75

CERN LIBRARIES, GENEVA

SCAN-9606196

SW9627

Topological Geometrodynamics

Matti Pitkänen

Torckelinkatu 21 B39, 00530, Helsinki, Finland

E-mail matpitkanen@phcu.helsinki.fi

May 30, 1996

Abstract

A short overview of Topological Geometrodynamics documented in the book 'Topological Geometrodynamics' (HU-TFT-IR-95-4, Helsinki University) is given.

T(opological) G(eometro)D(ynamics) [TGD1,TGD,homepage] is one of the many attempts to find a unified description of basic interactions. The development of the basic ideas of TGD to a relatively stable form took time of about half decade [Pitkänen 1985]. The basic physical picture behind TGD was formed as a fusion of two rather disparate approaches.

a) The first approach was born as an attempt to construct Poincare invariant theory of gravitation. Spacetime, rather than being an abstract manifold endowed with Riemannian structure, is regarded as a surface in $H = M_+^4 \times CP_2$, where M_+^4 denotes the interior of the future light cone of Minkowski (to be referred as light cone in the sequel) space and $CP_2 = SU(3)/U(2)$ is the complex projective space of two complex dimensions [Eguchi *et al*, Hawking-Pope, Gibbons-Pope, Pope]. The identification of the spacetime as a submanifold [Eisenhart, Spivak] of $M^4 \times CP_2$ leads to exact Poincare invariance and solves the conceptual difficulties related to the definition of energy and momentum in General Relativity [Misner-Thorne-Wheeler, Logunov *et al*]. The actual choice $H = M_+^4 \times CP_2$ implies the breaking of Poincare invariance in cosmological scales but only in quantum level. It soon however turned out that submanifold geometry, being considerably richer in structure than abstract manifold geometry, leads to a geometrization of all basic interactions. First, the geometrization of the elementary particle quantum numbers is achieved. The geometry of CP_2 explains electroweak and color quantum numbers. The different H-chiralities of H-spinors correspond to conserved baryon and lepton numbers. Secondly, the geometrization of the field concept results. The projections of CP_2 spinor connection and Killing vector fields of CP_2 and of H-metric to four-surface define electroweak and color gauge fields and metric on X^4 .

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

for instance, two-particle decay corresponds to a decay of 3-surface to two disjoint 3-surfaces.

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

The construction of working mathematical theory around these ideas turned out to be quite a nontrivial task. The first unpublished attempts were based on a naïve generalization of the canonical formalism of General Relativity and it turned out that the nonlinearities of the theory make this approach inadequate.

The second attempt was based on the functional integral formalism [Christensen, Izzykson-Zuber]: to obtain transition amplitude integrate over all possible four-surfaces connecting initial and final 3-surfaces. Again it turned out that although this approach produced more or less sensible sounding semiclassical arguments it didn't work in practice: in particular the functional integral was plagued by horrible divergence difficulties.

A turning point in the attempts to formulate mathematical theory was reached about six years ago [Pitkänen 1985]. The great insight was "Do not quantize". The basic ingredients to the new approach have served as the basic philosophy for the attempt to construct Quantum TGD since then and are the following ones:

a) Quantum theory for extended particles is free(!), classical(!) field theory for a generalized Schrödinger amplitude in the configuration space $C(H)$ consisting of all possible 3-surfaces in H . "All possible" means that

surfaces with arbitrary many components and with arbitrary internal topology and also singular surfaces topologically intermediate between different manifold topologies are included. Particle reactions are identified as topology changes [Milnor, Thom, Wallace]. For instance, the decay of 3-surface to two 3-surfaces corresponds to decay $A \rightarrow B + C$. Classically this corresponds a path of configuration space leading from 1-particle sector to 2-particle sector. At quantum level this corresponds to the dispersion of the generalized Schrödinger amplitude localized to 1-particle sector to two-particle sector. All coupling constants should result as predictions of the theory since no nonlinearities are introduced.

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

This book describes the recent state of art in trying to realize this program. The first part is devoted to the construction of the configuration space geometry. In the second part we shall describe the recent state of Quantum TGD and the remaining 3 parts of the book is devoted to what might be called Classical TGD. Experience has taught that the latest formulation is never final and contains blunders even at the level of basic principles. Despite this also now our irrational belief is that the essential principles concerning the construction of the configuration space geometry and quantum theory have been identified. The belief that all problems have been solved is however necessary psychologically since the problems involved are really difficult. Therefore we hope that the reader can forgive the fact that the theory to be represented is a system of mutually consistent beliefs rather than a list of results deduced from a few basic axioms through mechanical manipulation of symbols.

Construction of the configuration space geometry

The first geometrization attempt [Pitkänen 1986a] was based on purely local considerations. Try to construct the infinite dimensional counter part of the line element in the space of surfaces. Unfortunately, this approach did not provide any insights to the global (or even actual local!) geometry of the configuration space.

The second attempt [Pitkänen 1986b] was based on global considerations and some additional ideas.

a) The space of maps from 3-surface to H , $Map(X^3, H)$ is more tractable mathematical concept than the space of surfaces since it can be regarded as a generalization of the loop space appearing in mathematical literature [Freed, Pressley-Segal]. One can obtain effectively theory in the space of surfaces by requiring that the geometry of the Map is Diff invariant, possibly Diff degenerate and that the solutions of field equations are Diff invariant. Of course, one should somehow "glue" the Maps associated with different 3-topologies somehow together to obtain the whole configuration space and it is not at all obvious how this happens.

b) In the case of physical interest $H = M^4 \times CP_2$, configuration space can be regarded as a generalization of coset space to a local coset space: $Map(X, M^4 \times CP_2)$ can be regarded as the coset space G/H of the local gauge groups $Map(X; M^4 k \times SU(3))$ and $Map(X; SU(2) \times U(1))$. The naive expectation was that the theory of symmetric spaces [Helgason] generalizes. In particular, a natural expectation was that Map allows metric having as its isometry group $Map(X^3, M^4 \times SU(3))$, the local $M^4 k \times SU(3)$, or perhaps one might even replace $M^4 k$ with Poincare group. Furthermore, Map might be constant curvature space with Kähler structure inherited from CP_2 so that all geometry related quantities could be calculated by restricting consideration to a single point (!) of Map , that is single surface with a given topology: surfaces with different topologies are of course not expected to be related by local gauge invariance. It however turned out that constant curvature property doesn't generalize, not even for loop spaces [Freed].

It therefore seems that the problem reduces to an attempt to construct $Map(X^3; M^4 \times SU(3))$ -invariant Kähler geometry (so we believed!) for configuration space. The first attempt [Pitkänen 1986a] to realize this dream was based on imitation: try to generalize the geometrization of loop space $Map(S^1, G)$, which can be regarded as one-dimensional local gauge group [Freed]. These spaces indeed allow Map as isometry group and also Kähler metric, which turned out to be crucial for the construction of Quantum Theory. In fact, left invariant Kähler (!) geometry is not one possibility among infinite number of other possibilities. In order to have well defined Riemann connection one must assume that metric possesses local G as its

isometries [Freed]! The importance of this result cannot be overemphasized. In infinite dimensional context the geometry of the configuration space cannot be chosen freely and therefore is not a dynamical quantity: it is uniquely fixed by the requirement of mathematical consistency.

Also it was realized that the Abelian extension of the local gauge group to Kac Moody group must play same central role in TGD as it plays in string models [Schwartz, Green *et al*]. Local gauge group as spectrum generating group would lead to physically unacceptable theory: for example infinite degeneracy for a given mass level would be predicted. The problem is to understand how Abelian extension of the gauge group emerges. Does it emerge directly at the level of the configuration space geometry or dynamically: the projective representations of the local gauge group indeed correspond to those of the Kac Moody group.

It however turned out later that the direct generalization of 1- dimensional theory leads to pathologies [Pitkänen 1988a]. In particular, it seems that in the proposed realization of exact local G invariance configuration space metric is extremely degenerate: 3-surfaces behave as effectively one-dimensional objects with respect to the configuration space metric! Something really new was needed to attain a mathematically acceptable geometrization of the configuration space.

The lacking element was the realization that four-dimensional $Diff$ invariance (not only 3-dimensional $Diff$ invariance!) of General Relativity must have its counter part in TGD also. In order to realize this symmetry in the space of 3-surfaces, the definition of the configuration space metric should somehow associate to a given 3-surface a unique space time surface for $Diff^4$ to act on. In fact, physical considerations require that metric should be, not only $Diff^4$ invariant, but also $Diff^4$ degenerate so that infinitesimal $Diff^4$ transformations should correspond to zero norm vector fields of the configuration space.

To sum up the content of painful lessons, configuration space geometry should possess at least the following properties.

i) Metric ought to be Kähler metric. This property turns out to be necessary if one wants to geometrize the oscillator algebra used in the construction of the physical states and to obtain a well defined divergence free functional integration in configuration space.

ii) Metric should allow Riemann connection, which together with the Kähler property very probably implies the existence of an infinite dimensional isometry group.

iii) Metric should be $Diff^4$ invariant and degenerate and the definition of the metric should associate a unique spacetime surface $X^4(X^3)$ to a given 3-surface X^3 to act on.

The recent attempt is based on the realization that the construction of the Kähler geometry reduces to that of finding Kähler function $K(X^3)$ with the property that it associates a unique space time surface $X^4(X^3)$ to a given 3-surface X^3 and possesses mathematically and physically acceptable properties. Our guess for the Kähler function is the following one.

The value of the Kähler function K for a given 3-surface X^3 is obtained in the following manner.

a) Consider all possible 4-surfaces $X^4 \subset M_+^4 \times CP_2$ having X^3 as its submanifold: $X^3 \subset X^4$. If X^3 has boundary then it belongs to the boundary of X^4 : $\partial X^3 \subset \partial X^4$.

b) Associate to each four surface Kähler action as the Maxwell action for the Abelian gauge field defined by the projection of CP_2 Kähler form to the four-surface. Besides the Maxwell term Kähler action could contain Chern Simons term associated with the boundary of X^4 [Jackiw, Manes, Faddeev]: this term is however excluded unless one makes the un-natural assumption that physical spacetime surfaces are orientable.

c) Define the value of the Kähler function K for X^3 as the absolute minimum of the Kähler action S_K over all possible four-surfaces having X^3 as its submanifold: $K(X^3) = \text{Min}\{S_K(X^4) | X^4 \supset X^3\}$.

This definition of Kähler function has several physically appealing features.

1. Kähler geometry associates with each X^3 a unique four-surface, which we shall interpret as the classical spacetime associated with X^3 . This means that the so called classical space time (and physics!) in TGD approach is not defined via some approximation procedure (stationary phase approximation of functional integral) but is an essential part of not only quantum theory, but also of the configuration space geometry, which in turn might be determined by a mere mathematical consistency!

2. The space time surface associated with a given 3-surface is analogous to Bohr orbit of old fashioned quantum theory. The point is that the initial value problem in question differs from the ordinary initial value problem in that although the values of H coordinates h^a as functions $h^a(x)$ of X^3 coordinates can be chosen arbitrarily, the time derivatives $\partial_t h^a(x)$ at X^3 are uniquely fixed by the absolute minimization requirement unlike in the ordinary variational problem encountered in classical physics. This implies something closely analogous to the quantization of the canonical momenta so that space time surface can be regarded as a generalized Bohr orbit. The classical quantization of electric charge and mass are possible consequences of the Bohr orbit property.

3. Kähler function defines what might be called generalized catastrophe theory: the value of the Kähler function is analogous to the minimum of thermodynamical free energy and its value can jump in discontinuous manner, when some configuration space coordinate playing the role of a control parameter is changed. The jump, which is completely analogous to phase transition, occurs along what might be called 'Maxwell surface'.

4. Kähler function is $Diff^4$ invariant in the sense that the value of the Kähler function is same for all 3-surfaces belonging to the orbit of given 3-surface. As a consequence configuration space metric is $Diff^4$ degenerate. The implications of $Diff^4$ invariance have turned out to be decisive, not only for the geometrization of the configuration space but also for the construction of quantum theory.

a) $Diff^4$ invariance implies the absence of tachyons. Time like vibrational modes tangential to the 4-surface imply tachyonic mass spectrum unless they correspond to zero modes of the configuration space metric. $Diff^4$ invariance guarantees the required kind of degeneracy of the metric.

b) In order to have Kähler structure one must define complexification of the configuration space. Also one should identify the Lie algebra of the isometry group. In case of CP_2 this is not a problem of principle since configuration space inherits the complexification of CP_2 . In M^4 degrees of freedom the Minkowskian signature of the metric produces troubles and it is clear that metric of the configuration space should be degenerate so that the actual physical degrees of freedom reduce from 4 to 2 Euclidian

degrees of freedom allowing complexification. The physical counter part of this degeneration is familiar from quantum field theories: for massless particle only two polarizations instead of four correspond to states with nonzero norm and physical polarizations define 2-dimensional Euclidian subspace of M^4k allowing complexification.

The solution to the problem is provided by $Diff^4$ degeneracy: all 3-surfaces on the orbit of 3-surface X^3 must be physically equivalent so that one can effectively replace all 3-surfaces X^3 on the orbit of X^3 with suitably chosen surface Y^3 on the orbit of X^3 . The Lorentz and $Diff^4$ invariant choice of Y^3 is as the intersection of the 4-surface with the set $\delta M_+^4 \times CP_2$, where δM_+^4 denotes the boundary of the light cone: effectively the imbedding space can be replaced with the product $\delta M_+^4 \times CP_2$ as far as vibrational degrees of freedom are considered. More precisely: configuration space has fiber structure: 3-surfaces $Y^3 \subset \delta M_+^4 \times CP_2$ correspond to the base space and 3-surfaces on the orbit of given Y^3 and diffeomorphic with Y^3 correspond to the fiber and are separated by zero distance from each other in configuration space metric.

The unique feature of δM_+^4 is its metric degeneracy: light cone boundary is metrically 2-dimensional sphere although it is topologically 3-dimensional! This implies that lightcone boundary allows infinite dimensional group of conformal symmetries generated by algebra, which is a generalization of ordinary Virasoro algebra! δM_+^4 allows also complexification and Kähler structure unlike the boundaries of higher dimensional light cones so that it becomes possible to define complexification in the tangent space of the configuration space, too. Therefore 4-dimensional Minkowski space is in a unique position in TGD approach.

The complexification of the configuration space in turn is inherited from the complex structure of the light cone boundary. The complexification is induced from the inversion $r_M \rightarrow 1/r_M, z \rightarrow 1/\bar{z}$ of the lightcone boundary and from the complex conjugation for CP_2 and for Virasoro generators it reduces to the standard hermitian conjugation $L_n \rightarrow L_n^\dagger = L_{-n}$.

c) These observations lead to the identification of the isometry group. CP_2 vibrational tangent space is generated by the algebra of local $SU(3)$: the product of real function algebra of the light cone boundary with the global $SU(3)$ algebra generated by holomorphic Killing vector fields

of CP_2 : the required complexification is induced by CP_2 complexification. Rather unexpectedly, the gauge algebra is local with respect to the boundary of the light cone rather than with respect to 3-surface. This implies an enormous mathematical simplification although is not in accordance with the original idea that $Map(X^3, M^4 \times SU(3))$ acts as isometry group.

The identification of isometry group associated with $M^4 k$ degrees of freedom is more delicate since M^4 translations do not leave light cone invariant. It turns out that the isometry algebra must be contained in the algebra generated by the diffeomorphisms of the light cone boundary. A convenient basis for $Diff(\delta M^4_+)$ generators is obtained by using the coordinates $(r_M, z, \bar{z})$, where r_M denotes the radial coordinate of M^4_+ and z denotes complex coordinate of the sphere r_M constant. The basis for $Diff$ generators is given by the vector fields

$$V^{klm} = z^k \bar{z}^l r_M^m (z d/dz) \text{ and}$$

$$R^{klm} = z^k \bar{z}^l r_M^m (r_M \partial_{r_M}) + \text{c.c.}$$

The action of the complexification amounts to the replacement $(k, l, m) \rightarrow (-k, -l, -m)$. Not all these generators need to act as isometries. In fact, it turns out that the generators R^{klm} , $m > 0$ are as such probably not isometry generators as such but that it is possible to identify infinite set of radial scalings acting as zero norm isometries.

A particularly nice feature of the proposed isometry group is that it automatically acts in the whole configuration space. This implies that the matrix elements of the metric for 3-surfaces of different topology and sizes can differ from each other only through their dependence on isometry invariant variables! Therefore the calculational simplifications are expected to be even larger than in case of $Map(X^3, H)$. What makes possible this independence on topological and other details of the 3-surface is that the deformations of the 3-surface are not described using vector fields $\delta h^k(x)$ having the point x of X^3 as their argument but as vector fields $\delta h^k(h)$ having as their argument the coordinates of the light cone boundary.

d) The effective two-dimensionality of the light cone boundary solves some no-go theorems associated with higher dimensional Abelian extensions. First, in dimensions $D > 2$ Abelian extensions of the gauge algebra are extensions by an infinite dimensional Abelian group

rather than central extensions by the group $U(1)$. In present case the extension is symplectic extension analogous to the extension defined by Poisson bracket $\{p, q\} = 1$ rather than standard central extension but is indeed 1-dimensional and well defined provided configuration space metric is Kähler. Secondly, $D > 2$ extensions possess no unitary faithful representations (satisfying certain well motivated physical constraints) [Mickelson]. The point is that light cone boundary is metrically and conformally 2-sphere and therefore gauge algebra is effectively the algebra associated with 2-sphere and as a consequence also configuration space metric is Kähler.

5. Besides $Diff^4$ degeneracy the metric possesses additional degeneracy following from the minimization conditions for the Kähler action. A possible identification of this degeneracy is in terms of the conformal transformations of the light cone boundary and conformal color transformations (TGD counter part of the local color group). The requirement that Riemann connection exists also for zero norm vector fields generating isometries of the light cone boundary in fact implies that the subspace of zero norm vector fields contains the generators of the conformal transformations and color conformal transformations as its subspace. This implies surprisingly close resemblance between mathematical structures associated with string models and TGD.

6. We have already mentioned that the existence of Riemannian connection together with the Kähler property seems to force the local gauge invariance property and one might think that the proposed identification of the isometry group is not in accordance with Freed's result. The closer inspection of the Freed's argument however shows that the isometry group of the configuration space need not be necessarily $Map(X^3, M^4 k \times SU(3))$: any group with sufficiently large Lie algebra (tangent space vectors with nonvanishing norm are superpositions of isometry generators modulo zero norm vector) makes it possible to define Riemannian connection.

In fact, one can strengthen the conditions guaranteeing the existence of Riemann connection. The requirement $\nabla_Z(g(X, Y)) = Zg(X, Y)$, although trivial, when both X and Y have nonvanishing norm, specifies the general form of the configuration space metric to a surprisingly high degree, when applied to the inner products of zero norm vector fields with nonzero norm vector fields. The conditions fix

i) uniquely the complexification.
 ii) the zero norm isometries of the metric
 iii) the general form of the matrix elements in isometry basis apart from two conformal factors associated with M^4 and CP_2 degrees of freedom! These conformal factors depend on 3-surface via a finite number of isometry invariant variables only. The resulting metric is also invariant under configuration space isometries without any further assumptions.

7. In the case of loop spaces left invariance implies that Ricci tensor in vibrational degrees is a multiple of the metric tensor. In the sequel we shall show that the requirement of mathematical consistency (essentially the absence of divergences in the integration over the configuration space) forces the geometry to be Ricci flat : in other words vacuum Einstein's equations are satisfied. We show that the metric obtained by applying the consistency conditions of Riemann connection is indeed Ricci flat .

The construction of the spinor structure for configuration space is the second central part of the geometrization program. All previous attempts have been implicitly based on the assumption that configuration space spinors are fermion number one objects and carry half odd integer spin. In particular, the different chiralities of the configuration space spinors should correspond to lepton and quark numbers. The whole Super field formalism was based on this assumption, which has turned out to be wrong! What finally (after the work of six years!) led us to the correct track were following observations.

a) Since the classical bosonic physics is coded into the definition of the configuration space metric the classical physics associated with the spinors of the imbedding space should be coded into the definition of the configuration space spinor structure! This means that the generalized massless Dirac equation for the induced spinor fields on $X^4(X^3)$ should be closely related to the definition of the configuration space gamma matrices.

b) Since complex probability amplitudes (scalar fields) in configuration space correspond to second quantized boson fields in X^4 then spinor fields of the configuration space should correspond to the second quantized, free

induced spinor fields on X^4 ! The space of configuration space spinors should be just the Fock space of the second quantized fermions on X^4 !

The realization of these ideas is simple. Perform second quantization for free induced spinor field in X^4 . Express configuration space gamma matrices as superpositions of the fermionic oscillator operators. Configuration space gamma matrices are therefore analogous to spin 3/2 fields and can be regarded as super symmetric counter part of the gravitational field at configuration space level. The dimensions are indeed correct: gamma matrices are labeled by three integers as is labeled also the spinor basis of the 3-surface. Fermion number conservation forces the representation of M^4 type gamma matrices in terms of the leptonic oscillator operators and CP_2 type gamma matrices in terms of the quark like oscillator operators.

A particularly nice result is that the correspondence between the configuration space gamma matrices and the oscillator operator basis is reasonably one-to-one only provided the imbedding space is $M^4 \times CP_2$! This is easily understood. Configuration space gamma matrices in CP_2 degrees of freedom are labeled by 3 integers and 8(!) valued color label and oscillator operator basis for second quantized quarks by 3 integers and 8(!) additional labels corresponding to two M^4 chiralities for U and D quarks and their antiparticles! So: TGD works only for the physically motivated choice $H = M^4 \times CP_2$ of the imbedding space: the basis reason is that $SU(3)$ is the only simple Lie-group with dimension, which is some power of 2!

What is obtained is extremely close relationship with standard quantization procedures. What is lost is Super field formalism! All what is needed to construct Quantum TGD is to study classical spinor fields in configuration space!

The first part of the book is devoted to a more detailed description of these ideas. It must be admitted that the discussion is far from being mathematically rigorous and only the general ideas are represented: in particular we are not able to prove that the metric defined by Kähler function is indeed the metric found by applying the consistency conditions for Riemann connection. What we can do is to deduce a rather explicit form for the metric with

the proposed isometry group and to show its Ricci flatness. The last chapter is devoted to the construction of the configuration space spinor structure and the main result is that there is only one possible choice of the imbedding space and this choice is just the physically motivated choice $H = M_+^4 \times CP_2$.

Construction of the Quantum Theory

All attempts made to construct Quantum TGD have been based on what we call **Super field formalism** [Pitkänen 1986a, 1986b, 1988a, 1990a, 1990b]. Also this part of the TGD has developed only gradually and the main problems have turned out to be conceptual rather than technical in nature (contrary to our original beliefs). A brief account of the tortuous development of Quantum TGD to its version described in [TGD] would therefore be in order but we save the reader from painful details here.

Recall that the program of Quantum TGD in its original form was the following. Quantum TGD should be regarded as a free, classical field theory for a generalized Schrödinger amplitude in the configuration space $C(H)$ consisting of all possible 3-surfaces. The linear field equations satisfied by this amplitude should be derivable from a variational principle allowing phase invariance so that the conserved current associated with this phase invariance should be identifiable as a probability current. The matrix elements of the probability density defined by the normal component of the probability current between suitable incoming and outgoing states integrated over some codimension one surface of the configuration space (analog of time=constant surface of the Minkowski space) should define the S-matrix of the theory. It turned out that this program as such was not quite correct and the understanding of the configuration space geometry led to a considerably simpler formulation.

The basic dynamical entity of Quantum TGD was assumed [TGD] to be Grassmann algebra valued Super field $S(\Theta, \bar{\Theta})$, where the so called theta parameters generating the Grassmann algebra are in one-to-one correspondence with the spinor basis at a given point of the configuration space so that this field would describe states with arbitrary fermion number and spin. This assumption was necessitated by the idea that configuration space spinors are fermion number one objects. The construction of configuration

space spinor structure along the lines described above shows however that this approach is not at all necessary! What is needed is just **classical spinor field in configuration space**: the corresponding spinor space corresponds very closely to the Fock space of the standard quantum field theories. Super field would correspond to "third quantization" taking all states of the Fock space as single particle states and constructing quantized many particle system.

1. The basic dynamical entity of Quantum TGD is **classical spinor field in configuration space**. The spinor space corresponds to the Fock space associated with the free second quantized induced spinor field on X^4 so that a close relationship between TGD and standard quantum field theories results.

2. $Diff^4$ invariance fixes quantum dynamics completely if one requires that **physical states are $Diff^4$ invariant**! This means that configuration space spinor fields are "constant" for all 3-surfaces on the orbit of a given 3-surface and therefore are determined completely by their values at the boundary of the light cone: the moment of big bang. Quantum mechanical time development is closely related to the classical time development: if spinor field is strongly concentrated on a given 3-surface it is also strongly concentrated on all 3-surfaces on the classical orbit of X^3 . Therefore it is natural to identify the time development of $Diff^4$ invariant spinor field as the quantum counterpart of the macroscopic, irreversible time development: the minimization of the Kähler action indeed implies irreversible classical dynamics, when minimizing four-surface is submanifold of $M_+^4 \times CP_2$. The microscopic, reversible dynamics corresponds to the S-matrix description of the dynamics. Since $Diff^4$ invariance fixes the dynamics completely there is no need to postulate any variational principle for the spinor field.

3. In order to define S-matrix one needs a **unitary, divergence free inner product for spinor fields**. The **standard Fock space inner product provides a unitary inner product in spinor degrees of freedom**. In configuration space degrees of freedom the divergence cancellation requirement fixes the inner product uniquely. The inner products is of the form $\langle 1|2 \rangle = \int \bar{\Psi}_1(X^3) \Psi_2(X^3) \exp(K) \sqrt{G} DX^3$, where the exponent of the Kähler function K is analogous to the square of the oscillator Gaussian: in fact it is possible to include the vacuum functional into the definition of the configuration space spinors as a multiplicative factor of form $\exp(K/2)$. The

integration is over all 3-surfaces instead of 3-surfaces intermediate between two manifold topologies and implies a considerable simplification at the technical level. The properties of the Kähler geometry imply that this functional integral is free of divergences.

4. In order to define S-matrix one must define clearly what one means with energy momentum eigen states. In present context this is not at all trivial since Poincare invariance is lost at quantum level due to the presence of the light cone boundary so that translations lead out from M_+^4 . What one needs is a $Diff^4$ invariant representation of physical M^4 translations and ordinary translations certainly break $Diff^4$ invariance. $Diff^4$ invariant definition of the infinitesimal translations is obtained by considering 3-surface X^3 and denoting by $Z^3(a)$ the intersection of the space time $X^4(X^3)$ with the set $H_a \times CP_2$, where H_a denotes the hyperboloid with constant value a of the light cone proper time: $\sqrt{m_\mu m^\mu m^\nu m_\nu} = a$. The translation acts just like the ordinary translation at $Z^3(a)$ but induces a nontrivial deformation of the corresponding classical space time surface $X^4(X^3)$ and therefore of all 3-surfaces belonging to $X^4(X^3)$: only at $Z^3(a)$ does the deformation reduce to translation. What is important that the deformations and therefore also the energy momentum eigen states associated with different values of a are not identical. Furthermore, one can associate a unique value of a to a given energy momentum eigenstate. The identification of a as the subjective time experienced by a conscious observer looks rather natural. There is a quite recent result [Kehagias and Meessen] about the existence of Lorentz invariant deformations of Poincare algebra, which might provide a sound mathematical basis for the concept of infinitesimal $Diff^4$ invariant Poincare transformation.

5. The definition of the S-matrix is now obvious. Very roughly, S-matrix relates to each other energy momentum eigen states associated with two different values of the proper time a . These two times can be identified as times for beginning and the end of the experiment. S-matrix relates two time histories rather than the initial and final states of a single history so that quantum transition corresponds to a quantum jump between different histories and it seems that the identification of the state function reduction as a nondeterministic ($Diff^4$ noninvariant) time development of spinor field is not correct. The subjective time development corresponds

to a sequence of quantum jumps between energy momentum eigen states and one can associate a unique sequence of the values of M_+^4 proper time a to this sequence. The value of a can also decrease in individual quantum jump but since there is much more room in the future than in the past of the light cone a should increase on the average so that the arrow of time emerges naturally.

The topological and Fock space descriptions of the particle reactions are closely related. The point is that the oscillator operator basis associated with two 3-surfaces at the orbit of X^3 are related by a unitary linear transformation determined uniquely by the Dirac equation for the induced spinors. If these sections of X^4 possess different topologies (say different numbers of boundary components) this transformation mixes fermionic creation operators with antifermionic annihilation operators and makes pair creation possible. This in turn makes possible the emission of gauge bosons (they correspond to fermion antifermion pairs on single boundary component).

6. By $Diff^4$ invariance the construction of the theory reduces to that of constructing suitable basis for the spinor fields in $C(\delta M_+^4 \times CP_2)$, the light cone boundary or more generally, in some section of the configuration space determined by the $a = \text{constant}$ hyperboloid of the light cone. The choice of this basis must satisfy several constraints.

i) Inner product must be free of divergences. It turns out that Ricci flatness of the configuration space metric is necessary in order to guarantee the absence of the divergencies.

ii) Super Kac Moody symmetry [Fraenkel-Kac] gives very strong constraints on the choice of the spinor field basis.

7. A nice manner to realize Super Kac Moody symmetry is to require that the spinor fields on the light cone boundary are annihilated by what we call square of Kac Moody Dirac operator. Super Kac Moody algebra is generated by the symplectic extension of the spinorial isometry generators (extension exists by the effective two-dimensionality of the light cone boundary) and by the contractions of the isometry generators with the complexified gamma matrices of the configuration space. It turns out that the mass squared spectrum is integer valued in suitable units and colored states have mass of order Planck mass. The elementary particle-boundary component correspondence follows automati-

cally from the properties of the configuration space spinor structure. The vacuum for Super Kac Moody representations is infinitely degenerate since the fermionic oscillator operators associated with the boundary components anticommute with the configuration space gamma matrices. The reason is that they do not appear in the expansion of the configuration space gamma matrices in terms of the fermionic oscillator operators in "standard" gauge. Therefore massless particles can be identified as states created by the fermionic oscillator operators associated with the boundaries.

Besides the description of the basic principles of Quantum theory some applications of the theory are considered.

1. As in string models, a rather restricted set of particles predicted by theory is interesting experimentally: namely the massless states getting their masses through symmetry breaking. The properties of the massless sector of the theory are discussed and it is shown that it is possible to identify the known elementary particles as massless spinor fields annihilated by the square of Kac Moody Dirac operator. Elementary gauge bosons can be identified as fermion antifermion states created by the fermionic oscillator operators associated with single boundary component. Solutions allow two supersymmetries: first supersymmetry is infinite and second super symmetry corresponds to the ordinary $N = 1$ supersymmetry.

Massless states are color singlets and electroweak and color quantum numbers reside on the boundaries of the 3-surface in accordance with the basis ideas of TGD approach.

2. $Diff^4$ invariance suggest a general description of Higgs mechanism. $Diff^4$ invariant four-momentum operators depend on cosmic time: $p^k = p^k(a)$ and in general they do not commute for different values of Lorentz proper time. This implies that the expectation values of the mass operator $m(a)$ are nonvanishing for massless eigen states of $p^k(a_0)$ since the expansion of these states in terms of eigen states of $p^k(a)$ contains excitations with Planck mass. Higgs mechanism can be understood directly from the properties of the Dirac equation for the induced spinors. Elementary particle mass scale is shown to follow as a prediction of the theory and is fixed to a reasonable value, when one uses as input only the low energy value of the fine structure constant!

3. Genus-generation correspondence is one of the basis ideas of TGD approach and although it explains the similar properties of fermion families in an elegant manner there are several questions to be answered: why bosonic families are experimentally absent, why different lepton numbers are separately conserved, why there are apparently only three light fermion families. A construction of elementary particle vacuum functionals based essentially on the requirements of Diff invariance and 2- dimensional conformal invariance provides considerable understanding concerning these problems.

The experimental absence of $g > 2$ fermion families [Decamp *et al*] poses a serious problem for TGD approach. Hyperellipticity is a geometric property, which distinguishes between $g < 3$ and $g > 2$ 2-surfaces and therefore might explain the experimental absence of $g > 2$ families. Some scenarios implying three elementary particle families and based on the observation that elementary particle vacuum functionals vanish identically for $g > 2$ hyperelliptic surfaces are discussed.

4. The last chapter of second part of the book is devoted to the TGD inspired approach to the fundamental philosophical problems related to the measurement theory of quantum mechanics. What happens in state function reduction and what are the consequences of TGD concept of space time are the main questions to be considered.

Classical theory

In the third part of the book the emphasis is on the physical interpretation of the Kähler function and the aim is to develop a (necessarily highly biased) vision of the world as seen through classical TGD at (mostly) microscopic level. What we try to do is to answer to questions of following type. What do particle like 4-surfaces look like? What do classical space time surfaces look like? What happens in topological condensation and how is Higgs mechanism related to topological condensation? The strategy is simple:

- i) Try to derive the general consequences of renormalization group invariance
- ii) Study the simplest extremals of Kähler action and try to abstract general truths from their properties.

The assumptions defining classical TGD are the following ones:

- a) The definition of Kähler function associates unique 4-surface to a given 3-surface and this surface identified as the classical space time. As already noticed by its uniqueness this surface is analogous to Bohr orbit.
- b) The bosonic vacuum functional of the theory is the exponent of the Kähler function $\Omega_B = \exp(K)$. This assumption is the only assumption about dynamics of the theory and is necessitated by the requirement of divergence cancellation.
- c) The classical theory for fermions and elementary bosons corresponds to the Dirac equation for the induced spinors in accordance with the definition of the configuration space spinor structure.

The assumption about the form of the vacuum functional leads to principle, which we shall call "Yin-Yang" principle in what follows.

- a) Kähler function is essentially Maxwell action and as such not positive definite: the generation of Kähler electric fields gives negative contribution to Kähler action. Therefore the absolute minima of Kähler action are expected to have in general nonpositive Kähler action and to correspond to spacetimes carrying Kähler- electric fields. This tendency of the Kähler function to become negative corresponds to the "Yin"-aspect of our principle.
- b) Vacuum functional favours 3-surfaces with the property that the value of the Kähler function is positive. This tendency is the "Yang"-aspect of our principle. Together these tendencies stabilize the theory since they imply that for very large systems the average Kähler action per volume is essentially zero to guarantee that vacuum functional is nonvanishing and finite.

The topics discussed in the third part of the book divide into the following subtopics.

- a) The geometrization of various fields in terms of imbedding space geometry.

- b) The so called coupling constant evolution hypothesis.

Due to the fact that fields are not primary dynamical variables in TGD it is possible to interpret Kähler action as Einstein Yang Mills action having decomposition to electroweak, color, gravitational and fermionic parts. The hypothesis that Kähler action is renormalization group invariant is well motivated by its special properties, in particular by the self duality, which allows to identify elementary particles as magnetic monopoles, whose

Kähler magnetic flux runs in internal degrees of freedom so that no long range $1/r^2$ magnetic field is generated. RG invariance leads to extremely strong constraints on the evolution of the coupling constants appearing in the decomposition of the Kähler action and implies several predictions differentiating between standard model of electroweak and color interactions and TGD respectively.

A mathematically more precise manner to fix the value of α_K uniquely is based on the analogy between the vacuum functional $\exp(K)$ and $\exp(-H/T)$ appearing in the partition function of statistical mechanics. The characteristic features of the critical temperature are the non-analyticity of certain thermodynamical observables as functions of $T - T_c$ and the appearance of long range correlations. Since α_K corresponds to T the generalization is obvious. For $\alpha_K = \alpha_K(\text{phys})$ some configuration space integrals (not necessarily S-matrix elements) of type $\int \text{something} \exp(K) \sqrt{G} DV$ become nonanalytic functions of $\alpha_K - \alpha_K(\text{phys})$. Long range correlations mean the presence of arbitrary large volumes of new and old phase in statistical system. TGD: eish interpretation is that 3-surfaces with all possible sizes are possible and they are either spontaneously Kähler magnetized (recall the interpretation of Kähler function) or contain dominantly Kähler electric fields.

- c) The general theory of topological condensation.

The critical point property of the vacuum functional, the minimization of Kähler action through the generation of Kähler electric fields, the compactness of CP_2 and gauge charge conservation lead to a general picture about 3-space as a topological condensate having hierarchical, fractal like structure containing 3-surfaces with all possible sizes condensed on each other. Even macroscopic bodies should be regarded as 3-surfaces with boundary! The new picture of 3- space should have applications at all levels of physics, even in chemistry (molecules as 3-surfaces of finite size and outer boundary). There appears a new interaction to be called "join along boundaries", which seems to have a natural place in (bio)chemistry, to provide understanding concerning the formation of macroscopic quantum states and dissipative phenomena (loss of quantum coherence) topologically. A more quantitative manner to formulate the hypothesis is to assume the existence of a hierarchy of length scales $< L(n) < L(n+1) <$ associated with the infinite number (by criticality) of levels of the topological condensate, $L(n)$

having interpretation as minimum size for 3-surface at level n .

Quantitatively the emergence of the hierarchical structure is seen through the study of spacetimes representable as maps $M^4 \rightarrow CP_2$ provide a good model for the classical space time of GRT. It is found that these space time surfaces decompose into regions characterized by a handful of vacuum quantum numbers (a purely TGD:ish feature) and that CP_2 coordinates tend to have discontinuous or infinite derivatives on the boundaries of these regions so that they correspond to edges of the space times surface. In absence of neutralizing surface gauge charges the conserved Kähler gauge flux must flow somewhere and the only possibility is that it flows to lower condensate level (larger 3-surface) via topological sum contacts. The mechanism implies that spacetime surface reduces to vacuum extremal at its boundaries so that boundary conditions are identically satisfied. All these properties suggest that topological field quantization occurs: single topological field quantum is basic unit of space time (so that edges are avoided) and these surfaces condense on each other to form the actual space time surface.

d) An essential element of theory is provided by the precise formulation of the concept of classical gauge charge. Above non-Planckian length scales classical gauge charges are identified as gauge fluxes. Similar definition works for gravitational mass at nonrelativistic regime. Also the quantization of gauge fluxes in elementary particle length scales is assumed. This implies that gauge charges must flow to lower condensate levels near the boundaries of the topological field quanta and that vapour phase particles have vanishing gauge charges and gravitational (but not inertial) mass.

e) Topological condensation provides TGD: eish description of Higgs mechanism. Topologically condensed particle is a quantum superposition of the topologically condensed massless CP_2 extremal and a "hole" in the background space. The mass scale argument described in the first part of the book gives a correct order of magnitude for the particle mass. In topological condensation Kähler electric field is created in order to minimize Kähler action but simple order of magnitude estimates assuming that the classical size of particle is of the order of Compton length give the result that the contribution of the Kähler electric field of the "hole" component to the mass expectation value still dominates or is at least of same order

of magnitude as the contribution of the topologically condensed CP_2 type extremal. Criticality requirement implies that these contributions should be of same order so that the classical size of particle should be of the same order of magnitude as its quantum size: this means that the mysterious number 10^{-19} should be a purely intrinsic property of the Kähler action: the criticality of α_K only guarantees that quantum size and classical size are identical. This prediction provides a very strong test for the whole TGD approach!

A sharp difference between TGD approach and standard model is that gravitational long range interaction forces the existence of long range electroweak gauge fields. Classical Z^0 force leads to large parity breaking effects and it is assumed that the condensate levels $n < n_Z$ for which $L(n)$ is below cell length scale are purely electromagnetic. For $n \geq n_Z$ Z^0 gauge fields are assumed to be present, the idea being that classical Z^0 force explains chirality selection in biosystems. The length scale $L(n_Z) \sim 10^{-6} m$ is also of same order as neutrino Compton length if neutrino masses are of order few eV. This is as it should be since neutrinos screening of Z^0 charges is possible for condensate levels satisfying $L(n) \geq 1/m(\nu)$ only. The partial flow of the gauge fluxes associated with electroweak gauge bosons through the boundaries of topological field quanta provides a topological charge renormalization mechanism and is possible thanks to the induced gauge field concept.

A more quantitative approach to Higgs mechanism is based on the study of the extremals of Kähler action.

i) The so called CP_2 type extremals serve as a good model for free massless elementary particles. Their M^4 projection is light like curve, they are metrically equivalent with CP_2 (and therefore possess Euclidian metric) and one can construct the TGD counter parts of Feynmann diagrams as connected sums of several CP_2 : s: in good approximation each line of Feynmann diagram is isometric to CP_2 locally.

ii) The study of spherically symmetric, stationary extremals of the Kähler action provide a simple model for the "exterior metric" of the topologically condensed particle gives support for the general ideas about Higgs mechanism.

The study of spinorial aspects of Higgs mechanism supports the general view. For the generalized massless Dirac equation for induced spinor

fields the mixing of M^4 chiralities and therefore massivation takes place in general. It is however found that CP_2 type extremals are special in the sense that no mixing takes place. Also neutrino chiralities get mixed in general with one exception: under rather general conditions (boundary component is minimal surface) right handed neutrino remains massless particle.

f) Also color confinement and the color-electric flux tube picture of hadrons can be understood in terms of topological condensation. The point is that the generation of Kähler electric fields implies the generation of color electric fields (in particular flux tubes) since color field is proportional to Kähler field in TGD.

TGD at astrophysical and cosmological length scales

This part is devoted to the problem of understanding the relationship between TGD and GRT and the consequences of TGD at astrophysical and cosmological length scales.

a) The relationship of TGD and GRT is studied. The basic ideas are following. The requirement that classical four momentum is conserved exactly combined with the fact that GRT spacetime is experimentally well established concept leads to the conclusion that matter must be in two phases, which we shall refer as condensate and "vapour phase". Condensate corresponds closely to the spacetime of GRT and vapour phase corresponds to "a gas of small 3-surfaces" ("Baby Universes") and nonconservation of energy for the condensate corresponds to energy transfer between the two phases.

Concerning the description of the condensate the basic idea is that the spacetime of GRT is idealization obtained by smoothing out all topological details (in particular particles) of size smaller than a given length scale L and by describing their presence using various current densities such as YM currents and energy momentum tensor. It is shown that Einstein equations correspond to special solutions to the field equations: Einsteins equations are not however true generally.

For spacetimes satisfying Einstein equations the equations governing the energy transfer between condensate and vapour phase are derived and it is

found that Schwarzschild metric corresponds to the stationary situation, for which energy-momentum transfer between the two phases vanishes. A purely TGD: eish feature is that any electromagnetically neutral mass distribution is accompanied by a long range Kähler electric and therefore also Z^0 electric gauge field and the requirement that Z^0 force is weaker than gravitational force gives strong constraints on the values of the vacuum quantum numbers: the space time at astrophysical scales must correspond to large vacuum quantum number limit of TGD.

b) A model for topological condensation and evaporation is proposed. The gauge interactions between the colliding particles of the condensate can lead to the evaporation of the condensate particle and by time reversal invariance also to the condensation of the vapour phase particle through the time reversal of this process. RGE invariance, Yin-Yang principle and the interpretation of Kähler action as EYM action give strong constraints on the form of the model and suggest that evaporation and condensation rates are to a good approximation proportional to the reaction rates associated with the ordinary gauge interactions. It is shown that the proposed model provides a possible explanation to several astrophysical anomalies.

c) The so called cosmic strings play a central role in TGD inspired cosmology. The basic feature of a topologically condensed cosmic string is that the surrounding space has a macroscopic boundary caused by the radial Kähler electric field of the string. In the condensate of strings the regions surrounding strings can however partially join along their boundaries: the condition guaranteeing this gives suprisingly detailed constraints on cosmology. Kähler electric field implies also CP breaking and suggests a mechanism generating matter antimatter asymmetry.

d) A proposal for what might be called TGD inspired cosmology is made. The basic ingredient of this cosmology is the TGD counter part of the cosmic string. It is shown that

- i) "Yin-Yang" principle
 - ii) the basic properties of the cosmic strings
 - iii) the existence of the limiting temperature (as in string model, too) and
 - iv) the assumption about the existence of the vapour phase
- imply a rather detailed picture of cosmic evolution, which differs from that provided by the standard cosmology in several respects. The presence of

vapour phase provides an explanation for several puzzles of GRT based cosmology and implies the most radical departures from it. In particular, vapour phase serves as a "cosmic paper basket" making possible the generation of order in the condensate through the entropy (and energy) transfer to the vapour phase.

Topological field quantization and the generation of structures

Topological field quantization is perhaps the most important signature differentiating between Maxwellian and TGD: eish gauge field concepts and we have realized some of its consequences only quite recently. What happens that spacetime surface decomposes into regions characterized by a handful of vacuum quantum numbers. These quantum numbers partially characterize the coordinate dependence of the two phase angles Ψ and Φ associated the two complex coordinates of CP_2 . In order to avoid edges of spacetime one must assume that single region with definite vacuum quantum numbers serves as a basic unit of 3-space.

Topological field quanta have in general outer boundary and renormalization group invariance suggests that all sizes are possible so that 3-space should have hierarchical, fractal like, structure containing 3-surfaces condensed on each other. Not only atoms and molecules but also macroscopic bodies correspond to 3-surfaces with outer boundary so that the visible world of the everyday life can be interpreted in completely new manner: instead of topologically trivial space E^3 with mysterious material objects we see empty but topologically extremely rich 3-space: the outer boundaries of the material objects correspond to the boundaries of this 3-space.

Topological field quanta can be partially joined together along their boundaries (join along boundaries bond). At the level of chemistry this means the formation of chemical bond, at macroscopic level macroscopic bodies touch each other. An exciting possibility is that the formation of macroscopic quantum systems from smaller units is possible by the formation of the joining along boundaries bonds.

So, topological field quantization might provide the first principle explanation for the generation of both spatial and temporal struc-

tures so that CP_2 geometry would manifest itself in all length scales, in particular at the visible structures of the everyday world.

The last part of the book is devoted to some applications of these ideas.

a) Topological field quantization implies as a special case the topological quantization of magnetic flux and a TGD inspired model for the discrete flux tube structure of the solar magnetic field is proposed and it is found that the vacuum quantum numbers inside magnetic flux tubes might be considerably smaller than for ordinary vacuum in astrophysical length scales so that Z^0 electric field becomes strong. A TGD inspired solution of the solar neutrino problem relying strongly on the properties of induced spinor structure and TGD description of the solar magnetic field is proposed. The key idea is that Z^0 force becomes strong enough to imply the trapping of neutrinos around the Z^0 magnetic field lines.

b) Any mass distribution is accompanied by Z^0 electric and magnetic fields and the generation of hydrodynamic turbulence might be understood as a spontaneous Z^0 magnetization. The radii of the vortices depend on vacuum quantum numbers and their is fractal hierarchy of vortex sizes depending on the value of the so called fractal quantum number. Correct value for the critical Reynolds number and correct power law dependence of the vortex distribution on vortex radius is predicted.

c) A TGD: eish description of Super conductivity, Super fluidity and Quantum Hall effect is suggested. Contrary to the original expectation it is found that TGD: eish ideas should provide new insight to the description of less exotic condensed matter phenomena: say the description of conductors, di-electrics and magnetism, too.

i) The basic assumption is that supra phases correspond to small vacuum quantum number limit of TGD. At this limit the size of the topological field quanta becomes small (typically of the size of the coherence length of supra phase: $\xi = 10^{-8} - 10^{-7}$ meters for super conductors). Supra phase corresponds to phase obtained by glueing these field quanta together by join along boundaries bonds to form a macroscopic quantum system: the presence of these bonds (or rather bridges) makes possible dissipation free flow.

ii) It is possible to identify the ratio of $\psi = \xi_1/\xi_2$ of CP_2 complex coordinates as the universal order parameter of the supra phase.

iii) The generation of vacuum Kähler and Z^0 fields suggests a possible unifi-

cation for the classical descriptions of super fluidity and super conductivity: the role of the magnetic field is taken by the Z^0 magnetic field in super fluidity.

d) **Biological phenomena** present the most richest known spatial and temporal structures and a proposal of how one might understand the basic features of biological information processing in terms of vacuum quantum numbers and topological field quantization is made. The basic ideas are the following ones.

i) Biosystems are identified as macroscopic quantum systems obtained by glueing together smaller basic units (proteins, cell membranes) by join along boundaries bond.

ii) Organic matter is assumed to be super conducting so that the order parameter ψ , $= \xi_1/\xi_2$ becomes the carrier of biological information and the "act of free will" corresponds to a quantum jump for ψ .

iii) Vacuum quantum numbers provide a universal code for information processing.

These ideas are applied at several levels including brain. A natural representation for long and short term memory is in terms of the integers characterizing the change of the phase of ψ , around the closed loops of the brain understood as a super conducting neural net. At neuron level the basic tools of the information processing are localized super currents ("kinks"). The hypothesis leads to a Josephson junction model for EEG waves explaining the existence of EEG waves as a consequence of membrane potential, predicting the order of magnitude of EEG amplitude correctly, and leading to a model for the generation of nerve pulse.

To summarize, it should be clear that TGD provides a completely new manner to see the world and TGD: eish effects seem to emerge at all length scales, even at the structures of the everyday world. This means that TGD differs drastically from other unifications such as string models, where the new effects appear at Planck length scale only. Of course, all what has been done is to a large extent heuristic guess work and only time will show which of the guesses are correct. What is certain is that TGD is not only just one unification scenario among a multitude of other unification scenarios and, if TGD is correct description of Nature, drastic changes in our world picture are necessary.

References

- [Christensen] Christensen, S., M. (1984): *Quantum Theory of Gravity* Adam Hilger Ltd.
- [Eguchi *et al*] Eguchi, T., Gilkey, B., Hanson, J. (1980): Phys. Rep. 66, 6.
- [Decamp *et al*] Decamp *et al* (Aleph Collaboration)(1989): CERN-EP/89-141, preprint.
- [Eisenhart] Eisenhart (1964): *Riemannian Geometry*. Princeton University Press
- [Faddeev] Faddeev, L., D. (1984): *Operator Anomaly for Gauss Law*. Phys. Lett. Vol 145 B, no 1,2
- [Fraenkel-Kac] Fraenkel I., B. and Kac V., G. (1980): *Basic Representations of Affine Lie Algebras and Dual Resonance Models*. Inventiones Mathematicae 62, 23
- [Freed] Freed, D., S. (1985): *The Geometry of Loop Groups* (Thesis). Berkeley: University of California
- [Gibbons-Pope] Gibbons, G., W., Pope, C., N. (1977): *CP₂ as gravitational instanton*. Commun. Math. Phys. 55, 53
- [Hawking-Pope] Hawking, S., W. and Pope, C., N. (1978): *Generalized Spin Structures in Quantum Gravity*. Physics Letters Vol 73 B, no 1
- [Helgason] Helgason, S. (1962): *Differential Geometry and Symmetric Spaces*. New York: Academic Press
- [Iztykson-Zuber] Iztykson, C., Zuber, J., B. (1980): *Quantum Field Theory*. New York: Mc-Graw-Hill
- [Jackiw] Jackiw, R. (1983): in *Gauge Theories of Eighties*, Conference Proceedings, Åkäslompolo, Finland (1982) Lecture Notes in Physics, Springer Verlag
- [Kehagias and Meessen] A.A. Kehagias and P.A.A. Meessen, Phys. Lett. B 324, p. 20 (1994)

- [Logunov *et al*] Logunov, A., A., Loskutov, Yu., M. and Mestrihvili, M., A. (1988): *Relativistic Theory of Gravity*. Int. J. of Mod.Phys. Vol 3 No 9 , 2067
- [Manes] Manes, J., L. (1986): *Anomalies in Quantum Field Theory and Differential Geometry* Ph.D. Thesis LBL-22304
- [Mickelson] Mickelson, J. (1989): *Current Algebras and Groups*. Plenum Press, New York.
- [Milnor] Milnor, J. (1965): *Topology form Differential Point of View*. The University Press of Virginia
- [Misner-Thorne-Wheeler] Misner, C., W., Thorne, K., S., Wheeler J., A. (1975): *Gravitation*. W. H. Freeman, San Fransisco
- [Pitkänen 1981] Pitkänen, M. (1981) International Journal of Theor. Phys. ,20, 843
- [Pitkänen 1983] Pitkänen, M. (1983) International Journal of Theor. Phys. ,22, 575
- [Pitkänen 1985] Pitkänen, M. (1985) International Journal of Theor. Phys. ,24, 775
- [Pitkänen 1986a] Pitkänen, M. (1986) International Journal of Theor. Phys. ,25, 1
- [Pitkänen 1986b] Pitkänen, M. (1986). International Journal of Theor. Phys. ,25, 973
- [Pitkänen 1988a] Pitkänen, M. (1988) Annalen der Physik. 45, 37, 235-248
- [Pitkänen 1988b] Pitkänen, M.(1988) Helsinki University preprint HU-TFT-88-32
- [Pitkänen 1990b] Pitkänen, M.,(1990): *Topological Geometrodynamics*, Internal Report HU-TFT-IR-90-4, Helsinki University.

- [TGD] M. Pitkänen (1995) *Topological Geometrodynamics* Internal Report HU-TFT-IR-95-4 (Helsinki University). Summary of of Topological Geometrodynamics in book form. Book contains construction of Quantum TGD, 'classical' TGD and applications to various branches of physics.
- [padTGD] M. Pitkänen (1995) *Topological Geometrodynamics and p-Adic Numbers*. Internal Report HU-TFT-IR-95-5 (Helsinki University). Report on application of p-adic numbers in attempts to understand quantum field theory limit of TGD.
- [homepage] The updated versions of both reports are available as ps-files from personal homepage
- <http://blues.helsinki.fi/~matpitka/>
- Homepage contains also hypertext representation of basic ideas and concepts of TGD. Homepage can be found also from YAHOO under title Science/...../Theoretical Physics/Theories.
- [archives] M.Pitkänen(1994), *p-Adic description of Higgs mechanism;I,II,III,IV,V*. hep/th 9410058,9410059, 94100560,9410061,941006 Elementary particle and hadron mass calculations are performed in parts III,IV. Part V is devoted to the new physics. The first version of p-adic mass calculations, which contained several errors. Also the construction of Kac Moody spinors as Super Virasoro representations contained many unsatisfactory features. The identification of elementary particle as CP_2 type extremal was not made in this calculation so that calculations did not predict neither graviton nor $N = 1$ super symmetry. The most recent calculations can be found from homepage.
- [Pope] Pope, C., N. (1980): *Eigenfunctions and Spin^c Structures on CP_2* D.A.M.T.P. preprint
- [Pope-Stelle] Pope, C., N., Stelle, K., S.(1988): *The Witten index for the supermembrane* , preprint Imperial/TH/87-88/27
- [Pressley-Segal] Pressley, A., N., Segal, G., B.(1986): *Loop Groups*. Oxford University Press

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

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

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

[Witten 1984] Witten, E. (1984): *Commun. Math. Phys.* 92, 455-472

[Witten 1987c] Witten, E. (1987): *Topological Quantum Field Theory*, IAS-PUB-IASSNS-HEP -87/72