General View About Physics in Many-Sheeted Space-Time: Part I

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Contents

Abstract

In this chapter the notion of many-sheeted space-time is discussed. Topological condensation and evaporation represent the basic new concepts of TGD and an attempt to formulate a general qualitative theory of the topological condensation and evaporation and TGD based space-time concept is made.

The notion of many-sheeted space-time used is roughly that as it was around 1990. The fusion of real and various p-adic physics to single coherent whole by generalizing the notion of number, the generalization of the notion of the imbedding space to allow a mathematical representation of dark matter hierarchy based on dynamical and quantized Planck constant, parton level formulation of TGD using light-like 3-surfaces as basic dynamical objects, and so called zero energy ontology force to generalizes considerably the view about space-time. These developments are discussed in the next chapter.

The topics to be discussed in the sequel will be following.

1. The general structure of topological condensate

The question what 3-space looks like in various scales and end up to a purely topological description for the generation of structures. Topological arguments imply a finite size for non-vacuum 3-surfaces and the conservation of the gauge and gravitational fluxes requires that 3-surface feeds these fluxes to a larger 3-surface via # contacts situated near the boundaries of the 3-surface. Renormalization group invariance (RGI) hypothesis suggests that 3-surfaces with all sizes are important in the functional integral and this leads to the idea of the many-sheeted space-time with hierarchical, fractal like structure such that each level of the hierarchy corresponds to a characteristic length scale.

2. Topological field quantization

The general space-time picture suggested by RGI hypothesis can be justified mathematically. Due to the compactness of CP_2, a general space-time surface representable as a map $M^4 \rightarrow CP_2$ decomposes into regions, "topological field quanta", characterized by certain vacuum quantum numbers and 3-surface is in general unstable against the decay to disjoint components along the boundaries of the field quanta.

Topological field quanta have finite size depending on the values of the vacuum quantum numbers: the size increases as the values of the vacuum quantum numbers increase. Topological field quantum is therefore a good candidate for a quantum coherent system provided some Bose Einstein condensate or quantum coherent state is available. The BE condensate or coherent state of the light # contacts near the boundaries of the topological field quantum is a good candidate in this respect. It came as a total surprise that this the generation of vacuum expectation value of Higgs field corresponds to the generation of this kind of macroscopic quantum phase.

The requirement of the gauge charge conservation in turn implies the hierarchical structure of the topological condensate: gauge fluxes must go somewhere from the outer boundaries of the topological field quantum

with finite size and this 'somewhere' must be a larger topological field quantum, which in turn feeds its gauge fluxes to a larger topological field quantum,.... Of course, the nonlinearity of the theory could allow vacuum charge densities which can cancel the net charge near boundaries.

Most importantly, topological field quanta allow discrete scalings as a dynamical symmetry. p-Adic length scale hypothesis states that the allowed scaling factors correspond to powers of $\sqrt{p}$, where the prime p satisfies $p \simeq 2^k$, k integer with prime values favored. p-Adic fractality (actually multi-p-fractality) can be justified more rigorously by a precise formulation for the fusion of real and various p-adic physics based on the generalization of the notion of number.

3. General physical consequences of new view about space-time

The physical consequences of the new space-time picture are nontrivial at all length scales.

a) A natural interpretation for the hierarchical structure is in terms of bound state formation. Quarks condense to form hadrons, nucleons condense to form atomic nuclei, nuclei and electrons condense to form atoms, how atoms condense to form molecules, and so on. One ends up with a general picture for the topology of 3-space associated with, say, solid state and with the idea that even the macroscopic bodies of the everyday world correspond to topologically condensed 3-surfaces.

b) The join of 3-surfaces along their boundaries defines a new kind of interaction, which has in fact has been used in phenomenological modelling of chemical reactions. Usually chemical bond is believed to result from Schrödinger equation. At the macroscopic level this interaction is rather familiar to us since it means that two macroscopic bodies just touch each other.

c) In TGD context there are purely topological necessary conditions for quantum coherence and a topological description for dissipative phenomena. The formation of the join along boundaries bonds plays a decisive role in the description and this process provides a universal manner to generate macroscopic quantum systems. There is also a topological description for the formation of the supra phases and the phase of the order parameter of the supra phase ground state contains information about the homotopy of the join along boundaries condensate.

4. Gauge bosons and Higgs boson as wormhole contacts, electro-weak symmetry breaking, the weakening of Equivalence Principle, and color confinement

The proper understanding of the concepts of gauge charges and fluxes and their gravitational counterparts in TGD space-time has taken a lot of efforts. At the fundamental level gauge charges assignable to light-like 3-D elementary particle horizons surrounding a topologically condensed CP_2 type extremals can be identified as the quantum numbers assignable to fermionic oscillator operators generating the state associated with horizon identifiable as a parton. Quantum classical correspondence requires that commuting classical gauge charges are quantized and this is expected to be true by the generalized Bohr orbit property of the space-time surface.

There are however non-trivial questions. Do vacuum charge densities give rise to renormalization effects or imply non-conservation so that weak charges would be screened above intermediate boson length scale? Could one assign the non-conservation of gauge fluxes to the wormhole (#) contacts, which are identifiable as pieces of CP_2 extremals and for which electro-weak gauge currents are not conserved so that weak gauge fluxes would be non-vanishing but more or less random so that long range correlations would be lost?

It indeed turns that one can understand the non-conservation of weak gauge fluxes in terms of wormhole contacts carrying pairs of right/left handed fermion and left/right handed antifermion having interpretation as Higgs bosons. The average non-conserved light-like gravitational four-momentum of wormhole contact representing Higgs boson can be identified as the inertial four-momentum apart from the sign factor so that one can also understand particle massivation at fundamental level and a connection with p-adic thermodynamics based description of Higgs mechanism emerges. Also a detailed understanding about how Equivalence Principle is weakened in TGD framework emerges.

Later it became clear that all gauge bosons must be identified as wormhole contacts whereas elementary fermions correspond to wormhole throats assocaited with topologically condensed CP_2 type vacuum extremals.

Also color confinement can be understood using only quantum classical correspondence and general properties of classical color gauge field. Spin glass degeneracy allows to understand the generation of macro-temporal quantum coherence and the same mechanism allows also to understand more quantitatively color confinement by applying unitarity conditions.

5. Wormhole contacts, super-conductivity, and biology

Wormhole contacts, feeding gauge fluxes from a given sheet of the 3-space to a larger one, which are a necessary concomitant of the many-sheeted space-time concept. # contacts can be regarded as particles carrying classical charges defined by the gauge fluxes but behaving as extremely tiny dipoles quantum mechanically in the case that gauge charge is conserved. # contacts must be light, which suggests that they can form Bose-Einstein condensates and coherent states. The real surprise (after 27 years of TGD) was that the formation of these rather exotic macroscopic quantum phases could be identified as formation of vacuum expectation value of Higgs field for various scaled up copies of standard model physics. This kind of macroscopic quantum phases could be in a central role in the TGD inspired model for a bio-system as a macroscopic quantum system. Electromagnetically charged # contacts are also possible and would explain the massivation of photons in super-conductors implying that long ranged exotic W boson exchanges play a key role in super-conductivity.

6. 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 interpretation 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.

7. 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.

1 Introduction

The concept of topological condensation unifies two disparate approaches to TGD, namely TGD as a Poincare invariant theory of gravitation and TGD as a generalization of the string model. The idea is that classical 3- space with matter can be regarded as a 3-surface obtained by "gluing" particle like 3-surfaces to the background 3-surface with possibly macroscopic size: resulting topological in-homogenities correspond to matter. The "gluing" of two n-manifolds together by topological sum means the following operation: drill spherical holes to both n-manifolds and connect the resulting boundary components S^{n-1} with a tube $D^1 \times S^{n-1}$ (see Fig. 1.1). Of course, several # contacts, which are tiny 'wormholes' connecting two parallel space-time sheets, are expected to be present in the general case.

This chapter represents the view about many-sheeted space-time more or less in the form as it was before around 1990 with emphasis on the notions of topological condensation and evaporation. The fusion of real and various p-adic physics to single coherent whole by generalizing the notion of number, the generalization of the notion of the imbedding space to allow a mathematical representation of dark matter hierarchy based on dynamical and quantized Planck constant, parton level formulation of TGD using light-like 3-surfaces as basic dynamical objects, and so called zero energy ontology force to generalizes considerably the view about space-time.

1.1 Various types of topological condensation

One can in fact distinguish between three kinds of topological condensation.

1. 3-dimensional topological condensation, which is expected to give rise to the formation of bound states (not necessary all possible bound states).

2. 4-dimensional topological condensation, which results from the properties of the Kähler action: the minimizing four surface associated with a given set of 3-surfaces is in general connected so that long range interactions are generated between the 3-surfaces. This mechanism is in principle all what is needed to generate the so called classical space-time. Although the physical state can consist of arbitrarily many disjoint 3-surfaces, the space-time associated with these surfaces is connected and resembles the "classical" space-time, when topological inhomogenities are smoothed out. It should be noticed that 4-dimensional topological condensation corresponds to unstable 3-dimensional topological condensation. For the visualization purposes, one can consider a simplified example: instead of 3-surfaces consider strings so that space-time is replaced with a two-surface having strings as its boundaries.

3. 2-dimensional topological condensation: boundaries of the 3- surfaces are joined together by a tube $D^1 \times D^2$. This process will be referred as a formation of join along boundaries bonds.

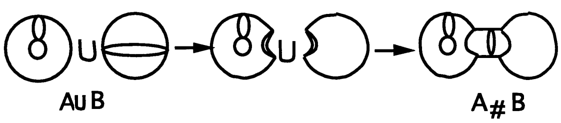

Figure 1: Topological sum of two manifolds

There are also reasons to suspect that the actual macroscopic 3-space is not connected but corresponds to a large macroscopic 3-surface, classical 3-space, plus a gas of small particle like 3-surfaces, "Baby Universes". It is to be expected that the effects related to the vapor phase particles are very small. An idealization is obviously needed in order to obtain something resembling the topologically trivial 3-space of the standard theories: topological inhomogenities of size smaller than a given length scale L are smoothed out and their presence is described using various currents, such as energy momentum tensor, gauge currents and particle number currents. To be precise, this works only provided one takes the limit $L \to \infty$ since TGD space-time could well be many sheeted in arbitrarily long length scales.

1.2 Implications of the topological non-triviality of macroscopic space-time

If one accepts that 3-space is topologically nontrivial, one must sooner or later end up asking following questions. What does 3-space actually look like in various scales? What are the general physical consequences of the new space time concept? Are they seen at elementary particle level only or perhaps at atomic, molecular, etc. levels? What is the 3-topology of the solid/liquid/gas state? What about macroscopic bodies: what do they correspond topologically?

In the following the general ideas about the topological condensation are discussed. These ideas have developed gradually in parallel with the development of the configuration space geometry and Quantum TGD, through the study of the extremals of Kähler action and through the attempts to apply TGD inspired ideas to many not so well understood phenomena like Higgs mechanism or more generally, particle massivation, color confinement, super fluidity, super conductivity, hydrodynamic turbulence, etc.. The ideas to be represented may look rather wild, when encountered outside the context defined by twenty years of personal work with many trials and errors and moments of discovery. It is the internal consistency rather than quantitative details, as well as the radically new approach provided to the problems of even macroscopic physics, which makes the scenario so exciting.

1.3 Topics of the chapter

The topics to be discussed in the sequel will be following:

1. The question what 3-space looks like in various scales and end up to a purely topological description for the generation of structures. Topological arguments imply a finite size for non-vacuum 3-surfaces and the conservation of the gauge and gravitational fluxes requires that 3-surface feeds these fluxes to a larger 3-surface via # contacts situated near the boundaries of the 3-surface. Renormalization group invariance (RGI) hypothesis suggests that 3-surfaces with all sizes are important in the functional integral and this leads to the idea of the many-sheeted space-time with hierarchical, fractal like structure such that each level of the hierarchy corresponds to a characteristic length scale.

2. The general space-time picture suggested by RGI hypothesis can be justified mathematically. Due to the compactness of CP_2, a general space-time surface representable as a map $M^4 \rightarrow CP_2$ decomposes into regions, "topological field quanta", characterized by certain vacuum quantum numbers and 3-surface is in general unstable against the decay to disjoint components along the boundaries of the field quanta. Topological field quanta have finite size depending on the values of the vacuum quantum numbers: the size increases as the values of the vacuum quantum numbers increase. Topological field quantum is therefore a good candidate for a quantum coherent system provided some Bose Einstein condensate or quantum coherent state is available. The BE condensate or coherent state of the light # contacts near the boundaries of the topological field quantum is a good candidate in this respect. It came as a total surprise that this the generation of vacuum expectation value of Higgs field corresponds to the generation of this kind of macroscopic quantum phase.

   The requirement of the gauge charge conservation in turn implies the hierarchical structure of the topological condensate: gauge fluxes must go somewhere from the outer boundaries of the topological field quantum with finite size and this 'somewhere' must be a larger topological field quantum, which in turn feeds its gauge fluxes to a larger topological field quantum,.... Of course, the nonlinearity of the theory could allow vacuum charge densities which can cancel the net charge near boundaries.

   Most importantly, topological field quanta allow discrete scalings as a dynamical symmetry. p-Adic length scale hypothesis states that the allowed scaling factors correspond to powers of $\sqrt{p}$, where the prime p satisfies $p \simeq 2^k$, k integer with prime values favored. p-Adic fractality (actually multi-p-fractality) can be justified more rigorously by a precise formulation for the fusion of real and various p-adic physics based on the generalization of the notion of number [E1].

3. The physical consequences of the new space-time picture are nontrivial at all length scales.

   i) A natural interpretation for the hierarchical structure is in terms of bound state formation. Quarks condense to form hadrons, nucleons condense to form atomic nuclei, nuclei and electrons condense to form atoms, how atoms condense to form molecules, and so on. One ends up with a general picture for the topology of 3-space associated with, say, solid state and with the idea that even the macroscopic bodies of the everyday world correspond to topologically condensed 3-surfaces.

   ii) The join of 3-surfaces along their boundaries defines a new kind of interaction, which in fact has been used in phenomenological modelling of and usually believed to result from Schrödinger equation. At the macroscopic level this interaction is rather familiar to us since it means that two macroscopic bodies just touch each other!

iii) The possibility to understand general qualitative features of the charge renormalization topologically in the proposed scenario for space-time, is considered. This rough vision represents one of the oldest strata in the evolution of TGD: in [C3] the recent view about space-time correlates of gauge charges is developed.

iv) In TGD context there are purely topological necessary conditions for quantum coherence and a topological description for dissipative phenomena. The formation of the join along boundaries bonds plays a decisive role in the description and this process provides a universal manner to generate macroscopic quantum systems.

v) There is also a topological description for the formation of the supra phases and the phase of the order parameter of the supra phase ground state contains information about the homotopy of the join along boundaries condensate.

4. The proper understanding of the concepts of gauge charges and fluxes and their gravitational counterparts in TGD space-time has taken a lot of efforts. At the fundamental level gauge charges assignable to light-like 3-D elementary particle horizons surrounding a topologically condensed CP_2 type extremals can be identified as the quantum numbers assignable to fermionic oscillator operators generating the state associated with horizon identifiable as a parton. Quantum classical correspondence requires that commuting classical gauge charges are quantized and this is expected to be true by the generalized Bohr orbit property of the space-time surface.

   There are however non-trivial questions. Do vacuum charge densities give rise to renormalization effects or imply non-conservation so that weak charges would be screened above intermediate boson length scale? Could one assign the non-conservation of gauge fluxes to the wormhole (#) contacts, which are identifiable as pieces of CP_2 extremals and for which electro-weak gauge currents are not conserved so that weak gauge fluxes would be non-vanishing but more or less random so that long range correlations would be lost?

   It indeed turns that one can understand the non-conservation of weak gauge fluxes in terms of wormhole contacts carrying pairs of right/left handed fermion and left/right handed antifermion having interpretation as Higgs bosons. The average non-conserved light-like gravitational four-momentum of wormhole contact representing Higgs boson can be identified as the inertial four-momentum apart from the sign factor so that one can also understand particle massivation at fundamental level and a connection with p-adic thermodynamics based description of Higgs mechanism emerges. Also a detailed understanding about how Equivalence Principle is weakened in TGD framework emerges.

5. # contacts, feeding gauge fluxes from a given sheet of the 3-space to a larger one, which are a necessary concomitant of the many-sheeted space-time concept. # contacts can be regarded as particles carrying classical

charges defined by the gauge fluxes but behaving as extremely tiny dipoles quantum mechanically in the case that gauge charge is conserved. # contacts must be light, which suggests that they can form Bose-Einstein condensates and coherent states. The real surprise (after 27 years of TGD) was that the formation of these rather exotic macroscopic quantum phases could be identified as formation of vacuum expectation value of Higgs field for various scaled up copies of standard model physics!

This kind of macroscopic quantum phases could be in a central role in the TGD inspired model for a bio-system as a macroscopic quantum system. A related effect is the formation of exotic atoms, when some valence (say) electrons drop from the atomic space-time sheet to a larger space-time sheet. This process is accompanied by the generation of a # contacts. The process leads to the effective lowering of the valence of the original atom and thus to electronic alchemy! Under certain circumstances, the electrons on the nearly empty non-atomic space-time sheets could form a high temperature super conductor.

It took still some time to realize that all gauge bosons could be regarded as wormhole contacts and that fermions correspond naturally to wormhole throats of topologically condensed CP_2 type extremals. This picture follows unavoidably from the assumption that fermions are free at partonic level and leads to a detailed understanding of particle massivation at the level of first principles.

I have not discussed in this chapter the recent developments in quantum TGD except by references to the next chapter, where these developments are summarized.

2 What does 3-surface look like?

In the following a general picture of 3-space will be deduced from RGI hypothesis and spin glass analogy, the selection of preferred extremals of the Kähler action as generalized Bohr orbits, and from the special properties of the induced gauge fields implied by the compactness of CP_2.

2.1 Renormalization group invariance, quantum criticality and topology of 3-space

Renormalization group invariance, quantum criticality, and spin glass analogy are basic notions of quantum TGD but it is far from clear what these notions really mean at the level of space-time physics.

2.1.1 What quantum criticality means?

RGI (Renormalization group invariance) hypothesis states essentially that TGD Universe is quantum critical meaning that quantum theory is mathematically equivalent with a statistical system at critical point. S-matrix elements are analogous to thermal averages of observables, α_K corresponds to critical temperature and the vacuum functional $exp(K)$ corresponds to $exp(-H/T)$. The physical interpretation of the Kähler function suggests that $\alpha_K(phys)$ might correspond to a critical temperature at which spontaneous Kähler magnetization and formation Kähler electric fields compete.

The analogy with spin glass phase in four-dimensional sense is an additional characteristics feature. This allows the critical value of the α_K to depend on the zero modes of the configuration space metric.

The naive idealized interpretation for the quantum criticality would be that 3-surfaces with all possible sizes contribute to the functional integral. In realistic situations there is some upper bound for the size and duration quantum fluctuations and the size of the largest space-time sheet involved would define the scales in question.

Spin glass analogy leads to the idea that configuration space decomposes into regions D_p characterized by the p-adic prime p such that one can associate a hierarchy of p-adic length scales $L_p(n) = \sqrt{p}^{n-1} l$, $l \sim 10^4\sqrt{G}$ to each value of p [E5]. The critical value of α_K would depend on p. The dependence can be deduced from the requirement that gravitational constant is approximately invariant in the coupling constant evolution associated with the p-adic prime p . These scales define natural upper bounds for the scale of quantum fluctuations associated with the quantum critical space-time sheet. Dark matter hierarchy in turn assigns to each p-adic length scale a hierarchy of further length scales scaled up by the values of $\hbar/\hbar_0$. The typical duration of quantum fluctuation would correspond to the typical geometric duration of maximal deterministic region inside space-time sheet.

2.1.2 What are the competing phases?

Quite generally, critical systems are characterized by long range correlations (correlation length ξ diverges) for the competing phases present in the system. Physically this means the coexistence of arbitrarily large volumes of the two phases. Both Kähler magnetized 3-surfaces and 3-surfaces containing predominantly Kähler electric fields contribute significantly to the functional integral are present. At the infinite volume limit the Kähler action per volume must vanish since otherwise the vacuum functional vanishes: TGD cosmology to be studied later is in accordance with this picture.

If preferred extremals minimize (or maximize) the absolute value of Kähler action in each region with a definite sign of action density, the decomposition into magnetic and electric regions and vanishing of the Kähler action per volume follows automatically [E2]. For the absolute minimization of Kähler action Kähler electric fields dominate and it is not clear whether there are solutions for which the Kähler action of the entire Universe is finite.

2.1.3 How quantum fluctuations and thermal fluctuations relate to each other?

An experimental fact is that quantum critical systems such as high temperature superconductors [J1, J2, J3] exist in a rather narrow parameter range, and one can say that quantum criticality becomes visible only when quantum fluctuations are not masked by thermal fluctuations. One should express this fact using TGD based notions.

p-Adic and dark matter hierarchies correspond also to hierarchies for quantum jumps with time scales given the average geometric duration for quantum jump. This hierarchy means quantum parallel dissipation about which hadrons as quantum systems containing quarks as dissipating subsystem at shorter p-adic length and time scale give a basic example.

At given space-time sheet short scale thermal fluctuations would have interpretation as quantum parallel fluctuations at smaller space-time sheets topologically condensed to the space-time sheet in question whereas the quantum critical fluctuations would correspond to the quantum fluctuations in the scale of the space-time sheet. The duration of maximal deterministic space-time region would correspond to the duration of single quantum state in the sequence of quantum jumps. The interpretation would be that only at quantum criticality the quantal fluctuations in long time scales can mask the thermal fluctuations in shorter scales.

2.1.4 How quantum measurement theory relates to quantum criticality?

A further question is how quantum measurement theory relates to this picture. Configuration space zero modes represent non-quantum fluctuating classical observables correlating with quantum numbers and in quantum measurement a localization in zero modes occurs. Does this mean that the localization in zero modes breaks quantum criticality above the time scale corresponding to the typical geometric time duration of quantum jump by selecting precise values of zero modes?

2.1.5 Formation of join along boundaries condensates and visible-to-dark phase transitions as mechanisms giving rise to quantum critical systems

The phase transition from visible to dark matter, and more generally, the transitions increasing the value of Planck constant define the first mechanism leading to the formation of larger quantum critical system and long range quantum fluctuations can be assigned to dark matter.

The formation of a join along boundaries condensate means also a formation of a quantum critical system. The 3-surfaces with a typical size of order L_p combine together by join along boundaries bonds to form larger surfaces. Above criticality there are no bonds, below criticality all 3-surfaces combine to form larger condensates and at criticality there are join along boundaries condensates with all possible sizes up to the cutoff length scale. Note that, at least for small values of p, the surfaces with typical sizes $\sqrt{p}^n L_p$, $n = ..0, 1, 2, ...$ correspond to the presence of all surface sizes related by a fractal scaling for a given p. A more precise formulation for what the fusion of p-adic and real physics [E2] means supports the view that topological field quanta allow a discrete scaling symmetry identifiable as scalings by powers of $\sqrt{p}$.

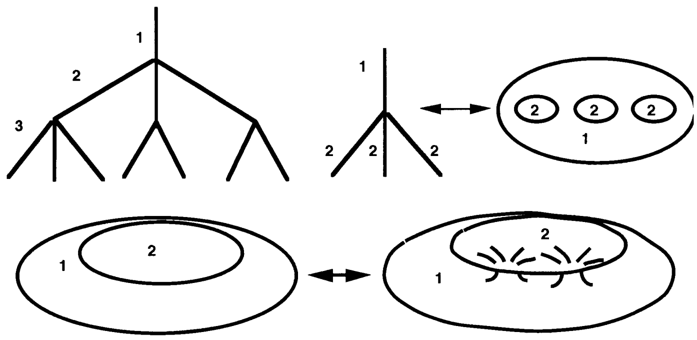

Figure 2: Hierarchical, fractal like structure of topological condensate predicted by RGI hypothesis: 2-dim. visualization

2.2 3-surfaces have outer boundaries

In length scales larger than hadronic length scale 3-surface with size L means roughly a condensate of smaller scale 3-surfaces on a piece of Minkowski space of size L. It is quite essential that these surfaces have finite size and therefore have outer boundary. The finite size of the 3-surfaces follows from the minimization of the Kähler action and from the compactness of CP_2. The argument goes as follows.

The matter inside a 3-surface creates gauge fields. In particular, the minimization of the absolute value of Kähler action in a region with definite sign of action density implies that matter serves as a source of either Kähler magnetic or Kähler electric fields. For instance, the Kähler electric field created by a constant mass distribution increases without bound. The smooth imbeddings of the gauge fields are however not possible globally and space-time decomposes into topological field quanta and their boundaries correspond to edges of space time. The elimination of the edges leads to a 3-space consisting of disjoint components. Simple examples are provided by a cylindrically symmetric imbedding of a constant magnetic field and the Kähler electric field created by a constant mass distribution, which fail for certain critical radii.

One can understand at general level how the compactness of CP_2 enters into the game. The point is that the gauge potentials associated with the induced gauge fields are bounded functions of CP_2 coordinates. For instance, for a geodesic sphere S^2 of CP_2 gauge potentials are just proportional to $A = sin(\Theta)d\Phi$. For a generic gauge field the gauge potential is not bounded (as an example consider gauge potentials of the Coulomb field or Kähler electric field created by a constant charge distribution or by a constant magnetic field). Therefore for certain values of CP_2 coordinates the representation of the gauge potential as an induced gauge potential fails. The failure takes place at some 3-surface of X^4. One can continue the embedding by changing the values of vacuum quantum numbers but certain CP_2 coordinates possess discontinuous or even infinite derivatives on the boundary so that undesirable edges of space time result. The manner to get rid of edges is to allow boundary for X^3 so that a region, where the the representation of the gauge potential as induced gauge potential works defines a natural unit of space-time, which might be called topological field quantum. In the sequel this phenomenon will be considered in more detail.

An obvious question is what happens to the gauge fluxes of long range gauge fields near the boundaries of the topological field quantum. Same question applies also to the gravitational flux associated with the Newtonian potential at the non-relativistic limit. One possibility is the appearance of neutralizing vacuum gauge charges and negative gravitational masses near the boundaries of the field quantum, perhaps related to vacuum polarization: this alternative must be realized for the particles of vapor phase. Second possibility is topological condensation on a larger topological field quantum so that gauge and gravitational fluxes flow to the larger topological field quantum via # contacts. The larger field quantum in turn must feed its gauge fluxes in a similar manner to larger field quantum so that the hierarchical structure of topological condensate is implied by the compactness of CP_2 and gauge flux conservation. Criticality implies only that 3-surfaces of arbitrarily large size are possible and therefore the number of the condensate levels and corresponding length scales $L(n)$ is infinite. Without criticality there would be some upper bound for 3-surfaces and only vapor phase would be possible.

The # contacts feeding the gauge fluxes from level p_n to level p_{n+1} are located near the boundaries of topological field quanta: otherwise long range gauge fields would not be possible inside the topological field quanta. A more quantitative hypothesis is that # contacts are located in the boundary layer having thickness of order L_{p_n}. If topological field quantum at level n has the minimum size of order L_{p_n} then the # contacts neutralize the physical gauge charges on the average.

2.3 Topological field quantization

Topological field quantization is a very general phenomenon differentiating between the TGD based and Maxwellian field concepts and results from the compactness of CP_2 only, being independent of any dynamical assumptions.

Topological field quantization occurs for surfaces representable as maps from M^4 to CP_2 and means that space time surface decomposes into regions characterized by certain vacuum quantum numbers characterizing the dependence of the phase angles Ψ and Φ associated with the two complex coordinates ξ_1 and ξ_2 of CP_2. There are two frequency type vacuum quantum numbers ω_1 and ω_2 characterizing the time dependence, two wave vector like quantum numbers k_1, k_2 characterizing the z-dependence and two integer valued vacuum quantum numbers n_1, n_2 characterizing the angle dependence of these phase angles. Topological field quantization fixes unique M^4 and CP_2 coordinates inside the field quantum and is analogous to a choice of a quantization axis.

2.3.1 Topological field quanta

Before considering the general form of the surfaces representable as maps $M^4 \rightarrow CP_2$ some comments about CP_2 coordinates are needed:

1. The so called Eguchi-Hanson coordinates for CP_2 are given $(r, u, \Psi, \Phi) \in [0, \infty] \times [-1, 1] \times [0, 4\pi] \times [0, 2\pi]$ (see Appendix). Ψ and and Φ are angle like coordinates closely related to the phases of the two complex coordinates of CP_2 and are the interesting variables in the sequel.

2. There are following types of coordinate singularities.
   i) For $r = 0$ all values of Ψ and Φ correspond to same point of CP_2.
   ii) For $r = \infty$ all values of Ψ correspond to same point of CP_2. For $u = 1$ and $u = -1$ also all values of Φ correspond to same point of CP_2.

Consider now the space-time surface representable as a graph of a map $M^4 \rightarrow CP_2$. The general form of the angle coordinates Ψ and Φ as functions of M^4 cylindrical coordinates (t, z, ρ, ϕ) is given by the expression

$$\begin{aligned} \Phi &= \omega_1 t + k_1 z + n_1 \phi + \text{Fourier expansion} \ , \\ \Psi &= \omega_2 t + k_2 z + n_2 \phi + \text{Fourier expansion} \ . \end{aligned} \tag{1}$$

There always exists a rest frame, where k_1 or k_2 vanishes. The Fourier expansion is single valued in ϕ and finite in z and t. The vacuum quantum numbers ω_1 and ω_2 are frequency type vacuum quantum numbers to be referred as "electric" quantum numbers. The quantum numbers (n_1, n_2) are integer valued and will be referred to as "magnetic" quantum numbers.

The values of the vacuum quantum numbers can change at the boundaries of the regions of space-time determined by the conditions
i) $r = 0$ and $(r = \infty, u = \pm 1)$: here all vacuum quantum numbers can change
ii) $r = \infty$: here only ω_2, n_2 and k_2 can change.
Also the choice of CP_2 coordinates and M^4 coordinates can in principle change: different CP_2 coordinates are related by color rotation and different M^4 coordinates by Lorentz transformation.

In general, the boundaries of the regions correspond to edges of space-time in the sense that CP_2 coordinates possess discontinuous or infinite derivatives at the boundaries of the field quanta. A natural manner to get rid of the edges is to consider 3- surfaces consisting of a single region only so that single region of this kind, topological field quantum, is a natural unit of 3-space. There is however an important exception to this. The join along boundaries interaction very probably means the gluing of two topological field quanta together along their boundaries and provides a manner to construct coherent quantum systems from smaller units.

The sizes of the topological field quanta are indeed finite so that the boundary of 3-space (quite essential for the ideas described before) is an unavoidable consequence of the compactness of CP_2 and the minimization of the Kähler action. The dependence of the size of the 3-surface on the vacuum quantum numbers is in accordance with the proposed interpretation: at the limit of large vacuum quantum numbers the size of the topological field quantum becomes macroscopic and at small vacuum quantum number limit the size of the surface becomes small.

Very complicated hierarchical structures predicted by the RGI are in principle possible since topological field quanta can suffer topological condensation on larger field quanta. Field quanta can become nested and both spatial and temporal structures (nesting in time like direction) are possible.

2.3.2 The vacuum quantum numbers associated with vacuum extremals

Vacuum extremals define a reasonable starting point for TGD based model for gravitational interactions. For vacuum extremals classical em and Z^0 fields are proportional to each other (see the Appendix of the book):

$$
\begin{aligned}
Z^0 &= 2e^0 \wedge e^3 = \frac{r}{F^2}(k+u)\frac{\partial r}{\partial u}du \wedge d\Phi = (k+u)du \wedge d\Phi \ , \\
r &= \sqrt{\frac{X}{1-X}} \ , \ X = D|k+u| \ , \\
\gamma &= -\frac{p}{2}Z^0 \ .
\end{aligned} \tag{2}
$$

For a vanishing value of Weinberg angle ($p = sin^2(\theta_w) = 0$) em field vanishes and only Z^0 field remains as a long range gauge field.

The study of the imbeddings of the Schwartshild metric as vacuum extremals (gravitational mass is non-vanishing but inertial mass vanishes) shows that astrophysical length scales correspond to large vacuum quantum number limit of TGD. Any mass vacuum extremal is necessarily accompanied by long ranged electro-weak and color fields and from the requirement that the corresponding force is weaker than the gravitational force one obtains that the value of the parameter ω_1 is of the order of $1/R \sim 10^{-4}\sqrt{G}$.

A simple example about the decomposition of space-time into topological field quanta is obtained by considering the cylindrically symmetric imbedding of a constant magnetic field in the z-direction as a vacuum extremal. Electromagnetic field can be written as $F^{em}_{\rho\phi} = B_0\rho$ and using the general results from the Appendix of the book one can write

$$\begin{aligned} u = u(\rho) \ \ , & \quad \Phi = n_1\phi \ \ , \\ r = \sqrt{\tfrac{X}{1-X}} \ \ , & \quad X = D|k+u| \ \ , \\ A^{em}_{\phi} = \frac{B_0\rho^2}{2} & = -\frac{p}{2}n_1(k+u)\partial_\rho u \ \ . \end{aligned} \tag{3}$$

Assuming that $(r,u) = (0,0)$ holds true at z-axis, the equation for em gauge potential A^{em} fixes the relationship between ρ and u as

$$u = -k \pm \sqrt{k^2 - \frac{2B_0\rho^3}{3n_1p}} \ \ . \tag{4}$$

The finite value range $0 \leq u \leq 1$ implies that the imbedding fails for certain values of ρ. Also the requirement that u is real implies an upper bound for ρ: the larger the value of n_1 the larger the critical radius. Imbedding can fail also for $X < 0$ and $X > 1$ corresponding to critical values of u equal $u_0 = -k$ and $D|(k+u_1)| = 1$.

3 Gauge charges in TGD

The concept of gauge charge has been a source of chronic headache for TGD. There are several questions waiting for definite answer. How to define gauge charge? What is the microscopic physics behind the 'anomalous' gauge charges implied by long range gravitational fields. Are the gauge charges quantized in elementary particle level or does the concept of anomalous gauge charge make sense? How gauge charges relate to the classical gauge fluxes.

3.1 Definition of the gauge charges in TGD

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 charge: group theoretical and classical.

3.1.1 Group theoretical definition of the gauge charges

In the purely group theoretical approach one can associate a non-vanishing gauge charge to a 3-surface of finite size and the quantization of the gauge charge follows automatically. This definition should work at CP_2 length scale, when particles are described as 3-surfaces of size $R \sim 10^4 \times \sqrt{G}$ and the classical space-time mediating long range interactions makes no sense. Gauge interactions are mediated by a gauge boson exchange, which in TGD has topological description. Gauge boson exchanges are in a well defined sense bridges along which also the classical fields can propagate. A naive geometric argument however suggests that the exchange of CP_2 type extremals gives rise to an extremely weak gauge interaction with cross sections characterized by the geometric size of the CP_2 type extremal. The solution of the paradox is that elementary particles are actually generated in topological condensation when the light-like causal determinant (elementary particle horizon) associated with the wormhole contact becomes a carrier of partonic quantum charges creating long range fields at the space-time sheet of size at least of order Compton length of the particle.

3.1.2 Classical definition of the gauge charges

The classical definition of the gauge charge is as a gauge flux over a closed 2-surface. The classical quantization of the gauge charges is perhaps possible for some subset of mutually commuting charges and would be implied by the absolute minimization of the Kähler action. For a closed 3-surface gauge flux vanishes and one might argue that this is the case for finite size 3-surfaces with a boundary since the boundary conditions might generate a gauge charge near the boundary cancelling the gauge charge created by the particles condensed on the 3-surface.

This picture seems to be in conflict with the quantum view. The resolution of the paradox is simple. In length scales longer than the size of space-time sheet gauge and gravitational interactions must be described in terms of particle exchanges whereas the description in terms of classical fields works only in length scales shorter than the size of the space-time sheet.

3.1.3 Color gauge charges

In the case of gluons it is not so clear whether the gauge charges correspond to classical gauge fluxes since the classical gluon fields (projections of the $SU(3)$ Killing vector fields to space-time surface) do not strictly speaking correspond to genuine gauge fields. In any case, gluon field can be defined and the components of the gluon field are of the form $g^A_{\mu\nu} \propto H^A J_{\mu\nu}$, where H^A is a Hamiltonian of the color isometry and J denotes the induced Kähler form. The holonomy group of the classical color field is always Abelian which by quantum classical correspondence suggests a weak form of confinement in the sense that the allowed quantum states corresponds to the states of color multiplets having vanishing color isospin and hyper charge. The explanation of Centauro events and Pomeron in terms of quantum coherent topological evaporation of the valence quarks [F5] suggests that only color singlet states can evaporate.

There are two possibilities.

1. The quarks in the vapor phase have color charges but the total color for the evaporated quarks vanishes. This statement makes physically sense since massless gluon exchange implies a long range interaction also in the

vapor phase. In this case the identification of the gauge charge as gauge flux is not possible.

2. Valence quark 3-surfaces are joined together via join along boundaries bonds so that it is this structure, which evaporates and has indeed vanishing total color gauge charge so that the identification of the color charges as gauge fluxes is possible. There is a temptation to accept this alternative since join along boundaries bonds can be identified as color flux tubes implying a string like structure for mesons. The evaporation of single sea quark or gluon is not possible in this picture. This raises the question about the definition of the quark gluon plasma: perhaps quark gluon plasma corresponds to a state in which the join along boundaries bonds between quarks are broken.

3.2 Questions related to gravitational interactions

3.2.1 Why gravitational interaction is so weak?

There are two explanations for the weakness of the gravitational interactions and although these explanations look quite different they could be consistent with each other.

1. The exchange of CP_2 type extremal would in a well defined sense create the bridge for the gravitational perturbation to propagate and also explain the extreme weakness of the gravitational interaction. As far as gravitation is considered, the evaporated particle would behave in very much the same manner as the condensate particle.

2. p-Adic fractality leads to a quantitative argument explaining the extreme weakness of the gravitational force and also predicting a hierarchy of strong gravities analogous to the force mediated by spin 2 mesons [E1]. The idea is simple: the geodesic distance $d(X^4)$ between interacting masses along space-time sheet is much longer than the distance $d(M^4)$ in M^4 and related by a very large scaling factor to the latter. This implies that strong gravitational coupling proportional to L_p^2 is scaled down to a weak coupling when $1/d^2(X^4)$ in gravitational force is expressed in terms of experimentally measured distance $d(M^4)$. A possible interpretation is that $d(X^4)$ corresponds to the length of topologically condensed gravitonic CP_2 type extremal performing random zitterbewegung. One could say that a kind of coast of Great Britain effect makes gravitational interaction weak. L_p^2 would in turn correspond to the area of the space-time sheet of the particle emitting gravitons.

Clearly, the first argument would explain the weakness of gravitational interaction described as an exchange of CP_2 type extremals whereas second argument would do the same when gravitation is described as a classical long range force.

3.2.2 How gravitational and inertial masses are related?

The general definition of gravitational mass is straightforward in terms of the M^4 projection of Einstein tensor and the definition involves no assumption about the space-time surface [C3]. Gravitational mass is in general not conserved. Gravitational four-momentum is in general non-vanishing and non-conserved for all kinds of vacuum extremals, in particular CP_2 type vacuum extremals, so that Equivalence Principle in strong form cannot hold true for them.

The assumption that gravitational energy corresponds to the absolute value of the conserved inertial (Poincare) energy is attractive but it is not clear whether it is really a general prediction of TGD. The identification of absolute value of inertial rest energy as the average value of non-conserved gravitational rest energy emerges very naturally in TGD based picture about particle massivation. This identification indeed allows the sign of inertial energy to depend on the time orientation of space-time sheet. At configuration space level the space-time surface with positive/negative time orientation can be assigned to the boundary of a union of future/past directed light cones.

3.2.3 Gravitational four-momentum of topologically evaporated particle

The interpretation of the gravitational mass as a gauge flux associated with gravitational potential makes sense in the non-relativistic limit. The problem is what happens to the particle's gravitational mass in the topological evaporation. Does gravitational mass of evaporated particle vanish? If this is the case, can gravitational energy be non-vanishing?

The answer to these questions emerges from the study of CP_2 type extremals. Einstein's tensor for CP_2 type extremal is proportional to the metric tensor so that the non-conserved gravitational momentum is non-vanishing and light-like being parallel to the light-like random curve defining M^4 projection of the CP_2 type extremal. Hence gravitational rest mass of cP_2 type extremal vanishes in the vapor phase but not gravitational energy.

Since wormhole contacts can be identified as pieces of CP_2 type extremals carry gravitational four-momentum, the net gravitational four-momentum of topologically evaporated space-time sheet carrying hierarchy of smaller space-time sheets is the sum of the gravitational four-momenta associated with wormhole contacts and non-vanishing.

In length scales shorter than the size of the topologically evaporated space-time sheet classical description of gravitational interaction makes sense whereas in longer length scales description in terms of graviton exchanges is the proper description.

3.2.4 What about $Diff^4$ invariant deformation of Poincare algebra?

The situation is complicated by the fact it is $Diff^4$ invariant Poincare algebra might correspond to a Lorentz invariant deformation of the ordinary Poincare algebra [16], which corresponds to the quantum mechanical four-momentum. A hypothesis worth of considering is whether the $Diff$ invariant four-momentum is equivalent with the gravitational four-momentum. An interesting possibility is that only the $Diff$ invariant rest mass rather than four-momentum vanishes in the vapor phase. It is needless to emphasize that this alternative has rather exciting implications in the (improbable) case that topological evaporation is possible for macroscopic objects.

3.3 The problem of the anomalous gauge charges

The concept of anomalous gauge charges, was introduced in the earlier versions of the book. The experience from the study of the extremals of the Kähler action shows that at astrophysical length scales gauges charges are apart from numerical constant equal to the mass of the system using Planck mass as unit:

$$Q = \epsilon_1 \frac{M}{m_{proton}} . \tag{5}$$

The condition $\frac{\epsilon_1}{\sqrt{\alpha_K}} < 10^{-19}$ holds true in astrophysical length scales since gauge forces must be weaker than gravitational interaction in astrophysical length scales. Any mass distribution which can be modelled gravitationally in terms of vacuum extremal long range em and Z^0 gauge fields.

The path to what seems to be the correct interpretation of this result was rather tortuous. This is understandable since the conclusion that theory predicts an entire fractal hierarchy of scaled up variants of standard model physics with arbitrarily long ranges of weak and strong interactions and having interpretation in terms of dark matter hierarchy labelled by p-adic length scales and by the values of a dynamical quantized Planck constant, is not not something which would pop first in mind.

3.4 The concept of the # contact, particle massivation, and weakening of Equivalence Principle

There are two views about # contacts. The first view is purely classical and developed first. The quantal view dictated by quantum classical correspondence emerged much later and leads to a detailed understanding of mechanisms of particle massivation (both p-adic thermodynamics and Higgs mechanism are involved in TGD framework), of how inertial and gravitational masses and related, and of breaking, or rather weakening, of Equivalence Principle.

3.4.1 Classical and quantum views about # contacts

If the net gauge charge of a given condensate level is non-vanishing, there must exist some mechanism feeding the gauge charge to the lower condensate levels. The only possibility is provided by the # contacts obtained by drilling small holes on the surfaces X^3_1 and X^3_2 and connecting the holes with at tube $D_1 \times S^2$.

The assumption that classical gauge charges are quantized and conserved forces also the quantization of the gauge fluxes associated with the # contacts.

The conserved gauge flux corresponds at quantum level to the partonic quantum numbers associated with either of the two light-like elementary particle horizon associated with the wormhole contact and are thus assignable to fermionic oscillator operators associated with second quantized induced spinor fields. Gauge flux is conserved only if the partonic quantum numbers sum up to zero. In this picture # contacts become special kind of particles.

3.4.2 # contacts as particles

contacts are expected to be very tiny, the size is presumably of the order of CP_2 radius and the simplest model is as a piece of CP_2 type extremal. This would mean that # contact can carry gravitational four-momentum but has a vanishing gravitational rest mass. If it possesses inertial mass it can be associated with the partons at the two elementary particle horizons carrying the partonic quantum numbers.

Wormhole contacts are bosons and one can associate to them color, em and Z^0 gauge fluxes $-Q_i$ so that contacts behave as charged particles and matter-contact and contact-contact interaction energies are non-vanishing. The gauge fluxes associated with the contacts can be identified as the gauge charges associated with either light-like elementary particle horizon in absence of possible renormalization and non-conservation effects.

Bose-Einstein condensates of charged # contacts are described by a complex order parameter quantum mechanically and the lightness of the wormholes implies BE condensation to the lowest energy state. Also coherent states are possible. These states could be present in all length scales and especially interesting are the applications of the concept to bio-systems [J3]. For instance, I have proposed that # contacts carrying quantum numbers of neutrino-antineutrino pair would be involved with cognitive representations [M6].

3.4.3 # 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 con-

tact. Therefore Equivalence Principle cannot hold true in a strict sense. 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 [C2]. 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 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 [C3] 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 $T_p = 1$.

3.4.4 Spatial distribution of # contacts

The existence of the # contacts allows also an elegant solution to the boundary conditions associated with the extremals of the Kähler action. If the space-time surface becomes vacuum near its boundaries the boundary conditions (dictated by the variational principle rather than being posed separately as in string models) are satisfied identically. Furthermore, one can obviously regard the hierarchical structure of the topological condensate more or less as a consequence of the boundary conditions.

Concerning the spatial distribution of the # contacts there are obvious constraints. Consider first the condensate blocks containing a large number of elementary particles:

1. Contacts behave as classical gauge fluxes and cause a screening of the classical gauge charges of the ordinary matter on both space-time sheets. The work with classical TGD led to the conclusion that long range classical Z^0 and/or electromagnetic gauge fields are necessary in order to have long range gravitational fields. This suggests that # contacts feeding the gauge flux to lower condensate levels are located near the boundaries of 3-surface. There is indeed a good mathematical reason for this: near the boundaries the imbedding of the gauge fields created by the interior gauge charges becomes impossible and the only possibility to satisfy the boundary conditions is that the gauge fluxes flow to lower condensate level and the surface becomes vacuum extremal near the boundary.

2. It must however emphasized that a random distribution of the # contacts inside entire condensate block is not totally excluded. The point is that the exchange of photon and graviton 3-surfaces can give rise to long range

force even in the absence of classical fields. As far as photon/graviton exchange is considered, # contacts behave as extremely small dipoles. It is the results of classical TGD, which support the idea of classical long range fields. For gauge bosons the density of boundary # contacts should be very small in length scales, where the matter is essentially neutral. For gravitational # contacts the situation is different. One might well argue that there is some upper bound for the gravitational flux associated with single # contact given by, say, Planck mass or CP_2 mass so that the number of gravitational contacts would be proportional to the mass of the system.

3. An important question is how # contacts are created and destroyed. The creation of charged # contact leads to the appearance of a radial gauge field in condensate and this seems to be impossible since it involves a radical instantaneous change in the field line topology. The simplest and the least exotic manner to solve the difficulty is to assume that # contacts are created in particle-antiparticle annihilation. The particle and antiparticle belonging to different space-time sheets can join along their boundaries via the emission of radiation so that both boundary components disappear and # contact is created. This conforms with the identification of # contacts as CP_2 type vacuum extremals condensed at two space-time sheets simultaneously.

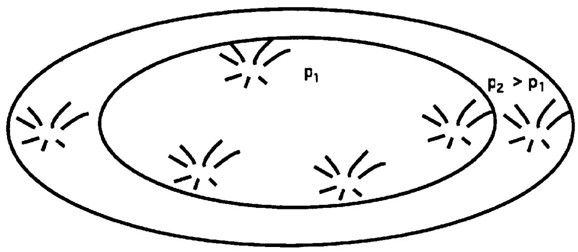

Figure 3: Gauge and gravitational fluxes run to lower condensate level via # contacts located near boundaries.

3.4.5 Quantum numbers of vapor phase particles

For a long time the attempts to characterize vapor phase particles remained a mixture of arguments involving classical gauge flux thinking and group theoretical quantum arguments which tended to be contradictory. The recent picture is free of these inconsistencies and allows understand how the quantum numbers of vapor phase particles are determined.

Gauge charges of vapor phase particles correspond to the net gauge charges of topologically condensed elementary particles plus those associated with # contacts and representing non-conservation: only weak isospin I_L^3 receives the latter contribution. The conserved inertial four-momentum is identifiable as the sum of average gravitational four-momenta assignable to the elementary particle horizons. The exchanges of space-time sheets, in particular CP_2 type extremals representing elementary particles provides a description for the interactions of vapor phase particles.

3.5 Are all elementary gauge bosons 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.

3.5.1 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 [C1] 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 [B4]. 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.

3.5.2 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 $X_1^2 \times X_2^2 \subset (M^1 \times Y^2) \times E^3$, 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 $X_1^2 \subset M^1 \times CP_2$ and X_2^2 have an Euclidian signature of metric except at light-like boundaries $X_a^1 \times X_2^2$ and $X_b^1 \times X_2^2$ defined by ends of X_1^2 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_1^2 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.

3.5.3 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 [D6, D7].

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].

3.6 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 [C3] 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.

4 The new space time picture and some of its consequences

The previous considerations suggest that TGD space-time has a hierarchical, fractal like structure consisting of an infinite number of condensate levels n characterized by length scale $L(n) < L(n+1)$ identifiable as a typical size for 3-surface at level n. Spin glass analogy suggests that the label n corresponds to preferred primes characterizing p-adic length scales and to values of Planck constant labelling levels of dark matter hierarchy. p-Adic fractality means that for each p there is actually a length scale hierarchy coming in powers of $\sqrt{p}$. An infinite hierarchy of copies of standard model physics is an unavoidable prediction if quantum classical correspondence is taken seriously and can be identified as dark matter hierarchy.

4.1 Topological condensation and formation of bound states

It is tempting to identify the physical counterpart of the topological condensate in the length scale L as a bound state with size L. If this assumption is accepted then one ends up to the rather beautiful general scenario for the hierarchical structure of the 3-space. Quarks (3-surface of size of CP_2 length, so called CP_2 type extremals to be discussed later) condense around the hadronic 3-surfaces, hadrons condense around a piece of Minkowski space with size of order $10^{-14}-10^{-15}$ meters to form nuclei, nuclei and electrons condense to form atoms of size of the order 10^{-10} meters or larger, atoms condense to form molecules, etc.

Generalizing the previous ideas, one ends up to a rather exciting possibility for a topological description of the macroscopic states of matter. Consider solids as an example. Solids correspond to a regular lattice of atomic or molecular 3-surfaces condensed to background 3-space. There are two kinds of forces binding the structure together.
i) There are interactions mediated via the the fields of the background 3-space and these correspond to the ordinary electric forces.
ii) There is interaction resulting from the "contacts" between the boundaries of the neighboring atoms (for a two-dimensional visualization see Fig. 4.1). Join along boundaries bond means mathematically a tube $D^2 \times D^1$ connecting the boundaries together or equivalently, topological condensation for the boundaries. This interaction is completely new and has as its counterpart the forces generated by the electron exchange between atoms believed to explain the binding between the atoms of certain solids. It is however clear that something quite new is introduced so that the conventional belief that Schrödinger equation in a flat 3-space alone explains these interactions would not be correct in TGD context. That the approach based on Schrödinger equation have not lead to contradictions can be understood also: what join along boundaries bond makes is to select among possible solutions of Schrödinger equation those realized in Nature by forcing the Schrödinger amplitude to the bridges connecting different structural units.

The topological description of the liquid state goes along similar lines. Now however the contacts between neighboring atoms are not so rigid the reason being that thermal noise continually splits these contacts. A completely new element is the emergence of the vacuum quantum numbers and should lead to effects differentiating between TGD and more conventional approaches.

4.2 3-topology and chemistry

The practical models for chemical systems rely on the assumption that a chemical element has a well defined geometric shape. If this assumption is made then Schrödinger equation in electronic degrees of freedom combined with symmetry considerations gives satisfactory results. The general belief is that the complete Scrödinger equation treating quantum mechanically also the positions of the atoms predicts also the geometric structure of the chemical compounds. Unfortunately, in practice it is not possible to check numerically the correctness of this belief.

The "join along boundaries" interaction is a second standard phenomenological concept in the chemistry. What happens that reactants join along a part of their boundaries together to form a transition state (or a final state) and

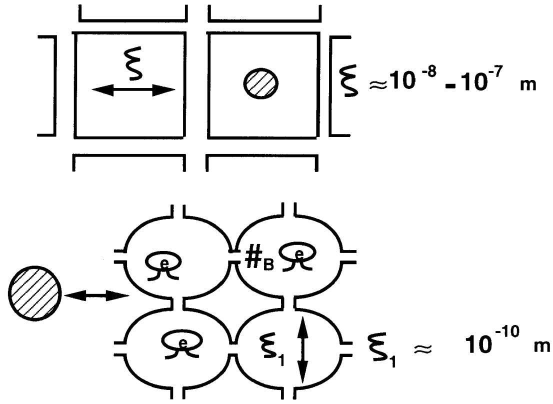

Figure 4: How one could understand the solid state topologically in terms of the join along boundaries interaction: 2-dim. visualization

the reaction takes place in the new geometry. The chemistry of the biological systems relies heavily on this concept. For example, the catalytic action of the enzymes is often understood on the basis of key and lock principle: enzyme acts on the protein only provided the surfaces of the protein and enzyme fit together like lock and key. Usually it is believed that the association of a geometric form to chemical compounds and the "join along boundaries" mechanism provide an easy short hand description, which is in principle derivable from the complete Schrödinger equations. TGD suggests that this is not be the case.

What is exciting that this kind of idea leads to a completely fresh approach to the understanding of bio-systems: the basic principles of the underlying the biochemistry could be formulated in terms of the 3-topology. The biological information processing could involve the manipulation of the 3-topology or more precisely: the manipulation of the boundary topology if "join along boundaries" is indeed the basic mechanism. It should noticed also that the emergence of the vacuum quantum numbers is purely TGD:eish feature and provides a possible means for realizing the Universe as Computer idea in biological systems. xc

4.3 3-topology and super-conductivity

The #-contacts (wormholes) feeding the gauge fluxes from a given sheet of the 3-space to a larger one, can be regarded as particles carrying classical charges defined by the gauge fluxes. These particles must be light, which suggests that #-contacts can form Bose-Einstein condensate or coherent state identifiable in terms of Higgs vacuum expectation value. This BE condensate provides a possible explanation of so called Comorosan effect [17] observed in organic molecules. A related effect is the formation of exotic atoms, when some valence electrons drop from the atomic space-time sheet to a larger space-time sheet. This process is accompanied by the generation of # contacts. The process leads to the effective lowering of the valence of the original atom and thus to "electronic alchemy". The claimed peculiar properties of so called ORMES [19] could have explanation as exotic atoms as suggested in [J1, J2, J3].

I have also suggested that the basic mechanism of super-conductivity somehow involves quantum coherent states of wormhole contacts. This might be the case although not quite in the original sense. There are two poorly understood problems involved with super-conductivity.

1. Super-conductor is often modelled as a coherent state of Cooper pairs. The conceptual problem is that the electric charge of this state is not well-defined and this is definitely in conflict with the conservation of electromagnetic charge.

2. The massivation of photons is a second poorly understood basic aspect of super-conductivity. The obvious question is whether this process could be interpreted in terms of a vacuum expectation value of a charged Higgs field and whether the charge of the Higgs field resolve the paradox otherwise created by the non-conservation of electromagnetic charge.

The obvious guess is that superconductor corresponds to superposition of quantum states with a well-defined total em charge such that electronic electromagnetically charge of some electronic Cooper pairs has been transferred to neutral wormhole contacts having quantum numbers of charged left/right handed positron and neutral right/left handed neutrino so that some Cooper pairs themselves have been transmuted to neutrino Cooper pairs.

In ordinary phase a space-time sheet carrying N Cooper pairs would feed em charge to a larger space-time sheet by $2N$ wormhole contacts consisting of e^+e^- parton pair. Super-conducting phase would correspond to a superposition of states for which $2M \leq 2N$ wormhole contacts have become electromagnetically charged and $2M$ electrons have transformed to neutrinos. Coherent state would thus correspond to a superposition of states with $M \leq N$ neutrino pairs, $N-M$ Cooper pairs, and $2M$ charged wormhole contacts.

The presence of exotic W bosons mediating weak interactions in the scale of the space-time sheet would make possible this kind of states (which involved entanglement between wormhole contacts and Cooper pairs). The model would require that neutrinos and electrons in the superconducting phase have nearly identical masses and thus correspond to $p = M_{127}$, the largest Mersenne prime which corresponds to non-super-astronomical p-adic length scale. This conforms also with the absence of electro-weak symmetry breaking below the p-adic length scale characterizing the size of the Cooper pair. Also the quantum model for hearing [M6] requires that exotic neutrinos with mass very near to electron mass are involved. The TGD based model for atomic nucleus [F8] in turn predicts that quarks with mass near to electron mass appear at the ends of the color bonds connecting nucleons.

4.4 Macroscopic bodies as a topology of 3-space

The natural generalization of the foregoing ideas is that even the macroscopic bodies of the everyday world correspond to 3-surfaces, which have suffered topological condensation to the background 3-space. The outer surfaces of the macroscopic bodies would correspond to the boundaries of a particular space-time sheet. When macroscopic bodies touch each other, a partial join along boundaries would take place. We would live in the middle of a wild science fiction without realizing it!

Paradoxically, this new interaction is extremely familiar for us. The surface of the Earth corresponds to a boundary of a rather big 3-surface. At smaller length scales we see flowers, trees and all kinds of things and also these are 3-surfaces, which have joined along their boundaries to the surface of the Earth. Our biological bodies correspond to 3-surfaces having boundaries. We have however the special ability to cut this contact rather easily and to move quite freely although the gravitational force acting in the background 3- space takes care that the join along the boundaries with the surface of Earth is the usual state of affairs. When I touch the surface of the table by finger, a join along boundaries interaction takes place: we even recognize different objects just by touching them. We also smell and taste and at the microscopic level these senses are based on the join along boundaries interaction. Despite all this it has not been explicitly recognized that the formation of the join along boundaries bond might be a fundamental physical interaction!

What is also amusing that the implicit assumptions of any physical model of the macroscopic world is based on the assumptions about the geometric form of the physical objects and also the join along boundaries interaction is introduced implicitly into the description. For example, in order to describe solid state one draws lattice: one draws atoms in this lattice and bonds between the atoms. A second example is provided by the description of mechanical system consisting of rigid bodies.

In present picture this description is obtained by projecting the boundary of the 3- space to flat space E^3 : matter in the conventional sense corresponds to the shadow of the boundary-topology of 3-surface (for a 2-dimensional illustration see Fig.4.4). The fact that this kind of description is so obvious masks the fact that it is far from trivial whether one can actually deduce this kind of description starting from wave mechanics or QED.

What is so exciting that we can deduce the rough features of the topology of the surrounding 3-space just by looking it in various scales! Single glance shows that this topology is extremely complicated and contains boundaries everywhere and in all scales. In any case, it is in principle possible to make a map of a 3-surface in H both by observation of the form of macroscopic bodies and by measuring the ordinary physical observables like electromagnetic fields. Note that the fractal properties of the world are in accordance with the predic-

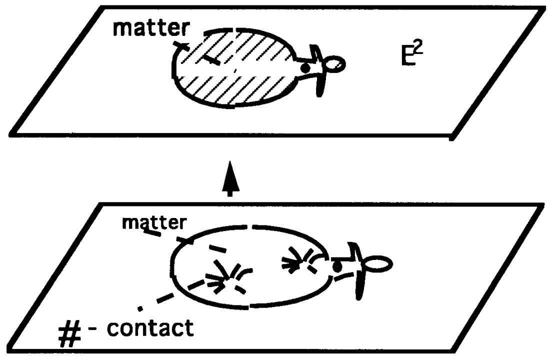

Figure 5: 3-dimensional matter as projection of the boundary of 3-surface to E^3: 2-dim. visualization

tion of RGI hypothesis that topological condensate has hierarchical structure containing 3-surfaces of all possible sizes.

To summarize, topological condensation seems to provide a purely topological description for the generation of structures. The concept of matter in topologically trivial, almost flat 3-space is replaced with an empty but topologically highly nontrivial 3-space. The idea leads to a concrete program of actually finding out what is the topology of a given form of matter and understanding the physical properties matter in terms of this topology! And it would surprising if this kind of understanding would not increase our abilities to control and manipulate the properties of the matter.

4.4.1 Topological field quantum as a coherent quantum system

There are several arguments suggesting that topological field quanta are good candidates for coherent quantum systems and that join along boundaries provides basic means for constructing larger quantum systems from smaller units.

1. The choice of the coordinates inside a given field quantum is analogous to the choice of the quantization axis. This suggests that the topological field quanta might provide a topological description of certain aspects of quantum phenomena. The choice of the quantization axis could indeed correspond to that taking place in quantum measurement. The fact that the quantization axes associated with different connected 3-surfaces need not be the same is in accordance with the idea that quantum coherence is possible for a connected 3-surface only. An exception is provided by a system consisting of several topological field quanta connected by "bridges"

(join along boundaries bonds), for which quantization axis are same and which therefore can be be regarded as a coherent quantum system. As an example consider a spinning particle in a constant magnetic field. To describe the situation one must construct the imbedding of the magnetic field on the particle 3-surface by requiring that the resulting 4-surfaces corresponds to a preferred extremals of Kähler action. The simplest manner to achieve this is to assume that the quantization axis defining the vacuum quantum numbers n_1 and n_2 is in the direction of the magnetic field so that one say that the external magnetic field fixes the quantization axis.

2. 3-surfaces consisting of several field quanta are in general unstable in accordance with that fact that the formation of macroscopic quantum systems is also a rare phenomenon. The argument goes as follows.
   i) CP_2 coordinates tend to have discontinuous or have even infinite derivatives at the boundaries of the topological field quanta if one poses some rather sensible physical requirements like the requirement that the 3-surface provides an imbedding for the Kähler electric field created by the mass distribution. As a consequence, Einstein tensor contains delta function type singularities and this is not nice. The best manner to avoid the edges is to allow boundaries.
   ii) The boundaries of a 3-surface consisting of several field quanta are in general carriers of surface Kähler (Z^0) charge as the following argument shows. The embedding of the Kähler electric field associated with a given matter distribution has certain critical radius, which corresponds to the boundary of a field quantum. In general, one cannot continue the imbedding to a neighboring field quantum without allowing infinite derivatives of CP_2 coordinates.
   iii) The 3-surface consisting of several field quanta is not stable unless the condition $u = cos(\Theta) = \pm 1$ is satisfied on $r = \infty$ surfaces. The point is that the excitations of Φ coordinate in general imply discontinuity of 3-surface at the boundary unless they are strongly correlated for neighboring field quanta.

3. The gluing of topological field quanta is probably possible by the join along boundaries bonds. The tube $D^2 \times D^1$ or the "bridge" between the two topological field quanta corresponds to a topological field quantum. The most probable "hot spots", where the gluing is possible correspond to parts of the surface, where the normal component of the Kähler electric field is vanishing. Now however the stability of the join along boundaries bond is not obvious. It can also happen that the directions of the induced Kähler fields are same on some portions of the boundaries and in this case the gluing by joing along boundaries bond serving as a Kähler electric flux tube is possible: in this case the stability of the bond is obvious. The color electric flux tubes between valence quarks provide a good example of this.

4.4.2 Topological description of supra phases

The topological construction recipe of a supra phase could be following. Take volumes of ordinary phase with a size of order of coherence length ξ, topologically condense them to the background 3-space and construct "bridges" between the boundaries of these structures. Supra phase is destroyed if the bridges are cut either thermally or by external magnetic field: the introduction of an external magnetic field indeed destroys the bridge since it implies that the quantum numbers n_1 and n_2 become in general non-vanishing inside the field quanta and bridge so that the order parameter ψ becomes discontinuous on the boundaries of bridges.

In the ground state of the supra phase the order parameter describing the supra phase is covariantly constant. Since the topology of the join along boundaries condensate is extremely complicated, the first homotopy group of the condensate is nontrivial. This means that one in general cannot find a global gauge transformation gauging the gauge potential associated with a vanishing magnetic field away. This implies that the phase increment of the order parameter along a closed homotopically nontrivial loop is in general nontrivial. These increments obviously contain information coded into the order parameter about the topology of the join along boundaries condensate.

The BE condensate of the charged # contacts, giving rise to pseudo super conductivity, playd a key role in the earlier TGD inspired model of brain as a macroscopic quantum system. In the model discussed in this chapter the coherent state of Cooper pairs is replaced with an entangled state involving product states of $2M$ charged wormhole contacts, $N-M$ electronic Cooper pairs, and M neutrino cooper pairs. One can also ask whether the vacuum quantum numbers might provide a realization for the idea about Universe as Computer. Biological information processing might be based on the manipulation of the vacuum quantum numbers. These ideas will be developed in some detail in the last part of the book.

4.4.3 Topological description of dissipation

The previous topological ideas lead to a general ideas about how structures are generated at macroscopic level. There is however a standard approach to the description of the generation of structures [20] and in this approach dissipative mechanisms play central role. The basic idea is that dissipation takes care that an open system ends up to some asymptotic state, which need not be thermal equilibrium but can be a complicated dynamic, non-equilibrium state.

The topological definition of the quantum coherence suggests that these approaches are in fact very closely related. Dissipation means certainly a loss of quantum coherence since for a coherent quantum system density matrix develops unitarily so that dissipation is impossible. Quantum coherence is lost at a given level of condensation hierarchy if the condensate consists of several 3-surfaces interacting through standard interactions only. The formation of the join along boundaries bonds however creates quantum coherence. Therefore the breaking of the join along boundaries bonds provides a good candidate for a fundamental dissipation mechanism.

To make the idea more concrete consider as an example liquid flow, assuming that there is a velocity gradient in a direction orthogonal to the velocity. What one wants to understand is the friction or how the energy of the liquid is dissipated. Liquid molecules have typically join along boundaries contacts (tube $D^2 \times D^1$) with the neighboring molecules (and due to thermal motion these contacts are continuously splitting and rejoining. The average age of a typical contact is much smaller than the time scale associated with the motion of a liquid so that the contact between two neighboring molecules suffers several thermally induced splittings and re-joinings, when the neighboring molecule pass by. A natural assumption is that the contact between two neighboring molecules is like a rubber band: energy is needed to stretch it. Assume that contact is formed between neighboring atoms moving with certain relative velocity so that the contact gets longer and splits after certain average time. The energy needed to stretch the contact longer is taken from the energy of the translational motion so that the relative motion becomes slightly slower.

As a second example, consider the understanding of the finite conductivity in metals. The neighboring atoms in the metal form a lattice and there are contacts between the neighboring atoms. These contacts are not completely stable but suffer splittings now and then. The large conductivity of the metal results from these contacts since they provide for the conduction electrons the bridges to move from one atomic 3-surface to a another one. The finiteness of the conductivity results from the fact that now and then a bridge between two neighboring atoms is broken. In the last part of the book it will be found that this kind of argument leads to a correct order of magnitude estimate for the metallic conductivity using a TGD inspired modification of the Drude model.

The concept of topological condensate affords also a second new point of view concerning the description of dissipation. The standard description of dissipation is in terms of inelastic collisions of particles. This description generalizes: particles at the condensate level n correspond to topological field quanta of level $n-1$ with typical size $L(n-1)$. In inelastic collisions of these particles join along boundaries contacts are created and split and part of kinetic energy is transferred to the kinetic energy of topological field quanta of level $n-2$ condensed on level $n-1$ field quanta. This mechanism makes possible the gradual transfer of the kinetic energy to the atomic length scales, where the collisions of ordinary particles take care of the further dissipation. Some potential applications of this picture are provided by hydrodynamics: ordinary hydrodynamics generalizes to a hierarchy of hydrodynamics, one for each condensate level plus a model for the energy and momentum transfer between two subsequent levels.

5 Topological condensation and color confinement

In this section a simple semiclassical model of color confinement is constructed as an application of the previous ideas. Also a view about color confinement being based on the same mechanism as the generation of macroscopic and macrotemporal quantum coherence (crucial for the TGD inspired theory of consciousness [K2] is discussed. These two arguments are separated by a temporal distance longer than decade and their different style reflects the development of my own thinking about TGD.

5.1 Explanation of color confinement using quantum classical correspondence

One can understand color confinement from the properties of the Kähler action by applying quantum classical correspondence.

1. The classical color gauge field is proportional to $H^A J_{\alpha\beta}$, where H^A is color Hamiltonian. This implies that the color holonomy group is Abelian. This suggests strongly that the physical states correspond states of color multiplets having vanishing color hyper charge and isospin. This would mean a weak form of color confinement.

2. The proportionality of the gluon field to the induced Kähler field, approximately satisfying free Maxwell equations, implies that the direction of the classical color field in M^4 is not random and that gluon field behaves in this sense as a massless field giving rise to long range interactions. The approximate canonical invariance of the Maxwell phase, which corresponds to the exact canonical gauge invariance of the configuration space geometry, is realized as approximately local $U(1)$ transformations which become constant color rotations below a cutoff scale identifiable as the size of space-time sheet carrying color charge.

3. The fact that the classical color field is proportional to a color Hamiltonian and Kähler field implies that the direction of the gluon field in the color algebra is random above the cutoff length scale so that color cannot propagate in length scales longer than the cutoff scale. Since color gauge currents are conserved for CP_2 type extremals representing wormhole contacts, color gauge flux is conserved in wormhole contacts which are therefore color neutral as particles so that colored variant of Higgs mechanism is not possible. The finite range of color interaction therefore leaves only the possibility that the net color charge of the elementary particles topologically condensed at the hadronic space-time sheet vanishes.

5.2 Hadrons as color magnetic/electric flux tubes

In this model quarks and gluons correspond to small M^4 type surfaces containing topologically condensed CP_2 type extremals and these surfaces are in turn condensed on a larger hadronic M^4 type surface. Valence quarks (at least) are connected by color electric or magnetic flux tubes (join along boundaries bonds) to form color singlets.

At elementary particle level, topological condensation means the condensation of the CP_2 type extremals around M^4 type surfaces. The condensed CP_2 type extremals perform zitterbewegung with a velocity of light although cm is at rest. The 3-space surrounding the condensed elementary particle has a finite size of the order of Compton radius (natural guess at this stage). At length scales $r << r_c$ (r_c denotes the Compton radius of the particle), condensed particles look essentially like massless particles whereas at length scales $r >> r_C$ they look like pieces of M^4 condensed to the background and moving with a velocity smaller than light velocity. CP_2 type extremals can be regarded as Kähler magnetic monopoles, whose magnetic flux runs in the internal degrees of freedom so that no long range $1/r^2$ magnetic field is generated. The fact that elementary particles are in a well defined sense Kähler magnetic monopoles supports criticality hypothesis: the strong Kähler coupling phase for the electric charges must be identical with the weak coupling phase for the magnetic monopoles and therefore Kähler action must correspond to a fixed point of the coupling constant evolution (this does not exclude the p-adic coupling constant evolution with respect to the zero modes of the Kähler metric).

The construction of the configuration space geometry and of quantum TGD lead to the conclusion that the description of the non-perturbative aspects of the color interaction must be based on the flux variables defined by the induced Kähler form. These variables include as a special case the generalized classical color fluxes. Since the low energy limit of TGD is expected to be more or less equivalent with the standard model, one can ask whether color confinement is signalled also by the divergence of the color coupling strength at low energies. p-Adic length scale hypothesis makes it possible to quantitative understand the confinement scale.

There are good reasons to expect that the quantum average space-time associated with a hadron could be regarded as an orbit of a 3-surface obtained by connecting the 3-surfaces (of size smaller than hadronic size) associated with the valence quarks with color electric flux tubes to get a color singlet state. Color singletness results from the randomness of the direction of the color field above hadronic length scales implying that the average radial color gauge flux emanating from the hadron vanish. This structure in turn has suffered a topological condensation on a larger hadronic 3-surface. The cutting of one or more color electric flux tube leads automatically to a generation of compensating color charges so that only color singlets can be created in the decays of the hadron. Also the topological evaporation of only color singlet objects is possible.

5.2.1 Color magnetic or electric flux tubes or both?

Both color magnetic and electric flux tubes have been used to model hadrons in TGD framework as well as in QCD, and one might wonder which of these options is the correct one. For absolute minimization of Kähler action Kähler electric fields are favored so that color electric flux tubes would be in a preferred position as models of hadron. For the more general variational principle discussed in [E2] the absolute value of Kähler action for space-time region with a definite sign of action density is either minimized or maximized (these options define dual dynamics and are consistent with the fact that 3-surfaces rather than 4-surfaces are fundamental dynamical objects). Therefore both Kähler magnetic and electric flux tubes are possible so that both color electric and magnetic models can be said to be correct.

The simplest model for the color flux tube connecting two quarks is based on the following picture.

1. The CP_2 type extremals with quark quantum numbers are topologically condensed at M^4 type 3-surfaces with size smaller than the hadronic size. These 2-surfaces are in turn condensed on the hadronic 3-surface. Quark like 3-surfaces are connected by join along boundaries contacts, which are color flux tubes connecting the boundaries of the quark 3-surfaces. These color flux tubes are the counterparts of the hadronic string.

2. The color magnetic/electric flux tube is a deformation of a vacuum extremal of type $M^2 \times D^2$ ("spring"), where D^2 is a disk orthogonal to M^2. This surface indeed looks like a tube of cross section D^2. The disk has an area of order $1/T$, where T is hadronic string tension.

3. The quarks at the ends of the flux tube serve as sources of approximately constant Kähler magnetic/electric fields (giving rise to chromo-electic fields of confining type), which generate the hadronic string tension. Since color field is proportional to Kähler field, also the Kähler charge of quark and gluon is of order $q \simeq 1$. The proportionality of the induced Kähler field and classical color field implies that hadrons can be regarded as chromo-electric flux tubes. Also QCD [22, 23] affords this kind of descriptions for color confinement.

5.2.2 A model for color electric flux tube

Consider now in a more detail the model for the Kähler electric flux tube understood as a preferred extremal of the Kähler action. Since the actual situation is rather complicated it is useful to consider a simplified situation that is solution of the field equations with essentially constant Kähler electric field in the axal direction inside a cylinder of M^4.

The join along boundaries contact (color electric flux tube) corresponds to a surface of representable as a map from $M^4 = M^2 \times D^2$ to the homologically nontrivial geodesic sphere of type II. Here D^2 is a disk corresponding to the transversal section of the color flux tube and has size not much smaller than a typical hadronic length. One expects the Kähler action to be lowered by the generation of the Kähler electric fields. Field equations for the small deformations reduce in the lowest order to free Maxwell equations

$$D_\beta J^{\alpha\beta} = 0 \ . \tag{6}$$

Topologically condensed valence quarks at the ends of the flux tube serve as sources for the Kähler electric field.

The solution ansatz describing a constant Kähler electric field is obtained as a map from $M^4 = M^2 \times D^2$ to the geodesic sphere of type II:

$$\begin{aligned} cos(\Theta) &= u(z) \ , \\ \Phi &= \omega t \ . \end{aligned} \tag{7}$$

The interesting components of the induced metric and induced Kähler form are given by the expressions

$$\begin{aligned} g_{tt} &= 1 - \frac{R^2\omega^2}{4}(1-u^2) \ , \\ g_{zz} &= -1 - \frac{R^2}{4}\frac{u_{,z}^2}{(1-u^2)} \ , \\ J_{tz} &= \frac{u_{,z}\omega}{4} \ . \end{aligned} \tag{8}$$

Field equations are obtained from the conservation of four-momentum and the conservation condition for the z-component of momentum gives

$$u_{,z}^2(g_{zz}^3 g_{tt})^{-1/2} = \frac{E}{\omega^2} \ , \tag{9}$$

where E can be interpreted as the constant field strength.

The lowest order solution is obtained by approximating the induced metric with a flat metric so that one has

$$\Theta = arccos(\frac{Ez}{\omega}) \ . \tag{10}$$

The solution obtained is well defined only for the values of z having absolute value smaller that $2\pi/E$ and the g_{zz} component of the induced metric becomes infinite at the critical values of z. One might think that the appearance of the singularity is an artefact of the approximation used but this is not the case. The closer examination of the field equations shows that the singularity is unavoidable and results from the compactness of CP_2 (vector potential is proportional to $u = cos(\Theta)$) and that one cannot continue the solution in any manner for larger values of z. The nice thing is that boundary conditions are satisfied due to the singularity of the metric in the direction of the Kähler electric field. The result implies that the length of the string, and therefore the size of the hadron, is of order

$$L \sim \frac{2\pi\omega}{E} \quad .$$

The hadronic string tension is generated dynamically. One can obtain an estimate for the string tension by noticing that the situation is to a good approximation one-dimensional. This means that the Kähler electric field of the point charge is constant. Since the Kähler charges of quarks serve as sources of the Kähler field the order of magnitude for the Kähler electric field is given from Gauss theorem

$$E = \frac{q}{S} \quad . \tag{11}$$

where $q \simeq 1$ is the Kähler charge of quark and S is the transverse area of the string. The order of magnitude estimate $q \simeq 1$ follows from the requirement that the color charges for quarks have this order of magnitude and from the fact that classical gluon field is proportional to the Kähler field. Hadronic string tension is obtained by integrating the energy momentum density over the transversal degrees of freedom

$$T \simeq \frac{1}{8\pi\alpha_K}\int E^2 dS \simeq \frac{1}{8\pi\alpha_K}\frac{q^2}{S} \quad . \tag{12}$$

This implies that the transversal size of the hadronic string is of the order of $S \simeq 1/GeV^2$. For ground state hadrons the length of the string is therefore of same order as the transversal size of the string. Despite this, hadrons are string like objects in a well defined sense: their topology is $D^1 \times S^2$ instead of $D^1 \times D^2$.

As already found, the imbedding of the constant Kähler electric electric field associated with the flux tube becomes singular for values $z = \pm 2\pi\omega/E$ of the coordinate variable z in the direction of E (ω is the frequency associated with the solution). The study of the spherically symmetric extremal revealed that the parameter ω has value of order $10^{-4}m_{Pl}$ in long length scales. For the hadronic space-time sheet ω must of the order $\omega \sim 1/L$, where L is a typical hadronic length in order to get reasonable length for the string like object.

5.3 Color confinement and generation of macro-temporal quantum coherence

How macroscopic quantum coherence is possible in macroscopic time scales? This pressing problem of quantum consciousness theories involves both the question what coherence and de-coherence really mean and what really happens in quantum jump, as well as the question how the de-coherence times in living matter could be much longer than predicted by standard physics. Color confinement is the pressing problem of particle physics apparently put under the rug during last two decades. There might be a close connection between these seemingly totally un-related puzzles as the following little argument tends to show.

5.3.1 Classical argument: the time spent in color bound states is very long

The TGD based solution to the problem how to achieve macro-temporal quantum coherence relies on the new physics predicted by quantum TGD. The decisive factor is the gigantic almost degeneracy of states due to the fact that CP_2 canonical transformations, which effectively act as $U(1)$ gauge transformations, are approximate symmetries of the Kähler action broken only by the classical gravitation.

The argument goes as follows.

1. The increment of the psychological time in single quantum jump is estimated to be about CP_2 time, that is about 10^4 Planck times. During this time interval quantum coherence is destroyed in zero mode degrees freedom representing macroscopic degrees of freedom as well as in all degrees of freedom in which there is no bound state entanglement. This time interval is extremely brief as compared to the actual de-coherence times, which standard quantum theory allows to estimate.

2. The formation of bound states can save the situation since bound state entanglement is not reduced during state preparation phase of the quantum jump consisting of self measurements. The transformation of the zero modes (macroscopic classical degrees of freedom in which localization occurs in each quantum jump) to quantum fluctuating degrees of freedom, when join along boundaries bonds are formed between two space-time sheets representing binding systems accompanies the formation of bound states. The reason is that only over all center of mass zero modes remain zero modes. This means that the generation of macroscopic quantum fluctuating degrees of freedom and the formation of bound states accompany each other.

3. When bound state entanglement is generated, state function reduction and state preparation cease to occur in these degrees of freedom and one has macro-temporal quantum coherence. The sequence of quantum jumps effectively binds to a single quantum jump just like elementary particles bind to form atom behaving effectively as single elementary particle. The lifetime of the bound state defines the de-coherence time.

4. This does not yet explain why the lifetimes of the bound states, or more precisely, why the time spent in bound states, is much longer than predicted by the standard physics. New physics is required for this, and spin

glass degeneracy provides it. What happens is following. When a bound state is formed, the space-time sheets representing the free particles are connected by join along boundaries bonds. By quantum spin glass degeneracy the number of bound states is huge as compared to the number of free states, since there is extremely large number of join along boundaries bond configurations and differing only by the classical gravitational energy. Accordingly, the time spent in bound states, and thus also de-coherence time, is much longer than that predicted by standard physics.

How could one understand color confinement in this picture? The idea is simple: when quarks form color bound states, they are connected by color flux tubes (this is the aspect of confinement which goes outside QCD). Also color flux tubes possess huge spin glass degeneracy. Free quark states do not possess this degeneracy since join along boundaries bonds are absent. Thus the time spent in free states in which color flux tubes are absent is negligible to the time time spent in color bound states so that the states consisting of free quarks are unobservable. If this picture is correct, the divergence of the color coupling strength in confinement length scale reflects mathematically the fact that number of bound states is overwhelmingly large as compared that for the free states.

5.3.2 Color confinement from unitarity and spin glass degeneracy

A more precise phrasing of the idea about the connection between spin glass degeneracy and color confinement relies on unitarity conditions and the assumptions $T_{MN} \simeq T$ and $T_{Mr} \simeq T_r$. Here capital subscripts refer to degenerate hadronic states and small letter subscripts to free many-quark states. In this idealization hadronic degenerate states are stable against decay to free many-quark states with only single exception. The exceptional state should act as a doorway making possible the transition to quark-gluon plasma phase.

The S-matrix can be written as sum of unit matrix and reaction matrix T: $S = 1 + iT$.

1. The unitarity conditions $SS^{\dagger} = 1$ read in terms of T-matrix as

$$i(T - T^{\dagger}) = TT^{\dagger} \ . \tag{13}$$

For diagonal elements one has

$$2 \times Im(T_{mm}) = \sum_r |T_{mr}|^2 \geq 0 \ . \tag{14}$$

What is essential that the right hand side is non-negative and closely related to the total rate of transitions. If this rate is high also the imaginary part at the left hand side of the equation is large and therefore also the rate for the diagonal transition. For instance, in the case of low energy strong interactions this implies that the total reaction rates are high but transitions occur mostly in the forward direction. In this case the mere large number of final many-hadron states implies that most transitions occur in the forward direction.

In the recent case one must consider both free many quark states and their bound states. Let us use capitals M, N as labels for bound states and small letters m, n as labels for free states.

2. The diagonal unitarity conditions can be written for both of these states as

$$\begin{aligned} 2Im(T_{mm}) &= \sum_r |T_{mr}|^2 + \sum_R |T_{mR}|^2 \geq 0 \ , \\ 2Im(T_{MM}) &= \sum_R |T_{MR}|^2 + \sum_r |T_{Mr}|^2 \geq 0 \ . \end{aligned} \tag{15}$$

In both cases there is a large number of the degenerate states involved at the right hand side so that one expects that the right hand side has a large value. For bound states the number of degenerate states is much higher due to the additional degeneracy brought in by the join along boundaries bonds (color flux tubes). Thus the lifetime and de-coherence time should be considerably longer than expected on basis of standard physics.

3. For the non-diagonal transitions from bound states to free states one has

$$i(T_{Mm} - \overline{T}_{mM}) = \sum_r T_{Mr}\overline{T}_{mr} + \sum_R T_{MR}\overline{T}_{mR} \ . \tag{16}$$

The right hand side is not positive definite and since a large number of amplitudes between widely different free and bound states of quarks are involved, one expects that a destructive interference occurs. This is consistent with a small value of the non-diagonal amplitudes T_{Mm} and with the long lifetime of bound states.

4. What happens for non-diagonal transitions between degenerate states? The unitarity conditions read as

$$\begin{aligned} i(T_{mn} - \overline{T}_{nm}) &= \sum_r T_{mr}\overline{T}_{nr} + \sum_r T_{mR}\overline{T}_{nR} \ , \\ i(T_{MN} - \overline{T}_{NM}) &= \sum_R T_{MR}\overline{T}_{NR} + \sum_r T_{Mr}\overline{T}_{Nr} \ . \end{aligned} \tag{17}$$

The right hand side is not anymore positive definite and there is a very large number of summands present. Hence a destructive interference could occur and the amplitude would be very strongly restricted in the forward direction. This need not however be true in the case of degenerate states since they are expected to be very similar to each other.

5. One can indeed play with the idealization that the transition amplitudes between degenerate states are identical $T_{MN} = T$ and that the amplitudes T_{Mr} are independent of M and given by $T_{Mr} = T_r$.

   In this case T-matrix would have the form $T = t \times X$, where X is a matrix for which all elements are equal to one. t can be written as $|t|exp(i\phi)$. T-matrix is maximally degenerate and the diagonalized form T^D of T-matrix has only a single non-vanishing element equal to Nt, N the number of degenerate states. t must satisfy the unitarity condition $|t| = 2 \times sin(\phi)/N$. S-matrix would reduce to an almost unit matrix for the diagonalized bound states.

   What about the stability of the bound states in this case? The decay amplitudes for bound states corresponding to the vanishing eigen values of T are given by $T^D(M,r) = \sum c_M T_{Mr} = \sum_M c_M \times T_r = 0$ by the orthogonality of these states with the state with a non-vanishing eigen value. Thus the lifetimes of all bound states expect the one with the non-vanishing eigen value of T are infinitely long in this idealization.

6 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.

6.1 Overview

6.1.1 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.

6.1.2 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.

6.1.3 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.

6.1.4 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 $r \simeq .3077$.

6.2 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.

6.2.1 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

$$\begin{aligned} J_i^{\mu} &= \frac{1}{g_i^2} \times J_{i,0}^{\mu} \ , \\ J_{i,0}^{\mu} &= (D_{\nu}F^{\mu\nu})_i \sqrt{g} \ . \end{aligned} \tag{18}$$

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:

$$\partial_{\mu} J_i^{\mu} = 0 \ . \tag{19}$$

or

$$J_{i,0}^{\mu} \partial_{\mu} log(g_i^2) = \partial_{\mu} J_{i,0}^{\mu} \ . \tag{20}$$

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

$$\frac{1}{2} Z_0^{\mu\nu} \partial_{\nu} p \ . \tag{21}$$

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

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

one obtains

$$\frac{dlog(g_i^2)}{dt} = \frac{\partial_{\mu} J^{\mu}_{i,0}}{\phi} = \nabla(log(\phi)) \cdot \nabla t + \nabla^2 t \ . \tag{22}$$

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

$$J_i^n = \frac{D_{\beta} F_i^{n\beta} \sqrt{g_4}}{g_i^2} = 0 \ . \tag{23}$$

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.

6.2.2 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. 22 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.

6.2.3 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 patters.

6.2.4 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.

6.2.5 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

$$G^\alpha = \frac{1}{16\pi G} \times G^{\alpha\beta}\partial_\beta a\sqrt{g} \ , \qquad (24)$$

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

$$g^\alpha = \frac{\Lambda}{16\pi G} \times g^{\alpha\beta}\partial_\beta a\sqrt{g} \ . \qquad (25)$$

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

$$\Lambda = \frac{x}{G} \ . \qquad (26)$$

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

$$\left(G^\alpha - \frac{2x}{G}g^\alpha\right) D_\alpha log(G) = D_\alpha \left(G^\alpha + \frac{x}{G}g^\alpha\right) \ . \qquad (27)$$

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

$$\Lambda = \frac{x}{L_p^2} \ , \qquad (28)$$

where L_p is a p-adic length scale of order of cosmic time a: $L_p \sim a$ [D6]. 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

$$\left(G^\alpha + \frac{x}{L_p^2}g^\alpha\right) D_\alpha log(G) = D_\alpha \left(G^\alpha + \frac{x}{L_p^2}g^\alpha\right) \ . \qquad (29)$$

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

$$D_\alpha \left(G^\alpha + \frac{x}{L_p^2} g^\alpha \right) = 0 \quad (30)$$

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.

6.3 p-Adic coupling constant evolution

6.3.1 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

$$\frac{Q_i + \Delta Q_i}{g_i^2 + \Delta g_i^2} = \frac{Q_i}{g_i^2} \ . \quad (31)$$

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.

6.3.2 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 [C9, 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 $\Delta\hbar/\hbar \sim 10^{-6}$ [D7] 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.

6.4 About electro-weak coupling constant evolution

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

6.4.1 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.

6.4.2 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

$$\begin{aligned} \gamma &= 3J - pR_{03} \ , \ \ p \equiv sin^2(\theta_W) \ , \\ Z^0 &= 2R_{03} \ . \end{aligned} \tag{32}$$

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

$$\begin{aligned} J &= 2\left[e_1 \wedge e_2 + e_0 \wedge e_3\right] \ , \\ R_{03} &= 2e_1 \wedge e_2 + 4e_0 \wedge e_3 \ . \end{aligned} \tag{33}$$

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

$$\begin{aligned} E_Z \cdot \nabla p + (\nabla \cdot E_Z)p &= F \ , \\ F &= -6\nabla \cdot E_K - 2F_1 \ . \end{aligned} \tag{34}$$

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

$$E_Z = \phi dt \ . \tag{35}$$

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

$$dE_Z \wedge E_Z \ = \ 0 \ . \tag{36}$$

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

$$\frac{dp}{dt} + \frac{\nabla \cdot E_Z}{\phi} p \ = \ \frac{F}{\phi} \ . \tag{37}$$

solutions can be written as

$$\begin{aligned} p = p_0 + p_1 \ , \\ \frac{dp_0}{dt} + \frac{\nabla \cdot E_Z}{\phi} p_0 \ &= \ 0 \ , \\ \frac{dp_1}{dt} + \frac{\nabla \cdot E_Z}{\phi} p_1 \ &= \ \frac{F}{\phi} \ . \end{aligned} \tag{38}$$

p_0 and p_1 are given by

$$\begin{aligned} p_0(x,t) \ &= \ p_{00}(x) + exp\left(-\int_0^t du \frac{\nabla \cdot E_Z(x,u)}{\phi} \right) \ , \\ p_1(x,t) \ &= \ p_0(x,t) \int_0^t du \frac{F}{p_0 \phi}(x,u) \ . \end{aligned} \tag{39}$$

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 [F10]? Does this phase of condensed matter emerge only above length scale defined by the cell size or cell membrane thickness?

7 Model for topological evaporation

7.1 General ideas

Topological condensation and evaporation are effects, which clearly differentiate between TGD and GRT. It has been already found that the absolute (with respect to M^4 time) velocity of the light propagation in the condensed phase differs from the propagation velocity in the vapor phase. Is this effect indeed observable? In order to answer this kind of question, one must have some model for the topological condensation and evaporation. This model should give a criterion for the stability of the condensate and give estimates for the condensation and evaporation lengths of a particle. There is no need to emphasize that the construction of this kind of model is guesswork at this stage, when even quantitative grasp on the orders of magnitude is lacking.

In principle, Kähler function provides a fundamental classical description for the condensation and evaporation phenomena. To determine condensation length of a given particle in a given background system one should determine the classical space-time associated with a state consisting of disjoint union of particle like 3-surface plus a connected 3-surface describing back ground system at $m^0 = 0$ hyperplane of M^4. The condensation length could be estimated from the time needed for the process $particle \cup background \rightarrow particle\#background$ to occur. In a similar manner, evaporation length could be estimated. Quantum states are actually quantum superpositions of 3-surfaces and one must use the concept of quantum average effective space-time defined as a maximum of the Kähler function with respect to nonzero-modes as a function of zero modes. The dependence of the quantum state on zero modes determines which quantum average effective space-times contribute to the appropriate S-matrix matrix elements. One cannot exclude the possibility that in this case vapor phase particles are absent.

In practice this kind of description is not useful at this stage. One can however construct general arguments.

1. The most general argument is based on the "Yin-Yang" principle. If the evaporated particle leaves its Kähler charge in the condensate, Kähler action is not changed drastically in the process. For massless particles action is expected to vanish in both phases (by conformal invariance): in fact

"plane wave type massless extremals" with vanishing action are natural candidates for the external space-time of the condensed massless particle. The action argument thus suggests that massless particles and massive relativistic particles in principle can propagate both in the condensed and non-condensed modes.

2. Topological condensate is expected to have a hierarchical structure with infinite number of condensate levels characterized by length scales $< L(n) < L(n+1) < ..$, $L(n)$ giving roughly the lower bound for the size of the particle like 3-surface of level n. One must distinguish between the primary and secondary condensations: in the primary condensation at level $n(prim)$ the originally massless vapor phase particle (CP_2 type extremal) becomes massive. For example, hadrons are expected to be massive in the vapor phase since the topological condensation of quarks and gluons around the hadronic 3-surface makes quarks and thus also vapor phase hadrons massive (see Fig. 22.1). In further condensations only the particle mass changes and this change can be regarded as mass renormalization: this change will be referred to as condensation energy E_c in the sequel. The concept of the condensation energy makes sense for the massive particles only. This suggests that a direct evaporation for particles, which are massless in both vapor and condensate phases, is not possible. Photon or graviton can however be emitted in the vapor/condensed phase and the emission vertex for the condensed/vapor phase photon is proportional to $cos(\theta)/sin(\theta)$ respectively, where the angle parameter θ is an unknown parameter at this stage: in principle θ also depends on whether the emitting charge in the vapor phase/condensate. For instance, the condensation and evaporation of a photon is possible via Compton scattering, whereas for the electron spontaneous condensation is possible via single photon emission. When gravitational interaction is taken into account the situation changes: for instance, photon can condense by emitting collinear gravitons.

3. The failure of the imbeddability of the strong gauge fields created by the colliding particles is a natural candidate for the microscopic mechanism causing topological evaporation besides particle emission. Also energetic considerations suggest that evaporation mainly occurs in the collisions between particles. For a massive particle evaporation from the primary condensate level means that particle becomes massless so that a large momentum transfer must take place in the collision. Momentum transfer must be mediated by the gauge fields of the condensate and high energy collisions of the particles indeed create large gauge fields since the minimum distance in the collision decreases with the energy of the colliding particles. Furthermore, if the energy of the colliding massive particle is relativistic in the cm frame, the momentum transfer becomes small ($|\Delta\bar{p}| < m^2/2E$) so that the evaporation is expected to take place more easily. Notice also that relativistic collisions create rapidly varying gauge fields making a topology change more probable.

4. The fundamental step in the condensation/evaporation process is the splitting of the # contact(s) and this process factorizes from the ordinary Yang Mills interactions. This suggests that one can model evaporation and condensation from the primary condensation level of the elementary particle using standard gauge field theory by introducing essentially one additional vertex. The vertex describes the evaporation of a massive particle or the reversal of this process and is characterized by some amplitude A, which is expected to be highly independent on the properties of the particle since the basic process is the splitting of the # contact(s). For fermions the amplitude A can be written as $A_F = \epsilon_F m_F$, where m_F is fermion mass and for bosons one has $A_B = \epsilon_B m_B^2$, where ϵ_F and ϵ_B are dimensionless quantities: clearly $|\epsilon_i|^2$, $i = F, B$ can be regarded as the probability for evaporation or condensation. It must be emphasized that this description applies to the evaporation of the CP_2 type extremal from the primary condensate level. The evaporation from the secondary condensation level is expected to involve the splitting of very many # contacts and therefore this process is expected to be highly improbable.

5. The assumption that quantum gauge charges are identical with classical gauge fluxes combined with the conservation of gauge flux implies that vapor phase particles have vanishing gauge charges and perhaps also vanishing gravitational mass (at least in length scales sufficiently above CP_2 length scale) and respond to the gauge and gravitational interactions only via dipole and higher multiple moments plus purely geometric interactions. The identification of gauge charges as classical gauge fluxes need not be sensible in CP_2 length scale and the evaporation of elementary particles from the primary condensation level might be possible without leaving the gauge charges to the condensate. The evaporation of gauge charged particle as a neutral particle requires that the gauge charges of the vapor phase particle are screened somehow, perhaps by purely classical vacuum charge densities made possible by the induced gauge field concept. The rates for the evaporation and condensation are assumed to be proportional to the reaction rates associated with the ordinary gauge interactions. From this it is clear that condensation via interactions takes place with a considerable rate at relativistic energies only. If the neutralizing charge distribution of the vapor phase particles is located near the outer boundaries of the vapor phase 3-surface, vapor phase particles should behave as charged particles at very high energies as a simple model of the charge distribution as point charge surrounded by a spherical cell of opposite charge demonstrates. A new process is a spontaneous condensation via a photon emission if the condensation energy E_c is positive.

6. Since several secondary condensations are in principle possible, the evaporation to the vapor phase takes place with a considerable probability only at the relativistic energies in accordance with the general features of the particle massivation and involves several steps. When the temperature of the condensate is larger than the mass of the intermediate bosons, the

topological evaporation of the intermediate gauge bosons becomes probable and since intermediate bosons are massless in the vapor phase, the interactions mediated by them become long ranged. That the evaporation of the intermediate gauge bosons becomes probable at the temperatures larger than the intermediate boson mass, is suggested by the fact that the average distance ($d \simeq 1/T$) between between the particles becomes smaller than the range of the weak interactions with the consequence that the action associated with single particle becomes so small that the evaporation doesn't cost much action.

7. One can imagine an additional evaporation mechanism: a condensed particle moving in the condensate enters to the boundary of the space-time sheet and gets evaporated! This evaporation mechanism, if at work, could in principle make possible also the evaporation from the secondary condensation levels and even the evaporation of macroscopic objects. Note however that Z^0 and electromagnetic gauge fluxes of the elementary particles are feeded on different space-time sheets and this mechanism need not lead to a total evaporation. It might well be that strong gauge fields near the boundary of the 3-surface make it impossible for particle to enter to the boundary or that 3-surface itself deforms so that the condensed particle does not 'fall overboard'. Also the # throats themselves might create the force making the evaporation impossible.

These arguments motivate the use of differential cross sections for the ordinary interactions as order of magnitude estimates for the topological evaporation and condensation by gauge interactions. The simplest mechanism for the evaporation of photons is provided by the Compton scattering with charged particles: from the behavior of the cross section ($\sigma \propto \alpha^2/m^2$) it follows that electrons give a dominant contribution to the evaporation of the photons. Compton scattering from photons and the scattering of the charged particles from each other provide the simplest evaporation mechanisms for charged particles: the cross section for charged particle scattering behaves at relativistic energies as $\sigma \propto \alpha^2/E^2$ as the function of center of mass energy.

The following topics will be considered in the sequel.

1. Order of magnitude estimates for the degree of evaporation of photons and electrons will be derived.

2. The possibility that the model could explain the anomaly in the energy distribution of the high energy cosmic electrons [28] is considered.

3. TGD predicts that the light velocities for the propagation in the condensate and vapor phase are different and the possible indications of this phenomenon are discussed.

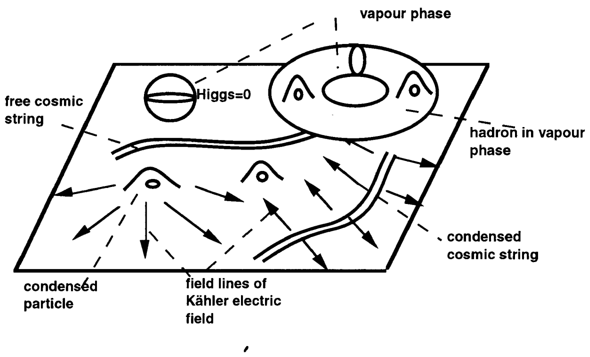

Figure 6: Basic properties of vapor phase and condensate

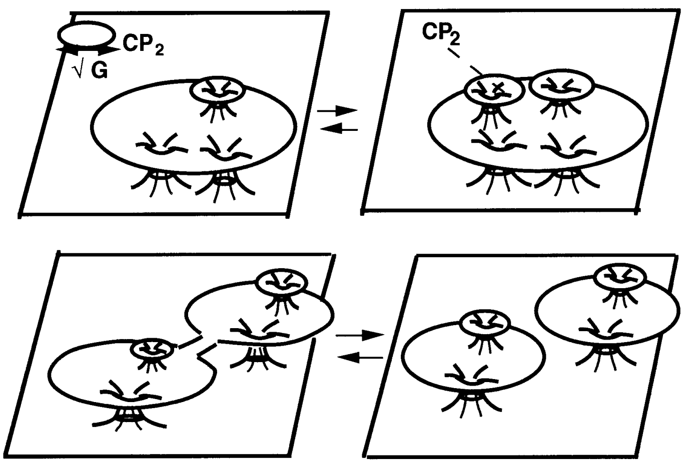

Figure 7: Mechanisms for a) topological condensation and evaporation: condensation and evaporation. b) formation of join along boundaries bonds.

7.2 Estimates for the evaporation of photons and electrons

We shall consider next some concrete estimates for the evaporation and condensation rates of photons and electrons in the ordinary matter.

7.2.1 Evaporation of photons

For photons the dominating condensation and evaporation mechanism is Compton scattering on electrons. The evaporation length for Compton scattering of topologically condensed photons with free electrons in the condensate is in the cm frame given by the expression

$$\begin{aligned} \frac{1}{L^C_{\#}} &\sim P_f n_e \frac{2}{3}\frac{\alpha^2 4\pi}{m_e^2} \ , \\ P_f &= sin^2(\theta) \ , \end{aligned} \tag{40}$$

where n_e denotes the density of free electrons an $P_f = sin^2(\theta)$ is the parameter describing the probability for a photon to be emitted in the vapor phase: by the time reversal invariance P_f equals to the corresponding probability $P_{\#}$ for the condensation. The dominating contribution to the evaporation length comes from the Compton scattering on free electrons since the cross section for the electronic Compton scattering is about 10^6 times larger than for protonic Compton scattering.

Compton scattering cross section diverges at the limit of a vanishing charged particle mass, which is taken as indication that charged particles are necessarily massive in the topologically stable condensate in accordance with the idea that topological condensation corresponds to particle massivation. The finiteness requirement suggests also that gauge interactions between the massless particles of the vapor phase must be effectively absent in accordance with the idea that cross sections are determined by the geometric sizes of the particles: note that the gauge interactions between particles of the vapor phase and condensate are not excluded by this argument.

The rate of Compton condensation and evaporation is very small if the average photon energy is much smaller than the average electron energy: the reason is that the the scattering of electron is in this case small angle scattering $(1 - cos\theta_e) < \langle E_\gamma\rangle/\langle E_e\rangle$ and therefore the average cross section for scattering is small. The decrease of the cross section can be understood also as resulting from the presence of a time dilation factor in the scattering rate. For low energy photons in non-ionized neutral matter the rates of condensation and evaporation are also very small. If the temperatures of the photon and electron distributions are same and matter is highly ionized or photons have a sufficiently high energy (so that electrons can be regarded as free charges) the ratio of the photon densities in the vapor phase and condensate equals to one in the kinetic equilibrium.

Some concrete order of magnitude estimates are illustrative.

1. In bulk matter ($n_p \simeq 10^{31}/m^3$) the values of the condensation and evaporation lengths are of the order $L_f \simeq L_\# \geq (1/P_f I) \cdot 10^{-4}$ *meters*, where I is the degree of ionization. It has been assumed that only free electrons contribute to Compton scattering and the cross section for cm scattering is used as upper bound for the scattering cross section.

2. In the gas densities typical to the lower atmosphere the condensation and evaporation lengths are of the order of $L_f \geq (1/P_f I)\ 10^{-1}$ *meters*, where I is the degree of ionization.

7.2.2 Evaporation of electrons

The following considerations make sense only if one assumes that the evaporation of electron as a neutral particle is possible. This requires that charge of vapor phase electron is screened somehow, perhaps by purely classical vacuum charge density made possible by the induced gauge field concept. For non-relativistic vapor phase electrons characterized by magnetic moment the condensation rate is small for obvious reasons. For relativistic electrons the dominating evaporation and condensation mechanisms are Compton scattering from photons and the scattering of electrons on charged particles. It should be noticed that the cross section for electron-electron scattering remains finite since the masses of electron in the vapor phase and condensate are different so that one avoids the singularity of the scattering amplitude in the forward direction. The cross section for the scattering of ultra-relativistic charged particles behaves roughly as [29]

$$\sigma \simeq \frac{\alpha^2}{E^2} , \tag{41}$$

where E denotes the energy in center of mass frame.

The evaporation length associated with Compton scattering from the black body radiation has the following order of magnitude

$$\frac{1}{L_f^C} \sim n_\gamma \sigma_{compton} \simeq \frac{T^3\alpha^2}{m_e^2}|\epsilon_F|^2 . \tag{42}$$

where ϵ_F is the amplitude for the splitting of # contact. Since electrons are relativistic the condensation rate by Compton scattering is very small unless photons are in a temperature of the order of average electron energy. The contribution of electron electron scattering on condensation rate is larger since the differential cross section for the ordinary charged particle scattering is peaked in the forward direction

$$\frac{d\sigma}{d\Omega} \propto \frac{1}{k^4} \propto \frac{1}{|\bar{p}_e|^4 sin^4(\theta/2)} . \tag{43}$$

In the present case the difference of the electron masses in the vapor phase and condensed phase cancels the singularity in the forward direction and one has $d\sigma/d\Omega \propto 1/m_e^4$ in the forward direction.

There exist some indications about the evaporation of electrons.

1. The scattering of relativistic conduction electrons from other electrons in sufficiently strong electric current is a possible evaporation mechanism for electrons. There are some indications [31] that under the experimental conditions used about 1 per cent of the electric signal propagates with a velocity about twice the velocity of light (identified as the velocity of the light in condensate). The evaporation of the relativistic conduction electrons to massless particles of the vapor phase might be a possible explanation for this effect.

2. Plasma phase is particularly interesting as far as the evaporation of electrons is considered. The evaporation rate for low energy photons is proportional to the degree of ionization so that in the plasma phase the evaporation probability for both low energy and high energy photons and electrons is large (it should be noticed that below plasma frequency (typically in radio frequency range) the propagation of light is not possible in plasma [30]).

A possible indication about the occurrence of the electron evaporation might be the so called "pump out" phenomenon [33] encountered in fusion experiments. The experimental situation is roughly the following [33]. An electron current in a volume with, say a shape of "eight", is created in order to create a plasma using an external electric potential. The electron density is typically about 10^{21} per cubic meter. Current ionizes He_2 gas. Gradually a complete ionization is reached. The problems are the following:

1. The ionization takes place too slowly as compared to the ionization rate predicted by the theoretical models.

2. Electrons disappear from plasma and therefore also plasma disappears. The number of the runaway electrons is larger than predicted by the theoretical models.

3. Initially one observes very high energy runaway electrons with relativistic energies (several MeV), which however disappear, when electron current gets larger than certain critical current [33]. Evidently the electrons run away before they get large enough energy, when current is larger than a critical current. When current gets smaller than the critical current one observes high energy runaway electrons again.

TGD suggests that runaway electrons might result, when the relativistic high energy tail of the electron distribution ($E < 3\ MeV$) created by the acceleration in the electric potential suffers a partial topological evaporation. This implies that the ionization rate is smaller than predicted by the theoretical models.

The evaporation length for the electrons in plasma is of the order of magnitude $1/L_f \simeq n^e\alpha^2/m_e^2 \simeq 1/10^5$ *meters* so that evaporation can indeed take place in the time scales considered. The disappearance of the high energy runaway electrons above the critical current is explained by the plasma instability possibly generated by the evaporation of the relativistic electrons. The confinement time for electrons becomes so short that very few electrons gain relativistic energies and evaporation ceases.

7.3 Does vapor phase exist? Astrophysical indications

Most of the matter in Universe is in the plasma phase so that the concept of topological evaporation could have several astrophysical applications. In following the aim is to demonstrate that one indeed can find explanation for several astrophysical anomalies in terms of this concept.

7.3.1 Topological evaporation inside the Sun

The matter inside the stars is neutral plasma and therefore the degree of evaporation for both photons and relativistic electrons should be high: $n_f/n_\# \simeq 1$. Also the condensation and evaporation lengths are short since the densities are high. This implies that a considerable part of the energy liberated in fusion should leave the Sun in vapor phase after having reached the solar surface. An argument supporting this picture comes from cosmology: the rate of energy transfer from the condensate to vapor phase in matter dominated cosmology is given by

$$\frac{(dE/da)}{E} = \frac{1}{2a} \ , \qquad (44)$$

where a denotes M^4 proper time. The value of the rate at present is $(dE/da)/E \simeq 10^{-11}/year$, which is of the same order of magnitude as the rate of energy production in Sun.

7.3.2 Anomalies in the energy distribution of the cosmic rays

It is well known [28] that the energy distribution of the cosmic ray electrons doesn't have a sharp cutoff at very high energies as it should. The sharp cutoff should result from the Compton scattering of the cosmic ray electrons with the microwave background leading to the loss of energy. The scattering length is of the order of $1/L_c \simeq \gamma\#\sigma_C \simeq T^3\alpha^2 m_e^{-2} \simeq 1/10^6\ ly$. As a consequence, the observed cosmic ray electrons at high energies should have a galactic origin unless there exist some mechanism allowing the propagation through intergalactic space.

TGD indeed suggests mechanisms of this kind. Cosmic ray electrons are emitted in the vapor phase and, due to the large condensation length in the Compton scattering, can travel over intergalactic distances if P_f is considerably smaller than one. A second possibility is that microwave photons are predominantly in the vapor phase so that the scattering in the microwave background is reduced considerably. Furthermore, electrons would propagate with the velocity of light since the vapor phase corresponds to a massless phase. Of course, the propagation of the higher fermion generations as massless particles in vapor phase is possible provided there exists some mechanism leading to their evaporation.

Note that the rates for the topological evaporation and condensation of the relativistic cosmic ray electrons by Compton scattering with the micro wave background are expected to have the same order of magnitude so that evaporation of the topologically condensed cosmic ray electrons is not expected to play significant role.

Also the energy distribution of the ultra high energy cosmic ray photons should have cutoff at energies of the order of 1 PeV caused by the scattering from microwave background [32]. Again the possibility that some fraction of the photons is in vapor phase, makes possible the absence of the cutoff.

7.4 Two velocities of light?

As already mentioned, the propagation of the massless particles in the topological condensate differs from the free propagation and this effect seems to provide a very simple test for the basic ideas of TGD. Free neutral particles propagate along the geodesics of the Minkowski space whereas the condensed particles propagate along the geodesics of 4-surface. In general, the path along the surface is longer than along Minkowski space geodesic. Only in case of the geodesic sub-manifolds the time taken to move along geodesic is the same. This implies that the absolute velocity of propagation defined using M^4 time as time coordinate is smaller in the condensate than in free space. In particular, for the massless particles, such as photons and neutrinos one expects the existence of two modes of propagation with different absolute velocities of light.

The surface in question need not be curved in order to make effect possible. To see this, consider the most simplest vacuum extremals of type $X^4 \subset M^4 \times S^1$, where S^1 denotes geodesic circle in CP_2 and assume that surface is a graph for a map

$$\Phi = \Omega m^0 \ , \tag{45}$$

where Φ denotes the angular coordinate of S^1 and m^0 denotes the time coordinate of M^4. The induced metric is flat and only its time component differs from M^4 metric

$$g_{00} = 1 - \frac{R^2}{4}\Omega^2 \ . \tag{46}$$

This implies that the absolute velocity of massless particle moving along the null geodesic of the surface is reduced from the maximal signal velocity corresponding to the motion along a null geodesic of M^4 and given by

$$v = \sqrt{1-\frac{R^2}{4}\Omega^2} \ . \qquad (47)$$

Of course, the velocity of light defined using the proper time as time variable is always one irrespectively of its value in terms of M^4 time: if standard clocks indeed measure proper time it is not possible to experimentally demonstrate the presence of the two light velocities. The only manner to measure the velocity of light with respect to M^4 time involves nontrivial topology of the space-time since one must compare the propagation velocity in the condensate with the propagation velocity in M^4.

Can one describe the reduction of the light velocity in the matter (described in terms of dielectric constant) in terms of this effect? One might think that the effect of the topological processes describing the absorption and emission of photons, leading to the generation of the effective velocity of light lower than the maximal signal velocity, could be described in terms of the geodesic propagation using the concept of space-time in length scale L. This is certainly not the case however since all massless particles, in particular photons and neutrinos would move with identical velocity in presence of matter. One cannot however exclude the possibility that the average velocity of light $c_{ave} = (1 - p_{\#} + pc_{\#})$ (where p denotes the fraction of photons in condensate) making sense, when the condensation and evaporation lengths of the photon are sufficiently small corresponds to the classical reduction of the light velocity so that one could estimate the degree of evaporation directly from the value of the dielectric constant! One must however add that there is still one complication involved: the many-sheeted nature of the space-time surface implies that there are actually several propagation velocities associated with the topological condensate.

In order that two propagation modes for light (or electrons) be observable the following conditions should be satisfied (see Fig. 7.4.

1. The source of the particles must produce particles of the vapor and condensed phase in a reasonable proportion. For instance, in the plasma phase this condition might be satisfied.

2. The distance between source and observer must be smaller than condensation and evaporation lengths. Otherwise photon suffers several condensations and evaporations during the travel from source to observer. For the light emitted from the Sun this condition is satisfied. In fact, it might be possible to test the prediction using photons emitted from satellites.

3. The velocities of light should differ considerably in the condensate and vapor phase. The study of the spherically symmetric extremals leads to conclusion that this could be the case. If the ratio of the velocities is, say of order two, it should be in principle possible to test the the prediction

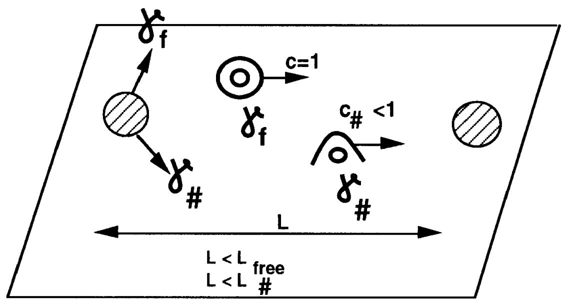

Figure 8: Conditions the for direct observability of two propagation modes of light

by studying the light coming from sufficiently nearby sources, say Sun and nearby stars.

A possible test for the prediction of two light velocities is obtained by comparing the propagation velocities of high and low energy photons. At energies larger than atomic binding energies part of photons is predicted to evaporate in the neutral matter and photons propagate with average velocity, which to a good approximation is same as the maximal signal velocity. At low energies the evaporation rate is considerably smaller and propagation takes place mostly in the condensed phase.

In fact, there is some experimental indication that the maximal signal velocity is considerably larger than the generally accepted value for the velocity of light propagation.

1. The first indication comes from a measurement conducted by A. Obolensky [31]. The measurements in question suggest that electric signals propagate in two modes and that the velocity of the fast mode is two times larger than the velocity of light (in condensate). The energy of the electric signal moving in fast mode is about 1 per cent from that moving in the usual mode. As already noticed the effect might be interpreted as an indication that 1 per cent of the relativistic electrons moves in the vapor phase. The mechanism of the evaporation in this case would be electron-electron scattering.

2. The difficulties related to the experimental determination of the Hubble constant might also have something to do with the two modes of light propagation. The measured values of the Hubble constant seem to vary by a factor of order two. The explanation based on two propagation modes for light is the following. The lower bound for the value of the Hubble constant corresponds to the free propagation of light. This means that

the red shift corresponds now to M^4_+ metric. The resulting Hubble constant is just $H_f = 1/a$, where a is Lorentz invariant time variable and correspond to the minimum value of this parameter. The upper bound for the Hubble constant corresponds to the propagation in the condensate. If Obolensky's result that the free absolute light velocity is about twice the velocity of the condensed light is correct then the value for the Hubble constant of the topologically condensed light should be about twice its value for the freely propagating light: $H_{cond} = 2H_f$ in accordance with the observations. That the ratio of the two Hubble's constant is of this order of magnitude is implied also by the requirement that gravitational force dominates over the Kähler force. One must however notice that each space-time sheet gives rise to its own Hubble constant and the explanation of the Hubble discrepancy might also involve two different space-time sheets in the condensate.

7.5 How to interpret the red-shift caused by the warping?

Space-time surfaces have enormous vacuum degeneracy partially characterized by vacuum quantum numbers. The simplest space-time sheets have metric equivalent with Minkowski metric but with the components of the metric differing by constant shifts from those of M^4_+. In particular, for a solution having a geodesic circle of CP_2 as CP_2 projection one has $\Phi = \Omega t$ and other coordinates constant, and the induced metric has a diagonal form ($g_{00} = 1 - R^2\Omega^2/4, -1, -1, -1$). Distant observer represented by a space-time sheet having approximately Minkowskian metric $(1, -1, -1, -1)$ would observe the radiation emanating from this space-time sheet as red-shifted. There would be also time dilatation. It would however seem that effects are not gravitational but caused by the mere warping of the space-time sheet. The red-shift can be quite large without any gravitational field. Of course, boundary conditions could reduce this red-shift to a gravitational red-shift, and the warping could represent in the lowest approximation the influence of an external slowly varying gravitational field at larger space-time sheet to the space-time sheet of the particle moving at the larger space-time sheet.

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