Topological Condensation and Conversion of "Vapour Phase" Photons into Kinetic Energy

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Abstract

A quantum topological network model that might allow for the production of energy through the employment of vacuum electromagnetic currents form is based upon foundational principles of topological geometrodynamics (TGD) [Pitkanen, 1995a, b]. Such a production photon-factory would have the capability of drawing upon a seemingly inexhaustible supply of what in TGD formalism is a "vapour phase" of photons. Particularly in the presence of Bose-Einstein condensate photons, it is theoretically possible to convert these "vapour phase" photons into condensed photons that can then be harnessed and transformed into useful kinetic energy by more traditional means. The problem of how to control the dynamics of transferring this energy into a useful and regulatable kinetic form, such as may be employed within an ion drive or any number of alternative propulsion methods, is significant and involves issues of developing coherence and resonance among locally chaotic and asynchronous systems. This difficulty may be solvable through the adaptation of algorithms and models developed for synchronizing heterogeneous nonequilibrium oscillator networks.

TGD presents a view, similar to certain string models, of spacetimes as surfaces within an 8-dimensional space H that is a product of Minkowski space future lightcone M^4_+ and a complex projective space CP_2. TGD model allows for topological merging, akin to the condensation process in classical physics, of free elementary particle like 3-surfaces to the background surface of larger size. "Topological evaporation" corresponds to the reverse of this process in which particles go "outside" the classical spacetime.

TGD predicts vacuum electromagnetic fields having as their source vacuum gauge currents instead of currents composed of elementary particles. The vacuum gauge currents generate coherent states of photons and the for lightlike vacuum currents the coherent state arises in a resonant-like manner. A presence of Bose-Einstein condensates of photons in a nearby spacetime sheet external to the coherent-state generator would allow for a transfer of photons from that sheet into a vapour phase. The capture of these photons into an electro-mechanical propulsion system may provide a source of energy which can be converted into a form useful for the propulsion and acceleration of a space craft. The prequisites can be summarized as follows:

(a) Spacetime regions with classical gauge fields with nonvanishing lightlike vacuum electromagnetic currents generating coherent photons

(b) Induction of topological condensation of vapour phase photons through presence of BE condensates

(c) Controllable transfer mechanism for creating a continuous flux of photons from the vapour phase region

An emission of coherent light from a region not containing charged particles would be a clear indication of vacuum current presence. Whether this entire process, if it is feasible, could generate enough useful energy for spacecraft propulsion is a major open question. However, it does appear that in the least such a mechanism could provide for some type of quantum communication with storage of information in both phase and intensity of the coherent emf and with the vacuum currents acting as quantum antennae.

An examination of certain models known as quantum cellular automata and networks (QCAM, CLAN) [Dudziak, 1993] and synchronized heterogeneous dynamical networks (SHDN [Chinarov, 1998] may provide some further insight into how the suggested stimulated coherent production of photons might be initiated, controlled, and stabilized in an application for space travel or communication.

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1 TOPOLOGICAL GEOMETRODYNAMICS

Topological geometrodynamics provides an alternative [5] approach to the unification of quantum theory and relativity. In this approach [5], there is a fundamental and radical generalization of the concept of 3-space. Spacetime is replaced by a surface of 8-dimensional space $H = M^4_+ \times CP_2$, where M^4_+ is the interior of the future light cone of 4-dimensional Minkowski space and CP_2 is complex projective space with real dimension four. The reasons forcing the use of (the interior of) the future light cone of M^4, denoted by M^4_+, rather than entire Minkowski space, are both mathematical and cosmological, as a matter fact, M^4_+ corresponds to an empty Robertson-Walker cosmology. This space possesses the symmetries of the empty Minkowski space broken only by the presence of the lightcone boundary plus some additional symmetries, namely those of the internal space CP_2. One can identify the isometries of CP_2 (cf. Figure 2. below) having dimension) as color symmetries characteristic for quarks and gluons and the theory becomes unique. It is easy to construct action principles allowing the symmetries of H as symmetries and giving spacetime surface as a solution of the field equations. This means a solution of the so called energy problem of General Relativity since energy now corresponds to time translations of 8-dimensional H rather than of 4-dimensional spacetime as in General Relativity.

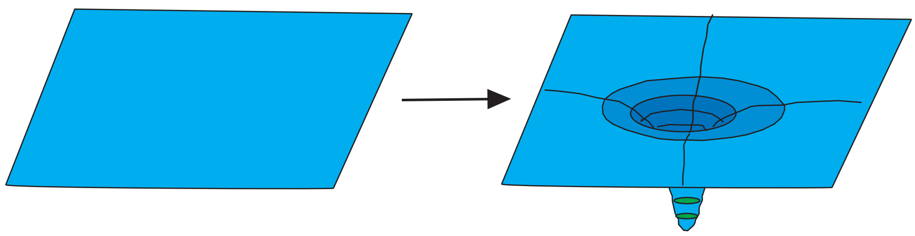

Figure 1: Gravitation makes spacetime curved and leads to a loss of translational symmetries in GRT.

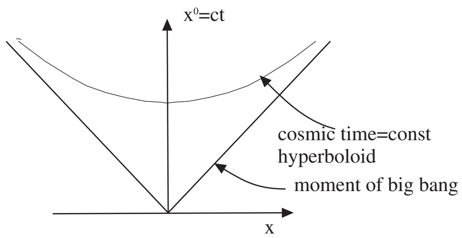

Figure 2: Geometry of the future lightcone M^4_+.

Sub-manifold geometry leads to a natural geometrization of gauge fields and quantum numbers. Induction procedure for the metric means that distances in spacetime surface are measured using the meter sticks of the imbedding space. In the case of gauge fields induction means that parallel translation is performed using the parallel translation defined by the spinor connection of the imbedding space. The requirement of electroweak gauge structure fixes the space S uniquely to $S = CP_2$. Also the geometrization of known elementary particle quantum numbers results.

In TGD framework spacetime can be regarded as a manysheeted surface. The distances between parallel sheets are extremely small, of the order of CP_2 size $R \sim 10^4$ Planck lengths. Sheets have a finite size and outer boundary and form a hierarchical structure ordered by the typical size of the sheet. A spacetime sheet is identified as a geometric representation of a material object so that 'matter' (in the sense of 'res extensa') reduces to spacetime topology in TGD and interactions between particles can be be understood topologically. Elementary particles correspond to surfaces with size of order R, which have suffered topological condensation ('gluing' by topological sum contact) to a larger spacetime sheet. Elementary particles can also topologically evaporate: vapour phase particles are 'outside' the macroscopic spacetime and analogous to the Baby Universies of General Relativity. An argument based on the conservation of Newtonian gravitational flux and gauge fluxes on the boundaries suggests that vapour phase particles

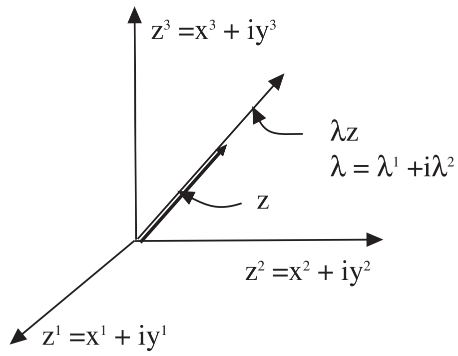

Figure 3: CP_2 as a complex projective space of real dimension 4.

have vanishing gravitational mass and gauge charges whereas inertial mass (or at least four-momentum) should be nonvanishing: this implies a breaking of Equivalence Principle for such particles.

In principle there is energy and momentum transfer between various spacetime sheets and also between spacetime sheets and 'vapour phase'. Assuming that Einstein's equations of GRT hold true, one can calculate the energy transfer from a given spacetime sheet to other sheets and to vapour phase. One can also construct a model for various particle transfer processes by assuming that standard interactions cause evaporation and condensation. In the case of a single spacetime sheet this means that each elementary particle species is effectively doubled corresponding to vapour phase- and condensate states. In each vertex of the Feynmann diagram both vapour phase and condensate states can occur with appropriate amplitudes. Also the classical gauge fields associated with the condensate can affect the condensation or evaporation and again appropriately generalized standard interaction vertices are assumed.

A futher purely TGD:eish phenomenon, deriving from the induced gauge field concept, is the existence of genuinely classical gauge fields, in particular electromagnetic and gravitational fields having standard couplings to the quantum fields. Unlike in classical electrodynamics, vacuum emfs can have nonvanishing divergence identifiable as a vacuum gauge current rather than as a current consisting of elementary particles. The presence of the vacuum gauge currents makes possible a generation of coherent states of photons: each Fourier component of the vacuum gauge field generates its own coherent state. A purely TGD:eish prediction are so called 'massless extremals' representing nonlinear em waves with associated lightlike vacuum currents for which the coherent state is generated in resonant-like manner. Thus lightlike vacuum currents can act as as ideal quantum antennas [5, 7].

In complete analogy with the stimulated emission and absorption, the presence of the BE condensate of photons (large number of photons in given Fourier mode) at some other spacetime sheet than the one creating the coherent state, implies a stimulated transfer of photons between this spacetime sheet and vapour phase.

The first application coming into mind is quantum communication with information stored in both the phase and the intensity of the coherent emf and lightlike vacuum currents serving as quantum antennas. The second application would be a mechanism of energy production based on the sucking of photons from the coherent state of vapour phase to condensate containing BE condensate of photons. The necessary prequisites for the mechanism are as follows:

a) There exist a region of spacetime containing classical gauge fields with nonvanishing lightlike vacuum em current generating coherent photons. Lightlikeness implies resonance and would lead to large density of photons in the vapour phase.

b) There is a device capable of inducing topological condensation of the vapour phase photons. The device in question could be smaller spacetime sheet containing BE condensate of photons in some Fourier modes of the quantized photon field.

b) There exists a mechanism for transferring the condensed photons away from the device so that a continuous flux of energy from the vapour phase becomes possible.

Since charged elementary particles are massive, they cannot give rise to coherent, macroscopic lightlike currents. Hence the emission of coherent light from a spacetime region not containing charged particles (the absence of emission and absorption lines, brehmstrahlung radiation, etc.) would be a signature of the vacuum currents. Also the lightlikeness of this current could serve as a signature in laboratory length scales (microtubules [5, 7]).

At best, the stimulated topological condensation of photons might be capable of generating sufficient release of energy that can be harnessed to be useful in the operation of a large interstellar or beyond-solar-system missions. The second possibility is quantum communication already mentioned. At worst, the energy density of the photons in the vapour phase might be of the same order of magnitude as the energy density of the microwave background or even smaller. Even in this case the mechanism might however provide a direct test of the TGD:eish spacetime picture.

2 TGD based spacetime concept and condensate/vapour phases

One can enter up with TGD also as a generalization of the old fashioned hadronic string model by generalizing the description of hadrons as strings having quarks at their ends with the description of particles as small 3-surfaces X^3 containing quantum numbers at their boundaries. This leads to a topological explanation of the family replication phenomenon and makes it possible to explain the known elementary particle quantum numbers in terms of H-geometry. The TGD resulting from the generalization of string is however quite different from the TGD resulting as a solution of the energy problem of GRT.

The only manner to unify these two TGD:s is provided by a generalization of the spacetime concept. The macroscopic spacetime with matter is identified as a many-sheeted surface with hierarchical structure. There are sheets glued on larger sheets glued on larger sheets..... Each sheet has outer boundary and material objects are identified as spacetime sheets. Gluing is performed by topological sum operation connecting different spacetime sheets by very tiny wormholes with size of order CP_2 radius. Wormholes reside near the boundaries of a given spacetime sheet and they feed various gauge fluxes to the larger spacetime sheet (external world from the view point of the smaller spacetime sheet). Elementary particles correspond to so called CP_2 type extremals, which have Euclidian metric and negative finite action and have very much the same role in TGD as blackholes in GRT.

Also 'vapour phase', i.e. small particle like surface residing (at least part of the time) outside the macrosocopic spacetime surface are possible, and are the counterpart of the Baby Universies of GRT. The requirement that gauge and gravitational fluxes are conserved on the boundaries of 3-surface implies that classical gauge charges and gravitational mass of the vapour phase particle vanish. There is no reason for the vanishing of the inertial four-momentum although one can consider the possibility that the rest masses of the vapour phase elementary particles vanish in accordance with the idea that topological condensation gives rise to the massivation of the elementary particle. One could argue that quantum gauge charges of topologically evaporated CP_2 type extremals cannot be identified as gauge fluxes and therefore can be nonvanishing. This problem does not however affect recent considerations.

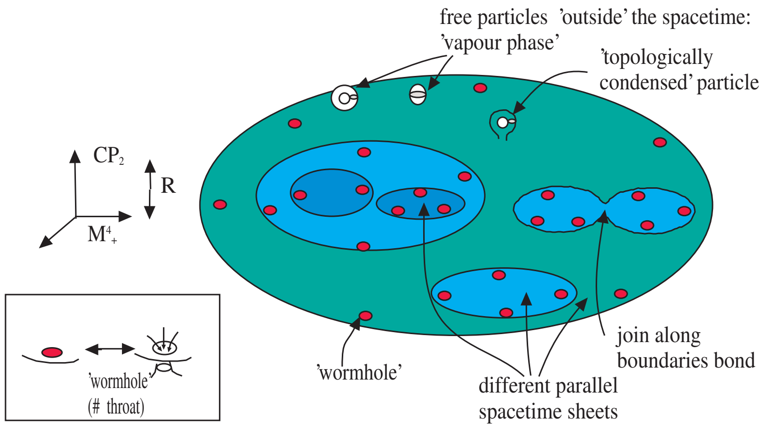

Figure 4: Topological condensate and vapour phase: two-dimensional visualization.

2.1 Quantum TGD very briefly

The construction of quantum TGD reduces to the construction of spinor geometry for the infinite-dimensional configuration space CH of TGD consisting of 3-dimensional surfaces in the 8-dimensional space $M^4_+ \times CP_2$ (for details see the first two parts of [5]) This means the construction of the metric and spinor structure. The requirement that the fermionic and bosonic oscillator algebras of the quantum field theories are geometrized leads to the conclusion that the geometry of CH must be so called Kähler geometry allowing complex structure in its tangent space. In Kähler geometry imaginary unit i is geometrically realized as an antisymmetric tensor, so called Kähler form J, whose square is -1, 1 being realized as the metric tensor. Physically Kähler form behaves like a sourceless Maxwell field and defines also symplectic structure. The simplest example of Kähler geometry is two-dimensional (q, p)- phase space for one-dimensional harmonic oscillator regarded as a complex plane with complex coordinate $(z = q + ip)$. So called Kähler function codes all information about Kähler metric and Kähler form. Therefore the construction of the CH metric reduces to that of identifying the so called Kähler function $K(X^3)$ as a functional of 3-surface. The construction of the gamma matrices associated with the spinor structure reduces to second quantization of free induced spinor fields on spacetime surface: anticommuting gamma matrices are superpositions of anticommuting fermionic oscillator operators.

2.3.1 General Coordinate Invariance

The basic physical requirement is 4-dimensional General Coordinate Invariance. This can be realized provided that the Kähler function associates to a given 3-surface X^3 appearing as its argument a unique spacetime surface $X^4(X^3)$ for 4-dimensional diffeomorphisms to act on. This spacetime surface could be called the classical spacetime associated with given 3-surface. A physically motivated guess for the Kähler function $K(X^3)$ is as the absolute minimum of so called Kähler action for all spacetime surfaces going 'through' X^3. A good analogy are the membranes going through a wire: one of them provides the surface with minimum area passing through the wire.

2.3.2 Quantum criticality

Kähler action involves only single a priori free parameter, the so called Kähler coupling strength. The fact that vacuum functional is precisely analogous to the partition function of a critical system with Kähler coupling strength in the role of temperature suggests that the physical theory corresponds to a critical value of the Kähler coupling strength. An important prediction is the existence of long range quantum correlations in all length scales: this suggests that TGD could provide the mechanisms needed for understanding biosystems as macroscopic quantum systems. Possible mechanisms leading to the formation of macroscopic quantum systems would be quantum entanglement in the degrees of freedom characterizing the shape and size and classical Kähler field associated with the 3-surface and also the formation of join along boundaries condensates of 3-surfaces making possible formation of larger quantum systems form composite systems.

2.3.3 Super Virasoro symmetry and spin glass analogy

Configuration space geometry is fixed by symmetry considerations and by the requirement of divergence cancellation (recall that the situation is infinite-dimensional!) to a very high degree. Super Virasoro and Super Kac Moody symmetries [?] of the string models generalize and play absolutely essential roles in the construction. The construction works only for $M^4_+ \times S$, where S is four-dimensional Kähler manifold: if one requires that S is homogenous space, only the alternatives $S = CP_2$ and $S = S^2 \times S^2$ remain. The special role of M^4_+ is due to the very special conformal properties of the 4-dimensional light cone boundary allowing the generalization of the ordinary 2-dimensional conformal invariance. The conformal symmetries of the string world sheet are replaced with the generalized conformal symmetries of the lightcone boundary just like Poincare invariance at the level of the spacetime is replaced with Poincare invariance at the level of the imbedding space. 8-dimensionality is in turn necessary in order to construct spinor structure: only in 8-dimensional case is the number of the spinor components of a fixed chirality the same as the dimension of the space itself. Super Virasoro invariance dictates the mass spectrum of the theory just as it does in string models. The S-matrix can be regarded as an exponential of a Hamiltonian, which is just Super Virasoro generator L_0.

A central role in the construction is played by the precise mathematical analogy with the spin glass phase, which implies the existence of an infinite number of zero modes, whose coordinates do not appear at all in the line element of CH. These zero modes can be regarded as universal order parameters characterizing the shape, size and classical Kähler fields associated with 3-surface.

2.3.4 The concept of quantum average effective spacetime

The concept of the 'quantum average effective spacetime' is crucial for relating the theory to QFT description. The exponent $exp(K/2)$ of the Kähler function defines unique vacuum functional for the theory analogous to oscillator Gaussian. The maxima of the Kähler function with respect to non-zero modes as function of zero modes can be identified as 'effective spacetimes', whose dynamics are dictated by the absolute minimization of Kähler action so that the 'effective action' defining the low energy limit of the theory selects only some of the maxima of the Kähler function. The hypothesis that the maximum of Kähler function as a function of zero modes is p-adic fractal [6] is motivated by criticality and spin glass analogy and leads to the connnection between quantum TGD and p-adic TGD (, which leads to very succesfull predictions of elementary particle masses [6]).

2.2 Macroscopic limit of TGD

'Quantum average effective spacetimes' correspond to the absolute minima of the Kähler action associated with the maxima of the Kähler function. Therefore the dynamics of the quantum average effective spacetime is fixed and the stationarity requirement for the effective action should only select some physically preferred maxima of the Kähler function. The topologically trivial space time of classical GRT (see the chapter 'The relationship between TGD and GRT' of [5] for details) cannot however directly correspond to the topologically highly nontrivial TGD:eish spacetime but should be obtained only as an idealized, length scale dependent and essentially macroscopic concept. In principle, this allows the possibility that also the dynamics of the effective smoothed out spacetimes is determined by the effective action. The criticality of the theory however suggests that Kähler function is renormalization group invariant in the sense that also the smoothed out spacetime surfaces are absolute minima of the Kähler action.

2.4.1 Smoothing out procedure

The spacetime in length scale L is obtained by smoothing out all topological details (particles) and by describing their presence using various densities such as energy momentum tensor $T^{\alpha\beta}_{\#}$ and Yang Mills current densities $J^{\alpha}_{a\#}$ serving as sources of electroweak and color gauge fields. It is important to notice that the smoothing out procedure eliminates elementary particle type boundary components in all length scales: this suggests that the size of a typical elementary particle boundary component sets lower limit for the scale, where the smoothing out procedure applies.

2.4.2 Einstein Yang Mills action for the induced gauge fields and topologically condensed matter

The action is obtained from the effective action for the low energy limit of the QFT limit of TGD by describing quantum fields phenomenologically using YM currents, particle densities, etc.. The action is therefore Einstein Yang Mills action with Yang Mills fields in one-one correspondence with the induced gauge fields. When quantum effects are neglected, only classical fields remain in the action and only electromagnetic and Z^0 fields can appear as classical fields in macroscopic length scales. Purely electromagnetic or Z^0 type fields are proportional to the Kähler field so that YM action is proportional to the Kähler action in this case.

The interaction between the point like particles (in a given scale!) and the long length scale fields of the smoothed-out spacetime is described by regarding the various currents describing the presence of point like matter as external currents coupled to the fields associated with Kähler action interpreted as Einstein YM action. The YM currents associated with topologically condensed matter will be denoted by $J^{\alpha}_{a\#}$, where 'a' refers to a specific component of YM field. The corresponding energy momentum tensor will be denoted by $T^{\alpha\beta}_{\#}$.

For YM fields the interaction term is just the external YM current multiplied with YM gauge potential. For the metric the corresponding term is the trace of energy momentum tensor. This assumption implies the addition of the various interaction terms to the EYM action density

$$L_{EYM} \rightarrow L_{EYM} + \sum_a Tr(J^{\alpha}_{a\#} A_{a\alpha}) + T^{\alpha\beta}_{\#} g_{\alpha\beta} \ . \tag{1}$$

Here the index "#" refers to topologically condensed matter. L can be decomposed into a sum of terms corresponding to color and electroweak interactions and gravitational interaction:

$$L_{EYM} = L_{ew} + L_c + L_{gr} \ . \tag{2}$$

The couplings associated with the various terms of the action density depend on the length scale considered. For Kähler function, the spacetime associated with a given 3- surface is fixed by the requirement that it corresponds to an absolute minimum of the Kähler action. In present case also the extremization in the sense of stationary phase approximation with respect to X^3 degrees of freedom is performed. This procedure is the same as applied usually, when finding the physically interesting solutions of the effective action. It must be emphasized that the spin glass nature of the TGD:eish Universe might imply complications: it might be impossible to define unique effective quantum average spacetime and one might be forced to consider a quantum superposition of the effective spacetimes.

2.3 Massless extremals

The so called massless extremals describe nonlinear waves propagating with light velocity and are a crucial element in the model to be represented. The characteristic feature is the presence of nonvanishing lightlike vacuum gauge currents not possible in ordinary QED by the fact that free Maxwell action represents free field theory.

Let $k = (k^0, k^3, 0, 0)$ be a light like vector of M^4 and $u = u(m^1, m^2)$ be an arbitrary function of Minkowski coordinates m^1 and m^2 in the plane ortogonal to the direction 3-vector $(k^3, 0, 0)$ associated with k. Denote by s^n the n:th coordinate of CP_2 and by $v = k \cdot m$ the Minkowski inner product of the wave vector k and $M4^4$ coordinate m. The surfaces defined by the map

$$s^n = f^n(v,u) , \tag{3}$$

where f^n and u are arbitrary functions, define massless extremals. They describe the propagation of massless fields in the direction of k: the fields are periodic with period $\lambda = 2\pi/k^0$ so that only k and its integer multiples are possible wavevectors. The polarization associated with various induced gauge fields depends on the position in (m^1, m^2)-plane and is in the direction of the gradient of u. Field equations involve tensor contractions of energy momentum tensor and gauge current. These are proportional to kk and k respectively and vanish by the lightlikeness of k. Linear superposition holds true only in a restricted sense since propagation direction is fixed and polarization direction in each (m^1, m^2)=const plane is fixed.

What is remarkable that these solutions are not solutions of the ordinary Maxwell equations in vacuum: gauge current densities are in general nonvanishing(!) and proportional to the light like four-momentum k. As a consequence, also lightlike electromagnetic current is in general (but not necessarily) present. The interpretation of the em current J as electron current is impossible and the correct interpretation as vacuum current is possible for induced gauge fields. The presence of the vacuum current implies that massless extremals act as quantum antennae in the sense that each Fourier component of the vacuum current, equivalent to an oscillating external force coupled to a harmonic oscillator, generates a coherent state of photons (coherent state is an eigenstate of the photonic annihilation operators). Since photons have lightlike 4-momenta, it is intuitively obvious that the coherent state is generated in resonance like manner for a lightlike current.

3 TOPOLOGICAL CONDENSATION OF PHOTONS AS A METHOD OF ENERGY EXTRACTION?

There are three principle issues that must be considered. First is the matter of topological condensation for which a foundational perspective was given in section 2 above. If this process does occur, there must be a kinetic model that would allow for the transfer of photon energy that can result in energy exchange with a macroscopic device such as an engine or drive system. The second issue concerns the amount of such photon exchange that could occur within a given volume of interstellar or even solar domain space. It may be that the conjectured process can generate realistically only such a modest amount of useable energy that it is not practical. The third issue concerns what practical mechanism could be employed, assuming a positive answer to the first two concerns, for controlling the use of this condensate energy. In this paper *only* the first issue, i.e. mathematical modelling of the quantum antenna and topological condensation of photons, is discussed in detail.

3.1 A kinetic model for the photon transfer

The proper description of the situation necessitates a kinetic model for the transfer of various particle species between various spacetime sheets and vapour phase. (see chapter 'A model for topological condensation and evaporation' in [5]). Vapour phase particles and the particles condensed on various spacetime sheets can be regarded as different particle species formally. Assuming that the gauge charges of the vapour phase particles vanish, the most interesting situation corresponds to photon transfer. When only one spacetime sheet is present there are condensed and vapour phase photons the amplitude for photon emission in Feynmann diagram can be assumed to be proportional to $cos(\theta)/sin(\theta)$ corresponding to the situations in which the emitted photon is/is not in the same phase as the emitter.

In principle, one can derive evaporation and condensation rates for photons for given charge densities and write the kinetic equations for the densities of photons in two phases. For instance, the ordinary free photon path multiplied by evaporation probability yields estimate for condensation length. If condensation and evaporation rates are large enough as compared with the characteristic time scale considered, one can assume kinetic or even thermal equilibrium. One could argue that the evaporation of the photon costs energy given by the gravitational energy of photon in the condensate and that condensation is therefore favoured and in thermal equilibrium the ratio of the photon densities is therefore given by the Boltzman weight $exp(-E(gr)/T)$.

3.2 A model for the transfer of photons and energy between vapour phase and condensate

In ordinary QED classical gauge fields can have only ordinary charged particles as their sources. In TGD genuine vacuum currents are possible. The coupling of the quantum field to the classical em field with a nonvanishing vacuum source implies the generation of a coherent state of photons such that each Fourier component present in the classical gauge current gives rise to an eigenstate of the corresponding photonic annihilation operator. In case of lightlike vacuum currents allowed by TGD, the coherent state is generated in resonant-like manner so tha lightlike vacuum current acts as an ideal quantum antenna.

If one introduces a second spacetime sheet, which contains BE condensate of photons for some modes of the photon field, a stimulated topological condensation of the vapour phase photons to this spacetime sheet occurs. This effect could be used to extract energy from the vapour phase.

The possibility of macroscopic quantum antennae has been explored in cell biology [7, 2, 8] giving rise to the notion that microtubules of the cytoskeleton may act as coherent quantum antennae with the result of creating an organizing network spanning large regions of cell surfaces and even acting across cell boundaries as in the case of neuronal axons and dendrites. The dynamical scaling symmetry of the massless extremals leads to ask whether something of the sort could be artificially constructed on a massive scale across many meters or kilometers of deep space.

3.2.1 Action for the vapor-condensate interaction

The simplest model is based on Maxwell action for electromagnetic field regarded as an induced field obtrained from superposition of the classical emf in CP_2 degrees of freedom and second quantized free emf in $M^4_+ \times CP_2$ having only M^4 components and depending on M^4_+ coordinates only and having decomposition into vapour phase and condensate parts ($\hbar = 1$ and $c = 1$ will defined the units used in the following).

$$
\begin{aligned}
F_{\mu\nu} &= F_{\mu\nu}(cl) + F_{\mu\nu}(qu) \ , \\
F_{\mu\nu}(cl) &= F_{kl}(cl)\partial_\mu s^k \partial_\nu s^l \ , \\
F_{\mu\nu}(qu) &= F_{kl}(qu)\partial_\mu m^k \partial_\nu m^l \ , \\
F_{kl}(qu) &= \partial_l A_k(qu) - \partial_k A_l(qu) \ , \\
A_k(qu) &= A_k(qu,v) + A_k(qu,c) \ .
\end{aligned} \tag{4}
$$

$F_{kl}(qu)$ satisfies empty space Maxwell equations, m^k and s^k refer to M^4_+ and CP_2 coordinates, and v and c refer to vapour phase and condensate.

Maxwell action density can be transformed to a sum of a total divergence reducing to a boundary term, to be neglected, plus free part and two interaction terms in the following manner:

$$
\begin{aligned}
\frac{L}{\sqrt{g}} &= \sum_i L(free,i) + L_1(int) + L_2(int) \ , \\
L(free,i) &= \frac{1}{4}F_{\mu\nu}(qu,i)F^{\mu\nu}(qu,i) \ , \ i = c,v \ . \\
L_1(int) &= \frac{1}{2}j^\mu(cl)\sum_i A_\mu(qu,i) \ , \\
L_2(int) &= \frac{1}{2}\sum_i J^\mu(qu,i)A_{mu}(cl) \ , \\
J^\mu(qu,i) &= F_k^\mu(i)M_\nu^{k\nu} + F_k^{\ \nu}(i)M_\nu^{k\mu} \ , \ i = c,v \\
M^k_{\alpha\beta} &= D_\beta\partial_\alpha m^k \ .
\end{aligned} \tag{5}
$$

$L(free,i)$ denotes the free action for the classical emf and vapour phase and condensed quantum emfs and defines photon propagators. Standard propagator is obtained, when Minkowski coordinates are used for spacetime surface.

$L_1(int)$ corresponds to the action of the vapour phase and condensed quantum emf with the vacuum current and leads to generation of coherent state of photons both in vapour phase and condensate.

$L_2(int)$ is nonvanishing only, when $J^\mu(qu,i)$ is nonvanishing. $J^\mu(qu,i)$ represents a purely geometric contribution to the current and is non-vanishing when the M^4_+ part of the second fundamental form $M^k_{\alpha\beta}$ for 4-surface is non-vanishing. In this case the em current associated with $A_{mu}(qu)$ is nonvanishing despite the fact that it vanishes for $A_k(qu)$! Second fundamental form describes the external curvature of the 4-surface as opposed to the internal curvature described by the curvature tensor. In general, the external curvature can be large even when the gravitational field vanishes. It must be however emphasized that this term is proportional to the metric of CP_2 and, assuming that the gradients of the CP_2 coordinates are characterized by length scale L, by a factor R^2/L^2 smaller than the other terms in the action. In the case of the massless extremals, this term is significant only if the dependence of

CP_2 coordinates on the transversal coordinates of M^4_+ is strong: this in turn requires a huge value for the lightlike Einstein tensor. This term will be neglected in the sequel.

The representation

$$\begin{array}{l} A_+(k,\lambda) = \sqrt{\frac{2\pi}{\omega_k}} a^\dagger(k,\lambda) \ , \\ \left[a(k_1,\lambda_1), a^\dagger(k_2,\lambda_2)\right] = \delta^3(k_1-k_2)\delta_{\lambda_1,\lambda_2} \ , \end{array} \tag{6}$$

for which the density of states factor for photon states is $dN = d^3k$, will be used in the sequel.

3.2.2 Coherent state is generated in resonant-like manner for lightlike vacuum currents

The presence of the vacuum current leads to the generation of coherent state of two modes of coherent photons: vapour phase and condensate. Coherent states states are eigenstates of the photonic annihilation operators and in the estimates for the rate of topological condensation, one can replace $A_\mu(qu,i)$, $i = cond, vap$, with the classical photon field $A_\mu(coh,i)$. This has a classical vacuum current as its source and serves as order parameter for the coherent state. The Fourier component of a vector potential describes the eigenvalue of the annihilation operator part of the photon field is for a given momentum k and polarization direction λ and is given by

$$\begin{aligned} A^\mu(coh,v|\lambda,k) &= \sum_n c(k,k_n)\frac{\lambda_\mu J^\mu(k_n)\lambda^\mu}{k_n^2} \ , \\ exp(-ik\cdot m) &= \sum_n c(k,k_n) exp(-ik_n\cdot m) \ . \end{aligned} \tag{7}$$

Here $c(k,k_n)$ is the Fourier component of the planewave $exp(-ik\cdot m)$ expressed using a discrete planewave basis for the spacetime sheet containing the vacuum current and m denotes Minkowski coordinates.

If the classical vacuum current is associated with a 'massless extremal', any current is lightlike. This implies resonance for those frequencies for which the photon wave vector corresponds to a wave vector appearing in the vacuum current. The resonance is smoothed out by the finite spatial size of the spacetime sheet containing the lightlike vacuum current. At the limit of an infinitely large spatial size for the spacetime sheet, one obtains infinitely large amplitudes since one has $k_n^2 = k^2 = 0$ at this limit.

3.2.3 Stimulated topological condensation

The presence of the coherent state of photons implies the possibility of the topological condensation of photons. If the device contains $N(k,\lambda)$ photons in the the state (k,λ), stimulated topological condensation, completely analogous to the stimulated emission, occurs and the condensation rate is proportional to $(N(k,\lambda)+1)^2$.

Assume that there exists a coherent state generated by quantum antenna of possibly astrophysical dimension and associate label '1' with this spacetime sheet. Assume also a second spacetime sheet and associate with it label '2'. In the lowest order the matrix element for the topological condensation of single photon can be obtained as the matrix element of the creation operator part of the interaction term of the action

$$\begin{array}{l} iS_+ = \frac{i}{2}\int_{V_2} dV_2 j^\mu_\perp(coh,1)A_{\mu,+}(cond,2) \\ = \frac{i}{2}\sum_{\lambda_2}\int d^3k_2 X(k_2,\lambda_2)a^\dagger(k_2,\lambda_2) \ , \\ X(k_2,\lambda_2) = \sqrt{\frac{2\pi}{\omega_{k_2}}}\sum_{\lambda_1}\int d^3k_1 Y(k_1,\lambda_1,k_2,\lambda_2) \ , \\ Y(k_1,\lambda_1,k_2,\lambda_2) = j(coh,1|k_1,\lambda_1)c(k_1,k_2)e_{\lambda_1}\cdot e_{\lambda_2} \ , \\ c(k_1,k_2) = \int_{V_2} dV_2 exp\left[i(k_1-k_2)\cdot m\right] \ , \end{array} \tag{8}$$

between the initial and final states. $j^\mu(coh,1)$ is just the transversal part of the classical vacuum current creating the coherent state. The latter expression is obtained by using Fourier expansions for j and A_+ (, which denotes the creation operator part of the free photon field projected to the spacetime surface representing the device: Minkowski coordinates are used for both source regions and device).

In case that the region V_1 is box of length L in the direction of the vacuum current, the explicit calculation, writing the lightlike vacuum current as $j^\mu = Jp^\mu$, $p^0 = p^z = 1$, leads to the following expression for the Fourier component $j(coh,1|k_1,\lambda_1)$:

$$j(coh,1|k,\omega_k,\lambda) = j^{\mu}(coh,1|k,\omega_k)e^{\lambda}_{\mu} \ ,$$
$$= \sum_n \frac{exp(ik_zL)-1}{ik_z} J(\omega_n,k_T)p\cdot e^{\lambda}\delta(k^0-\omega_n) \ , \qquad (9)$$
$$\omega_n = \frac{n\pi}{L} \ .$$

Delta-function expresses the fact that only discrete freqencies are allowed for the vacuum current and one can write the condensation amplitude as a sum $iS_+ = i\sum_n iS_{+,n}$ over the allowed frequencies ω_n. k_T refers to the transversal part of the wave vector orthogonal to the lightlike vacuum current.

From this expression one can deduce the probability for the topological condensation of photon (k,λ) to a state containing $N(k,\lambda)$ photons as

$$|S(k,\lambda)|^2 \quad = \quad |\sum_n S_{+,n}|^2 (N(k,\lambda)+1)^2 \ , \qquad (10)$$

Clearly, $(N(k,\lambda)+1)^2$ factor corresponds to the induced condensation. By a standard trick one can eliminate the square of the delta-function by replacing the condensation probability with condensation rate $R(k,\lambda)$ obtained by dividing condensation probability with $T\rightarrow\infty$ eliminating one deltafunction. Furthermore, one can calculate the transition rate to a set of final states by multiplying the expression thus obtained with the density of states factor $dN = d^3k$, which after the elimination of the second delta function effectively reduces to $\omega_n^2 d\Omega$. In this manner one obtains for the differential condensation rate a a rather neat expression in terms of the vacuum current

$$\frac{dR(k,\lambda,n)}{d\Omega} = \frac{\pi}{2}\omega_n L^2 |M(k,\lambda|^2 (N(k,\lambda)+1)^2 \ ,$$
$$M(k,\lambda) = i\sum_{\lambda_1}\int d^3k_1 J(\omega_n,k_T^1)c(k^1,k)X(k_1,\lambda_1) \ , \qquad (11)$$
$$X(k_1,\lambda_1) = \frac{exp(ik_z^1L)-1}{ik_z^1L} p\cdot e_{\lambda_1}e_{\lambda_1}\cdot e_{\lambda} \ .$$

From this expression it is clear that resonance indeed occurs and at the limit $L\rightarrow\infty$ the rate for condensation diverges as L^2. In this expression the overlap integral $c(k_1,k_2)$ carries information about the geometry of the spacetime sheet associated with the 'device' whereas $J(\omega_n,k_T)$ characterizes the vacuum current and the remaining factor X is a purely 'kinematic' factor.

While cytoskeletal dynamics involving protein structures in a cytoplasmic medium is both in scale and substance radically different from the concept of large-scale structures in the vacuum of space, the similarity is not to be found in the substance of what would constitute such antennae and networks but in the geometric form and dynamics for sensitivity and interaction with vacuum currents and the transfer of photons from the vapour phase into condensate form. Hence the proposed model could apply also in the modelling of microtubules as quantum antennas.

3.3 The mechanisms for energy release from the vapour phase

The stimulated condensation of the photons from the vapour phase can be used to extract energy from the vapour phase. A continuous removal of the topologically condensed photons from the region of the topological condensation replaces kinetic equilibrium with a dynamical flow equilibrium and vapour phase photons are sucked from vapour phase (or from other space time sheets) to a given spacetime sheet. The absorption of photons requires a device containing BE condensates of photons for some photon modes and the possibility to transfer the condensed photons away in order to establish flow equilibrium. The maximum differential energy transfer rate in a state containing $N(k,\epsilon)$ photons in mode (k,ϵ) is given by

$$\frac{dP_{max}}{d\Omega} = \omega_n \frac{dR}{d\Omega} \ , \qquad (12)$$

where $dR/d\Omega$ is given by the Eq. 11. The optimal regions of spacetime for the process are the regions at which the lightlike vacuum current generates a coherent state of photons in both condensate and vapour phase.

It will be necessary for the mechanism responsible for this photon removal process to maintain continuity through some type of charging mechanism. There are several designs for ion-drive engines fueled by either fission or fusion sources. The same type of ion drive mechanism could be fed instead by the flow of photons from the topological condensation process. What specific mechanism is at the output end of this channel is not the critical element; rather, the question which needs further investigation including development of an experimental approach is whether or not such a drive system could be adequately fed by the vacuum currents.

There is another issue which concerns the effect on evaporation and condensation rates due to the presence of a massive object such as a spacecraft moving at a constant or near-constant velocity. Even if such a craft were composed of several dispersed units, it might have a disturbance on the thermal equilibrium sufficient to alter the entire condensation process. This is a matter for further investigation.

4 EXPERIMENTAL VERIFICATION-SOME POSSIBLE TESTS

4.1 Evidence for many-sheeted spacetime concept?

Many-sheeted spacetime has some indirect cosmological evidence.

a) Since spacetime sheet is curved, it takes longer time for a topologically condensed photon to propagate from point A to B along the lightlike geodesics of spacetime surface than for vapour phase photons propagating along the lightlike geodesics of the imbedding space. Many-sheetedness implies the possibility of several light velocities and this could serve as a signature of manysheetedness even in laboratory length scales. This would require the re-investigation of a possible dependence of the light velocity on length scale.

b) In cosmological scales each spacetime sheet possesses its own Hubble constant (this is due to different mass density in various spacetime sheets). This could explain the problem of two Hubble constants (see the chapter 'TGD and cosmology' of [5]).

c) The recent evidence [9] for the increase of Hubble constant at short distances could be regarded as an evidence for many sheeted spacetime. Light coming from nearby sources propagates along smaller spacetime sheets, possessing larger mass density and larger Hubble constant than the light from distant sources having to propagate along large spacetime sheets.

d) Vapour phase photons could propagate from regions beyond cosmological horizon. This could explain why some stars seem to be older than the Universe (see the chapter 'TGD and cosmology' of [5]).

4.2 Test for the concept of the lightlike vacuum currents

In [5, 7] it has been suggested that microtubules and other linear structures in biological macromolecular assemblies might act as quantum antennas and that this property is fundamental for the ability of biosystems to function as macroscopic quantum systems. The mechanism would be based on the presence of classical lightlike vacuum currents associated with some microtubular spacetime sheet. The resonance phenomenon would enchance the interaction with laser light and also the interaction between different microtubules. The demonstration that biophotons of Popp [10] can be regarded as resulting from light like vacuum currents associated with microtubules or linear molecules (such as DNA), would provide a strong support for the concept.

If one has somehow detected astrophysical emf and found it to have (perhaps light like) gauge current as its source and there is no evidence for the ordinary charged matter in the region in question (no emission or absorbtion lines, no brehmstrahlung) then one could argue that genuine vacuum gauge current is in question. Note that macroscopic lightlike (or nearly lightlike) currents consisting of ordinary charged matter are rather unprobable.

4.3 Future directions

The design of satisfactory and reproducible experimental verification is certainly a necessary goal for the validation of the TGD model and its extension to condensed matter and biophysics as well as particle physics. However, there is much that remains yet to be accomplished first through mathematical and also computational modelling and simulation. More important still is the primary need to engender more dialogue and interaction of these concepts withing the broader physics community and to lead toward this state has been the principal goal of this introductory exposition.

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