coupling constant would be dictated by the requirement that Q_i/g_i^2 remains invariant.

4.1.4 p-Adic evolution in angular resolution and dynamical $\hbar$

For a given p-adic topology algebraic extensions of p-adic numbers define also a hierarchy ordered by the dimension of the extension and this hierarchy naturally corresponds to an increasing angular resolution so that RG flow would be associated also with it.

1. A characterization of angular scalings consistent with the identification of $\hbar$ as a characterizer of the topological condensation of 3-surface X^3 to a larger 3-surface Y^3 is that angular scalings correspond to the transformations $\Phi \rightarrow r\Phi$, $r = m/n$ in the case of X^3 and $\Phi \rightarrow \Phi$ in case of Y^3 so that X^3 becomes analogous to an m-fold covering of Y^3. Rational coverings could also correspond to m-fold scalings for X^3 and n-fold scalings for Y^3.

2. The formation of these stable multiple coverings could be seen as an analog for a transition in chaos via a process in which a closed Bohr orbit regarded as a particle itself becomes an orbit closing only after m turns. TGD predicts a hierarchy of higher level zero energy states representing S-matrix of lower level as entanglement coefficients. Particles identified as "tracks" of particles at orbits closing after m turns might serve as space-time correlates for this kind of states. There is a direct connection with the fractional quantum numbers, anyon physics and quantum groups.

3. The simplest generalization from the p-adic length scale evolution consistent with the proposed role of Beraha numbers $B_n = 4cos^2(\pi/n)$ is that bifurcations can occur for integer values of r=m and change the value of $\hbar$. The interpretation would be that single 2π rotation in δM^4_+ corresponds to the angular resolution with respect to the angular coordinate ϕ of space-time surface varying in the range $(0, 2\pi)$ and is given by $\Delta\phi = 2\pi/m$.

4. For $n = 3$ corresponding to the minimal resolution of $\Delta\phi = 2\pi/3$ $\hbar$ would be infinite. The evidence for a gigantic but finite value of "gravitational" Planck constant [J6] would mean that the simplest formula

   $$\frac{1}{\hbar(n)} = \frac{log(B_n)}{log(4)}$$

   for $\hbar$ fails for $n = 3$.

   The first cure of the problem would be a replacement of the formula for $\hbar(n)$ by a difference equation

   $$\frac{1}{\hbar(n)} - \frac{1}{\hbar(n-1)} = \frac{log(B_n)}{log(4)} - \frac{log(B_{n-1})}{log(4)}$$

   having interpretation as RGE difference equation and allowing additive constant in the expression of $1/\hbar(n)$ and thus yielding finite value for $\hbar(3)$.

A more elegant resolution of the problem is that for a given n characterizing von Neumann inclusion there is spectrum of values for $\hbar(r = n/m)$ expressible in terms of $B_r = 4cos^2(\pi/r)$ as

$$\frac{1}{\hbar(n/m)} = \frac{log(B_{n/m})}{log(4)}$$

such that $m/n < 3$ holds true. This would reflect the presence of an additional degree of freedom related to the Jones inclusion. m could characterize the scaling of Φ for X^3 and n the scaling of Φ for Y^3. A simple TGD inspired model for dark atoms and dark condensed matter [J6] predicts $\hbar/\hbar_0 = 1/v_0 \simeq 2^{11}$. This would correspond to $r \simeq .3077$.

4.2 The evolution of gauge and gravitational couplings at space-time level

The question is whether the RG evolution of all coupling constant parameters could have interpretation as flows at space-time level. This seems to be the case.

4.2.1 Renormalization group flow as a conservation of gauge current in the interior of space-time sheet

The induced gauge potentials relate to the gauge potentials A_i of perturbative gauge theory by the scaling $g_i \rightarrow g_i A_i$. Hence the gauge currents correspond to the scaled currents

$$\begin{aligned} J_i^\mu &= \frac{1}{g_i^2} \times J_{i,0}^\mu \ , \\ J_{i,0}^\mu &= (D_\nu F^{\mu\nu})_i \sqrt{g} \ . \end{aligned} \tag{2}$$

The simplest guess for the coupling constant evolution associated with g_i^2 is that the covariant gauge current J_i^a is conserved in ordinary sense (its is identically conserved in covariant sense). This gives meaning to the perturbative approach in which gauge charges are indeed conserved. Thus one would have:

$$\partial_\mu J_i^\mu = 0 \ . \tag{3}$$

or

$$J_{i,0}^\mu \partial_\mu log(g_i^2) = \partial_\mu J_{i,0}^\mu \ . \tag{4}$$

Note that the non-constancy of the Weinberg angle gives an additional term to the em current given by

$$\frac{1}{2} Z_0^{\mu\nu} \partial_\nu p \ . \tag{5}$$

This equation can be solved along the flow lines of the gauge current. When the flow is integrable:

$$J_{i,0}^\mu = \phi \partial^\mu t \ ,$$

one obtains

$$\frac{dlog(g_i^2)}{dt} = \frac{\partial_\mu J_{i,0}^\mu}{\phi} = \nabla(log(\phi)) \cdot \nabla t + \nabla^2 t \ . \tag{6}$$

When this flow is not integrable coupling constants become discontinuous functions with respect to the real topology but can be continuous or even smooth with respect to some p-adic topology and the previous discussion applies as such.

The ordinary divergence of the gauge current takes the role of beta function. RG evolution is trivial in the Abelian case since in this case ordinary divergence vanishes identically. This implies that Kähler coupling strength is indeed renormalization group invariant which has been the basic hypothesis of quantum TGD.

The natural boundary conditions to the coupling constant evolution state the vanishing of the normal components of the gauge currents at boundaries

$$J_i^n = \frac{D_\beta F_i^{n\beta}\sqrt{g_4}}{g_i^2} = 0 \ . \qquad (7)$$

and guarantee that the flow approaches asymptotically the boundaries. These conditions can become trivial if the four-metric at the boundary component becomes singular (effectively 2-dimensional) so that $D_\beta F_i^{n\beta}$ can approach to finite or even infinite value. This might happen in case of color gauge coupling strength if it approaches infinity near the boundary. Otherwise the conditions says nothing about coupling constants at the boundary.

4.2.2 Is the renormalization group evolution at the light-like boundaries trivial?

One can ask whether it is possible to define coupling constant evolution also for the gauge fields induced at light-like boundary components. The technical problems are caused by the vanishing of the determinant of the induced metric and the non-existence of contravariant metric but it is quite conceivable that the restriction to the 2-dimensional sections makes sense if one defines a contravariant metric as the inverse of the induced metric in the 2-D section.

Since CP_2 projection is 2-dimensional, RG equations suggest that coupling constants are constants on the 2-dimensional sections and that conformal invariance in the light-like direction implies constancy over the entire boundary component. Since boundary components are identifiable as parton like objects, the result would look highly satisfactory.

If the right hand side of Eq. 6 vanishes at the boundary of space-time surface g_i^2 approaches to a finite value. When the left hand side is finite and t becomes infinite as boundary is approached g_i^2 increases without limit. This happens for a finite value of t when the right hand side diverges. Classical color gauge fields are proportional to $H_A J$, where H_A are the Hamiltonians of the color isometries and J denotes the induced Kähler form. The non-triviality of renormalization group evolution is solely due to the presence of Hamiltonians. QCD suggests that α_s diverges at the outer boundary or that at least approaches to a very large value at the outer boundaries of the hadronic 4-surface.

4.2.3 Fixed points of coupling constant evolution

Consider now the fixed points of the coupling constant evolution.

1. The first class of fixed points corresponds to CP_2 type extremals. In this case however also gauge currents vanish so that the RG equation says nothing.

2. The second class of fixed points of the coupling constant evolution corresponds to space-time regions in which gauge fields become Abelian. This is the case for all space-time surfaces with 2-dimensional CP_2 projection: this includes vacuum extremals, massless extremals, solutions for which CP_2 projection corresponds to a homologically non-trivial geodesic sphere, and cosmic strings. This supports the view that these extremals correspond to asymptotic self-organization patterns.

4.2.4 Are all gauge couplings RG invariants within a given space-time sheet

No extremals for which the gauge currents would have non-vanishing ordinary divergence are known at this moment (gauge currents are light-like always). Therefore one cannot exclude the possibility that all gauge coupling constants rather than only Kähler coupling strength are renormalization group invariants in TGD framework, so that the hypothesis that RG evolution reduces to a discrete p-adic coupling constant evolution would be correct.

This implies that also Weinberg angle, being determined by the ratio of $SU(2)$ and $U(1)$ couplings, is constant inside a given space-time sheet. Its value in this case is determined most naturally by the requirement that the net vacuum em charge of the space-time sheet vanishes.

The fixed point property as an implication of Abelianity is obviously in conflict with the standard picture about gauge coupling evolution and supports the view that this evolution corresponds to a discrete p-adic gauge coupling evolution.

4.2.5 RG equation for gravitational coupling constant

In the case of gravitational coupling constant the renormalization group equation must be formulated the current representing the contribution of Einstein tensor to the gravitational mass being defined by Einstein tensor as

$$G^{\alpha} = \frac{1}{16\pi G} \times G^{\alpha\beta}\partial_{\beta}a\sqrt{g} \ , \tag{8}$$

where a refers the proper time of future light cone (or possibly to some other preferred time coordinate determined by dynamics). In the case of cosmological constant the corresponding contribution is

$$g^{\alpha} = \frac{\Lambda}{16\pi G} \times g^{\alpha\beta}\partial_{\beta}a\sqrt{g} \ . \tag{9}$$

A natural hypothesis is that the variation of G guarantees the conservation of gravitational mass. This does not mean that gravitational energy or four-momentum would be conserved or that conservation of gravitational mass would hold true except at a given space-time sheet. One can also assume that the two contributions to the gravitational mass are not independent. This means that there is a constraint between cosmological and gravitational constants. There are two options.

1. One has

$$\Lambda = \frac{x}{G} \ . \tag{10}$$

where x is renormalization group invariant of no other length scales are involved. The RG equation would in this case read as

$$\left(G^{\alpha} - \frac{2x}{G}g^{\alpha}\right) D_{\alpha}log(G) = D_{\alpha}\left(G^{\alpha} + \frac{x}{G}g^{\alpha}\right) \ . \tag{11}$$

2. On the other hand, if p-adic length scale hypothesis is accepted, one has

$$\Lambda = \frac{x}{L_p^2} \ , \tag{12}$$

where L_p is a p-adic length scale of order of cosmic time a: $L_p \sim a$ [D5]. This would mean that Λ is RG invariant. This option resolves the mysterious smallness of the cosmological constant so that it is the most plausible option in TGD framework.

The RG equations in this case is given by

$$\left(G^\alpha + \frac{x}{L_p^2} g^\alpha\right) D_\alpha log(G) = D_\alpha \left(G^\alpha + \frac{x}{L_p^2} g^\alpha\right) \quad . \tag{13}$$

and of the same general form as in the case of gauge couplings, which also supports option 2).

Vacuum extremals which correspond to asymptotic cosmologies with cosmological constant satisfying

$$D_\alpha \left(G^\alpha + \frac{x}{\mathrm{L}_p^2} g^\alpha\right) \quad = \quad 0 \tag{14}$$

represent examples of the fixed points of the coupling constant evolution with conserved gravitational four-momentum. Obviously much weaker conditions guarantee fixed point property.

For Schwartschild metric having imbedding as a vacuum extremal Einstein tensor vanishes so that the RG equations would say nothing about G for option 1). For Reissner-Nordstöm metric also having embedding as a vacuum extremal Einstein tensor corresponds to the energy momentum tensor of Abelian gauge field and the length scale evolution of G would be non-trivial in both cases.

4.3 p-Adic coupling constant evolution

4.3.1 p-Adic coupling constant evolution associated with length scale resolution at space-time level

If gauge couplings are indeed RG invariants inside a given space-time sheet, gauge couplings must be regarded as being characterized by the p-adic prime associated with the space-time sheet. The question is whether it is possible to understand also the p-adic coupling constant evolution at space-time level.

A natural view about p-adic length scale evolution is as an existence of a dynamical symmetry mapping the preferred extremal space-time sheet of Kähler action characterized by a p-adic prime p_1 to a space-time sheet characterized by p-adic prime $p_2 > p_1$ sufficiently near to p_1. The simplest guess is that the symmetry transformation corresponds to a scaling of M^4 coordinates in the intersection X^3 of the space-time surface with light-cone boundary $\delta M^4_+ \times CP_2$ by a scaling factor p_2/p_1, which in turn induces a transformation of $X^4(X^3)$, which in general does not reduce to M^4 scaling outside X^3 since scalings are not symmetries of the Kähler action.

This transformation induces a change of the vacuum gauge charges: $Q_i \rightarrow Q_i + \Delta Q_i$, and the renormalization group evolution boils down to the condition

$$\frac{Q_i + \Delta Q_i}{g_i^2 + \Delta g_i^2} \quad = \quad \frac{Q_i}{g_i^2} \quad . \tag{15}$$

The problem is that this transformation has a continuous variant so that p-adic length scale evolution could reduce to continuous one.

A possible resolution of the problem is based on the observation that the values of the gauge charges depend on the initial values of the time derivatives of the imbedding space coordinates. RG invariance at space-time level suggests that small scalings leave the gauge charge and thus also coupling constant invariant. As a matter fact, this seems to be the case for all known extremals since they form scaling invariant families. The scalings by p_2/p_1 for some $p_2 > p_1$ would correspond to critical points in which bi-furcations occur in the sense that two space-time surfaces $X^4(X^3)$ satisfying the minimization conditions for Kähler action and with different gauge charges appear.

The new space-time surface emerging in the bifurcation would obey effective p_2-adic topology in some length scale range instead of p_1-adic topology. Stability considerations would dictate whether $p_1 \rightarrow p_2$ transition occurs and could also explain why primes $p \simeq 2^k$, k integer, are favored. This kind of bifurcations or even multi-furcations are certainly possible by the breaking of the classical determinism.

4.3.2 The space-time realization of the RG evolution associated with the phase resolution

The algebraic extensions of a given p-adic number field define a hierarchy ordered by the dimension of the extension assigned to the RG evolution with respect to the phase resolution. The evolution of $\hbar$ inducing evolutions of other coupling constants have been assigned to this coupling constant evolution and an explicit formula in terms of Beraha numbers $B_n = 4cos^2(\pi/n)$ for the RG evolution has been proposed [C7, J6].

In this case the simplest candidates for the geometric transformations of space-time surface are rational scalings of the cyclic angular S^2 coordinate of $\delta M^4_+ = R_+ \times S^2$ given by $\Phi \rightarrow r\Phi$, $r = m/n$ replacing in the general case the space-time sheet with its n-fold covering acting on X^3 and inducing a transformation of $X^4(X^3)$. Single closed curve around origin in $X^4(X^3)$ would correspond to an $m2\pi$ rotation in M^4 and I have proposed that anyonic systems with fractional spin and other charges could correspond to this kind of space-time surfaces [E9, G2].

A more precise characterization consistent with the identification of $\hbar$ as a characterizer of the topological condensation of 3-surface X^3 to a larger 3-surface Y^3 is that angular scalings correspond to the transformations $\Phi \rightarrow r\Phi$, $r = m/n$ in the case of X^4 and $\Phi \rightarrow \Phi$ in case of Y^4 so that X^2 becomes analogous to an m-fold covering of Y^3. Rational coverings could also correspond to m-fold scalings for X^4 and n-fold scalings for Y^3.

The formation of these stable multiple coverings could be seen as an analog for a transition in chaos via a process in which a closed Bohr orbit regarded as a particle itself becomes an orbit closing only after m turns. TGD predicts a hierarchy of higher level zero energy states representing S-matrix of lower level as entanglement coefficients. Particles identified as "tracks" of particles at orbits closing after m turns [G2] would be natural space-time correlates for this kind of states.

The simplest generalization from the p-adic length scale evolution consistent with the proposed role of Beraha numbers is that bifurcations can occur for integer values of $r = m$ and change the value of $\hbar$. The interpretation would be that single 2π rotation in δM^4_+ corresponds to the angular resolution with respect to the angular coordinate ϕ of space-time surface varying in the range $(0, 2\pi)$ and is given by $\Delta\phi = 2\pi/m$. On the other hand, the evidence for a gigantic but finite value of "gravitational" Planck constant [J6] suggests that large values of $\hbar$ corresponding to $3 < n < 4$ and defining a "generalized" Beraha number are possible. For $n = 3$ corresponding to the minimal resolution of $\Delta\phi = 2\pi/3$ $\hbar$ would be infinite. This would allow to keep the formula for $\hbar(n)$ in its original form by replacing n with a rational number. This would mean that also rational values of r correspond to bifurcations in the range $3 < r < 4$ at least. An open question is whether the generalization of n to rational number somehow generalizes the notion of index $M : N = B_n$ of Jones inclusion.

If this picture and the explanation for the cosmological variation of the fine structure constant characterizing ordinary matter based on the relative variation of $\hbar$ of order $\Delta\hbar/\hbar \sim 10^{-6}$ [D6] are both correct, ordinary condensed matter phase would correspond to 3-surfaces X^3 condensed on larger surface Y^3 with m in the range 100-200.

4.4 About electro-weak coupling constant evolution

The classical space-time correlates for electro-weak coupling constant evolution deserve a separate discussion.

4.4.1 How to determine the value of Weinberg angle for a given space-time sheet?

The general picture about the massivation of electro-weak bosons and electro-weak gauge bosons based on the notion of induced gauge field allows to determined Weinberg angle from the condition that electromagnetic vacuum charge for a given space-time sheet vanishes.

The basic idea is that electro-weak vacuum charge densities are generated and screen weak charges transforming $1/r$ Coulomb potentials to exponentially screened ones. The massivation of fermions occurs by a different mechanism in TGD and they can be massive even in the case that electro-weak bosons are massless.

In gauge theories the screening of weak charges occurs in differential manner. In TGD framework RG invariance inside a given space-time sheet and p-adic coupling constant evolution support the view that this screening occurs in discrete manner in the sense that the weak fields would behave like massless fields inside a given space-time sheet but the net weak charges of the space-time sheets cause the screening of the weak charges and massivation in average sense. The masslessness of photons means that the vacuum em charge for a given space-time sheet vanishes. This condition allows to determine the value of Weinberg angle for a given space-time sheet.

4.4.2 Smoothed out position dependent Weinberg angle from the vanishing of vacuum density of em charge

A practical variant about the condition determining Weinberg angle for a given space-time sheet is obtained by a smoothing out procedure in which the distribution of discrete values of Weinberg angle is replaced with a continuous distribution interpreted as a constant below the typical size scale of space-time sheets involved.

The condition that the em charge density defined by the covariant divergence of electro-weak current vanishes, gives a differential equation allowing to solve for Weinberg angle. Using M^4_+ proper time a as a preferred time coordinate (identifiable as cosmic time and playing key role in the construction of configuration space geometry and quantum TGD [B2, B3])) this condition can be made general coordinate invariant. One can hope that with a proper choice of boundary conditions (fixed actually the the minimization of Kähler action) Weinberg angle can always have a physical value. Since gauge current is defined as the covariant divergence of gauge field the condition involves for $D > 2$ besides the ordinary divergence also a term proportional to $W_{+,\nu}W_-^{\mu\nu} - W_{-,\nu}W_+^{\mu\nu}$.

1. Simple special cases

For vacuum extremals ordinary em current vanishes for $p = sin^2(\theta_W) = 0$. In this case the 2-dimensionality of CP_2 projection guarantees that ordinary divergence equals to the covariant one. Hence $p = 0$ guarantees trivially the vanishing of em charge density also now but there are also other solutions.

For solutions with CP_2 projection belong to a homologically non-trivial geodesic sphere of CP_2 the condition determining the Weinberg angle reduces to the vanishing of the divergence of pJ^{0i} whereas the vanishing of γ would imply a non-physical value of p.

2. General solution of the conditions

The explicit expressions for classical em and Z^0 are given by

$$\begin{aligned} \gamma &= 3J - pR_{03} \ , \ p \equiv sin^2(\theta_W) \ , \\ Z^0 &= 2R_{03} \ . \end{aligned} \tag{16}$$

CP_2 Kähler form J and spinor curvature component R_{03} are given in terms of vierbein by

$$\begin{aligned} J &= 2\left[e_1 \wedge e_2 + e_0 \wedge e_3\right] \ , \\ R_{03} &= 2e_1 \wedge e_2 + 4e_0 \wedge e_3 \ . \end{aligned} \tag{17}$$

The general form of the condition determining Weinberg angle is given by

$$\begin{aligned} E_Z \cdot \nabla p + (\nabla \cdot E_Z)p &= F \ , \\ F &= -6\nabla \cdot E_K - 2F_1 \ . \end{aligned} \tag{18}$$

Here E_Z corresponds R_{03} term in em field and E_K to Kähler electric field and F_1 corresponds to the $W_{+,\nu}W_-^{\mu\nu} - W_{-,\nu}W_+^{\mu\nu}$ term. It is assumed that $1/e^2$ factor multiplying em current is constant. If this is not the case, the replacement $F \rightarrow F + 2E_{em}\nabla 2log(e^2)$ must be made on the right hand side.

These differential equations are of the same form as renormalization group equations and continuous solutions exist if one can introduce a coordinate system in which the flow lines of Kähler electric field correspond to one coordinate. This is possible if Z^0 electric field is of the form

$$E_Z = \phi dt \ . \tag{19}$$

This implies the integrability condition $dE_Z = d\phi \wedge dt$ implying

$$dE_Z \wedge E_Z = 0 \ . \tag{20}$$

By introducing space-time coordinates (x,t) (t does not refer to time now) the equation can be written in the form

$$\frac{dp}{dt} + \frac{\nabla \cdot E_Z}{\phi} p = \frac{F}{\phi} \ . \tag{21}$$

solutions can be written as

$$\begin{aligned} p &= p_0 + p_1 \ , \\ \frac{dp_0}{dt} + \frac{\nabla \cdot E_Z}{\phi} p_0 &= 0 \ , \\ \frac{dp_1}{dt} + \frac{\nabla \cdot E_Z}{\phi} p_1 &= \frac{F}{\phi} \ . \end{aligned} \tag{22}$$

p_0 and p_1 are given by

$$
\begin{aligned}
p_0(x,t) &= p_{00}(x) + exp\left(-\int_0^t du \frac{\nabla\cdot E_Z(x,u)}{\phi}\right) , \\
p_1(x,t) &= p_0(x,t)\int_0^t du \frac{F}{p_0\phi}(x,u) \ .
\end{aligned} \tag{23}
$$

Whether $p_{00}(x) = constant$ is consistent with field equations is an open question.

3. What happens when the integrability condition fails?

The failure of the integrability condition has interpretation as failure of the smoothing out procedure. A natural guess is that in this case the coupling constant is continuous or perhaps even smooth with respect to p-adic topology below the p-adic length scale for some prime p. Non-integrability would provide a rather satisfactory differential-topological understanding of how effective p-adic topology emerges.

3. Questions related to the physical interpretation

This picture raises several interesting questions related to the physical interpretation.

1. What is the TGD counterpart of Higgs=0 phase? The dimension of CP_2 projection is is analogous to temperature and one can argue that massivation is analogous to a loss of correlations due to the increase of D bringing in additional degrees of freedom. Massless extremals having $D = 2$ all induced gauge fields are massless so that they are excellent candidates for Higgs=0 phase. Does this mean that already $D = 3$ space-time sheets correspond to a massive phase?

2. Why electro-weak length scale corresponding to Mersenne prime M_{89} is preferred [F3]? Are there also other length scales in which electro-weak massivation occurs and thus scaled copies of electro-weak bosons? These questions reduce to the questions about the stability of the proposed bifurcations.

3. The basic problem of TGD based model of condensed matter is to explain why classical long range gauge fields do not give rise to large parity breaking effects in atomic length scale but do so in cell length length scale at least in the case of living matter (bio-catalysis). The proposal has been that particles feed electro-weak and em gauge fluxes to different space-time sheets. Could it be that blocks of bio-matter with size larger than cell the space-time sheets at which em and weak charges are feeded can be in Higgs=0 phase whereas for smaller blocks screening occurs already at quark and lepton level.

   This would be consistent with the fact that the dimension D of CP_2 projection tends to decrease with the size of the space-time sheet: the larger the space-time sheet, the nearer it is to a vacuum extremal. Robertson-Walker cosmologies are exact vacuum extremals carrying however non-vanishing gravitational 4-momentum densities. By previous argument W and Z masses are identical in this kind of phase if the vanishing of vacuum em field is used to fix p. The weakening of correlations caused by classical non-determinism might imply massivation.

4. Do long ranged non-screened vacuum Z^0 and W gauge fields have some quantum counterparts as quantum-classical correspondence would suggest? Does dark matter identified as a phase with large value of $\hbar$ [J6] correspond to a phase in which electro-weak symmetry breaking is absent in the bosonic sector?

   This phase would differ from the ordinary one in that the weak charges of leptons and quarks are not screened in electro-weak length scale but that their masses are very nearly the same as in Higgs=0 phase since the dominant contribution to the masses of elementary fermions is not given by a coupling to Higgs type particle but determined by p-adic thermodynamics [F2, F3].

Does bio-matter involve this kind of phase at larger space-time sheets as chirality selection suggests [F9]? Does this phase of condensed matter emerge only above length scale defined by the cell size or cell membrane thickness?

5 TGD based view about dark matter

5.1 Dark matter as macroscopic quantum phase with a gigantic value of Planck constant

A rather unexpected support for the macroscopic quantum coherence comes from the work of D. Da Rocha and Laurent Nottale who 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.

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

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

5.2 Dark matter as macroscopic quantum phase with gigantic Planck constant

D. Da Rocha and Laurent Nottale, the developer of Scale Relativity, have ended up with an highly interesting quantum theory like model for the evolution of astrophysical systems [23] (I am grateful for Victor Christianto for informing me about the article). The model is simply Schrödinger equation with Planck constant $\hbar$ replaced with what might be called gravitational Planck constant

$$\hbar \quad \rightarrow \quad \hbar_{gr} = \frac{GmM}{v_0} \quad . \tag{24}$$

Here I have used units $\hbar = c = 1$. v_0 is a velocity parameter having the value $v_0 = 144.7 \pm .7$ km/s giving $v_0/c = 4.6 \times 10^{-4}$. The peak orbital velocity of stars in galactic halos is 142 ± 2 km/s whereas the average velocity is 156 ± 2 km/s. Also subharmonics and harmonics of v_0 seem to appear.

The model makes fascinating predictions which hold true. For instance, the radii of planetary orbits fit nicely with the prediction of the hydrogen atom like model. The inner solar system (planets up to Mars) corresponds to v_0 and outer solar system to $v_0/5$. The predictions for the distribution of major axis and eccentrities have been tested successfully also for exo-planets. Also the periods of 3 planets around pulsar PSR B1257+12 fit with the predictions with a relative accuracy of few hours/per several months. Also predictions for the distribution of stars in the regions where morphogenesis occurs follow from the Schödinger equation.

What is important is that there are no free parameters besides v_0. In [23] a wide variety of astrophysical data is discussed and it seem that the model works and has already now made predictions which have been later verified. A rather detailed model for the formation of solar system making quantitatively correct predictions follows from the study of inclinations and eccentricities predicted by the Bohr rules: the model proposed seems to differ from that of Nottale which makes predictions for the probability distribution of eccentricities and inclinations.

I have proposed already earlier [E10] the possibility that Planck constant is quantized and the spectrum is given in terms of logarithms of Beraha numbers: the lowest Beraha number B_3 is completely exceptional in that it predicts infinite value of Planck constant. The inverse of the gravitational Planck constant could correspond a gravitational perturbation of this as $1/\hbar_{gr} = v_0/GMm$. The general philosophy would be that when the quantum system would become non-perturbative, a phase transition increasing the value of $\hbar$ occurs to preserve the perturbative character and at the transition $n = 4 \rightarrow 3$ 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.

The most interesting predictions from the point of view of living matter are following.

1. The dark matter is still there and forms quantum coherent structures of astrophysical size. In particular, the (Z^0) magnetic flux tubes associated with the planetary orbits define this kind of structures. The enormous value of h_{gr} makes the characteristic time scales of these quantum coherent states extremely long and implies macro-temporal quantum coherence in human and even longer time scales.

2. The rather amazing coincidences between basic bio-rhythms and the periods associated with the orbits in solar system suggest that the frequencies defined by the energy levels of the gravitational Schrödinger equation might entrain with various biological frequencies such as the cyclotron frequencies associated with the magnetic flux tubes. For instance, the period associated with $n = 1$ orbit in the case of Sun is 24 hours within experimental accuracy for v_0. Second example is the mysterious 5 second time scale associated with the Comorosan effect [24, 25].

5.3 How the scaling of $\hbar$ affects physics?

It is relatively easy to deduce the basic implications of the scaling of $\hbar$.

1. If the rate for the process is non-vanishing classically, it is not affected in the lowest order. For instance, scattering cross sections for say electron-electron scattering and e^+e^- annihilation are not affected in the lowest order since the increase of Compton length compensates for the reduction of α_{em}. Photon-photon scattering cross section, which vanishes classically and is proportional to $\alpha_{em}^4\hbar^2/E^2$, scales down as $1/\hbar^2$.

2. Higher order corrections coming as powers of the gauge coupling strength α are reduced since $\alpha = g^2/4\pi\hbar$ is reduced. Since one has $\hbar_s/\hbar = \alpha Q_1Q_2/v_0$, $\alpha Q_1 Q_2$ is effectively replaced with a universal coupling strength v_0. In the case of QCD the paradoxical sounding implication is that α_s would become very small.

3. The binding energy scale $E \propto \alpha_{em}^2 m_e$ of atoms scales as $1/\hbar^2$ so that a partially dark matter for which protons have large value of $\hbar$ does not interact appreciably with the visible light. Scaled down spectrum of binding energies would be the experimental signature of dark matter. The resulting atomic spectrum is universal and binding energy scale $\alpha^2 m_e$ is replaced with $v_0^2 m_e$ which corresponds to $\sim .115$ eV and wavelength of $\simeq 10.78$ μm, a typical size of cell. Bohr radius is 12.2 nm for dark hydrogen atom whereas the thickness of cell membrane is about 10 nm. It would be amazing if living matter would exhibit scaled down atomic spectra with this universal energy scale.

5.4 Simulating big bang in laboratory

An important steps in the development of ideas were stimulated by the findings made during period 2002-2005 in Relativist Heavy Ion Collider (RHIC) in Brookhaven compared with the finding of America and for full reason.

1. The first was finding of longitudinal Lorentz invariance at single particle level suggesting a collective behavior. This was around 2002.

2. The collective behavior which was later interpreted in terms of color glass condensate meaning the presence of a blob of liquid like phase decaying later to quark gluon plasma since it was found that the density of what was expected to be quark gluon plasma was about ten times higher than expected.

3. The last finding is that this object seems to absorb partons like black hole and behaves like evaporating black hole.

In my personal Theory Universe the history went as follows.

1. I proposed 2002 a model for Gold-Gold collision as a mini big bang identified as a scaled down variant of TGD inspired cosmology. This makes sense because in TGD based critical cosmology the initial state has vanishing mass per comoving volume instead of being infinite as in radiation dominated cosmology. Any phase transition involving a generation of a new space-time sheet might proceed in this universal manner.

2. Cosmic string soup in the primordial stage is replaced by a tangle of color flux tubes containing the color glass condensate. CGC is made macroscopic quantum phase by conformal confinement (the conformal weights of partons are complex and relate to zeros of zeta) and only the net conformal weight is real in this phase). Flux tubes correspond to flow lines of incompressible liquid flow and non-perturbative phase with a very large $\hbar$ is in question.

Gravitational constant is replaced by strong gravitational constant defined by the relevant p-adic length scale squared since color flux tubes are analogs of hadronic strings. Presumably L_p, $p = M_107 = 2^107 - 1$, is the p-adic length scale since Mersenne prime M_{107} labels the space-time sheet at which partons feed their color gauge fluxes. Temperature during this phase could correspond to Hagedorn temperature for strings and is determined by string tension. Density would be maximal.

3. Next phase is critical phase in which the notion of space-time in ordinary sense makes sense and 3-space is flat since there is no length scale in critical system (so that curvature vanishes). During this critical phase phase a transition to quark gluon plasma occurs. The duration of this phase fixes all relevant parameters such as temperature (which is the analog of Hagedorn temperature corresponding since critical density is maximal density of gravitational mass in TGD Universe).

4. The next phase is radiation dominated quark gluon plasma phase and then follows hadronization to matter dominated phase provided cosmological picture still applies.

Since black hole formation and evaporation is very much like formation big crunch followed by big bang, the picture is more or less equivalent with the picture in which black hole like object consisting of string like objects (mass is determined by string length just as it is determined by the radius for black holes) is formed and then evaporates. Black hole temperature corresponds to Hagedorn temperature and to the duration of critical period of the mini cosmology.

5.5 Living matter as dark matter

The most important gift of RHIC was that several theoretical notions and ideas emerged during last years, and applying in hugely different length and time scales by p-adic fractality, integrate nicely.

1. Dark matter is identified as a macroscopic quantum phase with large $\hbar$ for which particles have complex conformal weights and by conformal confinement behaves like single coherent whole. Dark matter controls living matter and this explains the weird looking findings about Bohr rules for planetary orbits.

2. Living matter would be also matter with large value of $\hbar$ and form conformally confined blobs behaving like single units with extremely quantal properties, including free will of course! Dark matter would be responsible for the mysterious vital force.

3. Any system for which some interaction becomes so strong that perturbation theory does not work gives rise to this kind of system in a phase transition in which $\hbar$ increases to not lose perturbativity gives rise to this kind of "super-quantal" matter.

4. Physically $\hbar$ means a larger unit for quantum numbers and this requires that single particle states form larger particle like units. This kind of collective states with weak mutual interactions are of course very natural in strongly interacting systems. At the level of quantum jumps quantum jumps integrate effectively to single quantum jump and longer moments of consciousness result. Conformal confinement guarantees all this. Entire hierarchy of size scales for conformally confined blobs is predicted corresponding to values of $\hbar$ related to Beraha numbers but there would be only single value corresponding to very large $\hbar$ for given values of system parameters (gravitational masses, charges,...). The value of $\hbar$ determines the characteristic time and length scales associated with the conscious living system. One could say that the claim that quantum mechanics in its recent form is not enough for understanding living matter is correct: dynamical $\hbar$ is needed.

5. The picture might have implications also for the understanding of condensed matter. For instance, liquids might be liquids because they contain dark some matter at magnetic/Z^0 magnetic flux tubes (darkness follows from the large value of $\hbar$). A rather detailed model for dark super nuclei consisting of a blob of dark nuclei and for dark atoms emerges if the criticality condition $NZ\alpha_{em}/v_0 \simeq 1$ is assumed to fix the number of nuclei of dark super-atom. The basic implication is that the energy levels of dark super atoms depend only weakly on the atomic charge.

6. The facts that that dark atoms have Bohr radii in the range .2-.8 mm, which corresponds to the size scales for the basic neuronal moduli of cortex, and the wavelength associated with the ionization energies is of order 9 cm (the size of brain hemisphere) plus many other co-incidences suggest that dark matter could play key role in grey matter.

5.6 Anti-matter and dark matter

The usual view about matter anti-matter asymmetry is that during early cosmology matter-antimatter asymmetry characterized by the relative density difference of order $r = 10^{-9}$ was somehow generated and that the observed matter corresponds to what remained in the annihilation of quarks and leptons to bosons. A possible mechanism inducing the CP asymmetry is based on the CP breaking phase of CKM matrix.

The TGD based view about energy [D3, D5] forces the conclusion that all conserved quantum numbers including the conserved inertial energy have vanishing densities in cosmological length scales. Therefore fermion numbers associated with matter and antimatter must compensate each other. Therefore the standard option is definitely excluded in TGD framework.

An early TGD based scenario explains matter antimatter asymmetry by assuming that antimatter is in vapor phase. This requires that matter and antimatter have slightly different topological evaporation rates with the relative difference of rates characterized by the parameter r. A more general scenario assumes that matter and antimatter reside at different space-time sheets. The reader can easily guess the next step. The strict non-observability of antimatter finds an elegant explanation if anti-matter is dark matter.

5.7 Are long ranged classical electro-weak and color gauge fields created by dark matter?

The various model for the screening of electro-weak charges discussed during years cannot banish the unpleasant feeling that the screening cannot be complete enough to eliminate large parity breaking effects in atomic length scales The really elegant manner to avoid various catastrophes caused by long range electro-weak gauge fields could emerge only after a considerable increase in the understanding of the mathematical structure of TGD and the emergence of a view about what dark matter is.

p-Adic length scale hypothesis suggests the possibility that both electro-weak gauge bosons and gluons can appear as effectively massless particles in several length scales and there indeed exists evidence that neutrinos appear in several scaled variants [17] (for TGD based model see [F3]).

This inspires the working hypothesis that long range classical electro-weak gauge and gluon fields are space-time correlates for light or massless dark electro-weak gauge bosons and gluons, which are massless.

1. Ordinary quarks and leptons would be essentially identical with their standard model counterparts with electro-weak charges screened in electro-weak length scale so that the problems related to the smallness of atomic parity breaking would be trivially resolved.

2. TGD suggests an explanation of dark matter as a macroscopically quantum coherent phase residing at larger space-time sheets [J6]. The particles of dark matter carry complex conformal weights but the net conformal weights for blocks of dark matter would be real. This implies conformal confinement and macroscopic quantum coherence. TGD suggests that $\hbar$ is dynamical and possesses a spectrum expressible in terms of generalized Beraha numbers $B_r = 4cos^2(\pi/r)$, where $r > 3$ is a rational number [C7, J6]. Just above $r = 3$ arbitrarily large values of $\hbar$ and thus also macroscopic quantum phases are possible.

3. For this scenario to make sense it is essential that p-adic thermodynamics predicts for dark quarks and leptons essentially the same masses as for their ordinary counterparts [F3]. Only the electro-weak boson masses which are determined by a different mechanism than the dominating contribution to fermion masses [F2, F3] would be small or vanishing.

4. The hypothesis that classical long ranged electro-weak gauge fields serve as classical space-time correlates for dark electro-weak gauge bosons, which are massless, could explain the special properties of bio-matter, in particular the chiral selection as resulting from the coupling to dark Z^0 quanta. Long range weak forces present in TGD counterpart of Higgs=0 phase should allow to understand the differences between biochemistry and the chemistry of dead matter.

5. For ordinary condensed matter quarks and leptons Z^0 charge would be screened in electro-weak length scale whereas in dark matter phase Z^0 electric flux would be feeded to say $k = k_Z = 169$ space-time sheet corresponding to neutrino Compton length and having size of cell. In condensed matter blobs of size larger than neutrino Compton length (about 5 μm if $k = 169$ determines the p-adic length scale of condensed matter neutrinos) the situation could be different.

The facts that parity breaking effects are strong in living matter and the p-adic length scales $k = 151, 157, 163, 167$ spanning the range between 10 nm (cell membrane thickness) and 2.5 μm cell size correspond to Gaussian Mersennes [K2], suggest that dark neutrinos are condensed at these space-time sheets. An interesting possibility is that dark matter phase quite generally condenses at the space-time sheets corresponding to Gaussian primes, in particular Gaussian Mersennes, which are much more abundant than ordinary Mersennes. Perhaps the fact that conformal weights are complex corresponds to the complex character of the primes involved. Only a fraction of the condensed matter consisting of regions of size $L(k)$ need to be in the dark phase.

Nuclear length scale $L(113)$ corresponds to Gaussian Mersenne: this raises the possibility that strong force binding nucleons can increase the value of $\hbar$ so that perturbation theory applies. By the general considerations of [J6] this would make nucleons atom sized structures so that ordinary nuclear nucleons cannot be dark. Nuclear scattering cross sections would not be however changed in the lowest order perturbation theory. In [F8, J6] a model of cold fusion based on the assumption that nuclear protons transform to dark protons is discussed.

The basic prediction of TGD based model of dark matter as a phase with a large value of Planck constant is the scaling up of various quantal length and time scales. A simple quantitative model for condensed matter with large value of $\hbar$ predicts that $\hbar$ is by a factor $\sim 2^{11}$ determined by the ratio of CP_2 length to Planck length larger than in ordinary phase meaning that the size of dark neutrons would be of order atomic size. In this kind of situation single order parameter would characterize the behavior of dark neutrinos and neutrons and the proposed model could apply as such also in this case.

Dark photon many particle states behave like laser beams decaying to ordinary photons by de-coherence meaning a transformation of dark photons to ordinary ones. Also dark electro-weak bosons and gluons would be massless or have small masses determined by the p-adic length scale in question. The decay products of dark electro-weak gauge bosons would be ordinary electro-weak bosons decaying rapidly via virtual electro-weak gauge boson states to ordinary leptons. Topological light rays ("massless extremals") for which all classical gauge fields are massless are natural space-time correlates for the dark boson laser beams. Obviously this means that the basic difference between the chemistries of living and non-living matter would be the absence of electro-weak symmetry breaking in living matter (which does not mean that elementary fermions would be massless).

In conformally confined phase phase Fermi statistics allows neutrinos to have same energy if their conformal weights are different so that a kind "fermionic Bose-Einstein condensate" would be in question. If both nuclear neutrons and neutrinos are in dark phase, it is possible to achieve a rather complete local cancellation of Z^0 charge density. On the other hand, the large parity breaking effects in living matter dramatically manifesting themselves in bio-catalysis, suggest that Bose-Einstein condensates of dark electro-weak gauge bosons could appear already in molecular length scales.

6 Model for topological condensation and evaporation

It is useful to distinguish between total and partial topological evaporation and condensation.

In total topological evaporation all # ($\#_B$) contacts of the particle to various space-time sheets (small holes inside 3-surfaces) are split and the particle is 'outside the space-time' after the evaporation.

Since gravitational mass and gauge charges of the particle give rise to long ranged classical fields, one might argue that these charges are nullified by the charges associated with the classical gauge fields and that boundary conditions actually require this. For CP_2 type vacuum extremals classical color charges can be however non-vanishing in vapor phase. In the case gravitational mass boundary contribution to the gravitational mass should take care of the vanishing of the net gravitational mass. The interactions be mediated by the exchange of CP_2 type vacuum extremals could be interpreted in terms of topological gravity. This picture would conform with effective 2-dimensionality stating that the light-like causal determinants and corresponding partonic 2-surfaces characterize physical states as well as with quantum holography stating the duality of interior and boundary degrees of freedom. There is however no absolutely compelling reason why the conserved inertial four-momentum of the evaporated particle should vanish.

In partial topological evaporation only the # and $\#_B$ contacts connecting the particle to some space-time sheets are split. If primarily condensed CP_2 extremal evaporates as a vacuum extremal, nothing happens to the parton quantum numbers. Thus for the topological evaporation of the space-time sheet containing condensed CP_2 type extremal the microscopic mechanism is same as for the partial topological evaporation. In the following the considerations are restricted to the modelling of total topological evaporation and condensation.

6.1 The description of topological condensation and evaporation in terms of partons

The causal horizons associated with # contacts and presumably also the orbits of the holes connected by $\#_B$ contacts are light-like 3-surfaces and carry parton quantum numbers. Hence the description of the topological condensation and evaporation should reduce to parton scattering with the splittings of # and $\#_B$ contacts introduced as additional vertices.

Concerning topological condensation and evaporation via the splitting or generation # contact one can distinguish two cases according to whether the space-time sheets involved have opposite or same time orientation.

1. If the time orientations are identical the partons associated with wormhole contact carry net quantum numbers and it seems that the # contact can form only as a fusion of CP_2 type extremals associated with partons at the two space-time sheets involved. This would represent a formation of a new kind of bound state with binding due to CP_2 type vacuum extremal allowing interpretation as a gravitational instanton. Also color binding might be an appropriate interpretation since strong classical color fields are indeed present. This process can of course occur also when the space-time sheets have opposite time orientations.

   The splitting of CP_2 type extremal leading to topological evaporation could occur as a consequence of ordinary scattering event in which the ends of the "dipole" formed by the causal horizons scatter from particles at their respective space-time sheets and could be described by introducing additional vertex. These "dipoles" couple also to the difference of classical gauge fields associated with with the two space-time sheets.

2. In the case that the time orientations are opposite, # contact could be created in the double topological condensation of CP_2 type vacuum extremal to the two space-time sheets generating a pair of partons. Net quantum numbers, in particular four-momentum, must vanish for this pair. The reversal or this process would be emission of # contact as CP_2 type vacuum extremal and could be associated with a scattering taking care of conservation of quantum numbers.

If one requires that the evaporated elementary particle has vanishing gauge charges, the partons associated with the "lower" ends of the # contacts must have same net gauge charge as the elementary particle itself. The evaporated particle must also carry an additional energy associated with the partons appearing in # contacts and having same sign as particle's energy. This could give the dominant contribution to the condensation energy when space-time sheets have same time orientation. One could say that topological condensation forms a gauge copy of elementary particle at the larger space-time sheet.

For $\#_B$ contacts analogous processes are possible and correspond to formation/splitting of bond between light-like partonic 3-surfaces. Also in this case color bond provides an attractive manner to understand the binding. Induced color fields in the bond are indeed non-vanishing for non-vacuum extremals. Also in this case scattering of partons would be an essential for the topological evaporation and condensation.

Note that the partons scattered in topological condensation and evaporation do not correspond to ordinary elementary particles and the interpretation in terms of dark matter could be more appropriate. Hence the earlier phenomenological model to be discussed in sequel assuming that these processes accompany ordinary scattering of elementary particles cannot be regarded as a microscopic model and can be of phenomenological value only.

6.2 Model for the structure of the topological condensate

One can consider two basic alternative structures for the topological condensate.

1. The strictly hierarchical structure for which the non-screened gauge charges at level k are feeded to the next level. In this case one can consider even the possibility of topological evaporation for objects of macroscopic size. Previous arguments however make strictly hierarchical structure improbable.

2. A non-hierarchical structure for which say a fraction of order $(L(k_0)/L(k))^3$ of the gauge charge at level k_0 is feeded to the level k. This scaling law would be in accordance with the fractality of the topological condensate. In this case topological evaporation in long length scales becomes highly improbable process as a single particle process since given condensate

level (in particular, the nuclear condensate level) has # and $\#_B$ contacts to many levels. It might however be that the maximization of the Kähler function forces this process to occur as a macroscopic quantum phase transition rather than as a classical deterministic process. This alternative leads to some exotic effects at atomic physics level (atom with nuclear charge Z can have electrons bound on orbitals of the lighter atoms, say, hydrogen atom if part of the nuclear charge is feeded to some level with $k > k_{em} = 131$) and the breaking of the hierarchical structure must be rather small.

These considerations suggest the following general picture of topological condensate, which is not totally hierarchical as believed earlier [F5].

1. The electro-weak charges of ordinary quarks and leptons are screened in electro-weak length scale so that all problems related to electro-weak parity breaking in hadronic, nuclear, and atomic length scales are resolved. Color gauge fluxes are feeded to the hadronic space-time sheet having $k = 107$. According to the considerations of [F5] quarks feed their em gauge fluxes to a space-time sheet characterizing the mass scale of the quark. Somewhat surprisingly u, d and s quarks correspond to $113 \leq k < 107$, where $k = 113$ is the nuclear space-time sheet.

2. Dark quarks with non-vanishing Z^0 charge feed their gauge fluxes to the space-time sheet at which dark neutrinos are condensed. Chiral selection of bio-molecules in vivo suggests that at least $k_Z = 151, 157, 163, 167$, which correspond to Gaussian Mersennes, correspond to dark space-time sheets with typical sizes varying between cell membrane thickness and typical cell size. This would conform with the rule that massless gauge bosons with real conformal weights correspond to Mersenne primes and those with complex conformal weights to Gaussian Mersennes.

3. Ordinary nuclei feed their em gauge fluxes to $k_{em} = 127$ or $k_{em} = 131$ level. It is possible that the entire electromagnetic gauge flux is feeded to the level k_{em}. Em charge at k_{em} level is almost totally neutralized by electrons condensed on this level. Fractality suggests that the fraction $1/\sqrt{\epsilon}$ of the unscreened gauge charge obeys scaling law $1/\sqrt{\epsilon} \propto 1/L^3(k)$. The levels $k = k_{em}, ..., 167, ..$ are purely electromagnetic and one could have $sin^2(\theta_W) = 1/4$ guaranteing the vanishing of the vectorial part of Z^0 charge of proton and electron for them. This is however not necessary if long range electro-weak fields are created by dark matter.

4. Dark quarks, hadrons or nuclei feed their Z^0 fluxes to the levels $k \geq k_Z$ and practically all flux goes to $k = k_Z$ level. Dark neutrino screening enters into game at level $k = k_Z$ for the first time. Fractality suggests scaling law for the partial screening of the dark nuclear Z^0 charges by dark neutrinos.

It is not necessary to assume that dark $k > k_Z$ levels are purely electromagnetic or Z^0 type since the field strengths are weak by screening effects and the ratio of dark Z^0 and electromagnetic charge and current densities are expected to be constant in length scale resolution $L(k)$ so that one can find imbeddings describing both classical Z^0 and electromagnetic fields. This picture means that the notion of topological evaporation must be replaced with partial evaporation since different gauge fluxes are feeded to different space-time sheets.

6.3 Energetics and kinetics of condensation and evaporation

Condensation corresponds to a formation of certain kind of bound states and certain condensation energy E_{cond} is liberated in the process. Part of the particle's energy is transformed to the total energy associated with the # contacts formed in the condensation but in the following considerations this delicacy is not mentioned. Condensation leads to a generation of various YM fields

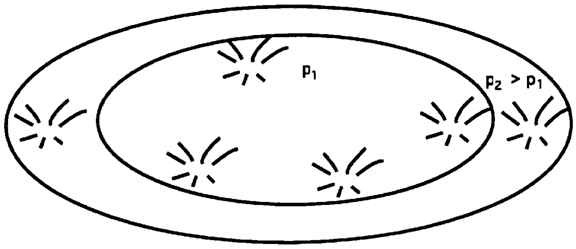

Figure 1: Gauge and gravitational fluxes could run to lower condensate level via # throats located near boundaries.

associated with the particle: some of these fields, in particular long range Z^0 field, are vacuum screened in the length scale defined by the Compton length of associated copies of weak bosons. In lack of better term, the energy associated with the gauge fields will be referred as Kähler interaction energy E_K. The quantum mechanical zero point energy E_0 related to the zero point motion of the particle on the condensate level must also be taken into account, when condensation takes place to a 3-surface with finite size. In length scales much larger than p-adic length scale also gravitational interaction energy E_{gr} with the condensate is important and dominates over E_K. Condensed particles (say nucleons in atomic nucleus) can form join along boundaries bonds and this gives additive contribution E_{join} to the binding energy. In topological evaporation the particle gains energy $E_{cond} + E_{join} + E_{gr} - E_K - E_0$ from the condensate so that this energy difference measures the stability of the condensed particle against evaporation. The problem is to derive general order of magnitude estimates for E_{cond}, E_{join}, E_K and E_0 as well as condensation and evaporation times τ_{cond} and τ_{evap} for a condensation of 'particle' of level $p_1 < p_2$ on level p_2.

6.3.1 Condensation energy

Consider first the estimation of the condensation energy. The mass spectrum of any system is fixed by p-adic Super Virasoro invariance. Particle massivation results from the primary condensation of elementary particle surfaces (CP_2 type extremals) on $p = p_{cr}$ surfaces and further condensation correspond to a formation of bound states and mass renormalization. It is natural to assume that the scale for the change E_{cond} of the rest mass in the condensation at the level $p > p_1$ is just the natural mass scale of p:th level given by the inverse of the p-adic length L_p

$$\begin{aligned} E_{cond} &= \frac{c}{L_p} \ , \\ L_p &= \sqrt{p}l \ , \\ l &\simeq k10^4\sqrt{G} \ , \\ k &\simeq 1.288 \ . \end{aligned} \tag{25}$$

l is the fundamental p-adic length scale and of the same order of magnitude as CP_2 size: at this length scale it is not possible to regard elementary particles as point like objects so that space-time cannot be idealized as a slightly deformed piece of Minkowski space containing point like particles anymore. The cutoff length scale L_p is important in the physics of the p:th condensation level since ordinary real physics is expected to apply, when regions of size L_p are idealized as points. The expectation is that p-adic length scales give favored size scales for 3-surfaces, which by topological field quantization have finite size. c is some numerical constant not very far from unity.

The guess applies also, when it is not possible to speak of a well defined experimentally measurable binding energy: a good example is the condensation of quarks around hadronic 3-surface. The binding energy hypothesis leads to a quite unique physical identification for the fundamental condensation levels. Hadrons correspond to M_{107} -adic 3-surfaces, u and d quarks and atomic nuclei correspond to $p \simeq 2^{113}$-surfaces with $L(113) \simeq 1.5910^{-14}$ meters, atomic length scale correspond to prime p near 2^{131} and there are several indications that prime powers of two define physically favored length scales above atomic length scales (see later chapters).

An important point to notice is that E_{cond} corresponds to renormalization of mass and is therefore Lorentz scalar. From the requirement that mass stays positive in condensation it follows that the condensation is not possible unless the condition $m - E_{cond} \geq 0$ is not satisfied. This condition excludes the condensation on surfaces with size much smaller than the Compton length of the particle. At the non-relativistic limit of the theory condensation energy can be described as a potential well of depth E_{cond}. A good example is the description of atomic nuclei as a condensate of nucleons on $p \simeq 2^{113}$ surface: condensation energy provides a first principle explanation for the self consistent potential well used in the shell model.

E_{cond} is of same order of magnitude for, say the condensation of single nucleon and nucleus on atomic condensation level so that E_{cond} is negligible for large condensing systems. An estimate for the parameter c is obtained by identifying the condensation energy with mass renormalization in standard model. The justification for this identification comes from the idea that p-adic coupling constant and mass renormalization results from secondary condensation. This kind of estimate leads to values in the range $c \sim .5 - .7$.

6.3.2 Join along boundaries energy

The formation of join along boundaries bonds leads to a reduction of the kinetic energy since translational degrees of freedom are transformed to vibrational degrees of freedom. In the limit of a strong join along boundaries bond, the energy reduction is essentially the difference between the kinetic energies of the initial and final states. Also the classical long range interactions between the particles forming join along boundaries bond contribute to E_{join}. A general order of magnitude estimate for the binding energy part of E_{join} is $E_{join} \sim b/L(k)$, $b < 1$. The formation of the join along boundaries bonds plays key role in TGD based description of the nuclear force and also in the color confinement of valence quarks. Join along boundaries bonds make also possible the formation of larger macroscopic quantum systems from basic blocks with a typical size L_p and realize the quantum criticality of TGD in this manner.

6.3.3 Kähler energy and gravitational energy

Topological condensation is in general accompanied by the generation of long range gravitational, electromagnetic and possibly also Z^0 gauge fields. The gauge charges and gravitational mass of the vapor phase particle are assumed to vanish due to the presence of the vacuum charges and the negative gravitational mass associated with the vacuum of the evaporated particle. In principle, one can consider the possibility that it is energetically favorable to not develop some long range fields in some circumstances. In the case of the Z^0 field this option solves the problems associated with Rutherford scattering (Z^0 # contacts split for a nucleus having a kinetic energy larger than $1/L(k_Z)$ in the rest frame of the condensed matter system). In case of electromagnetic and gravitational fields the occurrence of this phenomenon would have rather dramatic technological consequences (cold fusion, antigravity vehicles).

Order of magnitude estimates for the Kähler interaction energy E_K (just the sum of various Yang Mills energies, of graviton energy and of fermionic contribution and gravitational interaction energy E_{gr} can be written down once the mass m and other quantum numbers of the condensing system, the size L of the p_2-adic background surface, its total mass $m(tot)$ and the value of the $\epsilon_1(p_1, p_2)$ is known. For example, if condensing system is neutral many particle system with $Q_K = \frac{\epsilon_1 m}{m_{proton}}$ one can write in good approximation

$$\begin{aligned}
E_K &= E_{self} + E_{int} \ , \\
E_{self} &= c_s \alpha_K \frac{Q_K^2}{L_{p_2}} \ , \\
E_{int} &= c_{int} \alpha_K \frac{Q_K Q_K(tot)}{L} \ , \\
Q_K &= \epsilon_1 \frac{m}{m_{proton}} \ , \\
Q_K(tot) &= \epsilon_1 \frac{m(tot)}{m_{proton}} \ .
\end{aligned} \tag{26}$$

Here E_{self} is the energy associated with the Kähler field created by the condensed particle: the proportionality to $\frac{1}{L_{p_2}}$ is natural since p_2-adic cutoff length scale gives a natural lower bound for the integral of the Kähler energy density over p_2-adic condensate level. E_{int} is the Kähler interaction energy of the condensed particle with the other condensed particle on the p_2-adic surface of size L. c_s and c_{int} are numerical constants depending on condensing system and condensate.

Similar order of magnitude estimates hold true for the gravitational interaction energy. Kähler energy transforms as the time component of a four-vector in Dirac equation. In the non-relativistic limit (Schrödinger equation) Kähler interaction energy reduces the depth of the potential well from E_{cond} to $E_{cond} - E_K(self)$.

The representation in terms of Kähler charges is not very useful in nuclear physics and condensed matter length scales since $\epsilon(p_1, p_2)$ depends on the properties of the condensing system. It is more useful to write Kähler action as sum of electromagnetic and Z^0 contributions: for neutral condensed matter systems the latter contribution dominates. For the condensing electron the Kähler self energy is essentially electromagnetic self energy.

6.3.4 Zero point kinetic energy

Zero point motion is a purely quantum mechanical effect deriving from the finite size of the condensate surface. The effect is not important in the macroscopic length scales. Idealizing the condensate level p_2 as a box with size L, the order of magnitude estimate for the zero point energy is obtained from the zero point momentum of the condensed particle equal to $p = \frac{\pi}{L}$: $E_0 \simeq \sqrt{\frac{3\pi^2}{L^2} + m^2}$. At the non-relativistic limit $E_0 \simeq \frac{3\pi^2}{2mL^2}$ zero point kinetic energy becomes important factor in the condensation, when the size of the background surface is small and the competition between condensation and zero point energies determines the most stable condensation level for particle. At the relativistic limit the contribution to the condensation energy behaves as $\frac{\pi}{L}$ and has same dependence on L as condensation and Kähler energies. Zero point kinetic energy plays key role in TGD based quantum model of metabolism [K6].

6.4 Fraction of particles in vapor phase in thermal equilibrium

Whether thermal equilibrium between vapor phase and condensate particles makes sense, depends on the rates for topological evaporation and condensation and at this stage one can make only guesses. The proposed QFT description implies that rates can be estimated using ordinary field theory and that the analog of Rutherford scattering can make evaporation and condensation rates large for charged particles. The evaporation rates become small, when the number of # contacts increases. Evaporation might well be rapid enough also above elementary particle length scales if the numbers of Z^0 # contacts and photon/graviton # contacts (near the boundaries) scale A/L_p^2 respectively, as suggested by scale invariance.

In thermal equilibrium (incoherent evaporation) the Boltzmann factor $exp(\Delta E/T)$ defined by the difference ΔE between particle energies in vapor phase and condensate determines the fraction of time spend in vapor phase and condensate respectively. Since the dynamics is basically determined by the minimization of the Kähler action, ΔE should involve only condensation energy, join along boundaries energy, gravitational energy and zero point and Kähler energies so that one has

$$\begin{aligned} \frac{\tau(vapor\ phase)}{\tau(condensate)} &= exp(-\frac{\Delta E}{T}) \ , \\ \Delta E &= E_{cond} + E_{join} + E_{gr} - E_K - E_0 \ . \end{aligned} \tag{27}$$

$\Delta E < 0$ favors evaporation.

The inclusion of the gravitational contribution to the formula implies thermal stability against topological evaporation in long length scales for massive particles. For the astrophysical values of the Kähler charge the fraction of the time spent in the vapor phase is completely negligible.

What is interesting that for the particles with mass larger than $\sqrt{\frac{\epsilon_Z}{\alpha_Z}}M_{Pl}$ the Z^0 contribution to energy can become larger than gravitational contribution so that in thermal equilibrium vapor phase dominates. Same can happen also in electromagnetic case. There is no upper bound for the size of the evaporated condensate block since purely Coulombic potential is in question. Needless to emphasize, the possible consequences of the evaporation are quite dramatic.

6.5 Quantum field model for topological evaporation and condensation

In the following a phenomenological model for topological evaporation and condensation processes reducing the estimation of evaporation and condensation rates to ordinary field theory model is discussed. The model was constructed more than a decade before the parton description of topological condensation and must be taken as the first noble attempt to understand what might be involved. What makes the model phenomenological is that that topological condensation and evaporation are assumed to occur in the ordinary scattering of particles without any attempt to model what happens microscopically. As found, the microscopic description would be based on the scattering of partons associated with # and $\#_B$ contacts inducing their formation or splitting. The basic unknowns of the model are the splitting amplitudes.

The model relies on following assumptions.

1. For a given elementary particle P condensed and vapor phase state can be regarded as two different states P_c and P_v. The vapor phase state has vanishing charge but the neutralizing charge is near the boundaries of the 3-surface. This implies that vapor phase particle behaves at sufficiently high momentum exchanges as a charged particle, as can be easily seen by modelling the neutralizing charge distribution near the boundary as a spherical shell. At sufficiently low energies vapor phase particles should behave as dipoles: the smallness of the parity breaking effects suggests that the modelling as a magnetic dipole is a good approximation as far as the modelling of electro-weak exchanges is considered.

2. The exchange of gauge bosons between two elementary particle surfaces corresponds to the following geometric process.

i)The emission of a gauge boson condensed on $p = p_{cr}$ primary condensation level of the elementary particle is the basic process. In general, this process is followed by the splitting of the $p = p_{cr}$ surface to two pieces (the original particle and emitted boson) by the reverse of the join along boundaries process, which can happen also for $p_1 \neq p_2$ surfaces. The boson can be either condensed on background surface $p = p_1 > p_{cr}$ or can propagate in vapor phase.

ii) The absorption of the gauge boson is just the reverse of this process. When join along boundaries bond is formed the gauge boson condensed on exchanged 3-surface propagates along the resulting 'bridge' to the 3-surface associated with the second particle and gets absorbed.

iii) This model does not differentiate between vapor phase particles and condensate particles in any manner. One must however notice that the exchanged vapor phase boson are always neutral! The basic approximation of this description is the neglect of dynamical complications related to the flow of charges to lower condensate levels. For instance, the absorption of vapor W boson by condensate electron $e_c$is followed by the formation of new # contacts feeding the gauge flux neutralizing W to lower condensate levels so that at level p the process indeed transforms e_c to ν_c.

3. The basic vertices are the standard model vertices describing the emission of gauge bosons condensed on the primary condensation level of the condensing particle. The second basic vertex describes topological condensation or evaporation. The ordinary vertices for can be replaced with vertices for which each line corresponds to a condensate or vapor phase state. Unitary requires that the sum of coupling strengths associated with the emission of vapor phase and condensate state sum up to the observed coupling strengths. This leads to description analogous to Cabibbo mixing: to each elementary particle one can associate angle θ, which can depend on particle. If condensate state $P(\#)$ is emitted in the vertex one uses coupling $gcos(\theta)$ and if vapor phase state $P(vap)$ is emitted one uses the coupling $gsin(\theta)$.

4. Evaporation and condensation processes correspond to the generation of a # contact or splitting of a # contact. At least in atomic length scales there are many kinds of # contacts (those feeding Z^0, electromagnetic and gravitational fluxes between condensate levels and also the contacts feeding quantized magnetic flux). For elementary particles one can use as a good starting hypothesis the assumption that all contacts are identical so that two amplitudes $a(cond)$ and $a(evap)$ describe the formation and splitting of # contact respectively. Microscopic reversibility suggests that one has $a(evap) = a(cond)$. In Dirac equation one must introduce fields describing vapor and condensate fermions and the condensation/evaporation term correspond to non-diagonal mass term in the mass matrix. It is natural to assume that condensation term is proportional to the condensation energy so that, in case of fermions, one has

$$\begin{aligned} M_{vv} &= M_{op} \ , \\ M_{vc} = M_{cv} &= \epsilon \frac{E_{cond}}{M} M_{op} \ , \\ M_{vv} &= (1-\epsilon) \frac{E_{cond}}{M} M_{op} \ . \end{aligned} \tag{28}$$

For Kac Moody spinors reducing to H-spinors in cm degrees of freedom one must use M_{op}, which is linear combination of of CP_2 type gamma matrices. If one uses ordinary M^4 spinors M_{op} is just the particle mass. This description means that in the scattering amplitude leading to a condensation or evaporation of given fermionic external line, the addition of a condensation or evaporation vertex means just an insertion of the factor

$$\frac{1}{p^k\gamma_k - M_{op}}\epsilon E_{evap} \quad \rightarrow \quad \pm\epsilon \ , \tag{29}$$

between the outgoing spinor and rest of the diagram and since outgoing particle is on mass shell particle it is eigen state of propagator with eigenvalue $\pm E_c$. The diagrams describing evaporation and condensation are obtained by multiplying ordinary diagrams with the parameter ϵ identifiable as evaporation amplitude.

For bosons one obtains essentially identical description by using the mass squared matrix

$$\begin{aligned} M_{vv}^2 &= M^2 \ , \\ M_{vc}^2 = M_{cv}^2 &= \epsilon M^2 - (M - E_c)^2 \ , \\ M_{cc} &= (M - E_c)^2 \ . \end{aligned} \tag{30}$$

In principle, the evaluation of the evaporation and condensation rates should be performed using the p-adic QFT limit of TGD. The practical evaluation of evaporation and condensation rates can be done using standard model and apart from small kinetic modifications everything reduces to the calculation of standard processes at elementary particle level. An exception is formed by the quarks: in this case one must be able to evaluate the evaporation of the states formed by color singlet combinations of quark like 3-surfaces connected to each other by joing along boundaries bonds identifiable as color flux tubes. In this case the first guess is that free quark approximation works provided one assumes that all quarks evaporate simultaneously so that the vaporation of the baryonic valence quarks involves at least two gauge boson exchanges.

6.5.1 Spontaneous condensation

The estimation of the spontaneous condensation rates via photon emission a provides the first example. In vapor phase the charged particle is neutral due to the neutralizing charge near the boundary and therefore only magnetic moment can contribute to spontaneous condensation rate (electric dipole moment is probably very small). Spontaneous condensation can take place via emission of photon followed by the condensation vertex in order to take care of energy conservation (recall the presence of condensation energy E_{cond}.

As a concrete example consider the spontaneous condensation of neutron via one photon emission made possible by the anomalous magnetic moment $\mu = eg/m_n$ of the neutron. Dimensional considerations show that the rate is related to the condensation rate of the charged particle by the factor $(E_c/m_n)^2$ coming from the gradient coupling: the condensation time is given by

$$\tau_{cond} \quad = \quad = \frac{16(2\pi)^4}{c^3 g^2 \alpha_{em}\epsilon^2}(m_n L(k))^3 L(k) \ . \tag{31}$$

Spontaneous condensation rate is of order $\epsilon^2 10^{-3}/s$ on $k = 131$ level. The condensation length $L_{cond} = \beta\tau_{cond}$ is extremely long unless the velocity β is very small: $L_{cond}(k = 131) \sim (\beta/\epsilon^2) \cdot 10^{-1}\ m$. Topological evaporation becomes also possible, when neutrons or any other particles are irradiated with long wave length photons ($\lambda \sim 10^{-2}\ m$ for neutron in $k = 131$ case) having energy $\sim E_c \sim 10^{-8}\ eV$. Evaporation rate might be reduced if there are several # contacts per particle:

for n contacts per particle one expects the replacement of ϵ^2 with ϵ^{2n} whereas condensation rate does not suffer this reduction. This kind of mechanism might be at work already in case of neutron.

In long length scales spontaneous condensation rate becomes very small. For massive neutrino the spontaneous condensation rate is extremely small (Z^0 magnetic moment causes the condensation). Energetics requires the emission of photon and a loop diagram involving two W propagators is needed. The electromagnetic spontaneous condensation involves the emission of a photon with definite energy and the observation of this process gives a test for the theory.

Condensation and evaporation of photon seems at first impossible in the description idealizing the metric of the space-time surface with M^4 metric and neglecting the presence of the induced gauge fields.

1. The first observation is that condensation energy corresponds to a renormalization of mass and must vanish identically. A formal possibility is that condensation energy is replaced with a light like condensation momentum: condensation momentum would be characterized by the number ϵ telling the reduction of photon momentum in condensation: $P(\gamma) \rightarrow (1-\epsilon)P(\gamma)$.

2. Spontaneous condensation requires the existence of a vertex containing two photon lines plus some additional lines. This kind of a vertex does not exist since photon corresponds to an Abelian gauge field at QED limit (weak interactions introduce a nonlinear $[A, W][A, W]$ term). It seems that this conclusion holds quite generally: it is not possible for a photon to condense or evaporate directly if condensation momentum is non-vanishing. If the condensation momentum vanishes then one obtains just direct momentum conserving coupling of the condensate photon to vapor phase photon and one can find new photon basis states, which do not couple to each other at all. As a matter fact, in this basis photon would be massive! Perhaps the most natural interpretation is that photon propagates from the moment of emission to the moment of absorption in vapor or condensed phase. Photon can of course become absorbed and remitted and in this manner transform from vapor phase photon to condensate photon and vice versa.

3. If one gives up the idealization of the metric of the space-time surface with a flat metric the direct transformation from vapor phase photon to condensate photon becomes possible. This means that gravitational interaction is taken into account and in the flat space-time description condensation of photon corresponds to the emission of a virtual graviton followed by transformation into condensed state and reabsorption of graviton, which has emitted graviton. Needless to say, the rate for this process is extremely small.

4. The second idealization is the neglect of vacuum gauge fields. Unlike in ordinary QED, in TGD space-time surfaces can be carriers of non-vanishing, purely classical, vacuum electromagnetic currents. In particular, so called massless extremals allow light like vacuum gauge currents. The amplitude for the creation/annihilation of vapor photon must be proportional to the Fourier component of the interaction term $j^{\mu}_{vac}A_{\mu}(qu)$ and for light like currents one has even resonance! The quantum model for micro-tubules as quantum antennas [J4] is based on the idea that the light like currents associated with the micro-tubules serve as quantum antennas making possible generation of macroscopic quantum coherent states of photons in bio-systems. Similar argumentation applies also in the case of graviton and the light like vacuum Einstein tensor associated with the massless extremals generates also coherent state of gravitons.

6.5.2 Evaporation and condensation via interactions

The spontaneous evaporation of an elementary particle is not energetically possible. The process can however takes via interaction in external fields or via the interaction with the particles in condensate or vapor phase or condensate (in practice photon exchange in the latter case). The orders of magnitudes for the rates are apart from the factor ϵ_V^2 just rates for processes $P + X \rightarrow P + anything$. For instance, condensation length and evaporation rates in matter are related by a factor $1/\epsilon_V^2$ to the free path of elementary particle in system:

$$\begin{aligned} L(evap) &\sim \frac{L(free)}{\epsilon_V^2(evap)} \ , \\ \frac{1}{\tau_{evap}} &= \beta \frac{1}{L(evap)} \ , \end{aligned} \tag{32}$$

where β is the velocity of the particle with respect to the rest frame of the condensate surface. Also condensation can take place in the similar manner, the only complication being that for small momentum exchanges one must describe vapor phase particle as a magnetic dipole. This makes it possible to estimate evaporation and condensation rates readily in, say, condensed matter systems using standard physics.

From the result one can deduce the ratio of times spent by elementary particle in vapor phase and condensate respectively at the high energy limit, when vapor phase particles are expected to behave as charged particles:

$$\begin{aligned} \frac{t(vapor)}{t(cond} &= \frac{\tau_{cond}}{\tau_{evap}} \\ &\sim \frac{1}{1 + \frac{L(free)}{\beta \epsilon^2 \tau_{spont}})} \ . \end{aligned} \tag{33}$$

where τ_{cond} corresponds to total condensation rate for various condensate levels k available: the shortest available $L(k)$ dominate in spontaneous condensation rate. For non-relativistic velocities β condensate phase dominates. For instance, for electron and $k = 137$ level condensate phase dominates for $\beta << 10^{-6}$. When $L(k)$ and $L(free)$ are of same order evaporation comes important: in hadron physics this kind of situation is encountered and the proposed explanation of Pomeron relies on the simultaneous evaporation of valence quarks: the evaporation rate for valence quarks is reduced by the requirement that several # throats split whereas condensation rate is not restricted in this manner so that the fraction of vapor phase should be small. Note that Pauli Exclusion principle can greatly reduce the condensation rate for fermions (say electrons) if the available state are nearly filled and lead to large fraction of the vapor phase fermions.

For neutrinos the time fractions spent in vapor phase and condensate phase are very nearly identical since spontaneous condensation rate is extremely small (note that only Z^0 magnetic moment contributes to spontaneous condensation rate). The scattering in the classical fields associated with the condensate can however increase the condensation and evaporation rates drastically. An interesting possibility is the evaporation of neutrinos in the classical Z^0 fields created by the nuclei.

6.5.3 Topological evaporation at long length scales?

An exciting possibility is that topological evaporation could take place in macroscopic length scales and lead to a state possessing no gravitational mass in long length scales. Thermal considerations suggest that it might be possible to achieve the situation, where thermal equilibrium favors vapor phase. The problem is that thermal equilibrium is not possible unless evaporation and condensation rates are high enough.

For a hierarchical structure of topological condensate topological evaporation can be considered seriously even at macroscopic length scales since gauge fluxes from a given level run to the next level only and if level is electro-weakly neutral only gravitational # contacts must be split in evaporation. The gravitational flux associated with contact is probably limited (by Planck mass?) and this means that for systems not very much heavier than Planck mass the number of the # contacts need not be large. The possibility that topological condensate is in good approximation hierarchical at length scales supported by condensed matter physics considerations.

For a non-hierarchical condensate for which each level feeds its gravitational and gauge fluxes to very many condensate levels situation looks quite different. Even for nucleon there are Z^0 # contacts to $k \geq k_Z$ levels and electromagnetic # contacts to $k \geq 131$ levels plus the # contacts feeding gravitational gauge flux to these levels. The diagram describing the evaporation involves large number of vertices involving the number ϵ^2 (not known at this stage) and the incoherent evaporation rate is expected to be very small. This suggests that space-time looks in long length scales very classical.

Topological evaporation could also occur as a macroscopic quantum process proceeding like a phase transition. Space-time surface corresponds to a maximum (or quantum superposition of maxima) of the Kähler function. It is in principle possible for some values of the zero modes characterizing the size and shape and the induced Kähler field of the 4-surface to achieve a situation in which the dominant maximum corresponds to the surface for which # contacts are split. If condensed and evaporated configurations are quantum entangled with external system, also a quantum jump selecting the evaporated configuration becomes very probable.

One possibility to overcome the problem of small evaporation rate is that evaporated system corresponds to Bose-Einstein condensate consisting of elementary particles at the same level. Evaporation process involves a rather small change of energy and therefore it corresponds to almost forward scattering for the evaporated system. The almost forward scattering rate should be large. One possibility is that the number of bosons in condensate changes. If bosons are same quantum state the induced emission is in question and the probability of the process is proportional to $N^2(boson)$: this factor could help to compensate the large power of ϵ^2 in evaporation rate. A concrete realization of this mechanism might be possible for charged particles. The relevant diagrams describe exchange of $N+1$ photons between N so that from each charged particle line two photon-propagators start. It is possible to arrange the exchanged momenta so that the scattering is in forward direction apart from the correction coming from the condensation energy. The amplitude associated with this diagram is very large in the forward direction due to the appearance of the photon propagators. The diagram is proportional to $((m^2/k^2)\epsilon_V^2)^N$. Infrared cutoff implies $k^2 \geq 1/L^2(k)$ but if $L(k)$ corresponds to sufficiently long length scale the amplitude is large: this is the case if one has $L(k) > 1/(\epsilon_V m)$. For electron mass (Cooper pairs might be in question) one has $L(k) > 10^{-9}\ m$ assuming $\epsilon_V^2 \sim 10^{-7}$ suggested by the astrophysical considerations of later chapter.

Second possibility is quantum coherent evaporation. This means that for energetic reasons or by the requirement that action is minimized the classical evolution of the space-time surface leads to the splitting of all # contacts and evaporation. This process would be a phase transition like phenomenon and the quantum criticality of the TGD Universe raises some hopes about the realizability of this process. In fact, in TGD based picture ordinary liquid vapor phase transition corresponds to the splitting of the join along boundaries contacts and the splitting of the # contacts is completely analogous process geometrically. Of course, also a partial topological evaporation, where the condensate blocks evaporate from single condensate level, is possible.

The third possibility is so simple that it took considerable time to discover it. If condensate block $k_1 < k$ at level k is in motion, it is doomed to enter to the boundary of the block k sooner or later. If the energy of the k_1 block is not too large it is probably reflected near the boundary. For a large enough energy k_1 block could suffer topological evaporation. An alternative possibility is that the original k block decomposes into two pieces and the second, moving piece, contains k_1 block and some # contacts captured from the boundary of the original block feeding the gauge flux of k_1 block from level k to the next condensate level so that topological evaporation does not take place. At this stage it is not possible to estimate the rates of these processes.

6.6 Topological evaporation in particle physics

6.6.1 Topological evaporation, quark gluon plasma and Pomeron

Topological evaporation of elementary particles means nothing if CP_2 type vacuum extremal evaporates so that one must assume that it is quark space-time sheet or join along boundaries block of quark space-time sheets which evaporates. Second new element is the identification of valence quarks as dark matter in the sense of having large $\hbar$: $\hbar_s \simeq (n/v_0)\hbar$, $v_0 \simeq 2^{-11}$, $n = 1$ so that Compton length is scaled by the same factor. Quark gluon plasma would correspond to a phase with ordinary value $\hbar$ and possibly also sea partons can be regarded as this kind of phase. Color bonds between partons are possible also in this phase.

Concerning the evaporation there are two options.

1. The space-time sheets of sea partons are condensed at much larger space-time sheets defined by the space-time sheets of valence quarks connected by color bonds. Topological evaporation of the parton sea would correspond to the splitting of # contacts connecting sea partons space-time sheets to valence quark space-time sheets.

2. Sea partons condensed at a larger space-time sheet which in turn condenses at the space-time sheet of valence quarks. In this case topological evaporation occurs for the entire sea parton space-time sheet.

One can consider two possible scenarios for topological evaporation of quarks and gluons.

1. Color gauge charge is not identified as gauge flux and single secondarily condensed quark space-time sheet can suffer topological evaporation. In this case quark gluon plasma could be identified as vapor phase state for quarks and gluons.

2. Color gauge charge is identified as gauge flux and only join along boundaries blocks formed from quarks can evaporate. Join along boundaries contacts are naturally identified as color flux tubes between quarks. These tubes need not be static. Quark gluon plasma corresponds to condensed state in which the join along boundaries contacts between quark like 3-surfaces are broken. The evaporation of single quark is possible but as a consequence a compensating color charge develops on the interior of the outer boundary of the evaporated quark and the process probably can be interpreted as an emission of meson from hadron. The production of hadrons in hadron collision could be interpreted as a topological evaporation process for sea and valence quarks.

The problematic feature of scenario 1) is the understanding of color confinement In scenario 2) color confinement of the vapor phase particles is an automatic consequence of the assumption that color charge corresponds to gauge flux classically (gauge field is $H^A J_{\alpha\beta}$, H^A being the Hamiltonian of the color isometry. This does not however exclude the possibility that hadron might feed part of its color isospin or hypercharge gauge flux to surrounding condensate. The concept of anomalous hypercharge introduced in earlier work as proportional to electromagnetic charge indeed suggests this kind of possibility. It should be noticed that for the vacuum extremals of Kähler action induced Kähler field and thus also color fields vanish identically.

The alternatives 1) and 2) have an additional nice feature that they lead to elegant description for the mysterious concept of Pomeron originally introduced to describe hadronic diffractive scattering as the exchange of Pomeron Regge trajectory [18]. No hadrons belonging to Pomeron trajectory were however found and via the advent of QCD Pomeron was almost forgotten. Pomeron has recently experienced reincarnation [19, 20, 21]. In Hera [19] $e-p$ collisions, in which proton scatters essentially elastically whereas jets in the direction of incoming virtual photon emitted by electron are observed. These events can be understood by assuming that proton emits color singlet particle carrying a small fraction of proton's momentum. This particle in turn collides with the virtual photon (antiproton) whereas proton scatters essentially elastically.

The identification of the color singlet particle as Pomeron looks natural since Pomeron emission describes nicely the diffractive scattering of hadrons. Analogous hard diffractive scattering events in pX diffractive scattering with $X=\bar{p}$ [20] or $X=p$ [21] have also been observed. What happens is that proton scatters essentially elastically and the emitted Pomeron collides with X and suffers hard scattering so that large rapidity gap jets in the direction of X are observed. These results suggest that Pomeron is real and consists of ordinary partons.

The TGD identification of Pomeron is as sea partons in vapor phase. In TGD inspired phenomenology events involving Pomeron correspond to pX collisions, where incoming X collides with proton, when sea quarks have suffered coherent simultaneous (by color confinement) evaporation into vapor phase. System X sees only the sea left behind in the evaporation and scatters from it whereas dark valence quarks continue without noticing X and condense later to form quasi-elastically scattered proton. If X suffers hard scattering from the sea, the peculiar hard diffractive scattering events are observed. The fraction of these events is equal to the fraction f of time spent by sea quarks in vapor phase.

Dimensional arguments suggest a rough order of magnitude estimate for $f \sim \alpha_K \sim 1/137 \sim 10^{-2}$ for f. The fraction of the peculiar deep inelastic scattering events at Hera is about 5 percent, which suggest that f is about 6.8 times larger and of same order of magnitude as QCD α_s The time spent in condensate is by dimensional arguments of the order of the p-adic legth scale $L(M_{107})$, not far from proton Compton length. Time dilation effects at high collision energies guarantee that valence quarks indeed stay in vapor phase during the collision. The identification of Pomeron as sea explains also why Pomeron Regge trajectory does not correspond to actual on mass shell particles.

The existing detailed knowledge about the properties of sea structure functions provides a stringent test for the TGD based scenario. According to [20] Pomeron structure function seems to consist of soft ($(1-x)^5$), hard ($(1-x)$) and super-hard component (delta function like component at $x=1$). The peculiar super hard component finds explanation in TGD based picture. The structure function $q_P(x,z)$ of parton in Pomeron contains the longitudinal momentum fraction z of the Pomeron as a parameter and $q_P(x,z)$ is obtained by scaling from the sea structure function $q(x)$ for proton $q_P(x,z)=q(zx)$. The value of structure function at $x=1$ is non-vanishing: $q_P(x=1,z)=q(z)$ and this explains the necessity to introduce super hard delta function component in the fit of [20].

6.6.2 CKM matrix and the generation of matter antimatter asymmetry

Mass calculations and the number theoretic construction of CKM matrix give good hopes that CP breaking in elementary particle physics could be understood solely in terms of CKM matrix. The CP breaking seems to be to a large extend a number theoretic necessity following from rationality and unitarity of CKM matrix plus some other constraints. In [D6] a mechanism for the generation of matter antimatter asymmetry as resulting from the small difference of the evaporation rates for fermions and antifermions was suggested. One can quite well consider also the possibility that matter and antimatter reside at different space-time sheets: the model to be presented applies also in this case with minor modifications (evaporation rates are called transfer rates in the new formulation). If antimatter is in dark matter phase, the proposed simple model does not work as such. The difference was assumed to be caused by the presence of Kähler electric fields in condensate. The difference was associated with quark and anti-quark evaporation rates but color confinement forces to replace quarks with color neutral join along boundaries blocks of valence quarks. The difference in evaporation rates must be of order 10^{-9} in order to account for photon to baryon ratio. The net baryon number is generated in condensate, when cosmic temperature becomes so low that hadrons and anti-hadrons annihilate in condensate and vapor phase and vapor phase and condensate fall from mutual thermal equilibrium.

One can imagine several different scenarios for the generation of matter antimatter asymmetry. The common denominator is however CP non-invariant distribution of particles between different space-time sheets.

1. In the original scenario the difference in evaporation rates should result from interference of the ordinary non CP breaking contribution to evaporation amplitude and the amplitude associated with the external field, which has different sign for fermion and anti-fermion. The problem is to understand why the external field has just the needed strength.

2. The fact that CKM matrix provides a description for CP breaking in elementary particle physics suggests that also the difference for topological evaporation rates of baryon and anti-baryon should derive from CKM matrix. In the simplest picture valence and sea quarks are regarded as a single join along boundaries block. The evaporation of sea quark block (or equivalently valence quark block) is caused by the absorption of photon or any boson by one of the valence quarks leading to the splitting of # contacts. CP breaking results as interference of CP even and CP odd contributions to the diagrams describing topological evaporation. The simplest CP odd diagram involves besides the absorption of boson also W exchange between two valence quarks.

3. Matter antimatter asymmetry could be generated primordially in the sense that the rate for the generation of # contacts corresponding to $q_+\overline{q}_-$ pair differs from the rate for the generation $\overline{q}_+q_-$ pair. Here the subscript $\pm$ denotes the sign of the conserved energy. This would mean that the densities of quark and anti-quarks at given space-time sheet are different and matter antimatter asymmetry in its recent form is generated after annihilation. In this case there is no obvious connection with CKM matrix and this option will not be discussed in the sequel.

The nice feature of scenario 2) is that no further assumptions are needed. This does not mean that the basic idea of the original scenario 1) is wrong. The deeper mechanism implying CP-breaking of CKM matrix was left open in these calculations and it might that CP breaking caused by the presence of Kähler electric fields inside hadron manifest itself in the properties of CKM matrix. Therefore Kähler electric fields inside hadron rather than outside the hadron would imply different evaporation rates for hadrons and anti-hadrons.

A test for the scenario 2) is obtained using a simple order of magnitude estimate. The difference between evaporation amplitudes squared for baryon and anti-baryon can be estimated as the difference for the evaporation of the join along boundaries block formed by 3 valence quarks and is of the form

$$R = \frac{4Re(A\bar{B})}{A\bar{A}} . \tag{34}$$

A describes the CP non-breaking evaporation amplitude and B describes CP breaking part of amplitude involving W exchange. In order to simplify the description as much as possible consider following model.

1. Momentum is discretized in accordance with p-adic QFT field theory in space-time box with size L_p and instead of transition rates S-matrix elements are considered: this is necessary since in the lowest order diagram third quark does not scatter at all. p-Adic momentum

cutoff is applied so that the exchanged momenta are of order $\pi/L(107)$. The momenta in internal are measured in unit of $\pi/L(107)$. Instead of transition rates, S-matrix elements are considered since quantization volume is finite in time direction also (to guarantee the p-adic existence of the exponential defining the S-matrix).

2. Evaporation involves absorption of photon with momentum of order E_c by one of the quarks and subsequent scattering of this quark with second quark to make possible the evaporation without breaking momentum conservation. Since the relative momenta of quarks in the join along boundaries block can change by very small amount (otherwise join along boundaries block splits) it should be a good approximation to assume that scattering takes in forward direct in the approximation that condensation energy E_c vanishes. Infrared cutoff however means that the scattering into forward direction is kinematically impossible via photon or gluon exchange. The scattering in the forward direction via W exchange is however possible since due to the different values of quark mass masses kinematic constraints can be satisfied and W exchange just permutes the U and D type quarks of the initial state.

3. The lowest order diagram (see Fig. 6.6.2) for the topological evaporation involves just photon absorption by quark q_1 and scattering of q_1 and q_2 by W exchange whereas q_3 suffers no scattering. q_1 and q_2 must obviously correspond U and D type quarks of same generation i. The third quark must correspond to generation $j \neq i$ in order to obtain CP breaking. This scattering does not break CP invariance since CKM matrix element and its conjugate appear in vertices. Since photon absorption does not appreciably effect the value of the ration R a simplified situation without photon absorption will be studied.

4. The second order contribution (see Fig. 6.6.2) to the scattering involves two W exchanges. The second exchange must take place between q_2 and q_3. This diagram can be CP breaking. It is useful to restrict the consideration to the evaporation of cds baryon. There are to CP breaking diagrams if the quark in the propagator line is assumed to be light (see Fig. 6.6.2).

$$\begin{aligned} A &: csd \rightarrow sud \rightarrow sdc \ , \\ B &: csd \rightarrow dsu \rightarrow dcs \ . \end{aligned} \tag{35}$$

If t quark appears in the propagator line one obtains two additional diagrams but these are suppressed due to the large mass of the top quark. It is obvious that baryons of form $U_iD_iq_k$, $k \neq i$, where k and i label different quark generations, allow CP breaking.

5. The CP breaking contribution to the transition probability comes from the interference between the lowest order and second order contributions to the evaporation amplitude. For order of magnitude purposes the presence of photon in the line 1 is neglected and scattering in question is assumed to take place into forward direction. The ratio R is determined the CP breaking part of the forward W -exchange amplitude in the previous formula and the estimate for the asymmetry parameter R reads as

$$\begin{aligned} R(107, csd) &= 4N(channel)\frac{e^2 J}{sin^2(\theta_W)|V_{cs}|^4}\frac{\pi^2}{m_W^2 L^2(107)} f(m_i/m_j) \ , \\ N(channel) &= 2 \ , \\ L(107)m_p &\simeq .0745 \ , \end{aligned} \tag{36}$$

where f is some function of quark quarks mass ratios and J is the CP breaking parameter. The remaining parameters can be read directly from the general structure of Feynman diagrams in question (note that m_W^2 in propagator is measured in units of $\pi^2/L^2(107)$). Calculating the required Feynman diagrams (assuming that join along boundaries quarks are at rest and scatter in forward direction) on obtains for f in $U_iD_iD_j$, $j \neq i$ diagram with quark U_k in the propagator line the expression

$$\begin{aligned} f(q_i/q_j) &= \frac{1}{3}\frac{(1+x_{31}-x_{21})(3x_{13}+x_{23})}{(1+x_{23}^2+x_{13}^2-x_{43}^2+2(x_{13}-x_{23}-x_{13}x_{23}))} \ , \\ x_{ij} &\equiv \frac{m_i}{m_j} \ , \end{aligned} \quad (37)$$

where m_i, $i=1,2,3$ are the masses of U_i, D_i D_j and m_4 is the mass of the quark in the propagator line. For cds case one has $f \sim m_d/m_c \sim 10^{-1}$. For csb one has $f \sim 1$.

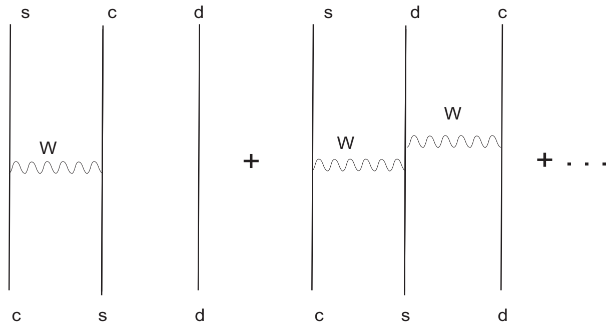

Figure 2: Typical diagrams contributing to topological evaporation rate of valence quarks inside hadron. The interference between first and second order diagrams gives CP breaking.

In the chapter devoted to the calculation of hadron masses in the third part of the book, the constraints posed by unitarity, rationality plus some physical requirements on CKM matrix were studied. The following CKM matrix provides a solution to the bounds for the moduli of CKM matrix elements and is consistent with all physical constraints: it is however an open problem whether the number theoretic constraints coming from rational unitarity allow physical solution.

$$V = \begin{bmatrix} 0.9741 & -0.2260-0.0000i & -0.0029+0.0023i \\ 0.2258 & +0.9734-0.0005i & +0.0222+0.0314i \\ 0.0096 & +0.0344+0.0149i & -0.2279-0.9729i \end{bmatrix}$$

$$|V| = \begin{bmatrix} 0.9741 & 0.2260 & 0.0037 \\ 0.2258 & 0.9734 & 0.0385 \\ 0.0096 & 0.0374 & 0.9992 \end{bmatrix} \quad (38)$$

J is the invariant characterizing CP breaking and in terms of CKM matrix defined as

$$J = Im(V_{11}V_{22}\bar{V}_{12}\bar{V_{21}}) = c_1c_2c_3s_2s_3s_1^2 sin(\delta) \ , \quad (39)$$

where the latter expression corresponds to Kobayashi-Maskawa parametrization. Unitarity triangle [22] bounds the value of the invariant J to be in the range

$$1.0 \times 10^{-4} \leq \quad J \quad \leq 1.7 \times 10^{-4} \ . \tag{40}$$

One obtains the following estimates for *csd* and *csb* channels

$$\begin{aligned} R(107, csd) &\simeq 6 \cdot 10^{-10}(m_d/m_c) \ , \\ R(107, csb) &\simeq 6 \cdot 10^{-10} \ , \end{aligned} \tag{41}$$

for the lower limit of J. The order of magnitude is perhaps somewhat too small for *csd* channel but correct for *csb* channel. This might produce problems if the asymmetry created by baryons containing t or b type quarks is washed out via the the decay to lighter quarks so that only the baryons containing quarks of the two lowest two generations determine the value of R. This is not expected to happen if the value of the evaporation probability ϵ^2 is sufficiently small. Note also that if several final states are possible then the ratio increases.

This rough estimate suggests that the evaporation of valence quarks inside ordinary baryons could indeed have generated the asymmetry below temperature $T = m_W$. The condensation evaporation rates (that is the parameter ϵ^2 should be so small that the thermal equilibrium between vapor phase and condensate is destroyed before the beginning of annihilation so that annihilation proceeds leaving net baryon number in condensate and vapor phase. The subsequent condensation from vapor phase should not lead to appreciable annihilation since the density of baryons in condensate is only a fraction 10^{-9} from the original density.

What about topological evaporation in the new hadron physics for M_n, $n = 89, 61, ..$? Already for M_{89} hadrons the the mass of W boson should not imply very drastic reduction of asymmetry and one obtains much larger asymmetry of order 10^{-3} if the parameter CKM remains same. It might well be that the matter antimatter asymmetry has been larger in temperatures larger than m_W and that the annihilation of M_{89} hadrons to ordinary hadrons has re-established the matter antimatter symmetry to be destroyed later again below temperatures of of order $\pi/L(107)$.

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