TGD and Quantum Hydrodynamics

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Abstract

The purpose of this article is to consider possible applications of Topological Geometrodynamics (TGD) to hydrodynamics. The basic question is what quantum hydrodynamics could mean in the TGD framework.

The mathematical structure of TGD is essentially that of hydrodynamics in the sense that field equations reduce to conservation laws for the charges associated with the isometries of $H = M^4 \times CP_2$.

Hydrodynamical turbulence represents one of the unsolved problems of physics and therefore as an excellent test bench for the TGD based vision. How turbulence is generated and how it decays? What is the role of vortices and their reconnections? These are the basic questions. The central notion of the TGD based model is that of a magnetic body (MB) carrying dark $h_{eff} = nh_0$ phases and controlling ordinary matter. Z^0 magnetic field is proportional to the circulation in the proposed model and electroweak symmetry restoration below scaled up weak Compton length is in an essential role. This picture is applied to several problems including also the problems related to the magnetic reconnection rate and to the survival of magnetic fields in even cosmic scales. Monopole flux tubes provide the solution here.

The hydrodynamic quantum analogs is a fascinating field and TGD picture is applied to this case. The basic prediction is that the Faraday wave length playing the role of Compton wavelength corresponds to the gravitational Compton length predicted by the generalization of the Nottale hypothesis. The value is very near to the minimal value predicted by TGD.

In the TGD framework it might be possible to understand viscosity in terms of dark angular momentum unit $\hbar_{eff}$. A proposal which allows us to understand the critical values of Reynolds numbers for the generation of turbulence in terms of the gravitational Compton lengths associated with Sun and Earth is made. Also this success supports the view that new quantum theory provided by TGD is needed in order to understand the generation of turbulence.

The universality of QHD according to TGD motivates the proposal for an application to hadron and nuclear physics. The general description of quantum tunnelling could be in terms of ZEO involving two BSFRs and therefore temporary time reversal at the MB of the system of colliding particles. Quantum hydrodynamics and large values of h_{eff} would be involved with this period. A model of "cold fusion" is one practical application.

1 Introduction

This work is devoted to the question of what quantum hydrodynamics could mean in the TGD framework. In the standard picture quantum hydrodynamics (`https://cutt.ly/JEAumRZ`) is obtained from the hydrodynamic interpretation of the Schrödinger equation. Bohm theory involves this interpretation.

1. Quantum hydrodynamics appears in TGD as an *exact* classical correlate of quantum theory [K1]. Modified Dirac equation forces as a consistency condition classical field equations for X^4. Actually, a TGD variant of the supersymmetry, which is very different from the standard SUSY, is in question.

2. TGD itself has the structure of hydrodynamics. Field equations for a single space-time sheet are conservation laws. Minimal surfaces as counterparts of massless fields emerge as solutions satisfying simultaneously analogs of Maxwell equations [L30]. Beltrami flow for classical Kähler field defines an integrable flow [L17]. There is no dissipation classically and this can be interpreted as a correlate for a quantum coherent phase.

3. Induced Kähler form J is the fundamental field variable. Classical em and Z^0 fields have it as a part. For $S^3 \subset CP_2$ em and Z^0 fields are proportional to J: which suggests large parity breaking effects. Hydrodynamic flow would naturally correspond to a generalized Beltrami flow and flow lines would integrate to a hydrodynamic flow.

4. The condition that Kähler magnetic field defines an integrable flow demands that one can define a coordinate along the flow line. This would suggest non-dissipating generalized Beltrami flows as a solution to the field equations and justifies the expectation that Einstein's equations are obtained at QFT limit.

5. If one assumes that a given conserved current defines an integrable flow, the current is a gradient. The strongest condition is that this is true for all conserved currents. The non-triviality of the first homotopy group could allow gradient flows at the fundamental level. The situation changes at the QFT limit.

6. Beltrami conditions make sense also for fermionic conserved currents as purely algebraic linear conditions stating that fermionic current is a gradient of some function bilear in oscillator operators. Whether they are actually implied by the classical Beltrami conditions, is an interesting question.

7. The requirement that modified Dirac operator at the level of space-time surface is in a well-defined sense a projection of the Dirac operator of H implies that for preferred extremals the isometry currents are proportional to projections of the corresponding Killing vectors with proportionality factor constant along the projections of their flow lines [L25]. This implies as generalization of the energy conservation along flow lines of hydrodynamical flow ($\rho v^2/2 + p = constant$).

   This also leads to a braiding type representations for isometry flows of H in theirs of their projections to the space-time surface and it seems that quantum groups emerge from these representations. Physical intuition suggests that only the Cartan algebra corresponding to commuting observables allows this representation so that the selection of quantization axes would select also space-time surface as a higher level state function reduction.

   One also ends up to a generalization of Equivalence Principle stating that the charges assignable to "inertial" or "objective" representations of H isometries in WCW affecting space-time surfaces as analogs of particles are identical with the charges of "gravitational" or subjective representations which act inside space-time surfaces. This has also implications for $M^8 - H$ duality.

8. Minimal surfaces as analogs of solutions of massless field equations and their additional property of being extremals of Kähler action gives a very concrete connection with Maxwell's theory [L30].

In the sequel some key challenges of hydrodynamics are considered from TGD point of view.

1. The generation of turbulence is one of the main problems of classical hydrodynamics and TGD inspired quantum hydrodynamics suggests a solution to this problem. Not only "classical" is replaced with "quantum" but also quantum theory is generalized.

   The key notion is magnetic body (MB): MB carries dark matter as $h_{eff} = nh_0$ phases and controls the flow at the level of ordinary matter. Magnetic flux tubes would be associated with the vortices. The proposal inspired by super-fluidity is that velocity field is proportional to Kähler gauge potential and that the cores of vortices corresponds to monopole flux tubes whereas their exteriors would correspond to Lagrangian flux tubes with a vanishing Kähler field so that velocity field is gradient. Vorticity field would correspond to the Z_0 magnetic field so that a very close analogy with superconductivity emerges.

   The model is applied to several situations. The generation of turbulence and its decay in a flow near boundaries is discussed. ZEO suggests that the generation of turbulence could correspond to temporary time reversal associated with a macroscopic "big" (ordinary) state function reduction (BSFR).

   Also the connection with magnetohydrodynamics (MHD) is considered. The reconnection of the field lines is replaced with the reconnection of flux tubes. The fact that monopole flux tubes require no current to generate the magnetic field provides a new insight to the problem of how magnetic fields in astrophysical scales are generated.

   The topological picture based on flux tubes can be applied to the collisions of circular vortices. Also the violations of the circulation theorem of Kelvin is discussed.

2. Second section is devoted to hydrodynamic quantum analogs studied by Bush *et al* [D4]. These intriguing phenomena, in particular Couder walker bounces along a Faraday wave that it generates. Also surfing mode is possible. The energy feed comes from shaking the

water pool and plays a role of metabolic energy feed leading to self-organization. This phenomenon allows in the TGD framework a modelling based on quantum gravitational hydrodynamics. MB serves as a "boss" and therefore takes the role of the pilot wave proposed by Bush. The key prediction that the Faraday wave length analogous to Compton wavelength equals to the gravitational Compton length $\Lambda_{gr} = GM/v_0$ is correct.

3. Also the electromagnetic and Z^0 analogs of $\hbar_{gr}$ make sense and one can ask whether in these scales the gravitational, Z^0 and electromagnetic Compton lengths are identical at gravitational flux tubes and that particles are at flux tubes with length of order this wavelength.

   The twistor lift predicts that also M^4 has Kähler structure and M^4 Kähler form could give contribution to electromagnetic and Z^0 fields. Kähler currents for M^4 and CP_2 parts are separately conserved and this leads to ask whether Magnus forces resembling Lorentz force could reflect the presence of classical Z^0 force or M^4 contribution to the Kähler force.

4. One section is devoted to the attempt to understand the origin of viscosity and interpret critical Reynolds numbers in the TGD framework. In TGD quantum gravitation involves quantum coherence in astrophysical scales so that it is not totally surprising that the critical Reynolds numbers associated with the turbulence in pipe flow and flow past a plate relate directly to the gravitational Compton lengths of Earth and Sun. In the case of Sun $\hbar_{gr}$ involves two values of the velocity parameter β_0 appearing in the Nottale formula. This would suggests that the turbulence has very little to do with ordinary viscosity. Also a model for the ordinary viscosity and its increase with a decreasing temperature is discussed.

5. Also nuclear and hadron physics suggests applications for QHD. The basic vision about what happens in high energy nuclear and hadron collisions is that two BSFRs ("big" state function reductions changing the arrow of time) take place. The first BSFR creates the intermediate state with $h_{eff} > h$: the entire system formed by colliding systems need not be in this state. In nuclear physics this state corresponds to a dark nucleus which decays in the next BSFR to ordinary nuclei. The basic notions are the notion of dark matter at MB and ZEO, in particular the change of the arrow of time in BSFR.

6. Some comments about quantum hydrodynamics for condensates of quasiparticles are represented.

2 TGD view about quantum hydrodynamics

In this section the general ideas of quantum hydrodynamics in TGD framework are introduced.

2.1 Some problems of the existing theories of turbulence

Hydrodynamical turbulence represents one of the unsolved problems of classical physics and therefore as an excellent test bench for the TGD based vision.

Turbulence is generated in many other systems besides hydrodynamical flow. Exotic systems consisting of quasiparticles of a condensed matter system (supra phases, atomic BECs, exciton-polariton BECs, magnon BECs, etc...) involve generation of vortices as the basic element of turbulence. Turbulence appears also in astrophysical systems such as neutron stars. All this suggests the generation of vortices as a universal mechanism in the generation of turbulence.

The understanding of the generation of turbulence is usually regarded as a problem of classical physics. TGD however predicts quantum coherence in all scales so that this assumption must be challenged. Both the new view about space-time and of classical fields (the notion of magnetic body (MB), the hierarchy of effective Planck constants predicting the possibility of quantum coherence in all scales, and the zero energy ontology (ZEO) predicting time reversal in ordinary ("big") state function reductions (BSFRs) could be involved. Even quantum physics in its recent form would not be enough to understand the generation of turbulence.

2.2 The problems of the existing theories of turbulence

The best starting point is to look for the problems of the existing theories. The many problems of the classical theories of turbulence are described in the article of Chaoqun Liu and Shuhyi Chen [D2] (`https://cutt.ly/xWMiMV3`). As the authors notice, a single wrong prediction in principle kills theory but the theories of turbulence make numerous wrong predictions. Also a general vision of Liu based on empirical facts is discussed.

The phase transition leading to turbulence involves a generation of vortices.

1. Vortex consists of a core region, where the flow has non-vanishing vorticity $\nabla \times v$ and an outer region, where the rotational flow is gradient flow and characterized by a conserved circulation. The gradient flow outside the core is a special case of a Beltrami flow: there is current conservation besides the existence of a global coordinate along the flow lines.

   Rigid body motion with a constant angular velocity is a reasonable approximation allowing to avoid singularity (infinite rotational velocity at the axis of the vortex).

   There are many vortex anatomies. The ends of hair-pin vortices are attached to the boundary and they tend to move with the flow. Λ vortices deserve their name from their shape. There are also circular vortices.

2. No-slippage boundary condition (velocity vanishes at the boundary) for a flow past a body or other medium forces a transversal gradient of the velocity, which is parallel to the boundary and this generates vorticity $\nabla \times v \neq 0$.

   The flow past a body with an over-critical Reynolds number R leads to a generation of vortices. Vortices are coherent structures and clearly separate units and one cannot superpose them as one can superpose eddes. Hairpin vortices are the simplest vortices (`https://cutt.ly/nWMiHrJ`). It would seem that Nature tends to avoid too large shears (velocity gradients) implying large dissipation and achieves this by generating vortices.

3. This mechanism can be used to generate vortex rings so that one can study the collisions of vortex rings demonstrating the basically topological dynamics of vortices (see the beautiful video at `https://cutt.ly/DWMiK3f`). The thesis of Ali Dasouqi [D1] (`https://cutt.ly/aWMiXWt`) gives an overall view about the formation of gas jets and vortex rings in various situations. In particular, collisions of vortex rings and the formation of vortex rings in the bursting of bubbles are discussed.

4. The proposal of Chaoqun Liu [D2] (`https://cutt.ly/kWMiVbj`) is that the vorticity near the boundary is transferred to the vorticity of the vortex cores. A separation of the flow from the boundary seems to take place. This allows it to avoid large shears and minimize dissipation.

   The generation of turbulence could be regarded as a self-organization process made possible by the energy feed from the flow and not a dissipative process.

5. Turbulence as the decay of vortices is a dissipative process - in a well-defined sense it looks like a reversal of the self-organization process.

   The proposal of Kolmogorov is that the decay of turbulence involves the decay of vortices to smaller ones. The authors argue that this process has not been observed for a single vortex. Presumably it is meant that a linear vortex tube should split into thinner parallel parallel flux tubes. In principle there is no obvious reason why conservation of circulation would prevent this process but this process is highly non-local and does not look plausible.

   It is however possible that a single vortex reconnects and emits a closed vortex ring. This has been observed in the collisions of two vortex rings. The decay process can also involve the reconnection of two vortices as happens in the collision of two vortex rings. This can lead to the decay of larger vortices to smaller vortices such as vortex rings and eventually to so small vortices that they are below measurement resolution.

2.3 Superflow as a starting point

TGD predicts quantum coherence at MB in arbitrarily long length scales. Hence one can motivate the TGD based model by starting from an observation related to the notion of conserved vorticity and its quantization in superfluid flow.

1. For supra flows the conserved vorticity $\Gamma = \oint v \cdot dl$ as integral over a closed flux line associated around the vortex axis in vorticity free region, is quantized as a multiple of $\hbar/m$, where m is the mass of the particle of flow.

2. A possible quantum interpretation could be in terms of a covariant constancy of the Schrödinger amplitude or of spinor field stating $(p_t - qA_t)\Psi = 0$ along flow lines. Here A_t is a projection of an effective $U(1)$ gauge potential, not necessarily electromagnetic.

   The condition $p = mv_t = qA_t$ effectively, where v_t is well-defined for a generalized Beltrami flow as a classical space-time counterpart of quantum coherence, could hold true as a classical correlate of the covariant constancy condition.

   The velocity projection $v_t = A_t/m$ would be proportional to a component of an effective $U(1)$ gauge potential quite generally along flow lines of Beltrami flows and their 4-D time dependent generalizations applicable to non-stationary flows.

3. $B = dA$ would define an effective $U(1)$ magnetic field and could be assigned to any flow. For a gradient flow, one would have $B = dA = 0$ and B would be non-vanishing only inside the vortex core. By Stokes theorem the circulation $\oint v \cdot dl$ would reduce to a conserved magnetic flux $\int BdA$ over the cross section of the vortex core.

   The quantization of the velocity circulation $\oint p \cdot dl = \oint v \circ dl = n\hbar$ is obtained from flux quantization $exp(iq \oint Adl/\hbar) = exp(i \oint d\Phi) = 1$ required by the existence of proper gauge structure. Apart from a gradient $\nabla\psi$ of a single valued function Φ is a multiple of angular coordinate ϕ changing by $n2\pi$ in 2π rotation.

4. It is important to notice that one cannot have a genuine gauge invariance. The gauge transform $A \rightarrow A + d\phi$ gives a new flow with the same circulation. Therefore the identification of A as a standard model gauge field, say U(1) part of the em field does not make sense in the standard model framework but could be sensible in TGD.

5. In Maxwellian electrodynamics B should have some current j as a source: $\nabla \times B = j$, which gives $D^2 A \equiv \nabla^2 A - \nabla(\nabla \cdot A) = j$.

   The simplest assumption is that B is constant inside the core and in the direction of the vortex, and can be therefore generated by a current rotating around the vortex axis at the surface of the core. The current would be parallel to A. Vortex core would act like a current coil. The vector potential is effectively massive at the surface of the core since $D^2 A$ is proportional to A: mass is formally infinite due to delta-function singularity. This is analogous to the "massivation" of the electromagnetic field in superconductivity for the vortex core inside which the super-conductivity fails.

6. The situation would be essentially quantum mechanical. If the commutator of covariant derivatives $D_i = p_i - qA_i$ given by $[D_i, D_j] = qJ_{ij} = q(\partial_i A_j - \partial_j A_i)$, is non-vanishing, spinors can be eigenstates of only a linear combination D_i, which acts along the flow lines of the integrable Beltrami flow. The classical condition $v_i = qA_i/m$ makes sense only for these components of velocity and about the other components one cannot say anything unless J vanishes or is degenerate. If J vanishes or is degenerate, one can say that some other components of the velocity vanish. This means genuine quantum hydrodynamics. One could perhaps say that $J = 0$ corresponds to classical hydrodynamics.

2.4 Is velocity field proportional to Kähler gauge potential of M^4, of CP_2 or to the sum of both?

The assumption that velocity field is proportional to Kähler gauge potential implies that it is gradient for the Lagrangian situation prevailing outside the vortex cores.

Cores would have non-vanishing Kähler field and Kähler action. What about the Beltrami property in the vortex core? If the CP_2 projection of the vortex core is 2-D complex surface, $A(CP_2)$ is Beltrami field. For instance, for a projection with is geodesic sphere S^2, the Kähler gauge potential is proportional to $A = cos(\Theta)d\Phi$ in the spherical coordinates and Φ defines the global coordinate along flow lines. $D > 2$-D deformations spoil the Beltrami property. Similar situation is true for the M^4 projection: when the projection as a string world sheet is deformed to a $D > 2$-dimensional surface, the Beltrami property of $A(M^4)$ is lost.

It took some time to realize that the velocity field, and in the compressible case generally mass current, could be proportional

1. to the Kähler gauge potential $A(M^4)$ of M^4,
2. to the Kähler gauge potentia $A(CP_2)$ of CP_2,
3. or to the sum $A(M^4) + (CP_2)$, which at first looks natural if Kähler covariant constancy along flow lines is the basic condition.

These options lead to dramatically different physical pictures, especially so for incompressible flows.

1. For option 1 *resp.* 2, Beltrami or gradient flow in M^4 *resp.* CP_2 is enough. Furthermore, if the velocity field is proportional to $A(M^4)$, there is no need to assume large h_{eff} implying that Z^0 field is massless below scaled up weak length scale and electroweak symmetry breaking is absent in long scales.

2. For option 3, the assumption that both M^4 and CP_2 projections are at most 2-D is a necessary condition and looks unrealistic. But this is not enough for Beltrami or gradient flow. These conditions alone would give a Kähler gauge potential, which is the sum $A(M^4)+A(CP_2)$ of two contributions $A(M^4) = \Psi_1 d\Phi_1$ and $A(CP_2) = \Psi_2 d\Phi_2$ satisfying the conditions separately.

   Besides this, the gradients $d\Psi_1$ and $d\Psi_2$ must be proportional to each other so that Ψ_1 and Ψ_2 are functionally dependent. This however implies that the space-time surface is actually 3-dimensional: the conditions can hold only for effectively 2-D flows at surfaces.

   For incompressible flow velocity and mass flow are proportional and this leads to the unrealistically strong conditions. For incompressible flow the situation changes. If the mass current is proportional to the sum of Z^0 currents of nucleons and neutrinos with same density guaranteeing local neutralization and having velocities proportional to each other, Beltrami/gradient property is possible. One would obtain essentially neutral Z^0 plasma formed by nucleons and neutrinos.

   A possible objection is that the required density of neutrinos is too large as compared to their estimated average density of 10^{-22} Angstrom^{-3}. However, the average density of nuclei is equivalent to nucleon density of 5×10^{-30} Angstrom^{-3}.

   Could one give up the assumption of incompressibility and require that the flow lines of the mass current are globally defined and the mass flow is proportional to Kähler current containing separately conserved contributions from M^4 and CP_2? The mass flow would vanish if both M^4 and CP_2 contributions are Lagrangian. This leaves only $A(M^4)$ and $A(CP_2)$ options.

How does this relate to dissipation? The first naive guess was that the classical dissipation is present if Beltrami property fails? One must however look at the situation more carefully.

1. It is is Kähler current, not Kähler gauge potential, which is proposed to have the generalized Beltrami property guaranteeing that the Kähler 4-force vanishes so that ordinary Lorentz forces and electric force compensate each other and there is no power consumption.

2. This condition does not require the strong conditions posed on the velocity field and Kähler gauge potential. The two conditions are equivalent only if Kähler gauge potential is proportional to current which would be analogous to the massivation of Kähler field. For instance, Kähler current can be vanishing although Kähler gauge potential is non-vanishing.

3. Whether the dissipative option is realized at all for preferred extremals is not at all clear. Dissipative effects might be solely due to the finite sizes of space-time surfaces, which are proportional to h_{eff}. What is however clear is that the loss of Beltrami property for the velocity field does not imply dissipation.

2.5 Could the velocity field be proportional to Kähler gauge potential of CP_2?

What could be the counterpart of the vector potential A in the TGD framework? It was found that there are 3 options corresponding to the proportionality of the velocity field v to $A(M^4)$, $A(CP_2)$ or $A(M^4) + A(CP_2)$. In this section only the option $A(CP_2)$ is considered.

1. A natural identification of A would be as Kähler gauge potential for CP_2. The symplectic transformations of CP_2 act like $U(1)$ gauge transformations and are isometries of WCW but do not (can not) leave Kähler action invariant since the induced metric changes. One can say that classical gravitation breaks the genuine gauge symmetry but the breaking is very small.

   Note in particular that both induced electromagnetic and Z^0 fields can be non-vanishing even if the Kähler form vanishes.

   At the level of fluid flows this means that addition of global gradient to the velocity field indeed gives a new flow but leaves the topology of the flow invariant. Preferred extremal property however restricts strongly the allowed symplectic transformations: one possibility is that they must act as Galois transformations in the cognitive representation so that the Galois images of the space-time surface would be identical in the measurement resolution defined by the cognitive representation. Note that the zero modes characterized by induced Kähler form and not contributing to Kähler metric of WCW remain invariant.

2. Single space-time sheet is certainly not a realistic approximation for a physical situation, and one has actually many-sheeted space-time. Standard model and general relativity would be obtained as an approximation as one replaces the space-time sheets with a single region of M^4 and identifies standard model gauge potentials with the sum over the induced gauge potentials for the space-time sheets. Same applies to the induced metric. This conforms with the idea that a small test particle of CP_2 size necessarily touches all space-time sheets and experiences the sum of the forces.

   If one assumes that various sheets in the experimental situations considered correspond to the same induced Kähler form J defining a symplectic invariant, i.e. have same values of zero modes, then the sum of the induced Kähler forms is a multiple of Kähler form since the sum of global gradients give no contribution: there would be no destructive interference. Both em and Z^0 gauge fields contain a part proportional to J.

What about the contributions from $SU(2)_L$ and $U(1)_R$ parts of the induced gauge fields to the sum [L1]. For the induced W boson fields the contributions are affected by symplectic transformations and the physics inspired guess is that they sum up to zero. This would conform with the short range of the charged weak fields. Note however that the dark weak scale is proportional to h_{eff} and p-adic length scales longer than weak scale in standard model can be considered, in particular in biological systems [K7].

What about the contributions to induced em and Z^0 fields?

1. Conserved vector current hypothesis is the starting point of the standard model. Induced em field γ is sum of $U(1)$ part proportional to J and part proportional to vectorial isospin generator Σ_{12}. Both contributions must be non-vanishing. Z^0 contributions should sum up to zero (note that Z^0 contains both left-handed and vectorial contributions).

2. Using the formulas of [L1], one can express the neutral part F_{nc} of the induced electroweak gauge field as

$$F_{nc} = 2R_{03}\Sigma^{03} + 2R_{12}\Sigma^{12} + J(n_+1_+ + n_-1_-) \ , \tag{2.1}$$

$n_+ = 1$ and $n_- = 3$ refer to quark and lepton chiralities: both were assumed to be present in the original view about fermions. If only quarks are fundamental spinors [L11, L16], one must drop the $n+ = 3$ contribution. Leptons as composites of 3 antiquarks however effectively behave like opposite H-chirality.

3. The axial part R_{03}, vectorial part R_{12} and $U(1)$ part are

$$\begin{aligned} R_{03} &= 2(2e^0 \wedge e^3 + e^1 \wedge e^2) \ , \\ R_{12} &= 2(e^0 \wedge e^3 + 2e^1 \wedge e^2) \ , \\ J &= 2(e^0 \wedge e^3 + e^1 \wedge e^2) \ , \end{aligned} \quad (2.2)$$

in terms of the fields γ and Z^0 (photon and Z- boson)

$$F_{nc} = \gamma Q_{em} + Z^0(I_L^3 - pQ_{em}) \quad p = sin^2(\theta_W) \ . \quad (2.3)$$

4. Here θ_W is Weinberg angle. Evaluating the expressions above, one obtains for γ and Z^0 the expressions

$$\begin{aligned} \gamma &= 3J - pR_{12} \ , \\ Z^0 &= 2R_{03} \ . \end{aligned} \quad (2.4)$$

Note that for $p = sin^2(\theta_W) = 0$ one has $\gamma = 3J$ and Z^0 has purely left handed coupling.

What condition should one pose on Z^0 and γ magnetic fields at the monopole flux tubes in hydrodynamics?

1. If one assumes that there are practically no parity breaking effects in long length scales as the standard model predicts, $\sum Z^0 = 0$ looks natural but implies that $\sum_\gamma$ is non-vanishing. Since no em currents are needed to generate the monopole magnetic field this might make sense.

2. $\sum_\gamma = 0$ looks however more natural and implies $\sum_{sheets} Z^0 \neq 0$. Also now one can argue that this makes sense since no currents carrying Z^0 charges are needed to generate Z^0 magnetic monopole fields. This would imply parity violation, which should be observable for vortices. In biology the chirality selection for the basic biomolecules is assumed to be induced by magnetic flux tubes.

This inspires the question whether ordinary hydrodynamics could be magnetohydrodynamics (MHD) for Z^0 magnetic fields at monopole flux tubes and whether MHD in the usual sense could be HD replacing Z^0 fields with ordinary magnetic fields. This question was also motivated a nice lecture about MHD of Alexander Schekochihin (`https://cutt.ly/RW24bTN`) suggesting that the generation of MHD is very similar to the generation of hydrodynamic turbulence in the TGD picture.

Could the basic difference between HD and MHD be that plasma flow replaces mass flow and Z^0 monopole flux tubes are replaced by electromagnetic monopole flux tubes? One can also consider the possibility that both kinds of flux tubes are present in MHD in the usual sense.

With this question in mind, one can consider the condition for the vanishing of $\sum Z^0$ and $\sum \gamma = 0$ at monopole flux tubes. It is important to notice that the induced Kähler form is given by $\sum(J_{M^4} + J_{CP_2})$ and weak fields receive contributions only from CP_2.

1. The condition $\sum Z^0 = 0$ perhaps relevant to MHD implies

$$\textstyle\sum_{sheets} 2(2Y + X) = 0 \ , \quad Y = e^0 \wedge e^3 \ , \quad X = e^1 \wedge e^2 \ . \quad (2.5)$$

There is no obvious reason for why this should be the case automatically.

This would give

$$\sum_{sheets} e^1 \wedge e^2 = \sum_{sheets} J_{CP_2} \quad . \tag{2.6}$$

This implies

$$\begin{aligned} &\sum_{sheets} e^1 \wedge e^2 = \sum_{sheets} J_{CP_2} \quad , \\ &\sum_{sheets} R_{12} = \sum_{sheets} 3J_{CP_2} \quad , \\ &\sum_{sheets} \gamma = \sum_{sheets} 3(1-p))J_{CP_2} + 3JM^4 \quad . \end{aligned} \tag{2.7}$$

The vanishing of $\sum J_{CP_2}$ (Lagrangian surface in CP_2) implies $\sum Z^0 = 0$ and $\sum \gamma = 3J_{M^4}$.

2. The condition $\sum \gamma = 0$ perhaps relevant for ordinary hydrodynamics can be treated in a similar manner. One obtains

   This gives

$$\sum_{sheets} 2(2X+Y) = 0 \quad . \tag{2.8}$$

From this one obtains

$$\begin{array}{lll} \sum_{sheets} X = -aY - bJ_{M^4} \quad , & a = -\frac{3-p}{3-2p} \quad , & b = -\frac{3}{2(3-2p)} \quad . \\ J_{CP_2} = 2(cY + dJ_{M^4}) & c = -\frac{2p}{6-4p} - \frac{6}{6-4p} \quad . & \end{array} \tag{2.9}$$

From the latter equation one can solve Y in terms of J_{CP_2} but at the limit $p = 0$, Y diverges unless one has $J = J_{CP_2} + J_{M^4} = 0$. For $p = 0, J = 0, \gamma = 0$ case, one has

$$Z^0 = 2(-Y - J_{M^4}) = 2(-Y + J_{CP_2}) \quad . \tag{2.10}$$

If this case corresponds to a Lagrange manifold of CP_2 it also corresponds to Lagrange manifold of M^4. This case might be interesting from the hydrodynamics point of view.

The $\gamma = 0$ condition quite generally implies parity violation and an interesting question is whether the large parity violation in living matter could be due to the long range classical Z^0 field. Could parity violation be present at MB and become chemically visible via the chiral molecules assignable to the helical monopole flux tubes serving as the templates for the formation of these molecules?

3. One can also argue that the sum vanishes for the part of $R_{03} = 2(2e^0 \wedge e^3 + e^1 \wedge e^2)$ orthogonal to J since it is not a symplectic invariant. The natural inner product is the one in which $e^0 \wedge e^3$ and $e^1 \wedge e^2$ are orthogonal and have norm $1/N = 1/8$ implying $(J, J) = 8/N = 1$. This would give $\sum Z^0 = \sum R_{03} = \sum R_{12} = (3/2) \sum J_{CP_2}$ and $\sum \gamma = 3(1 - p/2) \sum J_{CP_2} + 3J_{M^4}$. This would imply parity violation. Could this condition be relevant for MHD?

4. If one poses only the condition $\sum J_{CP_2} = 0$, both $\sum Z^0$ and $\sum \gamma$ are non-vanishing , and one has $\sum \gamma = -p \sum Z^0 + 3J_{M^4}$. Magnetohydrodynamics could correspond to this situation but does $\sum \gamma \neq 0$ make any sense in hydrodynamics?

   Could the value of Weinberg angle in hydrodynamical scales differ from its value in particle physics? For $p = 0$ Z^0 would be massless like γ suggesting that electroweak symmetry breaking is absent. For Lagrangian flux tubes $\sum Z^0$ would be non-vanishing and $\sum \gamma$ could vanish as one might expect.

Large value of h_{eff} means scaling up of the weak scale and the proposal has been that in living matter the weak scale can be as large as the cell scale. This would be allowed if one has $\hbar_{eff} = \hbar_{gr} = GMm/v_0$. The expectation is that below the scaled-up weak scale weak bosons are massless, electroweak symmetry is not broken, and $p = 0$ holds true.

It must be however emphasized that the identification as v in terms of $A(M^4)$ or $A(M^4) + A(CP_2)$ can be also considered.

2.6 Description in terms of monopole- and non-monopole flux tubes

In a condensed matter system the classical em field and weak fields should vanish in long length scales.

2.6.1 Kähler gauge potential is not associated with gauge invariance

In many-sheeted space-time, the standard model counterpart of em field is in the above model proportional to J so that the space-time surfaces in question should have at most 2-D Lagrangian manifold as CP_2 projection with the property that induced J vanishes. Kähler action would vanish and the space-time surface would be a minimal surface.

What is of central importance, is that $J = 0$ does not imply the vanishing of the induced Kähler gauge potential A. Since one does not have a genuine $U(1)$ gauge invariance, the situations corresponding to different Kähler potentials are physically different and correspond to space-time surfaces related by symplectic transformation and also to different hydrodynamical flows. Not all symplectic transformations are possible since symplectic transformations are not volume preserving.

2.6.2 Kähler magnetic structure of the vortices

Outside the core regions, A would be a gradient field but inside the core region J would be non-vanishing. The notion of many-sheeted space-time suggests a description in terms of two kinds of cosmic strings and their deformations giving rise to flux tubes is highly suggestive. Both cosmic strings are of the form $X^2 \times Y^2 \subset M^4 \times CP_2$, where X^2 is a minimal surface. M^4 projection is 2-D but for the flux tubes as deformations it becomes at least 3-dimensional.

1. For the first option Y^2 is a complex submanifold of CP_2 and the cosmic string carries a monopole flux (see glossary at 8.2 and **Fig. ??**) . Homologically non-trivial geodesic sphere represents the simplest example. Monopole flux tubes distinguish TGD from Maxwell's theory and for instance explain why the magnetic field of Earth has not disappeared long time ago and how magnetic fields in cosmic scales are possible. They play a crucial role in TGD inspired quantum biology as carriers of dark matter as $h_{eff} = nh_0$ phases controlling ordinary biomatter.

2. For the second option Y^2 is a Lagrangian manifold of CP_2 with a vanishing Kähler form. The simplest example corresponds to a homologically trivial geodesic sphere.

One can assign to MB consisting of monopole flux tubes the role of external controlling field H, which can induce magnetization M assignable to the controlled magnetic flux tubes of non-monopole type so that one has at the standard model limit $B = H + M$. Monopole flux tubes could have a similar role in condensed matter physics.

The core of the vortex would be associated with a monopole flux tube and the exterior of the core would be associated with the non-monopole flux tube. The monopole flux tube needs no current to generate its magnetic field. The cross section is a closed 2-surface rather than a 2-surface with a boundary (say disk).

The current at the surface of the vortex core creating the magnetic field B inside the core in Maxwellian framework would be replaced with a non-trivial topology of 3-space. If monopole flux tubes with larger h_{eff} control the space-time sheets carrying ordinary matter, the latter space-time sheets could contain a current creating magnetic field with non-mopole flux.

2.6.3 Magnus force as a direct evidence for the classical Z^0 force or for M^4 Kähler force?

Magnus force (https://cutt.ly/MEGn3TQ) means that a spinning object moving in fluid suffers a force, which tends to lift in a direction orthogonal to the spin axis and the direction of motion. Boomerang effect is the most dramatic example of Magnus effect and the effect is utilized in various ball games.

One manner to intuitively understand the Magnus force is in terms of friction at the surface of the spinning object. The drag of the liquid implies that the velocities of the liquid at the opposite sides of the spinning object differ and the conservation of the energy density $p + \rho v^2/2$ along the flow lines of the fluid flow, causes a pressure difference inducing the force. Actually, Magnus force is the sum of several effects and even its sign can change.

Here an example of the Magnus force known as a Kutta-Joukowski lift is considered. The idealized situation involves a long cylinder spinning in the liquid. The lift involves also the generation of a turbulent wake which also contributes to the effect. This situation could also apply to linear vortices.

The force per length of the cylinder is

$$\frac{F}{L} = \rho v \Gamma \quad , \quad \Gamma = \oint v \cdot dl = \int (\nabla \times v) \cdot dA \quad . \tag{2.11}$$

Here ρ and v are the density and velocity of the liquid at the cylindrical surface containing the cylindrical object.

The form of the expression brings in mind the Z^0 Lorentz force with Z^0 force proportional to Kähler force affecting vortex cores in hydrodynamics as Z^0 MHD.

The second option is that $A(M^4)$ or $A(M^4) + A(CP_2)$ gives rise to the Magnus force. Since the M^4 Kähler charges of leptons and quarks are opposite if leptons are composites of 3 antiquarks, the total charge density could vanish, and one would have a neutral plasma like state and the analog of MHD would describe hydrodynamics.

1. Z^0 option

In the following, only the Z^0 option is considered in detail since the discussion is similar for the M^4 case.

1. The first thing to notice is that the density is that of the fluid. This suggests that one must look at the situation using linear superposition property and regard the lack of the fluid inside the spinning cylinder as the effective presence of fluid with Z^0 current compensating that of the fluid. Z^0 current would reduce to Kähler current at the QFT limit.

   The Z^0 and Kähler charge densities would be opposite for nuclei and neutrinos but flow velocities would be of opposite sign. to that of the fluid and having inertial mass density of the object. The spinning object effectively would correspond to a fluid with a Z^0 charge density opposite to that of the fluid.

   Remark: One cannot exclude the possibility that also the spinning object carries Z^0 current. This would give rise to a force which would depend on the mass of the object since nuclear Z^0 charge is proportional to mass.

2. Suppose that the liquid particles have Z^0 charges of the same sign and average charge q_z so that the Z^0 charge density ρ_Z is given by $\rho_Z = (q_Z/m)\rho$. This assumption can be challenged. At which length scale do dark neutrinos neutralize the nuclear Z^0 charges and is also the nuclear Z^0 charge dark?

3. Suppose that the assumption $v = q_Z A_Z/m$ inspired by super-fluidity holds true at the MB. This implies that the vorticity is given by $\nabla \times v = q_Z B_Z/m$. This gives $\Gamma = (m/q_Z)\Phi_Z = (m/q_Z)\oint A_Z \cdot dl$. On the other hand, the Z^0 Lorentz force per unit length is $F/L = q_Z \rho_Z v \times B_Z dA = \int \rho v \times (\nabla \times v) dA$. Since v can be taken spatially constant inside the cylinder, one obtains $F/L = \rho v \Gamma$ by Stokes theorem.

If the dynamics of Z^0 fields controls fluid dynamics this picture can be generalized by allowing also Z^0 electric fields. The Z^0 charge densities and Z^0 currents of neutrinos and nuclei cancel each other, they move with the same velocity and one has a neutral Z^0plasma, and HD reduces Z^0 MHD.

For the Z^0 option, the appearance of the density of the fluid in the Magnus force has highly non-trivial implications since it means that *all* nucleons in the liquid flow are effectively dark with large value of h_{eff}, not only those, which reside at magnetic flux tubes. This might well kill this option where as the options in which $A(M^4)$ is involved, survive.

1. At the fundamental level, darkness must reduce to a property of weak bosons propagating along magnetic flux tubes. If magnetic flux tubes are dark also the particles, which touch them are dark. Already earlier it has been concluded that the coupling of ordinary matter to dark gravitational flux tubes by touching makes them effectively dark. For instance, in the case of fountain effect of superfluidity [K5] [L28], this seems to be the only possible interpretation: only superfluid particles touch to dark gravitational flux tubes: it is misleading to say that they are at magnetic flux tubes.

2. Darkness implies that the weak scale is scaled up by $\hbar_{eff}$. What does this mean from the point of view of particle masses? Weak bosons are effectively massless below their dark Compton scale, which for $\hbar_{gr}$ associated with M_E and $\beta_0 = .9$ would be $\Lambda_{gr} \simeq .9$ mm.

   In the standard model framework, this would imply that the Higgs mechanism is realized only in length scales longer than the dark weak scale so that below weak scale quarks would be massless if the Higgs mechanism determines the masses.

   This would not have a considerable effect on the nucleon masses since the contribution of quarks to their masses is only few per cent. In the TGD framework most of the nucleon mass comes from the mass of color magnetic flux tubes. Neutron and proton masses would be identical below the dark weak scale.

3. However, the prediction that electron mass vanishes below say Λ_{gr} looks unrealistic. The situation is saved by the fact that in the TGD framework Higgs mechanism does not determine masses of elementary fermions. Rather, p-adic mass calculations [K8, K2] based on p-adic thermodynamics predict them and weak interactions have nothing to do with the massivation of elementary fermions. Higgs vacuum expectation does not cause massivation but the gradient couplings of Higgs to fermions are naturally proportional to the fermion masses.

4. A further objection against the Z^0 option is following. If ordinary nuclei are dark in hydrodynamical flow, one can wonder what distinguishes between hydrodynamical and super-fluid flows. For instance, why has the fountain effect not been observed? For M^4 and M^4 plus CP_2 options macroscopic quantum coherence is not required but is possible and would explain super-fluid flow and be due to $h_{eff} = h_{gr}$.

2. $A(M^4)$ and $A(M^4) + A(CP_2)$ options

The discussion of the $A(M^4)$ and $A(M^4) + A(CP_2)$ options proceeds along similar lines. Now however large values of h_{eff} would not be necessary and their presence for a super-fluid flow would distinguish it from the ordinary fluid flow.

M^4 contribution to the Kähler charge would replace the Z^0 charge. In this case, nuclei and leptons would screen each other's Kähler charges and in liquid flow their velocities would have opposite directions but magnitudes could be different.

2.6.4 Quantum hydrodynamics is in question

For Lagrangian manifolds associated with non-monopole flux tubes the operators $D_i = p_i - qA_i$ commute and momentum components as eigenvalues determined by $(p_i - qA_i)\psi = 0$ are well-defined so that the interpretation as a classical limit makes sense. The irony is that in this case the value of h_{eff} would be large.

For monopole flux tubes, the Kähler form $J(CP_2)$ is non-trivial. The degeneracies of J determine how many components of v are well-defined.

Besides CP_2 Kähler form also the Kähler form of M^4, strongly suggested by the twistor lift, contributes. The notion of Kähler structure must be modified so that one has a slicing of M^4 by surfaces Y^2 and X^2 such that a given Y^2 with Minkowskian signature intersecting X^2 at point x is orthogonal to X^2 and vice versa.

Y^2 has a hypercomplex structure with an imaginary unit e satisfying $e^2 = 1$ rather than $i^2 = -1$. The square of $J(X^2) + J(Y^2)$ is naturally equal to $g(Y^2) - g(X^2)$. This gives a positive contribution to energy. The Kähler gauge potential contributing to the total Kähler gauge potential is real. The condition would $J^2 = -g$ would force imaginary Kähler gauge potential for Y^2 and make the contribution to energy negative.

Cosmic strings are not realistic models for hydrodynamics but their M^4 deformations could be so since the string tension of the flux tube having interpretation as a length scale dependent cosmological constant depends on the p-adic scale and approaches to zero in long scales. This gives motivation for looking more closely at the situation for cosmic strings $X^4 = X^2 \times S^2 \subset M^4 \times CP_2$. Assume Hamilton-Jacobi structure in M^4 defining an M^4 Kähler form.

1. For a general stationary cosmic strings $X^2 \times Y^2 \subset M^4 \times CP_2$, the covariant derivatives $D_i = p_i - qA_i$ do not commute in Y^2 and X^2 unless X^2 or Y^2 or both are Lagrangian submanifolds. There are 4 basic cases depending on whether X^2 (Y^2) is Lagrangian (L) or non-Lagrangian (n-L). These correspond to pairs (L,L), (n-L,L)(L,n-L),(L,L). In these situations the number of well-defined velocity components is 1+1=2, 2+1=3, 1+2=3, and 2+2.

   For instance, if $X^2 \times Y^2 \subset M^4 \times CP_2$ is a product of Lagrangian 2-surfaces for a given Hamilton-Jacobi structure, the action reduces to a volume term and there is maximum number 4 of well-defined velocity components.

   Only the component D_ϕ along the flow line can be diagonalized for non-Lagrangian $Y^2 \subset CP_2$ and the classical velocity $v_\phi = A_\phi/m$ along the flow line is well-defined. In the n-L situation in $X^2 \subset M^4$ only a single velocity component in $X^2 \subset M^4$ is well-defined and can correspond to a time-like or space-like direction.

   Harmonic oscillator with well-defined energy, momentum component in z-direction and angular momentum L_z would be a good analog for $(n - L, L)$ and $(L, n - L)$ situations. For L, n_L this would correspond to a helical hydrodynamic flow associated with the vortex core with non-vanishing v_z and v_ϕ. About the radial component v_ρ one cannot say anything.

2. The standard MHD picture is that the velocity for a vortex flow is proportional to the magnetic field due to the freezing of the charged particles to the magnetic field lines. This assumption is an idealization since already classically charged particles move along cyclotron orbits along flux lines. This conforms with the above result that the motion in the general case is helical. For cyclotron states this situation corresponds to non-vanishing momentum component p_z and non-vanishing angular momentum component J_z.

For the M^4 deformations of both Lagrangian and cosmic strings to M^4, one expects that the number of well-defined velocity components decreases to the minimal one 1+1=2 corresponding to energy and rotational velocity.

3 TGD view about the generation of turbulence

3.1 The TGD view about the flow near boundaries and the generation of turbulence and its decay

The proposal implies a new view about the hydrodynamical flow near boundaries and about the generation of turbulence and its decay.

3.1.1 The flow near boundaries

Consider first a TGD based model for the flow.

1. Outside the cores of vortices and in regions far away from boundaries, dissipation is absent and the flow is gradient flow. The TGD would be in terms of space-time surfaces with vanishing Kähler fields assignable to Lagrangian non-monopole flux tubes. At QFT limit electroweak fields would vanish if the above model is accepted.

2. The absence of dissipation suggests a macroscopic quantum coherence at Lagrangian space-time sheets so that one would have $h_{eff} > h$ at the MB of this region. Superfluid model suggests that the vector potential A is associated with the space-time sheet at which the dark variants of particles with $h_{eff} > h$ reside. Quantization of circulation would be in multiples of $\hbar_{eff} = n\hbar_0$.

   This conforms with the TGD based model for the generation of galactic jets [L27] in which the magnetic fields around galactic blackhole like object are relatively weak but correspond to $h_{eff} = \hbar_{gr} = GMm/v_0$ so that one has quantum coherence in the scale given by gravitational Compton length $\Lambda_{gr} = GM/\beta_0 = r_s/2\beta_0$, $\beta_0 = v_0/c$ which has no dependence on mass m and is in general larger than Scwartschild radius r_s. Λ_{gr} for Earth appears in the TGD based model for superconductivity [L17].

3. What about the monopole flux tube associated with the vortex core? In the model of galactic jets, it would have a considerably smaller value of h_{eff}, perhaps $h_{eff} = h$ [L27]. This assumption would conform with the fact that the flow would be ordinary dissipative flow in this region.

   Remark: One can also consider a fractal hierarchy in which one has at every level a non-dissipative flow apart from vortices. There would be vortices inside vortices inside..., and at the lowest level one would have monopole flux tubes.

4. Near the boundaries one must somehow describe the transversal gradient of the longitudinal velocity field. The natural idea is that small vortices below measurement resolution are present already below the critical value of the Reynolds number R ($R = ud/\nu$) so that the shear would be concentrated in vortex cores.

   Consider two nearby flow lines with slightly different velocities. One can go to a rest system so that the velocities are opposite and replace this pair with a long flattened velocity vortex analogous to a long dipole: A would have as its source B just like B has as its source current j. The vortex core would be now a thin line parallel to the flow. One can replace this structure with a sequence of small vortices just as one can replace a long dipole with a sequence of small dipoles and put them in motion. These vortices could be below the measurement resolution, say having radii in the micron range.

   The flow near boundaries would already contain vortices but they would in general be below the measurement resolution.

3.1.2 The generation of turbulence and its decay

The transition to turbulence would be essentially a self-organization process made possible by energy feed provided by the flow or by some other energy source.

1. In the transition to turbulence, a phase transition increasing h_{eff} for the non-mopole parts and possibly also for the monopole parts of MBs of already existing vortices would take place. It would increase the corresponding parts of flux tubes and make the vortices visible.

   The energy of the flow would not be dissipated but would be used as "metabolic energy" for self-organization. The critical Reynolds number could be due to the condition that circulation is quantized for the vortices as multiples of h_{eff}/m, m the mass of the particle of the flow. Also the formation of bound states of particles by Galois confinement at flux tubes could liberate energy. This would directly relate to the formation of quasiparticles in condensed matter systems.

   Reconnection and braiding would generate complex vortex structures and for high Reynolds numbers the situation would approach chaos.

2. In the hydrodynamic flow in the presence of boundaries the flow would provide the metabolic energy feed whereas in the head-on collision of circular vortices the energy would come from the kinetic energy of the jets. In the burst of a bubble, which scomplex circular vortex ring structures, the metabolic energy would come from the pressure difference between the interior and exterior of the bubble before the creation of the film rupture and from the energy associated with the string tension. In the case of BECs, laser light can serve as the metabolic energy feed.

3. $h_{eff} > h$ phases at the Lagrangian flux tubes would be generated and this increases the size of the flux tubes. h_{eff} could increase also for the monopole flux tubes implying a larger vortex core. The value of h_{eff} could be however considerably smaller for these flux tubes. Also the reconnection of smaller flux tubes (not plausible with a standard arrow of time) would give rise to larger flux tubes.

Turbulence decays as the metabolic energy feed ceases. How does this take place? The decay of a single linear vortex to parallel vortices has not been observed, which strongly suggests that the dynamics is based on braiding and reconnections leading to the emission of smaller vortices from larger vortices. The eventual outcome would be vortices which are so small that they are below measurement resolution present always near boundaries.

3.1.3 Who is the boss?

Who is the master and who is the slave in the self-organized system?

1. The MB of the entire flow would act as a master controlling the dynamics of the ordinary fluid flow.

2. What about the monopole and non- monopole parts of MB? Who is the master and who is the slave?

   The Lagrangian part of MB as an analog of supra flow could have considerably larger h_{eff}. Could it serve as the master and also control the monopole part of MB?

   However, monopole flux tubes would effectively act as a source of Kähler gauge potential A defining the gradient flow. The dynamics of MB would be essentially topological and involve phenomena like knotting, linking, braiding and reconnection. Could the dynamics of the monopole flux tubes dictate the dynamics of the non-monopole parts just like the moving sources define the non-radiative parts of fields in electrodynamics? Could the monopole part of MB serve as the master for the topological aspects of the flow as the analogy of monopole flux tubes with external field H suggests?

3.1.4 What about the role of time reversals?

What about the role of time reversals? ZEO [K15] [L10] together with the h_{eff} hierarchy predicts that both "small" and "big" (ordinary) SFRs (SSFRs and BSFRs) can occur in all scales.

1. BSFR changes the arrow of time and the outsider with an opposite arrow of time sees BSFR as a classical deterministic evolution leading to the final state of BSFR as the experimental findings of Minev *et al* suggest [L8]. The proposal is that BSFRs appear in all scales and allow us to understand why the world looks classical despite being genuinely quantal.

2. The generation of turbulence looks like self-organization whereas the decay of the turbulent patterns looks like dissipation. The self-organization aspect is usually explained in terms of non-equilibrium thermodynamics and the necessary energy feed is indeed present. In the TGD picture, the energy feed would make possible an increase of h_{eff} at the MB of the system and since MB controls the system, this would lead to the increase of vortex size and reconnection of microscopic vortices could be involved.

3. One can however ask whether time reversals could play a role in the process and even make spontaneous self-organization without energy feed possible. Could the transition to quantum turbulence in some situations involve a BSFR changing the arrow of time at MB, and lead to

maximally self-organized configuration? This would be followed by a second BSFR leading to the decay of the turbulence. In this kind of situation, the self-organization would be essentially decay of large vortices to smaller vortices by reconnections but with a reversed arrow of time occurring after the first BSFR.

Inverse cascade, which is described in [D5], is observed in 2-D hydrodynamic systems with energy feed and looks essentially like the inverse process for the decay of vortices. Large scale vortices and steady states of them are generated. Jupiter and soap films represent examples of systems of this kind. Lars Onsager proposed a model based on statistical mechanics of quantized vortices to explain such behavior. The energy feed would lead to a state with a negative temperature. Nuclear spin systems and condensed matter systems can be forced to states with population reversal by manipulating spins or signs of the interparticle interactions. Authors report the first experimental confirmation of Onsager's model of turbulence in 2-D atomic BEC, in which vortex radius is of ofer micrometer to be compared with 1 Angstrom size in Helium superfluid.

To sum up, although the picture described in this section is is applied to hydrodynamics, it is universal. What is assumed is that current defines integrable flow so that one can assign to it an order parameter defined in terms of space-time geometry. Gradient flow is obtained if the current is conserved and in this case Kähler vacuums provide a model for the complement of vortex cores with a vanishing vorticity. In hydrodynamics and superfluidity the flow corresponds to conserved mass current and in super-conductivity em current but can be something else. The flow of matter would be controlled by the monopole part of MB carrying dark matter and the dynamics would be basically topological as far as turbulence is considered.

Also the vortex core flow is non-dissipative classically if both the CP_2 projection and M^4 projection are at most 2-D. One would have string like objects and dissipation could be understood as a deviation from being a string like object. The very early TGD inspired cosmology [K4, K14, K9, K3] could correspond to this phase.

3.2 Some examples of universality

In the following some applications of the universality of the generation of turbulence are proposed.

3.2.1 The reconnection problem of magnetohydrodynamics

As already mentioned magnetohydrodynamics (MHD) and hydrodynamics (MHD) could have very similar structure. The basic difference could be that in HD Z^0 magnetic fields dominate whereas in MHD magnetic fields dominate. If Weinberg angle vanishes in HD, only $\sum Z^0$ would be non-vanishing, and the difference could relate to Weinberg angle suggesting that in MHD the value of h_{eff} for Lagrangian regions of the vortices is considerably smaller.

Reconnection of magnetic field lines is believed to be the main mechanism for the generation of turbulence in MHD. The problem is that the reconnection rate is systematically predicted to be too low by many orders of magnitudes (`https://cutt.ly/GEq5zDD`). For instance, for solar flares the discrepancy is 13-14 orders of magnitude! One proposed cure is the increase of the local resistivity and therefore the emergence of a new much smaller scale.

The dimensional estimate for the dimensionless reconnection rate R_{SW} in 2-D Sweet-Parker model relies on the observation that in the connection of field lines the frozen charge carrier are transferred from portions of initial flux lines to the portions of re-connected flux lines so that one can speak of incoming and outgoing velocities for charges.

The condition in 2-D case is that the component of electric field normal to the plane of reconnection is conserved: $E_y \sim v_{in}B_{in}v_{out}B_{out}$. E_y defines what is called non-normalized reconnection rate. $v_{out} \simeq v_A = B/\sqrt{\rho}$ follows from the condition that upstream kinetic pressure equals the downstream magnetic pressure. The mass conservation gives $vinL = v_{out}\delta$. The ratio $R_{SP} = v_{in}/v_{out} = B_{out}/B_{in}$ is called normalized or dimensionals reconnection rate. The prediction for the non-normalized reconnection rate is

$$R_{SP} \sim \frac{1}{Re_m^{1/2}} \ ,$$

where the magnetic Reynolds number is given by $Re_m = v_A L/\eta$. $eta = 1/\sigma_0$ is magnetic diffusivity analogous to viscosity, $v_A = B\sqrt{\rho}$ is the Alfven velocity, and L is the scale of the system. What looks strange to me is that the reconnection rate is dimensionless. Is it impossible to deduce a genuine rate if the reconnection takes place for field lines?

R increases as the effective value of L decreases or the conductivity σ_0 decreases, and it has been proposed that the local increase of resistivity could save the situation but it is difficult to imagine this kind of mechanism in standard MHD.

What is the situation in the TGD framework?

1. The hierarchical structure of many-sheeted space-time brings in an entire hierarchy of scales (dark and p-adic ones). This makes possible the transfer of energy from long to short scales before it is dissipated at short scales. This is the intuitive vision originated by Kolmogorov.

2. The reconnection of magnetic field lines is replaced with that for monopole flux tubes (see 8.2 and **Fig. ??**) at the vortex cores. In the simplest model, Lagrangian flux tubes associated with the exteriors of the vortex core would have the generalized Beltrami property and have large h_{eff} - perhaps even $h_{eff} = h_{gr}$ - and be therefore quantum coherent and therefore non-dissipative ($\sigma = \infty$ is the approximation often made in MHD). Lagrangian property would imply vanishing induced Kähler field but non-vanishing em field $\sum \gamma = p \sum 4e^1 \wedge e^2$. Kähler gauge potential would be proportional to velocity field.

3. The monopole flux tubes at vortex cores would have h_{eff} not much larger than h and the vortex core would be therefore dissipative, meaning a large resistivity. The scale L for the entire system appearing in Re_m would be replaced with the size scale of the flux tube, say its length or transversal dimension so that the estimate for the reconnection rate R would increase dramatically if one believes in the naive dimensional analysis based estimate of MHD. Clearly, monopole flux tubes represent symmetry breaking: if the Lagrangian phase has $p = 0$, electroweak symmetry breaking would be in question.

4. The Alfven velocity v_A appearing in R is associated with Alfven waves (`https://cutt.ly/fEq5onl`) plays a key role in the energy transfer in MHD. In the TGD framework, Alfven waves would correspond to two kinds of waves for flux tubes. Either the thickness of the flux tube oscillates but preserves the monopole flux or the shape of flux the tube oscillates but preserves its thickness.

   The estimate $\beta = v/c$ for the phase velocity of the Alfven wave using units with $c = 1$ $\mu_0 = \epsilon_0 = 1$ can be expressed in terms of the relative permittivity $\epsilon_r = \epsilon/\epsilon_0$

$$\begin{aligned} \beta &= \sqrt{1/\epsilon_r} = \frac{1}{\sqrt{1+\rho/B^2}} = \frac{\beta_A}{\sqrt{1+\beta_A^2}} \ , \\ \beta_A &= \sqrt{\frac{B}{\rho}} \ . \end{aligned} \tag{3.1}$$

   The density ρ could correspond to that at the monopole flux tube or with the space-time regions associated with it.

In the TGD framework it is possible to deduce an estimate for the reconnection rate with a correct dimension.

1. Consider monopole flux tubes that are long and restrict the consideration into plane. The flux tubes intersect this plane at points so that effectively one has point-like particles in 2-D space if one neglects the transversal dimension of the flux tubes. Flux tubes are effectively strings and their orbits are string world sheets.

   The moving flux tubes are bound to intersect sooner or later due to a simple topological fact that the dimension of the string world sheets exceeds the dimension of 3-space by one unit. This means that string world sheets have a discrete set of intersection points in the generic case.

2. The estimate for the rate is obtained from the average velocity v for the flux tube motion and from the average distance L between flux tubes.

$$R_{rec} \sim \frac{1}{\tau_{rec}} = \frac{v}{l} \quad . \tag{3.2}$$

The average distance l between flux tubes in plane can be obtained from the density n of the intersections of flux tubes with the plane:

$$l = \frac{1}{n^{1/2}} \quad . \tag{3.3}$$

3. The magnetic flux for monopole flux tubes is conserved and quantized as

$$\Phi_{tube} = \oint_{tube} q_K B_K dS = nm\hbar \ , \quad \frac{\hbar_{eff}}{\hbar} = m \quad . \tag{3.4}$$

   Note that the cross section of the flux tube is a closed surface!

4. The density of the intersections with the plane with area L^2 the estimate

$$n = \frac{N_{tube}}{L^2} \quad . \tag{3.5}$$

5. The number N_{tube} of flux tubes intersecting the plane can be estimated in terms of total magnetic flux as

$$N_{tube} \sim \frac{\Phi_{tot}}{\langle \Phi_{tube} \rangle} \quad . \tag{3.6}$$

6. This would give for R_{rec} the expression

$$lR_{rec} = \frac{1}{\tau_{rec}} = v \times n^{1/2} = v \times \frac{N_{tube}^{1/2}}{L} \sim v \times \sqrt{\frac{\Phi_{tot}}{\Phi_{tube}} \frac{1}{L}} \quad . \tag{3.7}$$

7. One should estimate the value of v. v corresponds either to the center of mass motion of plasma or to the transverse oscillations of flux tubes which can lead to reconnection if the density of flux tubes is high enough.

   Alfwen waves propagate with the Alfven velocity

$$v = v_A = \frac{B_K}{\sqrt{\rho}} \quad . \tag{3.8}$$

   That there would be no dependence on conductivity would conform with the idea that reconnection is a purely topological process of monopole flux tubes rather than that of plasma.

   An analogous result is expected if v corresponds to the cm velocity of the flux tube.

3.2.2 The generation of magnetic fields in cosmic length scales

The problem is discussed in the article [D9] of Alexander Schekochihin can be used to summarize basic differences between TGD and standard approach. The problem discussed is the presence of long range magnetic fields in cosmic scales. Maxwellian magnetic fields always require currents to generate them by dynamo effect. In cosmic scales the plasma is however almost collisionless and it is very difficult to understand how magnetic fields could be generated by dynamo mechanism applied in MHD and why they could have such a long range and be preserved. Currents in long ranges are simply missing and if they exist they decay.

The proposal of Schekochihin is that this is possible. The observation is that magnetization M of molecules can be induced already in very weak long range magnetic fields H if such exist. Assuming the existence of H in cosmic scales, a numerical model providing evidence for the claim is constructed.

What I see as the problem is that such fields H in long scales should not exist if standard cosmology is right! Currents would be random in cosmic scales and long range coherence is lacking.

In the TGD based cosmology the situation is different. Monopole flux tubes carrying magnetic fields analogous to external magnetizing fields H exist already in the primordial cosmology as cosmic strings. Cosmic string world sheets (actually 4-D surfaces) are space-time surfaces with 2-D M^4 projection unstable against thickening of this projection. The thickening of cosmic strings to monopole flux tubes would have produced monopole flux tubes, whose motion induces currents at flux tubes which carry Maxwellian non-monopole magnetic fields analogous to magnetization M requiring the presence of currents. This is a dynamo effect but monopole flux tubes are necessary to generate it by taking the role of H missing from the model of Schekochihin. [This process would have liberated energy transforming to ordinary matter very much like inflaton fields are assumed decay to ordinary matter. The outcome is a solution to the galactic dark matter problem.]

Schekochihin discussed in his lecture (`https://cutt.ly/RW24bTN`) the conjecture that hydrodynamic turbulence in dense plasma could lead to an exponential amplification of magnetic fields (analogous to M) near to the equipartition of energy between kinetic and magnetic degrees of freedom: this equipartition has been observed but is not understood.

In the TGD framework the transfer of energy in plasma turbulence would be due to the generation of vortices, whose cores are accompanied by monopole magnetic flux tubes (H), vortex exteriors can carry ordinary magnetic fields (M) although Kähler gauge field vanishes. They can decay by reconnections to smaller vortices but it would seem that there is lower bound for the vortex size due to the conservation of monopole flux and this would correspond to equipartition of magnetic and kinetic energies in thermal equilibrium [Even nuclei, hadrons and elementary particles would correspond to this kind of flux tubes: flux tubes inside flux tubes inside...].

3.2.3 Bursting bubbles associated with optical cavities in photonic crystals generating jet vortex rings

One can take as an example the bursting bubbles associated with optical cavities in photonic crystals generating jet vortex rings. I am not a specialist so the first challenge is to to understand the above sentence.

1. Photonic crystal (PC) means a periodic structure with a lattice constant, which is half of the wavelength of light in micrometers scale. Photons in this crystal behave like electrons in a lattice. The lattice constant is roughly 10^4 larger than for atomic lattices.

2. Optical cavities (OP) are of size of order 100-1500 nm. Standing waves coupling to plasmons are formed inside the cavity, which leads to amplification of a laser beam. One can speak of a laser without population inversion. The modes inside the cavity are polaritons, which are mixtures of photons and plasmons. They form polariton BEC which can be described by an analog of hydrodynamics.

3. BEC can be regarded as an analog of liquid, it can contain bubbles presumably plasma ions. These bubbles can end up to the boundary of the optical cavity as analogs of soap bubbles and burst. The polariton BEC would form the analog of liquid film bounding a bubble containing plasma.

4. The burst of a bubble would mean generation of a hole at the bubble boundary so that the plasma would burst out. A vortex ring of BEC would be formed around the hole as it is thrown out as a jet. Pressure difference and surface tension for ordinary bubbles would have counterparts. Jet vortex ring would consist of a polariton BEC as an analog of liquid.

If the general vision is correct, an analog of MHD would describe the dynamics of the vortex ring jet. The monopole flux tubes carrying ordinary magnetic fields would define the cores of the BEC vortices.

3.2.4 Generation of vortices in the collision of two circular vortices

It is interesting to see whether the proposed picture allows us to understand a head-one collision of two circular vortices. The article of Chen *et al* [D8] discusses numerical simulations of the head-on collisions of circular vortex rings of opposite circulations. The article contains illustrations giving a good idea about the time evolution in the collision creating extremely beautiful flow patterns (see **Figs. 5**) and **6**).

In the head-on collision the circular vortex rings with opposite circulations separate from the rest of the fluid, which remains on the collision site, and their radii start to increase. The flux tubes almost reconnect and eventually reconnection inducing splitting to small vortex rings takes place.

In the TGD based model the vortex cores would accompany Kähler magnetic monopole fluxe tubes, which start to increase in size. Liquid flows fuse but flux tubes would stay separate. Eventually they annihilate to smaller monopole flux rings by reconnection. This gives rise to vortex ringlets. **Fig. 5**) illustrates the complexity of the resulting patterns. **Fig. 6**) illustrates a real collision of flux tubes.

The challenge is to see whether the formation of local flux loop extrusions associated with wavy motions of flux tubes preserving topology, and braiding and reconnections of the monopole flux tubes could explain the patterns. Reconnection for a single flux tube can produce a closed flux tube and emission of a closed vortex ringlet. Reconnection between *antiparallel* flux tubes produces two U-shaped flux tubes. Reconnection between *parallel* flux tubes 1 and 2 can produce elementary braiding AC +BD → AD +BC. Two reconnections produce a braiding consisting of two subsequent elementary permutations. After thar a reconnection for flux tube 1 (2) can yield a vortex ring around V2 (V1). This is possible also for opposite flux directions if the second flux tube develops a local fold.

The pairs of spikes or "teeth" (Λ vortices) (see sub-figures b) and c) of **Fig. 5**) look strange and it is not obvious how to understand them in the TGD framework. If there is a circular flow around the tooth axis with a non-vanishing circulation and if it corresponds to a monopole flux tube, the monopole flux tube must continue beyond the tip of the tooth. The vortex could disappear because there is no liquid, or could become invisible because the amount of liquid is too small. The members of the tooth pair would be naturally associated with the same flux loop and have opposite circulations and their behaviors should be strongly correlated. This interpretation is supported by the fact that when the Reynolds number is increased, tooth pairs are replaced by vortex loops (sub-figure d) of **Fig. 5**).

3.3 Breaking of the circulation theorem of Kelvin

This section was motivated by the article of Tobias *et al* [D3] about non-conservation of hydrodynamics circulation for 2-D flows caused by the presence of even weak magnetic fields. The following is just an attempt to interpret the findings described in the article.

3.3.1 Background

It is good to start with the abstract of [D3].

> *In this paper we examine the role of weak magnetic fields in breaking Kelvin's circulation theorem and in vortex breakup in two-dimensional magnetohydrodynamics for the*

physically important case of a low magnetic Prandtl number (low Pr_m) fluid. We consider three canonical inviscid solutions for the purely hydrodynamical problem, namely a Gaussian vortex, a circular vortex patch and an elliptical vortex patch.

We examine how magnetic fields lead to an initial loss of circulation and attempt to derive scaling laws for the loss of circulation as a function of field strength and diffusion as measured by two non-dimensional parameters.

We show that for all cases the loss of circulation depends on the integrated effects of the Lorentz force, with the patch cases leading to significantly greater circulation loss. For the case of the elliptical vortex the loss of circulation depends on the total area swept out by the rotating vortex and so this leads to more efficient circulation loss than for a circular vortex.

For a 2-D incompressible flow, the velocity can be expressed either as a gradient of a scalar function or a rotor of a vector potential in z-direction and thus determined by a scalar function known as stream function. The two scalar functions correspond to real and imaginary parts of an analytic function. The presence of the Lorentz force destroys incompressibility and one loses the conservation of circulation since the velocity field for the vortices is not a gradient anymore. Symmetry breaking as loss of conformal invariance is in question.

The article describes situations in which a stably stratified and hence effectively 2-D flow can lead to a generation of long range correlation and large scale flows. Conservation laws and so called inversion procedure, which I interpret as a generation of large scale vortices from smaller ones than vice versa, is believed to be the reason for this.

Small magnetic field can however inhibit the generation of large scale flows. Magnetic fields can also inhibit shear flow instabilities and lead to a disruption of coherent structures such as vortices. Magnetic fields can also turn the direction of spectral transfer of 2-D turbulence: inverse cascades turn to forward cascades. Magnetic fields seem to be an enemy of the HD turbulence. Why?

3.3.2 TGD view about dissipation and loss of circulation

In the TGD framework, dissipation would mean the reduction of the values of h_{eff} for MBs of vortices: $h_{eff} = nh_0$ as a unit for the quantization of monopole flux is effectively reduced. This could mean several things.

Before continuing one must make clear that one must distinguish between the space-time sheet and the "fundamental region" of the Galois group. There are m sheets corresponding to the "roots" of an irreducible polynomial of order m. The Galois group with $n = h_{eff}/h_0$ elements gives rise to n fundamental regions and their number equals to m for cyclic extensions only. If the Galois group is a permutation group of m objects, its order $m!$ and much larger than the order m of the polynomial.

n is in general not equal to m and corresponds to the order of the Galois group and the order of extension of rationals is expected to decrease. This changes the dimension of algebraic extension of rationals and is expected to lead to both dissipation, the reduction of quantum coherence length scale and of the size of the vortex, and a genuine loss of circulation.

1. Quantum jumps transforming an irreducible polynomial to a reducible polynomial

Irreducible polynomials define connected space-time surfaces formed by m "roots". As the polynomial becomes reducible, say a product of two polynomials, it defines 2 space-time regions with a discrete set of intersection points citebtartGaloisTGD. This is what typically happens in particle reactions and also in SFR so that the processes might relate to each other.

If the WCW quantum state is a superposition of space-time surfaces associated with polynomials of the same degree with rational parameters it can occur that for some parameter values the irreducibility is lost [L15]. An SFR performing localization to these values of parameters would correspond to the decay of the space-time surfaces.

This suggests the following scenario.

1. m as the degree of polynomial is identifiable as the number of space-time sheets and is different from $n = h_{eff}/h_0$. m can correspond to number sheets as a covering of M^4 and also as a covering of CP_2. The latter case corresponds to a bundle of flux tubes and the

number of flux tubes can be very large. Both cases can appear simultaneously in which case m is expected to factorize as $m = m(M^4) \times m(CP_2)$.

2. For M^4 coverings, dissipation could correspond to a decay in which the polynomial for critical values of parameters decomposes to a product of polynomials of degrees m_1 and m_2 and vortex decays to vortices with m_1 and m_2 sheets. These structures then leave each other and form separate vortices.

3. In the M^8 picture, in which space-time region corresponds to a "root" of a polynomial, this could mean that the m_2 roots of the polynomial defining the vortex region coincide. The simplest case, perhaps the only realistic situation, corresponds to a co-incidence of $m_2 = 2$ roots so that the polynomial of order m reduces to a product of a second order polynomial and a polynomial of order $m - 2$. The second order polynomial with rational coefficients would correspond to a single root disjoint from $m-2$ roots. The vortex with $m_2 = 2$ should be small. The interpretation as a reconnection is highly suggestive.

   For CP_2 coverings the flux tube bundle decomposes to flux tube bundles consisting of m_1 and m_2 flux tubes.

4. The orders n_1 and n_2 of Galois groups are expected to be smaller than n so that the vortex sizes would be scaled down. Circulation as magnetic flux proportional to $n\hbar_0$ is not expected to be conserved.

2. Cognitive measurement cascade

One can consider the situation also from the point of view of the Galois group with order $n = h_{eff}/h_0$. Dissipation would correspond to the reduction of n.

1. What I call cognitive measurement cascades [L14, L15] occur for extensions of extensions... of rationals Q reprentable as $Q \rightarrow E_1 .... \rightarrow E_n$ would mean a stepwise sequence of symmetry breakings in which the representation of Galois group G_n of E_n would first reduce to the product of Galois groups G_n/G_{n-1} for E_n as extension of E_{n-1} and G_{n-1} of E_{n-1} as extension of Q, and the process continues in the similar manner downwards [L15].

2. A given step process would have as a space-time counterpart decay of flux tube to two flux tubes. Various factor groups G_k/G_{k-1} could act in extension of rationals. Only simple Galois groups such as alternating groups A_n would be stable against this process.

   One cannot exclude the possibility that the polynomial decomposes into a product of polynomials and the outcome is two separate space-time surfaces. Also the interpretation in terms of reconnection might make sense.

3. The dimensions n_i of factor groups would be factors of n and one would have $n = \prod n_i$. In the final state the total flux would be equal to $n = \sum n_i$ if the number of flux units is 1 is the initial and final states. Hence the magnetic flux would not be conserved and this could correspond to the non-conservation of circulation. Dissipation would be in question as is clear also from the fact that state function reductions occur. These reductions could be SSFRs.

4. The dissipative period following the generation of turbulence could correspond to this phase and involve genuine loss of information and complexity at the level of a single flux tube. The decay by reconnections could correspond to this process. If BSFR corresponds to an intuitive heureka moment, the sequence of SSFRs would correspond to an analysis period realized quite literally as a decay of vortices.

5. During the generation of turbulence the complexity would increase and time reversal of this process seems to be in question. TGD suggests a genuine time reversal.

3.3.3 A concrete model in terms of flux tubes

Suppose that one takes seriously the model for the flux tubes assigned to the vortices.

1. The Lagrangian non-monopole flux tube associated with the exterior of vortex core would have vanishing Kähler field J. By a generalization of the basic quantization conditions for superfluidity one would have a gradient flow with velocity $v = A/m$, where $A = d\Phi$ is the Kähler gauge potential (note that one does not have genuine gauge invariance). The value of h_{eff} would be large and there would be no dissipation. There would be a macroscopic quantum coherence at the magnetic flux tube in the exterior of the vortex and Beltrami flow or even gradient flow would serve as its space-time correlate.

2. The earlier considerations suggest that electroweak symmetry breaking is absent inside the Lagrangian region in the case of HD vortices and possibly also MHD vortices.

   The reason is that in the Lagrangian region weak bosons or at least Z^0 should behave like a massless boson since the Z^0 field at QFT limit defined as $\sum_{sheets} Z^0$ is non-vanishing and proportional to the sum of $\sum J_{CP_2}$, which is symplectic invariant. The absence of electroweak symmetry breaking below the size scale of the vortex suggests that the Weinberg angle vanishes: $p = sin^2(\theta_W) = 0$. If so, the electromagnetic field is proportional to $J = J_{M^4} + J_{CP_2} = J_{M^4}$ and vanishes if also the M^4 projection of the flux tube is Lagrangian.

3. What about the vortices of MHD? According to [D3], the size of vortices in astrophysical scales is typically considerably larger than that of HD vortices. The same would hold true also for h_{eff}. $\hbar_{eff} = \hbar_{gr} = GMm/v_0$ is suggestive and mass M would be much larger in astrophysical scales: note that gravitational Compton length for particle with mass m is $\Lambda_{gr} = GM/v_0$ [L29, L28].

   Also now $p = 0$ would hold true in the Lagrangian region whereas $p > 0$ would be satisfied inside the vortex core in both cases. In MHD, the classical em field $\sum gamma$ would be non-vanishing both inside and outside the vortex core. This is the case if the M^4 projection of flux tubes is *not* a Lagrangian manifold anymore. Could the distinction between MHD and HD vortices be this?

4. The dissipation for $Re = UD/\nu \leq Re_{cr}$ would occur in HD in smaller scales than in MHD if $\nu/\eta \leq\leq 1$ is true. This suggests that kinematic viscosity ν and magnetic diffusivity $\eta \propto 1/\sigma$ are proportional to h_{eff} in the Lagrangian region.

   ν has dimensions of angular momentum divided by mass so that viscosity has dimensions of angular momentum density. How closely η could relate to the quantity $\hbar_{eff}/m$ serving as a unit of circulation? Could ν and η be proportional to minimal circulation?

5. One should also understand how the generation of the angular momentum of vortices can be consistent with the conservation of angular momentum. Could the angular momenta of dark matter at magnetic flux tube and the angular momentum of the ordinary matter at vortex sum up to zero? The generation of angular momentum of astrophysical objects is an unsolved problem and I have proposed this kind of mechanism as a possible solution to the problem [L18].

3.3.4 What could be the TGD interpretation of inversion

The inversion looks like dissipation meaning a decay of vortices but occurring in a reversed time direction. The most dramatic predictions of TGD based quantum theory is that the arrow of time changes in ordinary state function reductions (SFRs) (I call them "big" SFRs, briefly BSFRs) and that quantum coherence and therefore BSFRs are possible in arbitrary long scales [L10] [K15]. The physics would be apparently classical in long length scales: ZEO BSFRs imply that the physics looks classical for an observer with an arrow of time opposite to the system for which BSFR takes place [L8].

Could the inversion as a generation of larger vortices from smaller vortices, which in the TGD framework should occur in the first stage in the generation of turbulence, be associated with a BSFR in macroscopic scale?

If this interpretation is correct, the introduction of magnetic fields in the hydrodynamic system would induce BSFR and transform inversion back to dissipation. Why should this occur?

Energy feed is needed to increase h_{eff} assignable to vortex MBs. Could it be that electromagnetic and Z^0-magnetic vortices compete over metabolic energy. Could the generation of electromagnetic flux tubes steal the metabolic energy from Z^0-magnetic hydrodynamical flux tubes? If $\nu < \eta$ holds true the formation of magnetic vortices would become possible at smaller length scales and could steal the energy feed.

3.4 Kelvin-Helholtz and Rayleigh-Taylor instabilities

Kelvin-Helmholz instability (K-H) Rayleigh–Taylor instability (R-T) are instabilities of fluid flow.

1. Kelvin-Helmholz instability (K-H) (`https://cutt.ly/TENyKZ0`) is caused by shear at boundary of the fluid flow or inside the flow and leads to a generation of vortices. Surface waves in water represent a basic example of K-H. In this case, the perturbation theory fails because the water surface does not anymore allow a description as a graph of a single valued function.

2. Rayleigh–Taylor instability (R-T) (`https://cutt.ly/6ENyXzQ`) involves two immiscible fluids with different densities. When lighter fluid is pushed against the heavier one, the boundary layer becomes unstable. This pushing can be caused by the gravitational field. This raises the question whether the gravitational Compton length Λ_{gr} could play an essential role in the description of R-T.

   Oil suspended above water in the gravitational field of Earth is one example. The mushroom shaped cloud formed by volcanic eruptions and atmospheric nuclear explosions represents a second example. During the first stage the dynamics is lianer. The second stage of R-T involves a generation of mushroom shaped spikes as heavier fluid forms intrusions inside the lighter one and bubbles as the lighter fluid penetrates inside the heavier fluid. In the third stage, the mushroom shapes interact with each other. Merging of bubbles and spikes to large ones takes place. Also competition takes place as the saturated spikes and bubbles of smaller wavelength are enveloped by larger ones not yet saturated. The dynamics is thus fractal and the process repeats in shorter length scales. The fourth stage corresponds to turbulence and fractality provided that the Reynolds number is large enough.

It has been recently discovered that the fluid equations governing the linear dynamics of the system admit a parity-time symmetry (PT). According to Wikipedia article, K-H occurs when and only when the parity-time symmetry (PT) breaks spontaneously. However, the article about R-T however claims that simultaneous K-H and R-T occur only when PT is spontaneously broken. The intuitive guess is that the failure of PT symmetry must be a general feature for the transition to turbulence. Reynolds number serves as a criterion for the emergence of turbulence caused by K-H.

3.4.1 Complex Hamiltonians with PT symmetry are hermitian

What makes K-H and R-T quantum mechanically so interesting is that the spontaneous breaking of PT symmetry at the level of flow is involved. On the other hand, if PT replaces complex conjugation, complex Hamiltonians can act as Hermitian Hamiltonians.

One can generalize the notion of Hamiltonian (or any Hermitian operator) to that of complex Hamiltonian provided the operator is invariant under PT [B1] (`https://cutt.ly/mENpOdq`). It turns out that in the TGD framework, one could actually replace PT with CPT transforming the positive and negative energy parts of zero energy states to each other in ZEO. This requires a modification of the inner product so that hermitian conjugation induced by T is replaced with PT involving spatial reflection. The eigenvalues of this operator are real, time evolution is unitary, and states have positive and real norms. A simple example involving addition of term -ix to harmonic oscillator Hamiltonian demonstrates that this is indeed the case.

The addition of the term -ix makes the space complex by the shift $x \rightarrow x - i/2$. This is of special interest in TGD, where one must complexify M^8 and therefore also $M^4 \subset M^8$: there the quark momenta in $X^4 \subset M^8$ correspond to algebraic integers, which can be complex [L25].

1. The restriction to imaginary shifts $x \rightarrow x + iy_0$ of real M^4 coordinates implied by the generalized hermiticity condition allows only imaginary shifts for space-like M^4 coordinates in M^8_c interpreted as momentum space. The reality of the number theoretic norm requires $\sum x\ cdoty_0 = 0$. This selects a 3-D surface of M^4 and reduces M^4 to M^3 for spacelike y_0. This would require an effectively 2-D system.

2. $M^8 - H$ duality would map the momenta to the intersections of geodesic lines with momentum $x + iy_0$ intersecting the opposite boundary of a complexified CD. Quark momenta are algebraic integers in an extension of rationals and can be complex: the real momenta for Galois confined states would belong to M^3.

3.4.2 Spontaneous breaking of PT symmetry in TGD framework

What could PT symmetry and its spontaneous breaking mean in classical TGD having the structure of hydrodynamics (field equations as conservation laws)?

1. Quite generally, CPT symmetry implies PT symmetry in systems in which matter dominates. The theory would be PT invariant and spontaneous PT violation would occur for the solutions of field equations. Spontaneous violation of PT and even CPT occur in all systems at elementary particle level and large values of h_{eff} could make this possible even in macroscopic scales.

2. If the generalized Beltrami hypothesis is satisfied, the classical dynamics is non-dissipative in each scale. The hypothesis does require PT and C as separate symmetries but in TGD one could loosen this condition by defining the generalized unitary by assuming that hermitian conjugation corresponds to CPT with C realized geometrically as a complex conjugation the level of CP_2.

   C transforms complex structure to its conjugate and changes the sign of the induced Kähler form. This does not seem possible for monopole flux tubes at a given boundary of CD in systems containing only matter. Lagrangian flux tubes do not correspond to complex manifolds and have a vanishing induced Kähler form so that non-trivial action of C could be allowed. The WCW spinor field could be C invariant in this case.

   If the spontaneous breaking of CPT at the level of space-time surface is possible, it would mean CPT non-invariance of individual space-time surfaces with P and T depending on the CD containing given space-time surfaces. T defined with respect to the center point of CD would permute the 3-surfaces at the opposite boundaries of CD.

   The WCW spinor fields as superpositions of pairs of 3-D quantum states at opposite boundaries of CD are not invariant under this transformation: T and therefore also CPT would permute the 3-D states at the opposite boundaries. Bras would be mapped to kets and vice versa.

   At space-time level CPT violation could make itself visible as the change of the sign of Kähler form of CP_2 or of M^4. CPT violation would occur at the Lagrangian regions of vortices with $h_{eff} > h$ and therefore could take place in long scales.

What does the generalized Beltrami hypothesis imply?

1. The spontaneous violation of PT in ordinary hydrodynamics would correspond in TGD to the breaking of unitary evolution by the occurrence of SSFRs and BSFRs. The sole source of dissipation in ZEO would be reduction of h_{eff}. The reduction of h_{eff} would lead to the reduction of quantum coherence scale and flow of energy to shorter scales. Self-organization as the reverse process in presence of energy feed or induced by time reversal at MB induced by BSFR is also possible and the formation of larger vortices could correspond to this process.

2. PT symmetry would mean absence of dissipation and its spontaneous violation as analog of breaking of unitary time evolution via the occurrence of SFRs.

According to the Wikipedia article, a spontaneous breaking of PT occurs in simultaneous K-H and R-T and possibly already in K-H. What would TGD predict?

1. Consider first the spontaneous violation of PT symmetry classically. The generation of Kähler magnetic fields in vortex cores in the presence of spinning particles would induce T violation. The large value of h_{eff} imply large electroweak violation of P in long (say biological) scales (classical Z^0 fields). The exteriors of vortices carrying Z^0 fields would correspond to regions, where h_{eff} is large, perhaps even equal to $\hbar_{gr}$.

   Do these violations of P and T compensate for each other or is a spontaneous violation of PT possible. Or is the PT violation produced in SFRs?

2. Could the interpretation spontaneous violation of PT in the case of simultaneous K-H and R-T be that the generation of vortices by K-H inside the intrusions (spikes and bubbles) formed by T-H as a flow of energy to shorter scales serves as the counterpart for the dissipation as a counterpart for the breaking of PT.

3. Can K-H alone be enough for the spontaneous violation of PT? This would correspond to reconnection of vortices producing smaller vortices. The boundary of vortex and exterior flow would define the boundary region with shear giving rise to a boundary layer and smaller vortices. This suggests that spontaneous PT violation in the TGD sense characterizes both K-H, R-T and their combination.

Remark: PT symmetry is in a key role in the TGD based model for the role of time reversal at the level of DNA [L35].

3.5 Some comments about quantum hydrodynamics

In this section some questions related to TGD inspired quantum hydrodynamics for various quasi-particle BECs are considered.

3.5.1 Could one assign quantum hydrodynamics to photonic quasi-crystalline structures?

Photons and polaritons are analogous to conduction electrons in metals. Again I can only ask questions.

1. Could they have as a classical correlate classical induced gauge fields such that the induced Kähler form defines a Beltrami flow with periodic properties? Flow lines are light-like locally but there would be a zitterbewegung involved.

2. What does the quasicrystal structure mean? Photonic quasicrystal should have a description as a quasiperiodic X^4. The identification of quasicrystals in terms of algebraic extensions of the ordinary lattices has been already considered. As a matter of fact, space-time surface X^4 defines a curved generalization of a quasicrystal obtained as points of X^4 belong to the set of points of $M^4 \subset M^8$ for which the M^4 coordinates are algebraic integers in the extension of rationals. In the "cut and project" construction (`https://cutt.ly/IWjxpLv`) one only replaces the low-dimensional plane in higher-D space containing ordinary crystal with the curved space-time surface. One can also define in M^8 crystal lattices tilted with respect to the chosen $M^4 \times E^4$ and obtain quasi-crystals and M^4 projections.

3.5.2 Bernard-von Karman (BvK) vortex streets in TGD framework?

Bernard von Karman (BvK) vortex streets are observed in an exciton-polariton superfluid [?]`https://cutt.ly/FWy3cNw`). The formation of BvK vortex streets (`https://cutt.ly/YWy3mjC` and `https://cutt.ly/JWy3WYP`) is a hydrodynamical phenomenon due to dissipation.

Some facts about classical BvK are in order.

1. The flow past obstacle is laminar or turbulent. Turbulence occurs above critical Reynolds number this corresponds to a critical velocity of supraflow. Turbulence gives rise to BvK vortex streets observed in various macroscopically coherent phases analogous to hydrodynamic flows.

2. BvK involves a periodic emission of vortices from opposite sides of the body, say cylinder, occurring alternately. This means long range coherence in the scale of the body. Vortices grow after leaving the body. Boundary layer is at rest.

3. The role of pressure increase caused by velocity decrease. Change of the direction of velocity gives rise to vortices. Separation and formation of vortices occurs at critical fluid velocity at the thickest part of the obstacle.

3.5.3 Is BvK for supra flows basically quantum phase transition increasing h_{eff}?

One can ask whether BvK for supra flows could be quantum phase transition creating MBs of vortices with $h_{eff} > h_{eff,flow}$.

1. TGD suggests that hydrodynamic vortices at the fundamental level correspond to Z^0 magnetic vortices. If the CP_2 projection of the X^4 is U(2) invariant sphere of S^3, both em and Z^0 field are proportional to Kähler form and long range weak interactions are possible.

2. The picture based on minimal surfaces would suggest that dissipation occurs at the frames and elsewhere there is no classical dissipation. Obstacles of the flow would serve as analogs of frames. Vortices have singular cores: do they correspond to frames?

3. Separation and formation of vortices is a critical phenomenon. In the TGD framework, it could relate to quantum criticality at some level of dark matter hierarchy and lead to the formation of phases with a large value of h_{eff}. The "metabolic energy" needed to increase h_{eff} would come from dissipation.

4. Even ordinary hydrodynamical vortices would be accompanied by quantum coherent structures at the level of their MBs.

What could happen in the process? One can only ask questions.

1. The velocity pattern of the vortex has radial velocity gradient zero and means absence of dissipation. The reason for the formation of vortices are the facts that near the obstacle velocity gradient becomes too large and dissipation starts and flow separation occurs.

2. Quantum criticality would appear when the flow velocity is above critical value so that dissipation near the obstacle begins. Could it give rise to a metabolic energy feed driving generation of $h_{eff} > h_{eff,flow}$ phases? Above this the dissipating flow would serve as an energy source making possible the increase of complexity and self-organization and generation of vortices with $h_{eff} > h_{eff,flow}$.

3. Could the formation of vortices correspond to a formation of new MBs with a different value of h_{eff} expected to occur at quantum criticality? Metabolic energy feed would generate the MBs of the vortices as additional layers in the hierarchy of dark matter. Although the values of h_{eff} could be even smaller than for the entire MB, the complexity would increase since the number of levels would increase.

4. Could the integer value quantized vortices correspond to the values of $h_{eff}/h = n$?

3.5.4 Quantum friction in the flow of water through nanotube

The popular article "Quantum friction slows water flow" (`https://cutt.ly/eORFiQp`) explains the work of Lyderic Bockquet related to quantum friction [D7] published in Nature.

In the experiments considered, water flows through very smooth carbon nanotubes. Water molecules have a diameter of .3 nm. The radius of the nanotube varies in the range [20,100] nm. A small friction has been measured. The surprising finding is that the resistance increases with the radius of the nanotube although large tubes are as smooth as small tubes.

In classical hydro-dynamics the wall is just a wall. Now one must define this notion more precisely. The wall is made of mono-atomic graphene layers. Layers are smooth, which reduces drag and water molecules are not adsorbed on the walls. Therefore the friction is very small but non-vanishing.

The reason is that the electrons of graphene interact with polar water molecules and form bound states and follow the flow. Catching the flow takes however some time which causes resistance. In Born-Oppenheimer approximation this is not taken into account and electrons are assumed to adapt to molecular configurations instantaneously. For thin nanotubes the graphene layers are not so well-ordered due to the geometric constraints and the number layers and therefore also of co-moving electrons is smaller. This reduces the friction effect.

Could TGD help to understand the findings?

1. The model for hydrodynamic turbulence involved the notion of dark matter as phases of ordinary matter with effective Planck constant $h_{eff} = nh_0 > h$ even in macroscales. h_{eff} would characterize the "magnetic body" (MB) associated with the flow.

2. The quantum scale L associated with the flow is proportional to h_{eff} and could characterize the MB. L could be larger than the system size but would be determined by it. One could say that MB to some degree controls the ordinary matter and its quantum coherence induces ordinary coherence at the level of the ordinary matter. Quantum effects at the level of MB are suggested to be present even for the ordinary hydrodynamic flow. The detailed mechanism is however not considered.

3. The outcome is the prediction that kinematic viscosity is proportional to h_{eff}/m, where m is the mass of the unit of flow, now a water molecule.

4. What could be the quantum scale L now? The scale of classical forced coherence would be the radius R of the pipe or, as the study suggests, the size scale of the system formed by water flow and the ordered graphene layers. The scale L of quantum coherence associated with MB could be larger. The larger the number of layers, the larger the size L of MB.

   From $L \propto h_{eff}$, one has $\nu \propto hbar_{eff}/m \propto L$. In conflict with the classical intuitions, the friction would be proportional to L and decrease as the pipe radius decreases. This conforms with the proposal if the magnetic body associated with the electron system is the boss.

3.5.5 Mysterious lift of drill in downwards water flow

I learned of a very interesting and paradoxical looking phenomenon. Thanks for Shamoon Ahmed for the link. A drill with a helical geometry raises in a downwards fluid flow. This is in conflict with the naive expectations.

1. Suppose first that momentum is conserved. By momentum conservation water must get downwards directed momentum if the drill obtains upwards directed momentum. If there is no slipping, just the opposite should happen. Therefore the situation could be like in a turbulent flow: the water and the drill do not directly touch each other. There is indeed turbulence as one can see.

   But what makes possible the slipping? It has been quite recently learned that the surface of water in air has thin ice-like layer for which TGD suggests and explanation [L33, L24]. The surface between drill and water would be covered by a very thin ice layer so that slipping would take place naturally. Drill is like a skater. Also the boundary layer in the water (liquid) flow past a body could be a thin ice-sheet. Second analogy is as a screw penetrating upstream.

2. But is the momentum really conserved? Water is accelerated in the gravitational field: this gives it momentum. Water forms a vortex already before the drill is added. The downwards kinematic pressure, which increases downwards, pushes the drill having a helical geometry. If there is no friction fixing the drill to water flow, the drill has no other option than raise. The constraint due to helicality forces the drill to rotate.

   Water in the vortex and the drill would rotate in opposite directions and helicality constraint would transform the rotational motion of the drill to a translational motion and forces the rotation of drill to gain upwards directed momentum.

3. This raises some questions.

(a) Could there be a connection with the fact that in the Northern/Southern hemisphere water flowing in a water tub rotates in a unique direction (kind of parity breaking)?

(b) What is the role of the handedness of the drill? One would expect that the drill with an opposite handedness rotate in an opposite direction? What if the handedness of the drill does not favor the natural rotation direction for the vortex? Do these effects tend to cancel.

There might be a connection with the "ordinary" hydrodynamics. The drill raising in the fluid flow is analogous to a propeller. Could also ordinary propeller involve the same basic mechanism and act like a skater and in this way minimize dissipative energy losses? It is known that propellers induce cavitation as evaporation of water and there is anecdotal evidence from power plants that more energy is liberated in the process than one would expect. Recently it was found that the mere irradiation of water by light leads to its evaporation as a generation of droplets, which would have ice-like surface layer consisting of the fourth phase of water (this requires energy): Pollack effect again! Could dark photons with nonstandard value of Planck constant provide the energy needed for the cavitation creating a vapour phase with larger total area of fourth phase of water?

Runcel D. Arcaya informed me of the work of a brilliant experimentalist and inventor Victor Schauberger related to the strange properties of the flowing water. This work relates in an interesting manner to the effect discussed. I have written about Schauberger's findings about to the ability of fishes too swim "too" easily upstream. Gravitation and turbulence are involved also now. Could the bodily posture of the fish generate the counterpart of the helical geometry? Could the fish as a living organism help to generate the fourth phase of water in the water bounding their skin by Pollack effect, which requires the presence of a gel phase besides energy source (IR radiation for instance) to transform part of protons of water molecules to dark photons with a higher energy.

Schauberger also invented a method of water purification using vortex flow: the reason for why the method works remained unclear. In Pollack effect, the negatively charged exclusion zones (EZs) spontaneously purify themselves. This conflicts with the thermodynamical intuitions. The TGD explanation is in terms of reversed arrow of time which explains the purification process as normal diffusion leading to the decay of gradients but taking place with an opposite arrow of time. Could the purification of in vortex flow be caused by the Pollack effect creating the surface layers consisting of the fourth phase of water (EZs)?

Schauberger developed the notion of living water and believed that spring water is somehow very special in this respect. In TGD water is regarded as a multiphase system involving magnetic body with layers labelled by the values of effective Planck constant h_{eff}. The larger the value of the h_{eff}, the higher the (basically algebraic complexity) and "IQ" of the system. Gravitational magnetic body has the largest value of effective Planck constant. Spring water is pure and could be this kind of highly complex system. Also systems involving turbulence and vortices are very complex.

3.6 Why the water flowing out of bathtub rotates always in the same direction?

In FB Wes Johnson wondered whether Coriolis force could explain why the water flowing out of bathtub forms a vortex with direction which is opposite at Northern and Southern hemispheres.

Coriolis effect is a coordinate force proportional to $\omega \times v$, where ω is the angular velocity of Earth directed to Noth and v is the velocity of the object. For bathtub v would be downwards, that is in the direction of Earth radius. At the equator Coriolis force is along the equator and non-vanishing. On the other hand, the force causing rotation of water in the bathtub is of opposite sign below and above equator and therefore vanishes at equator. Therefore Coriolis force is excluded as an explanation.

My own view is that this is a hydrodynamical effect and new physics might be involved. Turbulence is involved and vortex is generated. The direction of the rotation of the vortex should be understood. The selection of a specific direction violates parity symmetry and this gives in the TGD framework strong guidelines.

1. The vortex is in the direction of the Earth's gravitational force. In the TGD framework, gravitational interaction is mediated by monopole flux tubes in the direction of the gravita-

tional field. Quantum gravitation is involved and it is quite possible that the gravitational magnetic body (MB) induces the effect since quite generally MB plays a control role, in particular in living matter.

2. The induced Kähler field contributes to both electromagnetic and classical (weak) Z^0 fields: since the matter is em neutral but not Z^0 neutral, it seems that the Z^0 field must be in question. Could the gravitational MB of Earth consist of Z^0 monopole flux tubes?

   If this is the case, a macroscopic quantum effect involving a very large value $\hbar_{gr} = GMm/\beta_0$ of gravitational Planck constant of the pair formed by Earth mass and particle must be in question since ordinary Z^0 has extremely short range. The gravitational Compton length $\Lambda_{gr} = \hbar_{gr}/m = GM/\beta_0 = r_S/2\beta_0$ does not depend on particle mass and is about .5 cm, one half of the Schwartschild radius of the Earth, for the favored $\beta_0 = v_0/c = 1$.

3. In the classical Z^0 field, particles with Z^0 charge rotate around the axis of the field and since magnetic flux is approximately dipole field, the flux lines are radial but are upwards/downwards above/below the equator. This would explain why the rotation directions of the vortex are opposite and Northern and Southern hemispheres. The presence of the classical Z^0 field, which violates parity symmetry, would also conform with the parity breaking and would be essential for the understanding of the mystery of chiral selection in biomatter.

3.7 Cymatics, ringing bells, water memory, homeopathy, Pollack, effect, turbulence

The following comments contain many words, which induce deep aggression in academic colleagues receiving a monthly salary: cymatics, the ringing bells of Buddhist monks, water memory, and homeopathy(!!). Pollack effect is perhaps not so aggression inducing and turbulence is quite neutral. All these words are linked. Cymatics is a very interesting phenomenon. Thanks to Jukka Sarno for a post inspiring this comment.

I came across a related phenomenon recently. The ringing of Buddhist monks' bells by running the bell along its edge has strange effects. The water started to boil so that a strong transfer of energy had to happen to the water by sound. Energy was supplied to the system by the ringer of the bells. This energy could play a role of metabolic energy and help in the problems resulting from its local deficiency in the patient's body.

Something analogous to turbulence also arises in cymatics. Turbulence and its generation are very interesting phenomena and poorly understood. Standard hydrodynamics, which was developed centuries ago, can't really cope with the challenges of the modern world: if only someone could tell this to the theoreticians working on it!

I myself have built a model for turbulence and related phenomena [L24, L33]. A core element of the model is the anomalous phenomenon observed by Pollack [I2, I1, I4, I3] related to water. When water is irradiated in the presence of a gel phase with, for example, infrared light, negatively charged gel-like volumes are created in the water: Pollack talks about the fourth phase of water. Living matter is full of them: for instance cell interior is negatively charged as also DNA.

Some of the water's protons disappear somewhere: in the TGD Universe they would go to the magnetic body of the water and form dark matter there precisely because we cannot detect them with standard methods. This dark matter would be a phase of ordinary matter with a nonstandard, and often very large value of effective Planck constant. This would make it quantum coherent in much longer scales than the ordinary matter.

Pollack's fourth phase resembles ice and very recently it has been discovered that there is a thin ice-like layer at the interface between water and air [L24, L33]. Could it be Pollack's fourth phase? The energy input is essential. In cymatics and in the case of bells the energy feeder would be sound rather than light. In homeopathy (one of the most hated phenomena of physics besides water memory; I have never understood why it generates so deep a hatred), the shaking of the homeopathic preparation would supply the energy. A fourth phase of water would be created and the water would become "living" as its magnetic body would "wake up" and start to control ordinary matter.

Homeopathy [K6] is one of the most hated phenomena of physics besides water memory (I have never understood why it generates so deep hatred), the shaking of the homeopathic preparation would supply the energy. A fourth phase of water would be created and the water would become "living" as its magnetic body would "wake up" and start to control ordinary matter.

In homeopathy, shaking would provide the metabolic energy making it possible to create magnetic organisms consisting of flux tubes associated with the water molecule clusters connected by hydrogen bonds. Their cyclotron frequency spectrum would mimic the corresponding spectrum of the molecules dissolved in water. Water would magnetically mimic the intruder molecule and from the perspective of biology this would be enough for water memory explaining homeopathic effects. This should be trivial for scientists living in the computer age but some kind of primitive regression makes it impossible for colleagues to stay calm and rational when they hear the word "homeopathy".

4 Are the hydrodynamic quantum analogs much more than analogs?

The hydrodynamic quantum analogs are highly interesting from TGD point of view and Wikipedia article gives a nice summary about them (`https://cutt.ly/xEk5Api`). The quantum-like aspects are associated with a hydrodynamical system consisting of a liquid layer and liquid drop. Liquid surface in a periodic accelerated motion due to shaking: this means energy feed. The fluid bath is just below the criticality for a generation of standing Faraday wave and the bouncind particle indeed generates this kind of wave.

Depending on the values of the parameters, the liquid drop is surfing, bouncing at a fixed position, or "walking" along the surface wave. The surface wave is created by the interaction of particle with the surface. These findings suggest that macrosopic quantum coherence could be involved and quantum phenomena have also classical description. There is energy feed to the systems.

The findings of the group led by Bush and describe in his Youtube lecture (`https://cutt.ly/xEk5Api`) give a nice overall view about the quantum analogs. Bush also suggests a generalization of theory of Vigier involving two pilot waves, which correspond to those associated with wave function and to classical system and theory of Bohm involving single pilot wave assigned to wave function.

The article of Bush *et al* [D4] describes the findings about the analog of quantum corral. The latter involves electrons inside a circular corral defined by negative ions.

> *Bouncing droplets can self-propel laterally along the surface of a vibrated fluid bath by virtue of a resonant interaction with their own wave field . The resulting walking droplets exhibit features reminiscent of microscopic quantum particles. Here we present the results of an experimental investigation of droplets walking in a circular corral. We demonstrate that a coherent wavelike statistical behavior emerges from the complex underlying dynamics and that the probability distribution is prescribed by the Faraday wave mode of the corral. The statistical behavior of the walking droplets is demonstrated to be analogous to that of electrons in quantum corrals.*

The key questions are following.

1. Could quantum classical correspondence (QCC) be more than an approximation (stationary phase approximation). Note that in TGD QCC is in a well-defined sense exact.

2. Can a macroscopic system can exhibit quantal looking behavior and is there a genuine quantum behavior behind it? In the TGD framework, the hierarchy of effective Planck constants $h_{eff} = nh_0$ labelling phases of ordinary matter located at magnetic body (MB). MB has a hierarchical structure and defines a master slave hierarchy.

   A given level of the hierarchy controls the physics at the lower levels. h_{eff} hierarchy makes quantum coherence possible in arbitrarily long scales at MB and this induces coherence at the level of ordinary matter and makes possible self-organization [L9] The increase of h_{eff} requires however the analogy of metabolic energy feed quite generally.

There is indeed energy feed to the studied system at frequency of $f = 50$ Hz of the vibrating cylindrical shaker. The standing wave resonance occurs at Faraday frequency $f_F = f/2$. The Faraday frequency has slow time variation with the frequency f and slightly below f_F.

The system system should be near criticality for the generation of h_{eff} phases. These phases at MB would induce long range correlations of ordinary matter near criticality. The system studied is indeed near criticality for the generation of standing Faraday waves.

3. What could the value of h_{eff} be? The Faraday wave length $\lambda_F = 2\pi\sqrt{2\nu/\mu}$ should be equal to the analog of Compton wavelength $\Lambda_c = \hbar_{eff}/m$, m the mass of the water droplet. λ_F does not however depend on the mass of the droplet and in the model of the Faraday waves hydrodynamical is determined in the model considered by the properties of the fluid that is friction and kinematic viscosity.

   The only possibility is that one has $\hbar_{eff} = \hbar_{gr} = GMm/v_0$, where $\hbar_{gr}$ is the gravitational Planck constant introduced by Nottale [E1] [L22] and also appearing in the TGD based model of superconductivity [L17]. This would give $\lambda_F = \lambda gr = GM/v_0 = r_s(M)/2v_0$, where $r_s(M)$ is Schartschild radius. M is naturally the mass of Earth. The minimum value of λ_{gr} corresponds to $v_0/c = 1$ and is $\lambda_{gr} = r_s/2$. Earth's Scwartschild radius is 8.7 mm so that one would have $\lambda_F = 4.35$ mm.

   The value of Λ_F for the system studied in the analog of quantum corral by Bush *et al* is 4.75 mm [D4] and about 10 per cent larger than the minimal value suggesting that $\beta_0 = v_0/c \simeq .92$!

   If this single testable prediction is not a nasty coincidence, it would mean an instantaneous breakthrough for the TGD view about quantum gravitation as macroscopic and even astrophysical phenomenon. The only parameter that can be varied in the prediction is β_0. One could measure $\lambda_F = 2\pi\sqrt{2\nu/\mu}$ for different liquids to see whether v_0 codes for the properties of the liquid or whether λ_F is independent of the liquid so that the classical model for Faraday waves could be wrong.

4. The system has a memory in the sense that the induced Faraday wave interpreted as an analog of pilot wave is affected by the bouncing particle and in turns determines particle behavior but not quite completely: an analog of non-deterministic "zitterbewegung" seems to be present for strong enough acccelerations. The observations about the double slit experiment and also about approach to chaotic behavior indeed suggests that the system is not completely deterministic. The findings also suggest that the statistical description of this non-determinism is analogous that in quantum systems.

   In ZEO quantum state as time= constant snapshot is replaced with a space-time surface as preferred extremal (PE) analogous to Bohr orbit. What comes in mind, is that the bouncing corresponds to "small" SFRs (SSFRs). The determinism of PEs is not quite exact that it would serve as correlate for what I call cognitive measurements [L30] as SSFRs. In the TGD inspired theory of consciousness, the loci of non-determism for space-time surfaces as analogs of soap filmds would serve as the seats of mental images quite universally and also represent conscious memories.

5. In this talk Bush interprets the Faraday wave induced by the motion of the droplet along the surface as a kind of pilot wave. In the TGD framework the counterpart of the pilot wave would be the magnetic body (MB) carrying $h_{eff} = nh_0$ phases quantum controlling the behavior of ordinary matter. The magnetic flux tubes assignable to the exteriors of vortex cores are proposed to be present in microscopic scale also below turbulence and to serve as correlates for the vorticity caused by the boundary conditions at the boundary of flowing liquid. Now these boundaries correspond to the boundary between air and liquid bath and air and liquid droplet and could explain how the gravitational magnetic body characterized by $\hbar_{gr}$ enters into the physics of the moving water droplet.

The results discussed in the talk of Bush and the article provide a benchmark test for the general picture provided by TGD and allows to sharpen the TGD view about QCC in quantum hydrodynamics (QHD).

4.1 Summary of the experiments

Consider first a brief layman interpretation of the experiments based on the Youtube lecture of Bush (`https://cutt.ly/xEk5Api`). I must apologize for possible mistakes: I am just a layman as far as hydrodynamics is considered. The description of Faraday waves (`https://cutt.ly/vEk6cSi` should be helpful for the reader.

4.1.1 Faraday waves

One considers a cylinder containing fluid and driven by a shaker, which is a piston, whose position varies in an oscillatory manner with some amplitude A and frequency f. At a certain critical frequency known as Faraday frequency $f_F = f/2$ a standing wave is generated at the surface of the water. This phenomenon is known as Faraday instability.

The parametric oscillator for an infinitesimal fraction of liquid surface is given by

$$\begin{array}{l} \frac{d^2x}{dt^2} + 2\mu\frac{dz}{dt} + \Omega^2(t)z = 0 \ , \\ \Omega^2 = \omega_0^2(1+\alpha(t)) \ . \end{array} \tag{4.1}$$

Here z is the vertical position of the fluid element, μ is the damping rate determined by viscosity of liquid, ω_0 and of shaker is the frequency of oscillation of the fluid element in absence of gravitational acceleration and $\alpha(t)$ is dimensionless oscillating parameter function. One could say that a harmonic oscillator with time dependent frequency $\Omega(t)$ under the damping of a viscous force is in question. Shaking defines the driving force feeding energy to the system.

The time dependent gravitational acceleration $g(t)$ is given in the moving frame of the shaker by the expression

$$g(t) = g + A\omega_0^2 cos(\omega t) = g(1 + \Gamma cos(\omega t)) \ . \tag{4.2}$$

Here A is the amplitude of the vibrations of the and $\omega = 2\pi f$ is its angular frequency of the shaker. From this one has $\Gamma = A\omega_0^2/g$. Note that ω_0 is determined by the properties of the fluid such as density and surface tension. The parameters involved are g, fluid density ρ, surface tension σ, and Faraday frequency $f_F \simeq f_0/2$.

For certain combinations of Γ and ω_0 resonance occurs so that the situation is unstable. The parametric resonance occurs for subharmonics $\omega_0 = \omega \simeq 2/n$. The lowest sub-harmonic corresponds to $n = 2$ and is studied in the recent case. In the recenf case one has $f = 50$ Hz.

The instability occurs in the parameter range

At $\Gamma = \Gamma_F = 4g$, a resonance occurs in the driving frequency range

$$\omega_{min} < \omega < \omega_{max}, \quad \Omega_\pm = 2\omega_0 \pm \sqrt{\Gamma\omega_0^2 - 4\mu^2} \ , \tag{4.3}$$

A standing wave formed at the instability and the damping rate and wave number $k = 2\pi/\lambda_F$ are related by $\mu = 2\nu k^2$, here ν is kinematic viscosity. Faraday wave length $\lambda_F = 2\pi\sqrt{2\nu/\mu}$ depends on the viscosity and friction.

Besides the standing wave, also propagating waves are possible. The instability depends sensitively on parameters like the meniscus at the walls of the vessel and the instability of the fluid layer characteristics and of driving frequency and amplitude can lead to spatiotemporal chaos.

4.1.2 Couder walker

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Floating droplets on vibrating bath were first described by by Jearl Walker in Scientific American in 1978. In 2005, bouncing droplets on vibrain bath were studied by Yves Couder and his lab they discovered most quantum analogs (`https://cutt.ly/TEk5XyN`). John Bush and his lab expanded upon Couder's work and studied the system in more detail.

The droplet can float (also surf), bounce at a single position and walk by bouncing. The essential condition is that no coalescence occurs. The air layer between droplet and water surface is believed to prevent the coalescence. Coalescence does not occur if the droplet does not touch the fluid surface: the air layer prevents this. For a bouncing droplet the frequency of bouncing determined by surface acceleration must be high enough in order to prevent the draining of the air from the layer. Bouncing could be seen as a kind of trampoline effect. Essential is that there is an air layer between droplet and water preventing the direct touching leading to coalescence. Since both the fluid and the droplet move with respect to air, there are surface layers involved and if quantum phenomena are involved, they might relate to the surface layers and the interaction. In the TGD framework, this suggests a possible connection with the proposed model of turbulence. For floating without coalescence, the surface layers should fuse to a single connected structure. The existence of some kind of mattress is suggestive. Mini vortices having interpretation in terms of closed flux tubes is a possible TGD based explanation. Even a surface layer giving rise to a mattress can be imagined. Below a critical acceleration, the droplet makes only a few bounces. Above the criticality the bouncing continues. As the acceleration increases the trajectory transforms from a straight line to chaotic trajectory.

The bouncing of the droplet induces the possibly propagating Faraday wave implying that the system has a memory. For high enough surface acceleration but still below the threshold for the formation of standing waves, the span of the memory increases and chaos is approached.

The initiation of a walking motion requires that the droplet meets the surface in a position in which the surface wave has a large enough slope. The bouncing preserves the particle's momentum component parallel to the surface. If a vertically moving particle meets the surface in a position with non-vanishing slope, it preserves the momentum component parallel to the surface.

After that the particle makes an approximately parabolic orbit and if it meets the surface in a position of a slope of the correct sign, the reflection preserves the parallel momentum component.

From the TGD point of view it is important that there is energy feed and the system is near criticality defined by the Faraday threshold. Also walking is possible in a range of surface accelerations.

Since the bouncing affects the surface and the bouncing indeed creates the Faraday wave. The process is non-Markovian and hereditary since the recent state of the surface is determined by previous bounces. The memory traces about bounces decay exponentially but at critical surface acceleration the memory span becomes formally infinite.

In the lecture of Bush the trajectory equations for both bouncing and surfing are given explicitly. Newton's equation involves beside drag force what is called wave force, which is gravitational force proportional to the gradient of height of the surface which for the walking is asum over exponentially decaying heights changes induced by the previous collisions and for surfing an integral. The collisions serve as instantaneous point sources for a Faraday wave. The collisions approach at the surfing limit continual touching and sum is transformed to an integral. The naive expectation would be that the wave force is present only when the drop (or its air layer) touches the water surface but according to the formula it is present all the time. The equation of motion is however written in an inertial frame of accelerating surface which depends on the position at the surface so that the wave force term is analogous to inertial force like centrifugal force.

4.1.3 Hydrodynamic quantum analogs

There is a long list of hydrodynamics quantum analogs and many of them are discussed in the lecture of Bush (`https://cutt.ly/xEk5Api`). Also the Wikipedia article (`https://cutt.ly/TEk5XyN`) discusses them .

1. Single particle diffraction and interference were studied already by Couder and Fort. According to the Wikipedia article, Bohr and Andersen, and the groups led by Bush and Batelan did not see the interference patterns. Bush however mentions the effects and informs that the experiments have been carried out later and the claimed effects have been found.

   The diffraction was studied in both single slit and double slit experiments. In a single slit experiment a 3 peak structure was observed. This differs from Fraunhofer diffraction appearing in a quantum mechanical situation. If the motion of the droplet is deterministic with the measurement resolution for initial state, this pattern should not be observed and random fluctuations in the experimental conditions should not produce this kind of structure. The diffraction angle also tends to favor quantized values.

In double slit experiment the diffraction pattern is modified due to the presence of the second slit. This can be understood at a qualitative level since the Faraday wave is affected by the presence of the second slit. Bush suggests that the differences from the quantum case are due to the fact that the droplet is not analogous to a plane wave as in the quantal case. Furthermore, the ratio of λ_F analogous to the de-Broglie wavelength $\lambda_{dB} = \hbar/p$- to the width of the slit is much larger than in quantum scale when it is of order 10^3.

2. Droplets for bound states analogous to molecules. Also walking droplets can form pairs. Bond lengths are quantized in terms of λ_F interpreted as analog of λ_{dB}.

3. The analog of quantum tunnelling through a barrier has been observed. The barrier is now a region of smaller depth. The droplet typically reflects from the barrier but sometimes also transmission takes place. There is an exponential decrease with the width of the barrier.

4. The analog of Zeeman splitting is observed for a bath rotating with a frequency Ω. $2m\Omega$ plays the role of a magnetic field. For a bound state of droplets, the distance between the droplets changes and the sign of the change depends on the relative sign, the direction of the rotation of the bath and of the droplet.

   Bush mentions also the notion of a hydrodynamical analog of spin realized in terms of the direction of the rotational motion of the droplet. The motivation is that there are only two directions of rotational motion and if one has angular momentum, there would be at least 3 different rotational states, with one state without splitting. If the rotational motion of the droplet were preserved at the limit of vanishing Ω, the interpretation as spin would become more convincing.

5. Walkers at circular orbits in a rotating frame are studied. For circular orbits in the rotating frame the centripetal and Coriolis accelerations cancel each other: this gives $\rho v^2/R = 2\rho\Omega v$ (here one must distinguish between rotation frequencies ω and Ω for particle *resp.* bath). This gives $v = 2\Omega R$.

   A quantization of R as in terms of λ_F is observed. According to the lecture, the orbital radii obey the analog of the formula for the cyclotron energies: $R = (n + 1/2)\lambda_F$. Note however that for Landau levels in a constant magnetic field, one has the formula is $R \propto \sqrt{n}$ as one finds from Bohr quantization of rom quantization of the magnetic flux for a constant magnetic field.

   One can however consider the possibility that Ω defines a magnetic field which depends on the distance from the rotation axes. One would actually expect that Ω for a liquid depends on this distance. Assuming that $qB_Z = 2m\Omega f(\rho/\rho_0)$, the quantization of magnetic flux would give $q2m\Omega \int_{\rho_0}^{\rho_n} f(\rho/\rho_0)\rho d\rho 2\pi = n\hbar eff$. This gives $f(\rho) = \rho_0/\rho$ and

$$\rho_n = n\frac{\hbar eff}{m2Q\Omega\rho_0^2} \quad . \tag{4.4}$$

   The vector potential qA_ϕ would be of form

$$qA_\phi = 2m\Omega log(\frac{\rho}{\rho_0}) \quad . \tag{4.5}$$

   In the TGD framework $v \propto A$, where A is Kähler potential is proposed and this would mean that the velocity of the liquid motion varies very slowly and gives rise to a spirals $\phi = (k/\rho)$.

   Given a quantized radius is observed for several values of Ω so that one has plateaus. Could the parameter $\frac{\hbar eff}{m\Omega\rho_0^2}$ be nearly independent of Ω? This would be the case for $\rho_0^2 \propto \hbar_{eff}/m\Omega$. Could this formula be interpreted in terms of Uncertainty Principle?

6. Also unstable rotational orbits with radii smaller than $\lambda_F/2$ are observed. The motions become chaotic for a large acceleration parameter and the jumps between orbits which tend to have a quantized radius of curvature have been observed so that statistical distribution for the radii becomes multimodal.

7. One can also mimic central force by using ferrofluids and magnetic fields to create central force. In this case one obtains analogs of orbitals labelled by integer value average angular momentum and radius R.

   The instantaneous pilot wave approaches the mean wave field at high Me.

8. Quantum corral is a system in which electrons are inside a circular corral formed by negatively charged ions. The hydrodynamical analog of the quantum corral is possible [D4]. In the corral the depth is smaller. Statistical description gives rise to a similar interference pattern as in the case of quantum corral with λ_{dB} replaced with λ_F. A correlation between position and fluctuation speed bringing in mind the Uncertainty Principle is found.

9. One can also study the analog of scattering. The first example is a walker interacting with a pillar which is represented by a water with smaller depth (surface Schlieren imaging). The surprising find was that the scattering orbit was a logarithmic spiral. It can be produced by an analog of either Coriolis force or Lorentz force $2\pi\gamma_B v \times \Omega$ if $2\pi\gamma_B\Omega$ serves as an analog of the magnetic field. Here Ω is the instantaneous angular velocity with respect to the pillar

   What looks strange is that the walker would create this force associated with the pillar. In the TGD framework the magnetic field would be a Z^0 magnetic field at the MB of the system and would determine the motion of the particle and thus also the value of Ω. In the TGD framework the process would correspond to a phase transition generating dark matter at the Z^0 magnetic flux tubes.

   The second analog is the analog of Friedel oscillations. Instead of a pillar, one studies scattering from a well realized as a region in which the depth of water is larger. In this case long range statistical signature is found to resemble the square of probability density for quantal Friedel oscillations. Also now the λ_F replaces λ_{dB}.

The summary of Bush about the findings is roughly as follows.

1. There are 3 time scales. The fast time scale of bouncing, the intermediate time scale of surfing and the long term time scale for the emergence of statistical behavior. Bush speaks of a mean pilot wave at this limit. There are even indications for the analog of mode superposition. In the TGD framework the counterpart of the pilot wave would be taken by the MB.

2. Resonant interaction between walker/surfer and quasi-chromatic Faraday wave created by droplet is essential.

3. Quantized states emerge from dynamical constraints.

4. Memory effects due the fact that the walker can be said to determine the Faraday wave are basically responsible for the quantum-like behavior.

Bush suggests the following three basic paradigms.

1. Chaotic pilot wave dynamics is proposed. It would involve intermediate switching and multimode quantum-like statistical behaviors.

2. In-line oscillations involve speed fluctuations leading to a correlation between position and speed bringing in mind the Uncertainty Principle. Faraday length $\lambda_F = 2\pi\sqrt{2\nu/\mu}$ analogous to λ_{dB} serves as a statistical signature and the challenge would be to understand its origin. The fact that it seems to be the same at least for a given fluid unlike in wave mechanism where it is proportional to the inverse $1/p$ of momentum, suggests that it is more like Compton wave-length depending on the droplet mass m only. In fact, it could be independent of even m.

   In TGD framework gravitational Compton length $\Lambda_{gr} = \hbar_{gr}/m = GM/v_0$ where M is naturally the mass of Earth and $\beta_0 = v_0/c = 1/2$ seems like a good guess implying that Λ_{gr} is Schartschild radius of Earth about .9 cm might be a possible interpretation. If this is the case, β_0 could code for the variation of ν/μ. Λ_{gr} does not depend on the mass of the droplet, which might serve as a test.

3. Quantized random walks are also a central element. Random walks have steps equal to λ_F, which seems to be a universal feature. Diffusivity is equal to $U\lambda_F = U\hbar_{gr}/m$.

4.2 TGD based view

4.2.1 Quantum classical correspondence

Quantum classical correspondence (QCC) in the TGD framework is much stronger than in standard quantum theory, where it is only approximate (stationary phase approximation). In zero energy ontology (ZEO), the quantum state is a superposition of classical deterministic time evolutions - that is space-time surfaces that are minimal surfaces of very special kind being also extremals of Kähler action: I talk about preferred extremals.

QCC implies many things.

1. Space-time surface is like Bohr orbit, meaning quantization rules. The findings of Bush *et al* demonstrate these kinds of rules at the level of HD.

2. One can assign to each SFR a superposition of classical evolutions and in good approximation single time evolution, the "average" one. In particular, BSFR with the change of arrow of time, has as a correlate time reversed classical time evolutions which leads from the final state 3-surface to the past. For an observer with a standard arrow of time it looks like deterministic time evolution leading to the final state. This is what Minev *et al* observed in atomic physics.

3. This implies that SFRs look classical. The world looks classical in all scales although SFRs occur in all scales by h_{eff} hierarchy. Of course, also the basic paradox of quantum measurement theory disappears by ZEO.

4.2.2 h_{eff} hierarchy and gravitational Planck constant

h_{eff} hierarchy realized at the level of magnetic bodies (MBs) acting as controlling agents of lower levels, implies that BSFRs and SSFRs occur in all scales. In particular, hydrodynamics systems should show Bohr quantization and various other quantum effects.

What could these effects be?

1. The interpretation of ordinary quantum measurements relies on classical physics. Without QCC we could not test quantum theory, since everything is based on classical physics at the level of experiment. All the statistical aspects of quantum measurement should have classical correlates.

2. For instance, in double slit experiments you have incoming beam replaced with water droplets in the experiments of Bush *et al.* 3 peak interference pattern is observed and a possible explanation would be in terms of Bohm's pilot wave. One could even argue that non quantum theory is needed. To me this proposal is obviously wrong.

   The classical interference patterns could be the statistical representation for the outcomes of SFR - actually BSFR at some level of MB hierarchy - which indeed occurs. The only difference between the ordinary double slit experiment and that described by Bush *et al* is that their experiment the h_{eff} at MB is much larger since the scale is dramatically larger. The first guess is that $h_{eff}/hbar$ is of order 10^{14} (roughly). An educated guess, to be discussed below, is that the scale would correspond to $hbar_{gr} = GMm/v_0$, where M is Earth's mass and $v_0/c = 1/2$. $v_0/c = .92$ turns out be a more realistic guess!

3. Viscosity and magnetic diffusivity could be proportional to $\hbar_{eff}/m$ as proposed inthe TGD based model for the generation of HD and MHD turbulence. Nelson has proposed in his model of stochastic quantum theory that $hbar_eff/m$ plays the role of diffusion constant.

4. Bush represents many examples how water drop experiments provide a statistical representation analogous to interference pattern represented in terms of wave function modulus squared. Double slit experiment is only one example.

What could the value of h_{eff} be?

1. The Faraday wave length

$$\lambda_F = 2\pi\sqrt{2\nu/\mu}$$

should be equal to either the analog of Compton wavelength $\Lambda_c = \hbar_{eff}/m$, m the mass of the water droplet or to de Broglie wavelength $\lambda_{dB} = \hbar/mv$. λ_F does not depend on the velocity of the droplet so that only Compton wavelength is a possible interpretation.

The problem is that there is no dependence on the mass of the doplet either. A further problem is that in the hydrodynamical model of the Faraday waves λ_F is determined in the model considered by the properties of the fluid, that is friction and kinematic viscosity. This model could be of course wrong.

2. The only remaining possibility in the TGD framework is that one has

$$\hbar_{eff} = \hbar_{gr} = \frac{GMm}{v_0} \quad , \tag{4.6}$$

where $\hbar_{gr}$ is the gravitational Planck constant introduced by Nottale [E1] [L22] and also appear in the TGD based model of superconductivity and superfluidity [L17]. This would give

$$\lambda_F = \lambda gr = \frac{GM}{v_0} = \frac{r_s(M)}{2v_0} \quad , \tag{4.7}$$

where $r_s(M)$ is Schwartschild radius associated with mass M. M is naturally the mass of Earth. The minimum value of λ_{gr} corresponds to $\beta_0 = v_0/c = 1$ and is $\lambda_{gr} = r_s(M)/2$. Earth's Scwartschild radius is 8.7 mm so that one would have $\lambda_F = 4.35$ mm.

The value of Λ_F for the system studied in the analog of quantum corral by Bush *et al* is 4.75 mm [D4] and about 10 per cent larger than the minimal value suggesting that $\beta_0 = v_0/c \simeq .92$! The error is about 10 per cent.

3. One can argue that this is a mere coincidence. The usual reductionist thinking is that the ν and μ appear as dissipative parameters in hydrodynamics and their values emerge from quantum theory in atomic scales. One can of course ask, whether the relationship

$$\frac{2\nu}{\mu} = (\frac{GM}{v_0})^2 \quad . \tag{4.8}$$

could emerge from a microscopic theory. The alternative option suggested by the numerous grave difficulties of the description of the hydrodynamic turbulence is the description of viscosity and friction require new quantum theory predicting quantum coherence in even astrophysical scales?

4. If this correct prediction is not a mere nasty coincidence, it would mean an instantaneous breakthrough for the TGD view about quantum gravitation as a macroscopic and even astrophysical phenomenon. The Equivalence Principle behind $\hbar_{gr}$ would become a cornerstone of models thought to have nothing to do with quantum gravitation.

The only parameter that can be varied in the prediction is β_0. One could measure λ_F for different liquids to see whether v_0 codes for the properties of the liquid or whether λ_F is independent of the liquid so that the classical model for Faraday waves could be wrong.

It might be also possible to measure λ_F in Mars for which mass is $.107M_E$ so that λ_{gr} should be by a factor .107 smaller unless v_0 is scaled down by factor .107.

5. It is needless to emphasize how profound implications the inherent connection between dynamics of systems with a size Earth and of size of liquid drop would have. The dependence of the liquid properties determining λ_F on the mass of the planet is totally unexpected and it could be that the classical model is wrong (this is the case in the case of turbulence).

4.2.3 Does the turbulence of air at the surfaces of the droplet and water bath prevent the coalescence?

The mechanism preventing the coalescence of the water droplet with water bath is poorly understood and here macroscopic quantum gravitation could enter the picture.

1. The magnetic flux tubes assignable to the non-dissipating exteriors of vortex cores with gradient flow around the axis of the vortex and assumed to carry Z^0 magnetic fields at their MBs are proposed to be present in microscopic scales also below the criticality for the development of turbulence. They would serve as a microscopic representation for the vorticity caused by the boundary conditions at the boundary of flowing liquid. The cores of Z^0 vortices would be monopole flux tubes and the shear would be concentrated at them.

2. In the recent case the boundaries are between air and liquid bath and air and liquid droplet and the dark matter at the magnetic bodies of air vortices could explain how the gravitational magnetic body characterized by $\hbar_{gr}$ enters into the physics of the moving water droplet.

3. The air layer and perhaps its separation from the surfaces of the liquid drop and liquid bath is analogous to the separation occurring in the generation of turbulence in a liquid flow past a solid body. The TGD based proposal is that in this case the formation of microscopic vortices plays a key role in the separation. The separation of the air layer prevents the touching of the droplet and fluid surface and the coalescence. Circular vortices of air flow analogous to smoke rings would represent the shear due to the radial variation of the vertical velocity component of air flow at the surface of liquid. They would also provide a representation for the separation.

4. The diameter of the circular vortex tube would be naturally $\lambda_F = \lambda_{gr}$. Could the spherical Faraday wave correspond to expanding concentric air vortex rings with radii coming as multiples of Λ_{gr} as a representation of the shear of air. Could they form the mattress preventing direct touch and coalescence?

4.2.4 Should one replace pilot wave with magnetic body?

In his talk Bush interprets the Faraday wave induced by the motion of the droplet along the surface as a kind of pilot wave providing a stastistical description of the system in long time scales resembling the description provided by Schrödinger amplitude. In particular, λ_F appears as a statistical signature in this description.

In the TGD framework the role of the pilot wave would be taken by the magnetic body (MB) of the system carrying $h_{eff} = nh_0$ phases quantum controlling the behavior of ordinary matter. In hydrodynamics magnetic flux tubes assigned with vortices would carry in their cores Z^0 magnetic fields proportion to induced Kähler form whereas the ordinary magnetic field vanishes.The exterior of the core would have vanishing Z^0 magnetic field but Kähler gauge potential would be gradient only in the exterior regions (note that symplectic transformations leaving induced Kähler form invariant are not genuine gauge transformations since they change the induce metric). The simplest model assumes that the Weinberg angle $p = sin^2(\theta_W)$ vanishes in this phase. The interpretation is that below the dark weak scale the electroweak symmetry breaking is absent.

What is encouraging, that the analog of rotation frequency Ω appears in the role of the magnetic field in several quantum-like phenomena discussed by Bush. The prediction is indeed that MB controls the fluid flow and that Ω, that is circulation, is proportional to B_Z whereas velocity is proportional to the vector potential of Kähler form. In one experiment, the instantaneous rotation frequency Ω around a "pillar" causes an analog of Lorentz force. In a second experiment the rotation frequency of the liquid bath gives rise to the analog of Zeeman splitting and analogs of cyclotron orbits.

4.2.5 Classical determinism is not exact

The analog of double slit experiment suggests classical non-determinism. Water drops with the same initial state (modulo measurement resolution) do not behave always in the same manner. If classical non-determinism were exact, this should not be the case.

The work with minimal surfaces [L30] demonstrated that classical non-determinism is probably not quite exact.

1. Space-time surfaces are analogous to soap films spanned by frames (which correspond to initial and final 3-surfaces plus intermediate partonic 2-surfaces) and already for soap films the same frame can allow several soap films. Same occurs now but because of boundary conditions at boundaries of CD (perceptive field) the non-determinism is extremely restricted.

2. There is a finite, discrete non-determinism associated with what I identified as the TGD counterparts of reaction vertices and "very special moments in the life of self". This finite determinism would be the counterpart for quantum non-determinism for space-time surfaces inside a single CD.

3. This non-determinism could have as an adelic counterpart the non-determinism of p-adic differential equations due to the fact that integration constants as functions with a vanishing derivative are not genuine constants as in real case but depend on finite number of the pinary digits. This non-determinism would correspond to cognitive non-determinism having a real counterpart. This non-determinism would correspond to what I call cognitive determinism occurring for the representations of Galois group [L14, L19]

Therefore, if one has a beam of identical droplets in the initial state, they behave differently and one could obtain in the long run a representation for quantum mechanical interference pattern as an analog of the modulus square for a wave function.

4.2.6 Does quantum entanglement have a classical representation?

Can quantum entanglement be represented as a property of the space-time surface?

1. In the TGD framework quantum entanglement has a classical correlate/prerequisite. The flux tube pairs connecting particles as 3-surfaces would serve as prerequisites for the entanglement. This is analog ro ER-EPR correspondence: I actually proposed flux tubes instead of wormholes in GRT sense much before ER-EPR correspondence.

2. The reduction of entanglement in quantum measurement/SFR could correspond to the splitting of a flux tube pair connecting two systems to two U-shaped flux tubes associated with particles or more generally decay of the space-time surface representing systems in measurement interaction to two disjoint space-time surfaces.

   Putting the interaction Hamiltonian on could correspond to the formation of flux tube pair by reconnection and after that the usual description by unitary evolution would be a reasonable model.

3. Entanglement has also a purely classical analog. For instance, superposition of spherical harmonics for a classical field can be seen as an entangled state. At the level of WCW this is also possible.

4. The crucial notion is however the tensor product of Hilbert spaces. I find it impossible to imagine any classical counterpart for it. An entangled two-particle state can have as a classical prerequisite two 3-surfaces connected by flux tube but I am unable to imagine how entanglement could be representable for *single* space-time surface. One must allow quantum superposition of these pairs of this kind of 3-surfaces connected by a flux tube. One has entanglement in WCW degrees of freedom. WCW is needed for entanglement. I see no way to avoid this.

   By the way, in TGD quarks are the only fundamental particles. One does not have fundamental bosons although one can assign to the deformations of 3-surfaces analog of Kac-Moody algebra involving bosonic oscillator operators.

   Quark entanglement due to Fermi statistics is always maximal and cannot be reduced in SFRs: something totally trivial but not realized by most colleagues. Only entanglement at the level of WCW can be reduced. This came as a surprise also to me!

The natural entanglement associated with hierarchies of normal subgroups of Galois groups can be reduced and is reduced in cognitive measurements to which SSFRs can correspond. Cognitive measurement cascades become possible. SSFR is a counterpart for analysis. BSFR is the intuitive eureka moment from the point of view of cognition [L14, L25].

4.2.7 Does Fermi statistics have a classical correlate?

A fermion with momentum p corresponds to a point of $X^4 \subset M^8$ and $M^8 - H$ duality as the TGD counterpart of momentum-position duality maps this point to a point at the 3-surface at either light-like boundary of CD in H depending on sign of the energy. One can put to the same point p several quarks with different spin or electroweak spin. This is not what one would want , that is one fermion per point.

What about twistor lift which provides a geometric description of spin as analog of partial waves in the twistor sphere: twistor space is indeed locally a product of space-time and twistor sphere S^2. Quantization axis of spin means a choice of one direction that is a point of S^2. But both the point and its diametric opposite give the same quantization axis. The interpretation would be that the two choices correspond to two spin directions for fermion. This makes sense for both spin and electroweak spin. The Fermi statistics would mean geometrically that a single point of twistor space can contain only a single fermion.

Twistor lift has a counterpart at the level of M^8 as I realized quite recently. At the level of M^8 twistor lift Fermi statistics would have a classical correlate at the M^8 level and would mean that one cannot put two fermions at the same space-time point. One can say that wave function is involved but there is a localization to a single point representing momentum p and spin.

5 Trying to understand viscosity and critical Reynolds numbers

It is interesting to see whether the critical Reynolds number could be interpreted in terms of criticality for the phase transition generation of dark flux tubes with $h_{eff} > h$ assignable to the flux tubes controlling vortices associated with them. One can also consider the possibility that the angular momenta of dark flux tubes and vortex compensate for each other.

5.1 The notion of viscosity

Kinematic viscosity (`https://cutt.ly/iRuXTsH`) for liquid can be fitted by using the expression

$$\nu(\frac{h}{m},\frac{T}{T_b}) = \frac{h}{m}\times f(\frac{T_b}{T}) \ , \quad f(\frac{T_b}{T}) = exp(3.6\frac{T_b}{T}) \ . \tag{5.1}$$

(note that one has $c = 1$). T_b is the boiling point for the liquid and m is the average mass of the liquid particle. The expression makes sense between freezing point and boiling point. The model is ad hoc and it is not especially good. The two essential features are proportionality to h suggesting quantum origin the rapid increase with temperature below the boiling point.

From the tables of viscosity (`https://www.engineersedge.com/fluid_flow/kinematic-viscosity-table.htm`), one finds that a natural unit for viscosity is CentiStokes = 10^{-6} m^2/s. CS/c corresponds to a size scale about 3×10^{-15} m/s, which is about $2.3\lambda_p$ where λ_p is proton Compton length. The factor having an exponential temperature dependence brings in mind the inverse of Boltzmann exponent with $3.6T_b$ having a possible interpretation as the energy for a transition of some kind. The formula explains qualitatively the variation of ν by roughly 4 orders of magnitude. This would correspond to a variation of T_b/T by factor 2.9.

5.2 Critical Reynolds numbers

The value Re_{cr} of the critical Reynolds number for the laminar-turbulent transition varies in a wide range (`https://www.ecourses.ou.edu/cgi-bin/ebook.cgi?topic=fl&chap_sec=09.3&page=theory`).

1. For a fully developed pipe flow turbulence with pipe diameter D the value is $Re_{cr} \sim 2300$.
2. For a flow over a flat plate the transition from laminar to turbulent flow occurs at critical distance $D = x_{cr}$ downstream from the leading edge for $Re_{cr} \sim 5 \times 10^5$.

A hydrodynamical model predicts for the laminar flow past plate for the thickness of the liquid layer thickness δ as function of the distances x from the leading edge

$$\frac{\delta}{x} = \frac{5}{\sqrt{Re_x}} \quad , \quad Re_x \leq Re_{x_{cr}} \simeq 5 \times 10^5 \quad . \tag{5.2}$$

For a turbulent flow past a flat plate of finite length L, the prediction is

$$\frac{\delta}{x} = \frac{.38}{Re_L^{1/5}} \quad , \quad 5 \times 10^5 \leq Re_L < 10^7 , \tag{5.3}$$

Above $Re_{cr} = 10^7$ only a thin boundary layer forms and the flow develops a thin wake.

5.2.1 Critical Reynolds number as a measure for the ratio of units of angular momentum for the final and initial state

The critical Reynolds number could be essentially a measure for the ratio of the units of dark and ordinary angular momentum. The following estimate suggests that this might make sense.

In the case of laminar flow and using the formulas above, one can estimate the angular momentum associated with a particle of flow as

$$L = m\delta \times U \quad , \quad \delta = 5\sqrt{\frac{\nu}{u}}\sqrt{x} \quad . \tag{5.4}$$

Here x is the length measured from the leading edge of the plate.

At the critical value of $\delta/x = 5/\sqrt{Re_{cr}}$ one cast this equation into the form

$$L = 5m \times Re_{cr}\nu \quad . \tag{5.5}$$

$L = \hbar_{eff}$ would give for the transition

$$Re_{cr} = \frac{\hbar_{eff,f}}{\hbar_{eff,i}} \quad \text{for} \quad \hbar_{eff,i} = 5m\nu \quad . \tag{5.6}$$

The estimate is of course very rough. What is however essential that the identification of kinematic viscosity in terms of h_{eff} could make sense.

Note that one can associated to the vortex a Reynolds number

$$Re_V = \frac{U\delta}{\nu} = \frac{\delta}{D} \times Re_{cr} = 5Re_{cr}^{1/2} \quad . \tag{5.7}$$

5.3 Laminar-turbulent transition as a quantum phase transition?

Could one understand the laminar-turbulent phase transition in terms of quantum hydrodynamics at the level of MB in terms of the formation of $h_{eff} > h$ flux tube structures accompanying the vortices?

1. Suppose that the kinematic viscosity related to angular momentum it makes to speak of "dark" viscosity ν_{dark} and that ν_{dark} decomposes to a product $\hbar_{eff}/m$ with the same temperature dependent factor $f(T/T_b)$ as the ordinary ν. Assume that the critical Reynolds number $Re = UD/\nu$ corresponds to a phase transition $h \rightarrow h_{eff}$ making possible a formation of vortices accompanied by pairs of monopole flux tube associated with the core of vortex and non-monopole Lagrangian flux tubes associated with the exterior of the vortex.

2. The transfer of angular momentum from the main flow to vortices is enough to take care of angular momentum conservation. Also the quantized dark angular momentum $m\hbar_{eff}$ at MB could compensate for the angular momentum of the vortex. In this case, the angular momentum of vortices could be considerably larger than one might estimate from the change of the angular momentum of the main flow. This option is of special interest in astrophysical systems.

3. Could the parameter UD at criticality have an interpretation as minimal angular momentum $\hbar_{eff}/m$ for the vortex? Could it be that the angular momentum of the fluid particle of the flow in the region $x \geq x_{cr}$ has angular momentum larger than $\hbar_{eff}$ so that dark magnetic flux tube so that the particle can transform to its dark variat at magnetic flux tube.

The basic question is what the fluid particle is. The intuitive picture is that the increase of viscosity means increase of the fluid particle mass and thus interia. The size of the fluid particle would be caused by the increase of h_{eff} at the MB controlling the ordinary matter in the flow.

If dark matter is formed it could emerge as fluid particles with mass larger than say proton mass which appears as factor h/m in the formula for ν involving also temperature dependent factor increasing at higher temperatures. The increase of the kinematical viscosity ν could mean that the mass m_f of a fluid particle increases with temperature. Suppose that one has $\nu(T/T_b) = \hbar_{eff}(T)/m_f(T)$. If ν would not depend on temperature one would have $\nu(T/T_b) = \nu(1)$, and $\hbar_{eff}(T)$ should be proportional to $m_f(T)$. This is of course not true since the $\nu(T)$ increases with the decreasing temperature. In the range between boiling point and freezing point the change is not however very large.

One should have

$$\frac{f(T/T_b)}{f(1)} = \frac{\hbar_{eff}(T)}{\hbar(T_b)} \times \frac{m(T)}{m_f(T_b)} \geq 1 \quad . \tag{5.8}$$

The increase of the viscosity would be indeed due to the formation of larger mass units due to long range correlations induced by MB with larger value of h_{eff}.

5.4 Nottale hypothesis and turbulence

Nottale hypothesis states that it makes sense to talk about gravitational Planck constant $\hbar_{gr} = GMm/v_0$, where M can be the Earth's mass M_E. The gravitational Compton length is given by $\Lambda_{gr} = \hbar_{gr}/m = GMm/v_0 = r_s/2\beta_0$. The "gravitational" kinematic viscosity would be given by $\nu_{gr} = \Lambda_{gr}c$ and independent of the mass m of the fluid particle unless β_0 does not depend on it.

Λ_{gr} does at all on the particle mass. This looks strange. The ratio $m_p/m_e = 1880$ is near to $2^{11} = 2048$ appearing defined by $v_0 = simeq 2^{-11}$ in the Nottale's model for the 4 inner planets. This inspires the question whether the proportionality $\beta_0 = m/m_p$ might hold true approximately and realize approximately the expectation that gravitational Compton length is proportional to $1/m$. For instance, could β_0 correspond to the ratio of the p-adic length scales $L(k) \propto 2^{k/2}$ for proton and for the particle with mass m. For the electron one has $k = 127$ and for proton $k = 107$ so that the prediction would be $\beta_0 = 2^{-10}$ and by factor 2 too large.

Interestingly, for a neutrino mass about .1 eV this hypothesis would give $\Lambda_{gr} \sim 200$ AU which is the length of the heliospheric magnetotail at the side of the downwind.

5.4.1 Encouraging observations

There are several encouraging observations.

1. Λ_{gr} for Earth appears both the TGD based model of superconductivity [L17] and in the model for the hydromic quantum analogues as a correct prediction for the Faraday wavelength.

   Λ_{gr} could relate to the length or radius of the vortex. Since the MB of the system is responsible for the generation of coherence as induced quantum coherence, the simplest interpretation would be in terms of the length of the dark magnetic flux associated with the vortex.

2. The Nottale model for the inner planetary orbits assumes $\beta_0 \simeq 2^{-11}$. From Schwartscild radius of Sun one has for the gravitational Compton length of Sun $\Lambda_{gr}(Sun) = GM_{Sun}/v_0 =$ 6 Mm to be compared with the radius $R_E = 6.4$ Mm of Earth. This would suggest a dark graviton BEC in the scale of Earth and a deep connection between the gravitational physics of Earth and Sun.

In MHD, magnetotail is analogous to a wake of hydrodynamic flow past a body. The length of the magnetotail is about $D_R \simeq 10^3 R_E$: "10^3" suggests that $\beta_0 = 2^{-11}$ appearing in $\hbar_{gr}$ for the inner planets is involved.

If the parameter UD appearing in Re corresponds $\nu_{gr} = \hbar_{gr} c/m\Lambda_{gr} c$, one has $D = \Lambda_{gr} c/U$. The velocity U of the solar wind varies in the range 300-800 km/s, that is $U/c \in \{2 - 5.4) \times \beta_0$, where $\beta_0 = 2^{-11}$, which is perhaps not an accident. $U = 4 \times 10^2$ km/s serves as a nominal value. $\Lambda_{gr}(Sun) = 6 \times 10^3$ km for $\beta_0 = 2^{-11}$ and for the nominal value of U gives the estimate $D = 700 R_E$ to be compared with $D_R \sim 10^3 R_E$.

One can look at the situation also in the case of solar magnetotail. The solar magnetotail has length about $D_R = 200$ AU ($AU \simeq 2.3 \times 10^4 R_E$) at the downside of the flow. The center of the Milky Way could contain the source of the galactic wind defining the mass M appearing in $\hbar_{gr}$. One can imagine two options.

1. The mass appearing in $\hbar_{gr}$ for the galaxy could be the total mass M_{MW} of the Milky Way. The estimates forM_{MW} vary in the range $M_{MW}/M_{Sun} \in [10^{11} - 10^{12}]$ and are based on the halo model of dark matter. Dark energy and matter are estimated to contribute about 95 per cent to the mass of the Universe.

   In the TGD framework, the flat velocity spectrum for stars rotating around galaxies is explained in terms of dark cosmic strings predicting automatically flat velocity spectrum. Since the galactic wind from the galactic jet emerging from the galactic blackhole-like entity should not affect to the gravitational field associated with solar magnetotail, the estimate for the visible mass of the galaxy reduces by a factor $\sim .05$ to $M(M_{MW}/MSun = 5.0 \times 10^{10}$ giving for the Schwarschild radius the estimate $r_S(MW) = 15 \times 10^{10}$ km. The estimate for the ratio $r_{S,MW}/D_R$ is $r_{S,MW}/D_R = 5.0$.

   The estimate of the ratio D_{pr}/D_R for the predicted value D_{pr} of D is

$$\frac{D_{pr}}{D_R} = \frac{r_{S,MW}}{D_R} \times \frac{c}{U\beta_0} \simeq 5 \times \frac{c}{U\beta_0} \quad .$$

   By $c/U\beta_0 \geq 1$, $D_{pr}/D_R \geq 5$ is true even for ($\beta_0 = 1, U = c$). Of course, the idea that the galactic wind would blow with the speed of light, does not seem plausible.

2. The galactic wind could correspond to a galactic jet emerging from the blackhole-like entity in the center of the Milky Way having mass about $4 \times 10^6 M_{Sun}$. In this case, r_S is reduced by a factor 10^{-6} and one obtains $D_{pr}/D_R = (r_{S,MW}/D_R) \times (c/U\beta_0) \simeq 10^{-6} \times (c/U\beta_0)$. If $\beta_0 = 2^{-11} \simeq m_e/m_p$ appears as a universal parameter then a good guess is ($\beta_0 = 2^{-11}, U/c = \beta_0$). For this guess, the ratio equals unity.

Remark: The mass of the Moon is $.012 M_E$. For $\beta_0 = 1$, this would correspond to $\Lambda_{gr} \simeq 10^{-4}$ m, which could be some biological length scale.

5.4.2 Does the transition to turbulence correspond to a large change of h_{eff}?

The simplest option is that the variation of β_0 explains the temperature variation of kinematic viscosity in terms of a slow variation of $\hbar_{eff} \leq\leq \hbar_{gr}$. h_{gr} is not a plausible candidate for understanding the kinematic viscosity but can be replaced with its electromagnetic analog $\hbar_{em}$ or Z^0

analog $\hbar_Z$. Z^0 option is attractive in hydrodynamics whereas the electromagnetic analog might have a role in MHD.

In the transition to turbulence, a dramatic change of h_{eff} seems to take place.

1. Are both $\hbar_{eff}$ and the mass m_f of the fluid particle scaled up by Re_{cr} so that ν would remain invariant? In the case of $\hbar_{gr}$ this would be naturally the case.

2. Is only $\hbar_{eff} = \hbar_{gr}$ scaled up by Re_{cr} so that $\nu = \hbar_{eff}/m_f$ would be scaled up by Re_{cr}? If one accepts the notion of gravitational quantum coherence, one can consider the change of M and Earth mass M_E and solar mass M_{Sun} appear as natural candidates.

5.4.3 Could critical Reynolds numbers be understood in terms of the Nottale's hypothesis and its generalization?

One can try to understand the two critical Reynolds numbers in terms of $\Lambda_{gr} = GM/v_0$. Assuming Nottale's formula and the proposed connection between $\hbar_{eff}$ and ν, the ratio M/β_0 would change at criticality by factor Re_{cr}. The masses of Earth and Sun are natural candidates to consider. The critical quantum numbers depend on the geometry of the flow but this could be explained by the change of β_0.

1. For the pipe flow, one has $Re_{cr} = 2300$. Perhaps it is not a mere accident that $Re_{cr} = 2300$ is not too far from $1/\beta_0 = 2^{11} = 2048 \sim m_p/m_e$ associated with the inner planets of the Solar system. If the initial state corresponds to $\beta_0 \simeq .92$ for the initial state as suggested by the model for the quantum-like aspects of hydrodynamics, one has $Re_{cr} = 2226$ and the error .5 per cent.

   Could the transition to a turbulent pipe flow correspond for the final state to $\beta_0 \simeq 1 \rightarrow 2^{-11}$ for $\Lambda_{gr} = GM_{Sun}/\beta_0 \simeq 3.2km$, $\beta_0 \simeq .9$ so that one would have $\Lambda_{gr} \simeq R_E$ after the transition. The Earth's crust has thickness between 5-70 km: could this variation relate to the variation of β_0 in range $(.64, .045)$?

2. Consider next the flow past a planar object with $Re_{cr} = 5 \times 10^5$. The ratio of the masses of Sun and Earth is $M_{Sun}/M_E \simeq 3 \times 10^5$, which is not far from $Re_{cr} \sim 5 \times 10^5$. Could $Re_{cr} \sim 5 \times 10^5$ correspond to a phase transition $M_E \rightarrow M_{Sun}$ and $\beta_0 \simeq 1 \rightarrow 3\beta_0/5$?

M_E, M_{Sun}, and the values $\beta_0 \simeq 1$ and $\beta_0 \simeq 2^{-11} \simeq m_e/m_p$ could appear in the model for the transition to turbulence. The dependence of the Re_{cr} for the pipe flow on the mass of the planet is a rather dramatic prediction, and could kill the proposal.

The natural assumption is that the gravitational flux tubes have length Λ_{gr} so that the phase transition would mean emergence of longer flux tubes corresponding to the gravitational Compton length hierarchy $\Lambda_{gr} \in \{.1\ m, 3.2\ km, 644\ Mm\}$.

Needless to emphasize, these proposals are only a light-hearted thought game taking seriously the notion of macroscopic quantum gravitational coherence.

5.5 Trying to understand kinematic viscosity

The model for the hydrodynamical quantum analogs leads to a proposal, which is completely crazy from the reductionistic point of view and looks like a return to astrology. The motivation is that the Faraday wave length λ_F appearing as analog of Compton length equals the gravitational Compton length associated with the gravitational Compton length associated with the gravitational Planck constant proposed by Nottale [E1].

5.5.1 Kinematic viscosity cannot be described in terms of $\hbar_{gr}$ for the masses of Earth and Sun

The first thing to notice is that ν_{gr} is several orders of magnitude larger than kinematic viscosity.

One obtains for ν_{gr}

$$\nu_{gr} = \Lambda_{gr} c = \frac{GMc}{\beta_0} = \frac{r_s c}{2\beta_0} \quad . \tag{5.9}$$

This corresponds for Earth's mass $M = M_E$ and $\beta_0 = 1$ to the Schwarshild radius 0.87 cm of Earth. This scale is by a factor roughly 10^{13} times longer than the Compton length of proton assignable to CentiStoke 10^{-6} m^2/s as a unit of kinematic viscosity.

Therefore the value of ν_{gr} is however very large as compared to the values of ν for ordinary liquids and the reduction of β_0 would make the value of ν_{gr} even larger. Therefore ordinary viscosity cannot correspond to $\hbar_{gr}$ for any astrophysical mass.

One can of course ask, whether h_{eff} could correspond to $\hbar_{gr}$ but for a smaller non-astrophysical - say mass M of some geological unit or of a unit assignable to atmosphere. Note that the variationof β_0 could allow us to understand the dependence on temperature.

5.5.2 Could one understand kinematic viscosity in terms of masses of geological or atmosperic objects?

Could one understand kinematic viscosity in terms of masses of geological or atmosperic objects?

1. As already noticed, the decrease of the velocity parameter β_0 with temperature perhaps related to the decrease of thermal velocity could be enough to explain the temperature dependence of ν. This raises the question whether the basic scale for ν could be set by some natural astrophysical or geological mass.

2. For M_E, one has $\Lambda_{gr} \simeq 10^6$ m^2/s whereas centiStoke as natural unit of η is 10^{-6} m^2/s and defines lower bound for it (the range of variation is 4 orders of magnitude) so that the mass M for ν should be smaller than M_E by 8-12 orders of magnitude. Therefore only geological objects appearing as basic building bricks of Earth's crust can be considered. Note that also β_0 appears as a parameter.

   The size scale L of an object of density $\rho_{ave} \sim 5.5 \times 10^3$ kg/m^3 with mass $M \sim 3 \times 10^{-13} M_E$ corresponding to $\nu = 1$ centiStoke would be about $L = 640$ m. There is no obvious identification.

   Could the object in question correspond to an atmospheric basic unit? The density of air is 1.2 kg/m^3 so that the size scale of the object would be 32 km. Note that the eye of the hurricane has a radius 16-32 km.

The basic objection is that the value of the kinematic viscosity would depend on local physics at Earth and this seems highly implausible.

It seems that one must distinguish between classical hydrodynamics assignable with ordinary matter with $h_{eff} = h$ and quantum hydrodynamics assignable to dark matter with $h_{eff} > h$. In particular, one must distinguish between quantum gravitational aspects of hydrodynamics assignable to $\hbar_{gr}$ involving mass of Earth or Sun.

5.6 Also the notions of $\hbar_{em}$ and $\hbar_Z$ make sense

It is of course not necessary to assume $\hbar_{eff} = \hbar_{gr}$. One can also consider the electromagnetic and weak variants of $\hbar_{gr}$.

1. For hydrodynamics, dark Z^0 interaction looks natural and one would have $\hbar_Z/\hbar = Q_Z 4\pi\alpha_Z/\beta_0$, where $Q_Z = N$ is the total Z^0 charge the number of elementary particles with Z^0 charge giving rise to the particle. Z^0 would be effectively massless below dark weak length scale.

   In the electromagnetic case, one has $\hbar_{em}/\hbar = Q_{em} 4\pi\alpha/\beta_0$. A highly interesting possibility suggested by the model of the vortices is that electroweak symmetry breaking is absent for the Lagrangian MB controlling the region of vortex exterior to the core (one would have $p = sin^2(\theta_W) = 0$). This raises the question whether electromagnetic and Z^0 situations are equivalent in this case.

2. These formulas make sense only for $\hbar_{em}/\bar{>}1$ and $\hbar_{em}/\bar{>}1$ and this gives the following criterion for darkness

$$
\begin{array}{l}
Q_Z \geq \frac{\beta_0}{4\pi\alpha_Z} \ , \\
Q_{em} \geq \frac{\beta_0}{4\pi\alpha_{em}} \ ,
\end{array}
\tag{5.10}
$$

In the electromagnetic case and for $\beta_0 = 1$, the transition would take place for completely ionized atoms with charge $Q_{em} > 10$. Natrium with $Z = 11$ would be the first dark completely ionized atom (ionization energy for the ground state electron is about 1.645 keV). Dark proton sequences at flux tubes consisting of dark proton triplets realizing genetic code would be the basic example from TGD inspired quantum biology [L37, L20, L19].

The interpretation would be that when a perturbation series fails to converge, a phase transition takes place. The new coupling strength is $Q_{em}e^2/\hbar_{em}$ resp. $Q_Z g_Z^2/\hbar_Z$ and is equal to $v_0/4\pi$ so that the perturbative expansion is universal and has the same coupling strength for all interactions. This conforms with the assumption that all classical fields are induced from the geometry of the embedding space.

Also now one can define dark Compton lengths for electromagnetic and Z^0 ions as

$$\Lambda_{em} = \frac{\hbar_{em}}{m} \ , \tag{5.11}$$

$$\Lambda_Z = \frac{\hbar_Z}{m} \ , \tag{5.12}$$

(5.13)

where m is the mass of the em or Z^0 charged particle at the flux tube. One can of course ask whether the notion of Z^0 makes sense.

The em charged particles at flux tubes could be protons or biologically important dark ions as proposed in the TGD based model for quantum biology. There would be $N = Q_{em}$ dark protons associated with or at the flux tube so that their density is $\Lambda_{eff}/\lambda_c(m)$. Similar interpretation applies in the Z^0 case.

If em and weak interactions are dark at gravitational flux tubes, the weak scale is scaled up by $h_{gr}/\hbar$ to $10^{-4}\ m, 3\ m, 6\ km\}$ corresponding to various dark gravitational Compton lengths. Therefore one could regard neutrons and protons as having weak Z^0 charge since the weak charge of neutrons is 50 times larger than that of protons. Dark neutrinos would be responsible for the screening of weak charge of dark nuclei.

5.6.1 Could one understand hydrodynamical viscosity and magnetohydrodynamical diffusivity in terms of $\hbar_{em}$ and $\hbar_Z$?

The variation of hydrodynamical kinematic viscosity could have explanation in terms of the variation of β_0. The basic units with Z^0 charge $Q_Z = Nq_z$ could correspond to vortex like entities. For gases one would have $\hbar_{em} = \hbar$ and dark matter would have no role in the dynamics.

For MHD plama the the picture would be similar and one can consider vortex like units and plasmoids as basic units with charge Q_{em}. TGD counterparts would be magnetic and Z^0 magnetic flux tubes: here one can consider the core of the vortex as a monopole flux tube or its exterior and Lagrangian flux tube.

Consider the kinematic viscosities.

1. Consider first the Z^0 case. The Z^0 charges of proton and neutrino are by a factor about 1/50 smaller than those of proton and electron. Stability requires that the weak charges of neutrinos and dark nuclear neutrons sum up to zero. It is convenient to talk about the length scale

$$L_\nu = \frac{\nu}{c} = \frac{\hbar_Z}{m} = \frac{4\pi\alpha_Z q_z^2 N}{\beta_0}\frac{\hbar}{m} \ . \tag{5.14}$$

Here N is the number of dark Z^0 charge carriers at magnetic flux tube.

The already described formula for the kinematic viscosity reads as $L_\nu = \lambda_c(n) \times f(T/T_b)$. This suggest the identification as $\hbar_{eff}/\hbar = f(T/T_b)/f(1)$, $f(1) = exp(3.6) \simeq 16.3$. At boiling point and above it one would have $\hbar_{eff}/\hbar = 1$.

This would give for $m = m_n$ the following formula

$$N = \frac{1}{4\pi\alpha_Z q_Z^2} \times \beta_0 \frac{f(T/T_b)}{f(1)} \quad . \tag{5.15}$$

N would be the total number of neutrons with Z^0 charge q_Z within volume defined by the scale L_ν. If one has $\beta_0 = k\frac{f(T/T_b)}{f(1)}$, N is constant and L_ν scales like $1/\beta_0$. Could N correspond to the number of neutrons for a dark atomic nucleus with $\hbar_{eff}/\hbar = \frac{4\pi\alpha_Z q_z^2 N}{\beta_0}$? The decrease of β_0 would increase quantum correlation length and viscosity.

2. Electromagnetic case can be treated in similar way.

5.6.2 Could dark quantum coherence scales for dark gravitation, dark Z^0 and dark em interaction be identical?

Could dark em, and Z^0, and gravitational quantum coherence scales be identical in some situation? Could this condition make possible astrophysical quantum coherence and symmetry restoration of electroweak interactions at the level of MB?

The general conditions for the equality of the quantum coherence scales are as follows.

$$\begin{aligned}
\Lambda_{em} &= \Lambda_Z = \lambda_{gr} \quad , \\
\Lambda_{em} = \frac{\hbar_{em}}{m_e} &= \frac{e^2q^2N_p}{\beta_0}L_{c,e} \sim \frac{10^{-2}N_p}{\beta_0} \times 2\times 10^{-12} \quad m \quad , \\
\Lambda_Z = \frac{\hbar_{em}}{m_\nu} &= \frac{e^2q^2N_n}{\beta_0}L_{c,\nu} \sim \frac{10^{-2}N_n}{\beta_0} \times 10^{-6} \quad m \sim \Lambda_{gr} \quad , \\
\Lambda_{gr} &= \frac{GM}{\beta_0} \quad , \\
(M,\beta_0) &\in \{(M_E, \beta \simeq 1), (M_{Sun}, \beta_0 \simeq 1), (M_{Sun}, \beta_0 \simeq 2^{-11})\} \quad .
\end{aligned} \tag{5.16}$$

This gives the conditions

$$\begin{aligned}
N_p &= \frac{\beta_0}{e^2q^2}\frac{\Lambda_{gr}}{L_{c,e}} \quad , \\
N_n &= \frac{\beta_0}{g_Z^2 q_Z^2}\frac{\Lambda_{gr}}{L_{c,\nu}} \quad .
\end{aligned} \tag{5.17}$$

This gives for $\Lambda_{gr} \in \{1.0 \ \ cm, 3.2 \ \ km, 6.4 \ \ Mm\}$.

$$\begin{aligned}
N_p &= \frac{4\pi\beta_0}{\alpha e^2}\frac{\Lambda_{gr}}{L_{c,e}} \in \frac{4\pi\beta_0}{\alpha e^2} \times \{.5\times 10^{10}, 1.6\times 10^{15}, \\
N_n &= \frac{4\pi\beta_0}{\alpha_Z q_Z^2}\frac{\Lambda_{gr}}{L_{c,\nu}} \in \frac{4\pi\beta_0}{\alpha_Z q_Z^2} \times \{2.5\times 10^{16}, 8.0\times 10^{21}, 1.8\times 10^{25}\} \quad .
\end{aligned}$$

The only natural interpretation is that these scales correspond to flux tube lengths. Assume that one has $\beta_0 = 1$.

1. For $\beta_0 = 1$, the density of protons would be in all three cases about 5×10^{12} per meter: of order 2 protons per electron Compton length. This is of the same order of magnitude as deduced for the density of dark protons in magnetic flux in the model of "cold fusion". For $\beta_0 = 2^{-11}$, where would be roughly one proton per 10^{-8} m, this is the p-adic length scale $L(151)$ and thickness of neuronal membrane.

2. For the Z^0 case with $\beta_0 = 1$ the density of neutrons would be roughly 2.5×10^{15} per meter for all options so that there would be one neutron per length 4×10^{-16} m. The Compton length of the neutron is $\lambda_n = 3.8 \times 10^{-16}$ m so that there would be roughly 1 neutron per neutron Compton length. This suggests that nuclear flux tubes are in question for $\beta_0 = 1$.

   If one assumes that $\beta_0 = 2^{-11} \simeq m_p/m_e$, the density would be roughly 1 neutron per electron Compton length. The TGD based proposal for solar cores is that they correspond to this kind of nuclear flux tubes.

Both dark neutrinos and neutrons and dark electrons and protons would neutralize each other. This suggests a connection with Pollack effect [I1] in which part protons of water molecules form sequences at dark flux tubes in the presence of a metabolic energy feed. Every fourth water molecule would give one proton which would be transformed to dark proton. Pollack effect is the cornerstone of the TGD inspired model of quantum biology [L37]. In the recent case, the flow would provide the energy needed to transform the protons to dark protons.

5.6.3 Gravitational de-Broglie wavelength and hydrodynamic length scale hierarchies

It is possible to define quantum gravitational de-Broglie wavelength as

$$\Lambda_{gr,dB} = \frac{\hbar_{gr}}{m(v/c)} = \frac{GM}{\beta_0 \beta} = \frac{r_s}{2\beta_0\beta} \quad . \tag{5.19}$$

The length scale $UD/c = \Lambda_{gr}$ suggests $D = \Lambda_{gr}c/U)$ giving $D = \Lambda_{gr,dB}$ for $v = U$ proposed to correspond to the length of magnetopause as an analog of wake in MHD.

In TGD, the p-adic length scale hierarchies $L_p \propto p^{1/2}$ assignable to $p \simeq 2^k$ for some integers k, play a central role [K13]. $p = 2$ defines length scale hierarchy in powers of $\sqrt{2}$ giving as a sub-hierarchy in powers of 2, which could correspond to a hierarchy of period doublings in approach to chaos.

This raises interesting questions.

1. Could this kind of hierarchy correspond to a hierarchy $\beta_{0,n} = p^{-n}\beta_{0,1}$ giving a period doubling hierarchy for $p = 2$? The velocity hierarchy and the associated length scale hierarchy would respect UP. Could the vortex lengths or radii for vortex hierarchies in hydrodynamic turbulence be described in this manner?

2. Could $\beta_0(Sun) \simeq 2^{-11}$ correspond to $\beta_{0,11}$ level for $\beta_{0,1} \simeq 1$. As found, $\beta_{0,1} \simeq .92$ predicts correctly the Faraday wavelength for hydrodynamic quantum analogs. For $\beta_{0,1} = .94$, $R_E = \Lambda_{gr,Sun}$ holds true exactly. For $\beta_{0,1} = .89$ $Re_{cr} = 2300$ for critical Reynolds number in pipe flow is predicted.

The original motivation for the Nottale hypothesis comes from the Bohr orbit model of the planetary system. This model involves an ad hoc feature. For the outer planets of the solar system, one must assume $\beta_0(out) = \beta_0(in)/5$. $p = 5 = 2^2 + 1$ is prime but not near a power of 2. Another interpretation is that β_0 is not changed but the principal quantum numbers come as $n = 2, 4, 5, 6$ for the 4 inner planets and as $n = 5k$ for $k = 2, ..., 6$, for the outer planets. Earth could be interpreted as an inner or outer planet.

This would suggest a secondary hierarchy in powers of 5 and $\beta_{0,1} = \beta_0(Sun)$.

Could 2-adic fractality conform with this rule? Could the rule be that the allowed 2-adic length scales proportional to $2^{k/2}$ must be as near as possible to the radius of an elliptic Bohr orbit for the principal quantum number n satisfying the Bohr conditions. For an elliptic orbit, the radius of the orbit could be defined as the geometric mean $\sqrt{ab}$. This condition also predicts the ellipticity of the orbit.

The fractal orbits with radii $r \propto 2^k$, $k = 3, 4$ have radii proportional to $2^3 = 8, 2^4 = 16$ and fit rather satisfactorily with the circular Bohr orbits with $n = 3, 4$ and radii proportional to $3^2 = 9, 4^2 = 16$ (Mercury and Venus). Earth and the outer planets would correspond to $2^{k+4+1/2}$ $k = 0, 1, ..6$ with $2^{4+1/2} \simeq 22.6$ as an approximation of $n^2 = 25$ for $n = 5$ orbit (Earth) in the Bohr model: the 2-adic length scale is 10 per cent smaller than the prediction of Bohr model for a circular orbit.

Since the inner and outer planets seem to be separate systems, one can consider the possibility that $\beta_{0,1}(out)$ for solar-planet gravitational flux tubes satisfies $\beta_{0,1}(out) = 1.1\beta_{0,1}(in)$. This requires $\beta_{0,1} \leq .9$. The values $k/2 \in \{2, 3, 4, 4 + 1/2, 5, 6\}$ would provide a reasonable fit for the outer planets and would correspond to $n \in \{1, 2, 3, 4, 5, 6\}$.

Remark: The Bohr orbits are assumed to correspond to magnetic flux tubes carrying dark matter delocalized along the orbit. The wave function for the dark matter BEC along the orbit could be a restriction of the 3-D hydrogen wave function at the orbit. For a circular orbit the angular dependence would be trivial in accordance with the interpretation that the angular momentum vanishes for these orbits in a quantum sense. Ordinary matter would be localized at the orbit and perform classical motion.

6 Why don't airplanes fall down?

Why do airplanes not fall down? Surprisingly, the physics of this phenomenon still remains poorly understood. In the sequel, a quantum hydrodynamics based proposal for the solution of the problem is discussed.

6.1 Some Background

I learned of an interesting step of progress in the description of the fluid flow over a lifting airfoil (`https://cutt.ly/mLHg3bh`) from a popular article "Pursuit of useless knowledge leads to a new theory of lift" (`https://cutt.ly/mLHg7gh`). The theory of Haithem Taha and his student Cody Gonzales is described in the article "A Variational Theory of Lift" [D6] (`https://cutt.ly/nLHheYH`).

6.1.1 What causes the lift on flying object?

The challenge is to explain the lift in terms of hydrodynamics. Surprisingly, this problem is still poorly understood mathematically and perhaps also physically. We do not understand why airplanes do not fall down! Partial progress in the understanding of the problem has however occurred.

1. Lord Rayleigh found the exact solution for a 2-D potential flow around an open disk. The incompressibility condition implies that the potential for the flow satisfies Laplace equation. The boundary condition is that the flow is tangential and the fluid and body move with the same velocity at the surface.

   By the conformal invariance of the Laplace equation, the problem can be solved for a general cross section of the object by mapping the geometry to that of the cylinder. The solution is however not unique: one can add to the flow vortices, which are irrotational except at the core of the vortex. The vortices appear in the real flow above the critical value of the Reynolds number and are essential for the occurrence of lift. The problem is to understand the generation of the distribution of the vortices. As a matter of fact, the generation and decay of turbulence as the generation and decay of vortices is an unsolved problem of hydrodynamics [L24].

2. Kutta's formula meant a progress in the understanding of the lift force. Kutta-Joukowski theorem assumes that the lift is caused by a single vortex surrounding an airfoil (`https://en.wikipedia.org/wiki/Airfoil`) and gives an explicit formula for the lift force. The lift force is identified as Magnus force (`https://cutt.ly/ALHhy1H`) L per span l on a fixed airfoil or any infinite 2-D shape with a rear becoming infinitely think at large distance is given by $\rho_\infty v_\infty \Gamma$. ρ denotes the density of the fluid. Γ is the velocity circulation around the object outside the viscous region (`https://cutt.ly/LLHg1Zy`). The interpretation is that the lift force is due to the viscosity.

   The formula of the lift force given by Kutta-Joukowski theorem holds true for a general geometry but conforms with empirical findings only in very special geometries in which the trailing edge of the wing is very sharp.

6.1.2 A variational principle for lift

Instead of Euler equations, which are essentially Newton's equations, Taha and Gonzales [D6] (https://cutt.ly/nLHheYH) propose a variational principle. One assumes a single vortex also now and the variational principle involves the circulation Γ as a single variational parameter, whose value is fixed by the minimization of the analog of action. There is no attempt to describe the generation of the vortex or its generation.

1. The variational principle at single particle level is Hertz's principle of least curvature (or acceleration). The analog of action, known as Appellian, is a 3-D integral of a quantity obtained from kinetic density by replacing velocity with acceleration: $\rho v^2/2 \rightarrow \rho a^2/2$. More generally, the deviation from the extremal of an action principle would be minimized instead of the action itself. This would allow non-extremals near to extremals.

   This gives as a special case solutions of Euler equations. Energy conservation must be assumed separately.

2. In the particle description there are two kinds of forces: external forces F_i and constraint forces R_i. In this situation, Gauss's Principle states that the quantity to be minimized is $\sum_i (m_i/2)(a_i - F_i)^2$. The constraint forces are eliminated by allowing a more general variational principle. At the continuum limit one obtains instead of sum a volume integral.

3. Hertz's principle is obtained by putting $F_i = 0$. Equivalently, force density f vanishes. For a steady state hydrodynamical flow the acceleration can be expressed as $a = v \cdot \nabla v + \nabla p + g$. In the approximation $f = (\rho(\nabla p + g) = 0$, one indeed obtains Hertz's principle.

4. One can start from an incompressible potential flow and add vortices to it. The simplest example is a single vortex rotating around a planar object, which is conformally related to a cylinder. In this case one has $u(\Gamma) = u_0 + \Gamma u_1$, where u_0 is a solution of the Laplace equation in absence of vortices representing potential flow and u_1 is a vortex solution with unit vorticity.

   The vorticity is given as $\Gamma = \oint u \cdot dl =$ (only u_1 contributes and gives $\oint u_1 \cdot dl = 1$). The integral is taken over a flow line around the object but staying outside the surface layer where the flow is not gradient flow fails. Note that one stays away from the region where the viscosity matters.

5. The varied quantity is known as Appellian

$$S(\Gamma) = \frac{\rho}{2} \int a^2 dV = \frac{\rho}{2} \int [u(\Gamma) \cdot \nabla u(\Gamma)]^2 dV \quad ,$$

   where one has $a = v \cdot \nabla v$. One takes vorticity Γ as the basic variable and minimizes Appellian S with respect to the value of Γ.

6. This approach works in the general case and predicts the value of the vorticity and therefore also the lift force by Kutta-Joukowksi formula (https://cutt.ly/LLHg1Zy).

In the following I will consider a TGD based microscopic model for lift assuming that the generation of the vortex is involved. The TGD based model involves new physics but is consistent with the model of Taha and also fixes the circulation of the vortex.

6.2 Some TGD inspired quantum hydrodynamics

The TGD inspired model for the lift involves the basic ideas of quantum hydrodynamics and these are discussed first.

6.2.1 h_{eff} hierarchy and the analogy with super-conductivity and super-fluidity

If the velocity field v is proportional to a gauge potential as in super-conductivity, the quantization of the circulation as quantization of angular momentum fixes the value of the parameter Γ and Kutta-Joukowski formula gives the value of the lift force.

1. The TGD based view of hydrodynamics involves macroscopic quantum coherence in an essential manner. Magnetic body consisting of magnetic flux tubes carrying ordinary particles as $h_{eff} = nh_0$ phases of ordinary particles is the role of controller of ordinary matter. In particular, gravitational Planck constant $\hbar_{gr} = GM_Em/v_0$ defining gravitational Compton length $\Lambda_{gr} = GM/v_0$ corresponds to the largest dark scale and would be important at quantum criticality accompanying ordinary thermodynamic criticality.

   The induced Kähler form decomposes to electromagnetic and Z^0 parts and both can be important. Z^0 vortices could accompany hydrodynamic vortices, which would imply a very close analogy between the descriptions of superconductivity and superfluidity. For instance, the very large value of $h_{eff} = h_{gr}$ can explain the fountain effect of super-fluidity as delocalization in scales, which are larger than gravitational Compton length $\Lambda_{gr} = GM_E/v_0$.

2. Also zero energy ontology (ZEO) is involved. ZEO predicts the possibility of ordinary ("big") state function reductions (BSFRs) in macroscopic scale. Generation of hydrodynamical turbulence and its decay are not understood in the standard framework based on Navier-Stokes equations.

   Quantum criticality associated with the flow near the boundary and BSFRs could play a central role in the generation of turbulence and its decay. The arrow of time changes in BSFR and this could explain hydrodynamic self-organization as dissipation with a reversed arrow of time.

6.2.2 Generation and decay of turbulence as quantum processes

The TGD inspired view of hydrodynamics [L24] leads to a proposal that the notion of viscosity is length scale dependent.

1. Kinematical viscosity ν has dimensions of L^2/T and ν/c has dimensions of length. This suggests for the ordinary kinematic viscosity a parameterization $\nu/c = L = f(T)\hbar/m$, which is indeed used.

2. The hierarchy of Planck constants $h_{eff} = nh_0$ suggests a hierarchy of length scales $L(n)$ and an associated hierarchy of viscosities defined as $L(n) = \nu(\hbar_{eff}/\hbar)/c = k\hbar_{eff}/m = kn\hbar/m$, $n = \hbar_{eff}/m$ and k a numerical constant possibly depending on temperature.

   Here the counterpart of Compton length is used. One can also consider the counterpart of de-Broglie wavelength and start from the length scales $L = UD/c = \beta D$, $\beta = U/c$ appearing in the definition of Reynolds number as $R = UD/\nu$. This would give a hierarchy of length scales $D_{dB}(n) = L(n)/\beta$.

Gravitational Planck constant $h_{gr} = GM/m$ defines a good candidate for the largest length scale in the hierarchy. The natural candidates for the large mass M are masses of Earth and Sun and the considerations of [L32, L34, L31] combined with earlier considers in [L24] suggest that both are important in both ordinary hydrodynamics and in quantum biology.

1. The original definition of gravitational Compton length as $\Lambda_{gr} = GM/\beta_0$. The gravitational de-Broglie length define as $\Lambda_{gr,dB} = GM/\beta_0\beta$, where β is a typical velocity, say in a hydrodynamical system was also considered in [L24].

   The physical interpretation of β_0 has remained somewhat unclear: in any case, for (quantum) hydrodynamics at the surface of Earth $\beta_0 = 1$ seems to be an excellent approximation [L24, L31].

2. One can ask why the velocity parameter β_0 appearing in the formula could not actually correspond to β so that $\Lambda_{gr} = GM/\beta_0$ for $\beta_0 < 1$ would correspond to $\Lambda_{gr,dB}$ for β_0. The

problem is that it is difficult to physically interpred the $\beta_0 = 1$ case applying at the surface of Earth. What could be the hydrodynamical entities flowing with light velocity? The rather science fictive candidate that comes into mind are dark N-photons forming Galois confined bound states of photons. For these states there exists quite recent experimental evidence [L23]. The fluid would consist of dark photons!

3. A natural guess would be that at the critical values of Reynolds number $R = UD/\nu$, the scale $L = UD/c$ coincides with a dark Compton or de-Broglie length for a particle of the fluid flow.

   This hierarchy of viscosities would apply to the description of the hydrodynamic turbulence as a generation of vortices in long scales characterized by a large value of h_{eff} quantum coherent in the scale.

   At quantum criticality new longer quantum coherence length would appear and lead to generation of larger vortices giving rise to turbulence. The decay of turbulence would be a reverse process. Vortices would decay in a cascade-like matter to smaller vortices characterized by smaller values of h_{eff}. Decay cascade would lead to the atomic level, where ordinary kinematic viscosity associated with $h_{eff} = h$ is a useful concept.

6.3 What prevents airplanes from falling down?

Could this conceptual framework provide insights to the question of what prevents airplanes from falling? Could the new physics predicted by TGD explain what happens in the generation of the vortex (or vortices). Could the variational principle introduced by Taha be interpreted in terms of this new physics?

1. It is known that vortices are essential for the generation of the lift force. They are generated above critical Reynolds number at the surface of the flying objects where the separation of the flow takes place. I have proposed that quantum criticality is associated with the critical Reynolds number: whereas superconductivity emerges below critical temperature, vortices emerge above critical Reynolds number. This is called flow separation.

   Flow separation is thought to occur in the following way (`https://cutt.ly/xLHhf3C`). The velocity of the fluid in the surface layer approaches zero at the surface. This increases the pressure near the surface and the average pressure in the layer. What happens is that the flow detaches from the surface via the formation of vortices and the pressure becomes constant.

2. One can express this more quantitatively. The conservation of energy along a flow line, expressed as $\rho v^2/2 + p = constant$, would imply that v decreases. Instead of this, a separation of flow occurs and vortices are generated and the average value of v inside the surface layer stays constant. For vortices the pressure increases near the core of the vortex so that the increase of pressure at the surface layer is replaced by its increase near the surfaces of vortices.

   Separation occurs above critical value R_{cr} of Reynolds number $R = UD/\nu$, where U is the velocity of flow above the surface layer, D is an appropriate length scale, say the distance from the tip of the airfoil, and ν is kinematic viscosity.

3. Separation generates vortices and in TGD they would correspond to quantum objects, perhaps Z^0 magnetic vortices inducing hydrodynamic flow. The simplest situation is that a single vortex for which fluid rotates around the object around axes orthogonal to the flow, is generated. This situation is assumed in the model of Taha. It is highly plausible that this vortex is unstable against decay to smaller vortices occurring also in standard hydrodynamics.

4. The conclusion of Taha and Gonzales [D6] is that momentum conservation is what matters rather than viscosity. If the fluid sticks at the surface of the moving body at the boundary layer, fluid flow loses momentum and could be transformed to the momentum of the vortices with respect to the rest system of fluid at larger distances.

Viscosity usually associated with the loss of momentum and energy in microscopic scales would be replaced with a transfer of momentum and energy to the vortices. The vortices would decay in a cascade-like manner to smaller ones and eventually the momentum and energy would be transformed to microscopic degrees of freedom. In a stationary situation there would be distribution of vortices of various sizes.

In the ZEO based picture, the occurrence of BSFR would change the arrow of time and the dissipation with a reversed arrow of time would in standard time direction look like self-organization based on the extraction of energy and momentum from the main flow to that of vortices.

5. The big vortex is analogous to a spinning object moving in fluid and would experience Magnus effect as a lift: Magnus force is proportional to the cross product of mass current and the angular velocity Ω of vortex defining vorticity and would cause the lift of the vortex. Since the object is inside the vortex, also the object would be lifted. This mechanism does not depend in an essential manner on the shape of the wing except it should be such that separation and generation of vortices is possible.

6.3.1 The strength of the lift force from the quantization of magnetic flux

TGD leads to a view about hydrodynamics [L24] involving a new view about classical fields and quantum coherence possible even in macroscopic scales. Actually, quantum hydrodynamics would be a more appropriate term.

It has been already found that the quantization of the Z^0 magnetic magnetic flux for the vortex fixes the possible values of Γ. Therefore variational principle is not needed for this purpose.

1. This gives a connection with the breaking of super-conductivity by a generation of vortices. In the TGD view about superfluidity, velocity vortices would correspond to Z^0 magnetic vortices carrying quantized monopole flux, whose existence distinguishes between TGD and standard model.

2. The unit of quantization would be $h_{eff} = nh_0$ and there would be a hierarchy of values of h_{eff} assignable to the hierarchy of vortices. The decay of vortices would decrease the scale of quantum coherences. The largest value of h_{eff} could correspond to h_{gr} with $\Lambda_{gr} = GM_E/v_0$ defining a lower bound for vortex scale.

   For $v_0 = c$, the scale would be above $\Lambda_{gr} = .45$ cm. Intriguingly, this scale occurs as a scale of snowflakes which are associated with the criticality of water against freezing: the TGD interpretation is in terms of quantum fluctuations associated with the quantum criticality of water generating a hierarchy of quantum phases with $h_{eff} \leq h_{gr}$ [L31].

3. This interpretation predicts a quantization of vorticity due to the quantization of $q \oint A \cdot dl$ as magnetic flux, completely analogous to that in super-fluidity. The quantization corresponds to a quantization of angular momentum for a particle of flow, such as proton. The quantization requires a non-standard value $h_{eff} = nh_0 > h$ of Planck constant or a very large value m of flux quanta for a small value of h_{eff}. The values of h_{eff} in the hydrodynamic situation are considered in [L24].

   Conservation of angular momentum requires that the vortex characterized by integer $n = h_{eff}/h_0$ decays to vortices characterized by integers n_i satisfying $n = \sum n_i$. If the vortices are identical ($n_i = n_1$) one has $m = n/n_1$ vortices and n_1 must divide n. If this condition holds true, the decay process corresponds to a division of n to its factors.

4. This quantization would take place even in ordinary hydrodynamics and would imply superfluidity-like phenomenon at the level of the magnetic body. The quantization of the magnetic flux as a multiple of h_{eff} fixes the value of the vorticity parameter Γ, which is also fixed by the minimization of Appellian so that it is not quite obvious whether the minimization of the counterpart of Appellian is needed.

   The quantization corresponds to that for the Kähler magnetic monopole flux of the flux tube. It would be interesting to test whether the quantization giving rise to a quantization of the lift force takes place. Outside the core at least, velocity vortices would naturally correspond to Z^0 vortices with vanishing electromagnetic B.

6.3.2 Bohr quantization for angular momentum as quantization of Kähler magnetic monopole flux

The Bohr quantization condition for angular momentum or equivalently quantization of Kähler magnetic flux having purely topological origin implies the quantization of circulation $\Gamma = \oint v \cdot dl$ as multiples of $\hbar_{eff}/M$, where M is the mass of the basic hydrodynamic unit.

1. The most plausible interpretation for velocity v would be as being proportional to a vector potential A for an analog of magnetic field, in a neutral fluid most naturally the induced Z^0 gauge potential A_Z, which would be proportional to Kähler gauge potential in the situation considered:

$$A_Z = q_Z A_K \ .$$

   Flow lines would be along those of A_K.

2. The covariant constancy $(p_t - qA_t)\Psi = 0$ satisfied along the flow lines has the condition $\oint (p - qA) \cdot dl = 0$ and stronger condition $p = Mv = q_Z A$ as classical counterparts. This gives the condition $v = A/M$ for the flow lines in the case of vortices.

3. The Bohr quantization of angular momentum for particle with mass M gives

$$M \oint v \cdot dl \ = m\hbar_{eff} = N\hbar \quad N = mm \ .$$

   The mass M can correspond to a mass of dark particle and proton is the most plausible candidate. In superfluidity it would be ^3He or ^4He atom which suggests that also atomic mass, which in a reasonable aprroximation is multiple of proton mass, is possible.

4. It is not completely clear whether the quantization for the gauge flux should be posed for Kähler flux associated with A_K or for Z^0 gauge potential. The quantization of Kähler flux follows from topology and is automatically satisfied. In fact, the quantization gives the same results under the conditions poses also in the model discussed in [L24].

   One would $p - A_K = mv - q_Z A_K = 0$ along the flow line. q_Z would correspond to the Z^0 charge of proton, or atomic nucleus which in good approximation is proportional to the neutron number (protonic Z^0 charges is roughly 2 percent of that for the neutron).

   The interpretation of A as Z_0 gauge potential proportional to Kähler gauge potential conforms with the model developed in [L24]. Depending on the situation, A can be reduced to electromagnetic or Z^0 gauge potential as in hydrodynamics.

5. If one has $A_Z = q_Z A_K$, the two quantization conditions are indeed equivalent. If one has $h_{eff} = nh$ (this is a special case of the most general condition $h_{eff} = nh_0$ satisfied if rationals are replaced with ground state extension of rationals with $h_{eff} = h = n_0 h_0$), one has

$$q_Z \oint A_Z \cdot dl = q_Z \int B_K \cdot dA = q_Z m\hbar_{eff} = q_Z mn\hbar = q_Z N\hbar \ .$$

   The Bohr quantization condition for angular momentum would be therefore equivalent with the quantization of Kähler magnetic monopole flux.

The situation is quantum critical.

1. Since the several values of $h_{eff} = nh_0$ correspond to the same value of total flux $N = mn$ for single flux quantum. There would also be a large degeneracy corresponding to various decompositions $N = mn$ to a product of integers. This degeneracy can be interpreted in terms of quantum criticality involving fluctuations in the value of h_{eff}.

2. One can also have a decomposition to several flux quanta analogous to a decomposition of a vortex to a set of vortices. The interpretation would be as a decomposition of the big vortex to smaller ones.

6.3.3 Appellian or a magnetic part of gauge action for a massive gauge boson?

One can consider two basic options for the choice of the magnetic action based on hydrodynamic and gauge theoretic intuition respectively.

1. For the model of vortex associated with the lift forces, the vector potential $a_0 \propto v_0$ would define a vanishing Z_0 magnetic field and satisfy the analog of gauge condition $\nabla \cdot A_0 = 0$. The vector potential assignable to v_1 would give a magnetic field, which is non-vanishing along a line singularity that is a thin Kähler magnetic monopole flux tube.

2. The counterpart of Appellian follows from hydrodynamic intuition and would be proportional to $S = \int (A \cdot \nabla A)^2 dV$ and would be varied with respect to Γ, which is however fixed to an integer N by flux quantization.

   Without the core contribution the minimization would reduce to minimization with respect to $N = mn$. The core with a finite size would give a finite contribution proportional to N^2. Appellian contribution from the exterior of the core would give terms coming as powers of $(n/A)^k$, $0, 1, 2, 4$, where A is the transverse area of the core tube.

   Therefore the minimization is with respect to the value of n and the parameter characterizing core size, say the area A. For $h_{eff} = h$ the value of m is very large so that one has a quasi-continuum for the values of N. For large values of h_{eff} only few values of m are possible. Flux quantization would fix the value spectrum of N and minimization with respect to $1/A$ would fix the value of A for a given value of N as a root of a third order polynomial in (N/A). A further minimization with respect to $m = N/n$ would fix the value of m.

3. Gauge theoretic intuition motivates the consideration of the analog of magnetic energy density for a massive gauge field. The Maxwellian contribution would be proportional to $\int B^2 dV$ and concentrate to the vortex core. By flux quantization, one would have $\int B^2 dV \propto m^2 \Phi_n^2 L/A = m^2 n^2 \Phi_0^2 L/A$, where $\Phi_n = (h_{eff}/h)\Phi_0 = n/n_0$ is flux quantum, m is the number of flux quanta, A is the transverse area of the flux tube and L its length. Minimization with respect to A would allow only $n = 0$.

   By adding the analog of mass term $m^2 \int A^2$ would give rise to terms proportional to powers $(n/A)^k$, $k = 0, 1, 2$. Outside the vortex core this option corresponds to Eulerian $\rho v^2/2$ option and apart from flux quantization to standard hydrodynamics.

   The minimization for a given value of N would fix the value of A as a root of a first order polynomial. A further minimization with respect to m, would fix the value of m for a given value of n.

6.3.4 Electromagnetic gauge invariance is not a strict gauge invariance

For both options, the action fails to be gauge invariant. For the second option the presence of the A^2 term could be interpreted as reflecting the massivation of the Z^0 magnetic field. This also takes place for electromagnetic fields in superconductivity, where the cores of flux quanta correspond to regions, where super-conductivity is broken.

In TGD the breaking of gauge invariance is only apparent since gauge invariance is broken by classical gravitation from the beginning and the breaking becomes large in presence of monopole flux tubes not possible in the standard model and in general relativity.

1. The gauge transformations for the induced Kähler form correspond to symplectic transformations of CP_2 and affect the induced metric and therefore also Kähler action unlike genuine gauge transformations would do: the effect is small for Einstein space-time regions with large 4-D M^4 projection since it is gravitational. In long scales, where Einsteinian space-regions with 4-D M^4 projection dominate, this leads to huge spin glass degeneracy and approximate gauge invariance.

   As a matter of fact, the sub-algebra SSA_n of super-symplectic algebra SSA with conformal weights coming as n-ples of those of SSA annihilate the physical states as also does the commutator $[SSA_n, SSA]$. SSA_n acts effectively as gauge transformations and gauge symmetry for conformal weights smaller than n is replaced with isometries of the "world of classical worlds" (WCW): they correspond to long length scales. One can assign to these generators charges of dynamical symmetries emerging in long scales.

2. For the magnetic flux tubes, which are deformations of string-like entities with 2-D M^4 projection, the effect of gauge symmetry breaking can be large. One indeed assigns the breaking of gauge invariance to the cores of the flux quanta in superconductivity.

   Electromagnetic gauge invariance is believed to break down in superconductivity. This is in conflict with the expectation from the standard model. This conforms with the TGD view of electromagnetic gauge invariance as an approximate gauge invariance. Symplectic transformations of CP_2 are however identified as isometries of WCW and one can say that the in symmetry breaking only those symplectic transformations corresponding to SSA_n remain gauge transformation and the rest become genuine symmetries generating dynamical symmetry group.

   It should be also noticed that in the general case classical em and Z^0 gauge potentials contain besides the Kähler part also an $SU(2)$ part.

7 QHD in nuclear physics and hadron physics

Also nuclear and hadron physics suggests applications for QHD. The basic vision about what happens in high energy nuclear and hadron collisions is that two BSFRs take place. The first BSFR creates the intermediate state with $h_{eff} > h$: the entire system formed by colliding systems need not be in this state. In nuclear physics this state corresponds to a dark nucleus which decays in the next BSFR to ordinary nuclei.

The basic notions are the notion of dark matter at MB and ZEO, in particular the change of the arrow of time in BSFR.

7.1 Cold fusion, nuclear tunnelling, $\hbar_{eff}$, and BSFRs

This model allows us to understand "cold fusion" in an elegant manner [L4, L12, L3]. The dark protons at flux tubes associated with water and created by the Pollack effect have much smaller nuclear binding energy than ordinary nucleons. This energy is compensated to a high degree by the positive Coulomb binding energy which corresponds roughly to distance given by electron Compton length.

Dark nuclear reactions between these kinds of objects do not require large collision energy to increase the value of h_{eff} and can take place at room temperature. After the reaction the dark nuclei can transform to ordinary nuclei and liberate the ordinary nuclear binding energy. One can say that in ordinary nuclear reactions one must get to the top of the energy hill and in "cold fusion" one already is at the top of the hill.

Quite generally, the mechanism creating intermediate dark regions in the system of colliding nuclei in BSFR, would be the TGD counterpart of quantum tunnelling in the description of nuclear reactions based on Schrödinger equation. This mechanism could be involved with all tunnelling phenomena.

7.1.1 Where does the heat energy go in Tokamak?

Magnetic body is an essential element of quantum hydrodynamics irrespective of the scale considered. Flux tubes are systems with infinite number of degrees of freedom and this implies the phenomenon of Hagedorn temperature which could serve as an empirical signature of the magnetic body.

Quite recently, I learned about a 12 year old puzzle related to fusion reactors discovered at the U.S Department of Energy's (DOE) Princeton Plasma Physics Laboratory (PPPL) (`https://cutt.ly/bZteLdB`).

The heat energy feed to the reactor should increase the temperature of the reactor to make reaction possible but the temperature raise slows down. Now Stephen Jardin has proposed a solution of the problem [?]. The heating energy would go to the plasma degrees of freedom and increase plasma pressure. At some point the pressure would start to destroy magnetic surfaces near the center of the Tokamak and the temperature would stop growing up. Skeptic can can argue that that there is a limiting temperature and that standard physics does not allow this.

TGD suggests a solution involving new physics. The heat heat energy could go to new degrees of freedom which open up as the temperature slowly decreases. The notion of Hagedorn temperature T_H as a limiting temperature was originally introduced in string theory. In this case, the feeded energy would go to opening up degrees of freedom of a vibrating string. The heat capacity of the combined system increases and temperature rise slows down and one approaches T_H. The threshold temperature for nuclear fusion is around 10^4 eV, which corresponds to an atomic length scale about 1 Angstrom and T_H should be below and near this temperature.

This happens always in the presence of extended objects with an infinite number of degrees of freedom. In TGD the strings are replaced by monopole flux tubes representing new physics and there is an entire hierarchy of Hagedorn temperatures corresponding to the spectrum of string tensions predicted by p-adic length scale hypothesis - new physics again. In cosmology the hierarchy of Hagedorn temperature plays an important role in the TGD inspired cosmology [L7, L27] and also in the model of stars and blackhole-like objects [K3].

Also in the living matter, the physiological temperature could be Hagedorn temperature [L36, L38]. The idea is that the temperature at the magnetic body containing quantum coherent dark matter as phases of the ordinary matter with large value of Planck constant, which controls the biological body, slowly approaches T_H, the entropy increases and the biocontrol by MB starts to fai. This would give rise to aging.

In nuclear fusion reactors, magnetic monopole flux tube structures carrying dark particles could be formed and they would "eat" the feeded energy.

7.2 QHD and hadron physics

Hadron physics suggests applications of QHD.

7.2.1 Quark gluon plasma and QHD

In hadron physics quark gluon plasma (`https://cutt.ly/xEDQNZA`) has turned out to be what it was thought to be originally. Instead of being like a gas of quarks and gluons with a relatively large dissipation, it has turned out to behave like almost perfect fluid. This means that the ratio η/s of viscosity and entropy is near to its minimal value proposed by string model based arguments to be $\eta/s = \hbar/m$.

To be a fluid means that the system has long range correlations whereas in gas the particles move randomly and one cannot assign to the system any velocity field or more general currents. In the TGD framework, the existence of a velocity field means at the level of the space-time geometry generalized Beltrami flow allowing to define a global coordinate varying along the flow lines [L17, L25]. This would be a geometric property of space-time surfaces and the finite size of the space-time surface would serve as a limitation.

In the TGD framework the replacement $\hbar \rightarrow \hbar_{eff}$ requires that s increases in the same proportion. If the fluid flow is realized in terms of vortices controlled by pairs of monopole flux tubes defining their cores and Lagrangian flux tubes with gradient flow defining the exteriors of the cores, this situation is achieved.

In this picture entropy could but need not be associated with the monopole flux tubes with non-Beltrami flow and with non-vanishing entropy since the number of the geometric degrees of freedom is infinite which implies limiting temperature known has Hagedorn temperature T_H which is about 175 MeV for hadrons, and slightly higher than pion mass. In fact, the Beltrami property holds for the flux tubes with 2-D CP_2 projection, which is a complex manifold for monopole flux tubes. The fluid flow associated with (controlled by) the monopole flux tubes would have non-vanishing vorticity for monopole fluxes and could dissipate.

The monopole flux tube at the core of the vortex could therefore serve as the source of entropy. One expects that η/s as minimal value is not affected by $h \rightarrow h_{eff}$. One expects that $s \rightarrow (\hbar_{eff}/hbar)s = ns$ since the dimension of the extension of rationals multiplies the Galois degrees of freedom by n.

Almost perfect fluids are known to allow almost non-interacting vortices. For a perfect fluid, the creation of vortices is impossible due to the absence of friction at the walls. This suggests that the ordinary viscosity is not the reason for the creation of vortices, and in the TGD picture the situation is indeed this. The striking prediction is that the masses of Sun and Earth appear as basic parameters in the gravitational Compton lengths Λ_{gr} determining $\nu_{gr} = \Lambda_{gr}c$.

7.2.2 The phase transition creating quark gluon plasma

The phase transition creating what has been called quark gluon plasma is now what it was expected to be. That the outcome behaves like almost perfect fluid was the first example. TGD leads however to a proposal that since quantum criticality is involved, phases with $\hbar_{eff} > h$ must be present.

p-Adic length scale hypothesis led to the proposal [K11, K12] that this transition could allow production of so called M_{89} hadrons characterized by Mersenne prime $M_{89} = 2^{89} - 1$ whereas ordinary hadrons would correspond to M_{107}. The mass scale of M^{89} hadrons would be by a factor 512 higher than that of ordinary hadrons and there are indications for the existence of scaled versions of mesons.

How M_{89} hadrons could be created. The temperature $T_H = 175$ MeV is by a factor 1/512 lower than the mass scale of M_{89} pion. Somehow the colliding nuclei or hadrons must provide the needed energy from their kinetic energy. What certainly happens is that this energy is materialized in the ordinary nuclear reaction to ordinary pions and other mesons. The mesons should correspond to closed flux tubes assignable to circular vortices of the highly turbulent hydrodynamics flow created in the collision.

Could roughly 512 mesonic flux tubes reconnect to circular but flattened long flux tubes having length of M_{89} meson, which is 512 times that of ordinary pions? I have proposed this kind of process, analogous to BEC, to be fundamental in both biology [L37, L13, L20] and also to explain the strange findings of Eric Reiter challenging some basic assumptions of nuclear physics if taken at face value [L26].

The process generating an analog of BEC would create in the first BSFR M_{89} mesons having $\hbar_{eff}/\hbar = 512$. In the second BSFR the transition $\hbar_{eff} \rightarrow \hbar$ would take place and yield M^{89} mesons. It would seem that part of the matter of the composite system ends up to n M_{89} hadronic phase with 512 times higher T_H. In the number theoretic picture, these BEC like states would be Galois confined states [L15, L19].

7.2.3 Can the size of a quark be larger than the size of a hadron?

The Compton wavelength $\lambda_c = \hbar/m$ is inversely proportional to mass. This implies that the Compton length of the quark as part of the hadron is longer than the Compton length of the hadron. If one assigns to Compton length a geometric interpretation as one does in $M^8 - H$ duality mapping mass shell to CD with radius given by Compton length, this sounds paradoxical. How can a part be larger than the whole? One can think of many approaches to what might look like a paradox.

One could of course argue that being a part in the sense of tensor product has nothing to with being a part in geometric sense. However, if one requires quantum classical correspondence (QCC), one could argue that a hadron is a small region to which much larger quark 3-surfaces are attached.

One could also say that Compton length characterizes the size of the MB assignable to a particle which itself has size of order CP_2 length scale. In this case the strange looking situation would appear only at the level of MBs and the magnetic bodies could have sizes which increase when the particle mass decreases.

What if one takes QCC completely seriously? One can look at the situation in ZEO.

1. The size of the CD corresponds to Compton length and CDs for different particle masses have a common center and form a Russian doll-like hierarchy. One can continue the geodesic line defining point of CD associated with the hadron mass so that it intersects the CDs associated with quarks, in particular that for the lightest quark.

2. The distances between the quarks would define the size scale of the system in this largest CD and in the case of light hadrons containing U and D quarks it would be of the order of the Compton length of the lightest quark involved having mass about 5 MeV: this makes about $.2 \times 10^{-13}$ m. There are indeed indications that the MB of proton has this size scale.

One could also require that there must be a common CD based on such an identification of h_{eff} for each particle that its size does not depend on the mass of the particles.

1. Here $\hbar_{gr} = GMm/\beta_0$ provides a possible solution. The size of the CD would correspond to $\Lambda_{gr} = GM/v_0$ for all particles involved. One could call this size the quantum gravitational size of the particle.

2. There is an intriguing observation related to this. To be in gravitational interaction could mean $\hbar_{eff} = \hbar_{gr} = GMm/v_0$ so that the size of the common CD would be given by $\Lambda_{gr} = GMm/v_0$. The minimum mass M given $\hbar_{gr} > \hbar$ would be $M = \beta_0 M_{Pl}^2/m$. For protons this gives $M \geq 1.5 \times 10^{38} m_p$. Assuming density $\rho \sim 10^{30} A/m^3$, A the atomic number, the length L for the side cube with minimal mass M is $L \sim \beta_0 \times 10^2/A^{1/3}$. For $\beta_0 = 2^{-11}$ assignable to the Sun-Earth system, this gives $L \simeq 5/A^{1/3}$ mm. The value of Λ_{gr} for Earth is 4.35 mm for $\beta_0 = 1$. The orders of magnitude are the same. Is this a mere accident?

One solution to the problem is that the ratio $\hbar_{eff}(H)/\hbar_{eff}(q)$ is so large that the problem disappears.

1. If $\hbar eff(1) = \hbar$, the value of $\hbar_{eff}$ for hadron should be so large that the geometric intuitions are respected: this would require $h_{eff}/\hbar \geq m_H/m_q$. The hadrons containing u, d, and c quarks are very special.

2. Second option is that the value of h_{eff} for quarks is smaller than h to guarantee that the Compton length is not larger than $\hbar$. The perturbation theory for states consisting of free quarks would not converge since Kähler coupling strength $\alpha_K \propto 1/\hbar_{eff}$ would be too large. This would conform with the QCD view and provide a reason for color confinement. Quarks would be dark matter in a well-defined sense.

3. The condition would be $\hbar_{eff}(H)/\hbar_{eff}(q) \geq m(H)/m_q$, where q is the lightest quark in the hadron. For heavy hadrons containing heavy quarks this condition would be rather mild. For light hadrons containing u,d, and c quarks it would be non-trivial. Ξ gives the condition $\hbar/\hbar_{eff} \geq 262$. The condition could not be satisfied for too small masses of the value of $\hbar = 7!\hbar_0 = 5040\hbar_0$ identifiable as the ratio of dark CP_2 deduced from p-adic mass calculations and Planck length.

8 Appendix

8.1 Comparison of TGD with other theories

Table 1 compares GRT and TGD and **Table 2** compares standard model and TGD.

8.2 Brief glossary of the basic concepts of TGD

The following glossary explains some basic concepts of TGD and TGD inspired biology.

- ***Space-time as surface***. Space-times can be regarded as 4-D surfaces in an 8-D space $M^4 \times CP_2$ obtained from empty Minkowski space (M^4) by adding four small dimensions (CP_2). The study of field equations characterizing space-time surfaces as "orbits" of 3-surfaces (3-D generalization of strings) forces the conclusion that the topology of space-time is non-trivial in all length scales.

- ***Geometrization of classical fields***. Both weak, electromagnetic, gluonic, and gravitational fields are known once the space-time surface in H as a solution of field equations is known.

  Many-sheeted space-time (see **Fig. 1**) consists of space-time sheets with various length scales with smaller sheets being glued to larger ones by ***wormhole contacts*** (see **Fig. 3**) identified as the building bricks of elementary particles. The sizes of wormhole contacts vary but are at least of CP_2 size (about 10^4 Planck lengths) and thus extremely small.

	GRT	**TGD**
Scope of geometrization	classical gravitation	all interactions and quantum theory
Spacetime		
Geometry	abstract 4-geometry	sub-manifold geometry
Topology	trivial in long length scales	many-sheeted space-time
Signature	Minkowskian everywhere	also Euclidian
Fields		
classical	primary dynamical variables	induced from the geometry of H
Quantum fields	primary dynamical variables	modes of WCW spinor fields
Particles	point-like	3-surfaces
Symmetries		
Poincare symmetry	lost	Exact
GCI	true	true - leads to SH and ZEO
	Problem in the identication of coordinates	$H = M^4 \times CP_2$ provides preferred coordinates
Super-symmetry	super-gravitation	super variant of H: super-surfaces
Dynamics		
Equivalence Principle	true	true
Newton's laws and		
notion of force	lost	generalized
Einstein's equations	from GCI and EP	remnant of Poincare invariance at QFT limit of TGD
Bosonic action	EYM action	Kähler action + volume term
Cosmological constant	suggested by dark energy	length scale dependent coefficient of volume term
Fermionic action	Dirac action	Modified Dirac action for induced spinors
Newton's constant	given	predicted
Quantization	fails	Quantum states as modes of WCW spinor field

Table 1: Differences and similarities between GRT and TGD

	SM	TGD
Symmetries		
Origin	from empiria	reduction to CP_2 geometry
Color symmetry	gauge symmetry	isometries of CP_2
Color	analogous to spin	analogous to angular momentum
Ew symmetry	gauge symmery	holonomies of CP_2
Symmetry breaking	Higgs mechanism	CP_2 geometry
Spectrum		
Elementary particles	fundamental	consist of fundamental fermions
Bosons	gauge bosons, Higgs	gauge bosons, Higgs, pseudo-scalar
Fundamental fermions	quarks and leptons	quarks: leptons as local 3-quark composites
Dynamics		
Degrees of freedom	gauge fields, Higgs, and fermions	3-D surface geometry and spinors
Classical fields	gauge fields, Higgs	induced spinor connection
	SU(3) Killing vectors of CP_2	
Quantal degrees of freedom	gauge bosons,Higgs,	quantized induced spinor fields
Massivation	Higgs mechanism	p-adic thermodynamics with superconformal symmetry

Table 2: Differences and similarities between standard model and TGD

Many-sheeted space-time replaces reductionism with ***fractality*** . The existence of scaled variants of physics of strong and weak interactions in various length scales is implied, and biology is especially interesting in this respect.

- ***Topological field quantization (TFQ)*** . TFQ replaces classical fields with space-time quanta. For instance, magnetic fields decompose into space-time surfaces of finite size representing flux tubes or -sheets. Field configurations are like Bohr orbits carrying "archetypal" classical field patterns. Radiation fields correspond to topological light rays or massless extremals (MEs), magnetic fields to magnetic flux quanta (flux tubes and sheets) having as primordial representatives "cosmic strings", electric fields correspond to electric flux quanta (e.g. cell membrane), and fundamental particles to CP_2 type vacuum extremals.

- ***Field body*** (FB) and ***magnetic body*** (MB). Any physical system has field identity - FB or MB - in the sense that a given topological field quantum corresponds to a particular source (or several of them - e.g. in the case of the flux tube connecting two systems).

  Maxwellian electrodynamics cannot have this kind of identification since the fields created by different sources superpose. Superposition is replaced with a set theoretic union: only the *effects* of the fields assignable to different sources on test particle superpose. This makes it possible to define the QFT limit of TGD.

- ***p-Adic physics*** [K13] as a physics of cognition and intention and the fusion of p-adic physics with real number based physics are new elements.

- ***Adelic physics*** [L5, L6] is a fusion of real physics of sensory experience and various p-adic physics of cognition.

- ***p-Adic length scale hypothesis*** states that preferred p-adic length scales correspond to primes p near powers of two: $p \simeq 2^k$, k positive integer.

- A ***Dark matter hierarchy*** realized in terms of a hierarchy of values of effective Planck constant $h_{eff} = nh_0$ as integers using $h_0 = h/6$ as a unit. Large value of h_{eff} makes possible macroscopic quantum coherence which is crucial in living matter.

- ***MB as an intentional agent using biological body (BB) as a sensory receptor and motor instrument*** . The personal MB associated with the living body - as opposed to larger MBs assignable with collective levels of consciousness - has a hierarchical onion-like layered structure and several MBs can use the same BB making possible remote mental interactions such as hypnosis [L2].

- ***Cosmic strings Magnetic flux tubes*** belong to the basic extremals of practically any general coordinate invariant action principle. Cosmic strings are surfaces of form $X^2 \times Y^2 \subset M^4 \times CP_2$. X^2 is analogous to string world sheet. Cosmic strings come in two varieties and both seem to have a deep role in TGD.

  Y^2 is either a complex or Lagrangian 2-manifold of CP_2. Complex 2-manifold carries monopole flux. For Lagrangian sub-manifold the Kähler form and magnetic flux and Kähler action vanishes. Both types of cosmic strings are are simultaneous extremals of both Kähler action and volume action: this holds true quite generally for preferred extremals.

  Cosmic strings are unstable against perturbations thickening the 2-D M^4 projection to 3-D or 4-D: this gives rise to monopole (see **Fig. ??**) and non-monopole magnetic flux tubes. Using $M^2 \times Y^2$ coordinates, the thickening corresponds to the deformation for which $E^2 \subset M^4$ coordinates are not constant anymore but depend on Y^2 coordinates.

- ***Magnetic flux tubes and sheets*** serve as "body parts" of MB (analogous to body parts of BB), and one can speak about magnetic motor actions. Besides concrete motion of flux quanta/tubes analogous to ordinary motor activity, basic motor actions include the contraction of magnetic flux tubes by a phase transition possibly reducing Planck constant, and the change in thickness of the magnetic flux tube, thus changing the value of the magnetic field, and in turn the cyclotron frequency. Transversal oscillatory motions of flux tubes and oscillatory variations of the thickness of the flux tubes serve as counterparts for Alfwen waves.

  Reconnections of the U-shaped flux tubes allow two MBs to get in contact based on a pair of flux tubes connecting the systems and temporal variations of magnetic fields inducing motor actions of MBs favor the formation of reconnections.

  In hydrodynamics and magnetohydrodynamics reconnections would be essential for the generation of turbulence by the generation of vortices having monopole flux tube at core and Lagrangian flux tube as its exterior.

  Flux tube connections at the molecular level bring a new element to biochemistry making it possible to understand bio-catalysis. Flux tube connections serve as a space-time correlates for attention in the TGD inspired theory of consciousness.

- ***Cyclotron Bose-Einstein condensates (BECs)*** of various charged particles can accompany MBs. Cyclotron energy $E_c = hZeB/m$ is much below thermal energy at physiological temperatures for magnetic fields possible in living matter. In the transition $h \rightarrow h_{eff}$ E_c is scaled up by a fractor $h_{eff}/h = n$. For sufficiently high value of h_{eff} cyclotron energy is above thermal energy $E = h_{eff}\ ZeB/m$. Cyclotron Bose-Einstein condensates at MBs of basic biomolecules and of cell membrane proteins - play a key role in TGD based biology.

- ***Josephson junctions*** exist between two superconductors. In TGD framework, ***generalized Josephson junctions*** accompany membrane proteins such as ion channels and pumps. A voltage between the two super-conductors implies a ***Josephson current***. For a constant voltage the current is oscillating with the ***Josephson frequency*** . The Josephson current emits ***Josephson radiation***. The energies come as multiples of ***Josephson energy***.

  In TGD generalized Josephson radiation consisting of dark photons makes communication of sensory input to MB possible. The signal is coded to the modulation of Josephson frequency depending on the membrane voltage. The cyclotron BEC at MB receives the radiation producing a sequence of resonance peaks.

- ***Negentropy Maximization Principle*** (NMP). NMP [K10] [L21] is the variational principle of consciousness and generalizes SL. NMP states that the negentropy gain in SFR is non-negative and maximal. NMP implies SL for ordinary matter.

- ***Negentropic entanglement*** (NE). NE is possible in adelic physics and NMP does not allow its reduction. NMP implies a connection between NE, the dark matter hierarchy, p-adic physics, and quantum criticality. NE is a prerequisite for an experience defining abstraction as a rule having as instances the state pairs appearing in the entangled state.

- ***Zero energy ontology (ZEO)*** In ZEO physical states are pairs of positive and negative energy parts having opposite net quantum numbers and identifiable as counterparts of initial and final states of a physical event in the ordinary ontology. Positive and negative energy parts of the zero energy state are at the opposite boundaries of a ***causal diamond*** (CD, see **Fig. 2**)) defined as a double-pyramid-like intersection of future and past directed light-cones of Minkowski space.

  CD defines the "spot-light of consciousness": the contents of conscious experience associated with a given CD is determined by the space-time sheets in the embedding space region spanned by CD.

- ***SFR*** is an acronym for state function reduction. The measurement interaction is universal and defined by the entanglement of the subsystem considered with the external world [L10] [K15]. What is measured is the density matrix characterizing entanglement and the outcome is an eigenstate of the density matrix with eigenvalue giving the probability of this particular outcome. SFR can in principle occur for any pair of systems.

  SFR in ZEO solves the basic problem of quantum measurement theory since the zero energy state as a superposition of classical deterministic time evolutions (preferred extremals) is replaced with a new one. Individual time evolutions are not made non-deterministic.

  One must however notice that the reduction of entanglement between fermions (quarks in TGD) is not possible since Fermi- and als Bose statistics predicts a maximal entanglement. Entanglement reduction must occur in WCW degrees of freedom and they are present because point-like particles are replaced with 3-surfaces. They can correspond to the number theoretical degrees of freedom assignable to the Galois group - actually its decomposition in terms of its normal subgroups - and to topological degrees of freedom.

- ***SSFR*** is an acronym for "small" SFR as the TGD counterpart of weak measurement of quantum optics and resembles classical measurement since the change of the state is small [L10] [K15]. SSFR is preceded by the TGD counterpart of unitary time evolution replacing the state associated with CD with a quantum superposition of CDs and zero energy states associated with them. SSFR performs a localization of CD and corresponds to time measurement with time identifiable as the temporal distance between the tips of CD. CD is scaled up in size - at least in statistical sense and this gives rise to the arrow of time.

  The unitary process and SSFR represent also the counterpart for Zeno effect in the sense that the passive boundary of CD as also CD is only scaled up but is not shifted. The states remain unchanged apart from the addition of new fermions contained by the added part of the passive boundary. One can say that the size of the CD as analogous to the perceptive field means that more and more of the zero energy state at the passive boundary becomes visible. The active boundary is however both scaled and shifted in SSFR and states at it change. This gives rise to the experience of time flow and SSFRs as moments of subjective time correspond to geometric time as a distance between the tips of CD. The analog of unitary time evolution corresponds to "time" evolution induced by the exponential of the scaling generator L_0. Time translation is thus replaced by scaling. This is the case also in p-adic thermodynamics. The idea of time evolution by scalings has emerged also in condensed matter physics.

- ***BSFR*** is an acronym for "big" SFR, which is the TGD counterpart of ordinary state function reduction with the standard probabilistic rules [L10] [K15]. What is new is that the arrow of time changes since the roles of passive and active boundaries change and CD starts to increase in an opposite time direction.

  This has profound thermodynamic implications. Second law must be generalized and the time corresponds to dissipation with a reversed arrow of time looking like self-organization for an observed with opposite arrow of time [L9]. The interpretation of BSFR is as analog of biological death and the time reversed period is analogous to re-incarnation but with non-standard arrow of time. The findings of Minev *et al* [L8] give support for BSFR at atomic level. Together with h_{eff} hierarchy BSFR predicts that the world looks classical in all scales for an observer with the opposite arrow of time.

8.3 Figures

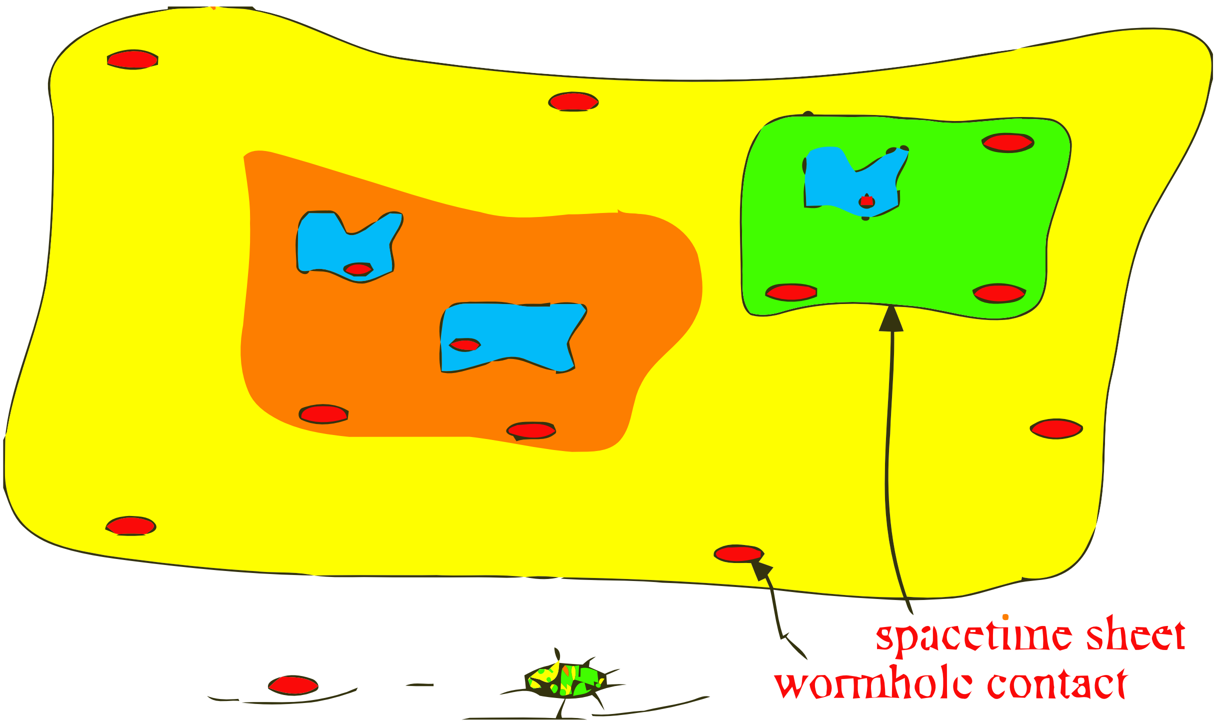

Figure 1: Many-sheeted space-time.

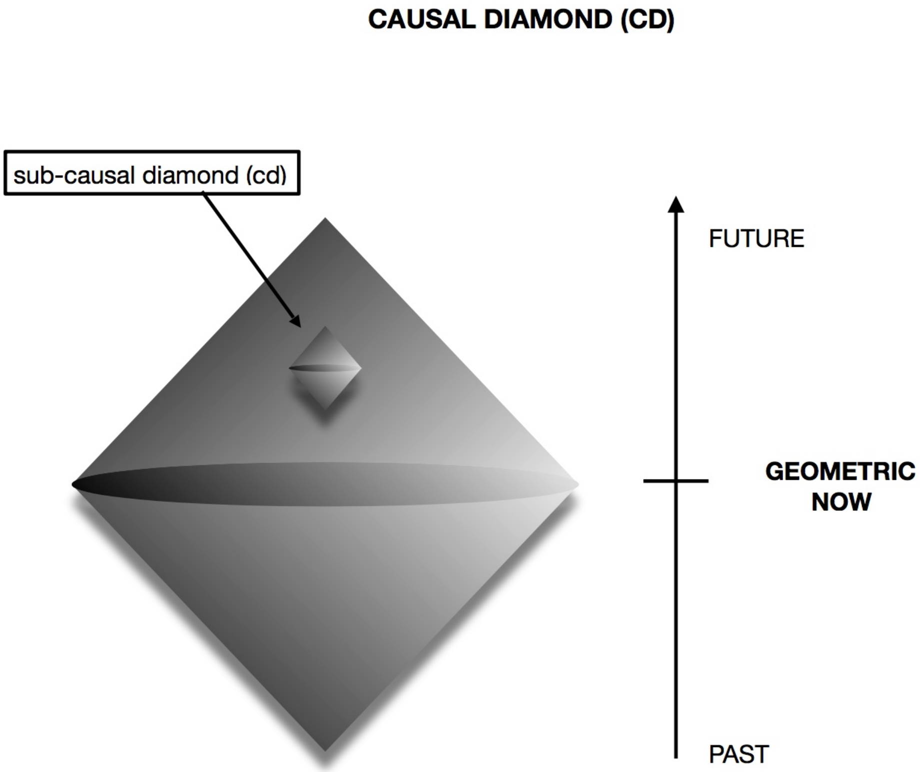

Figure 2: Causal diamond

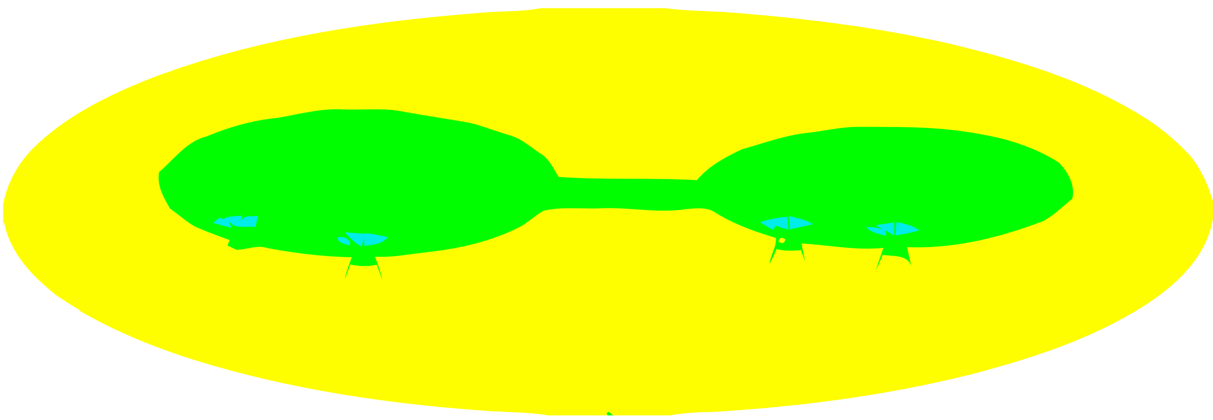

Figure 3: Wormhole contacts.

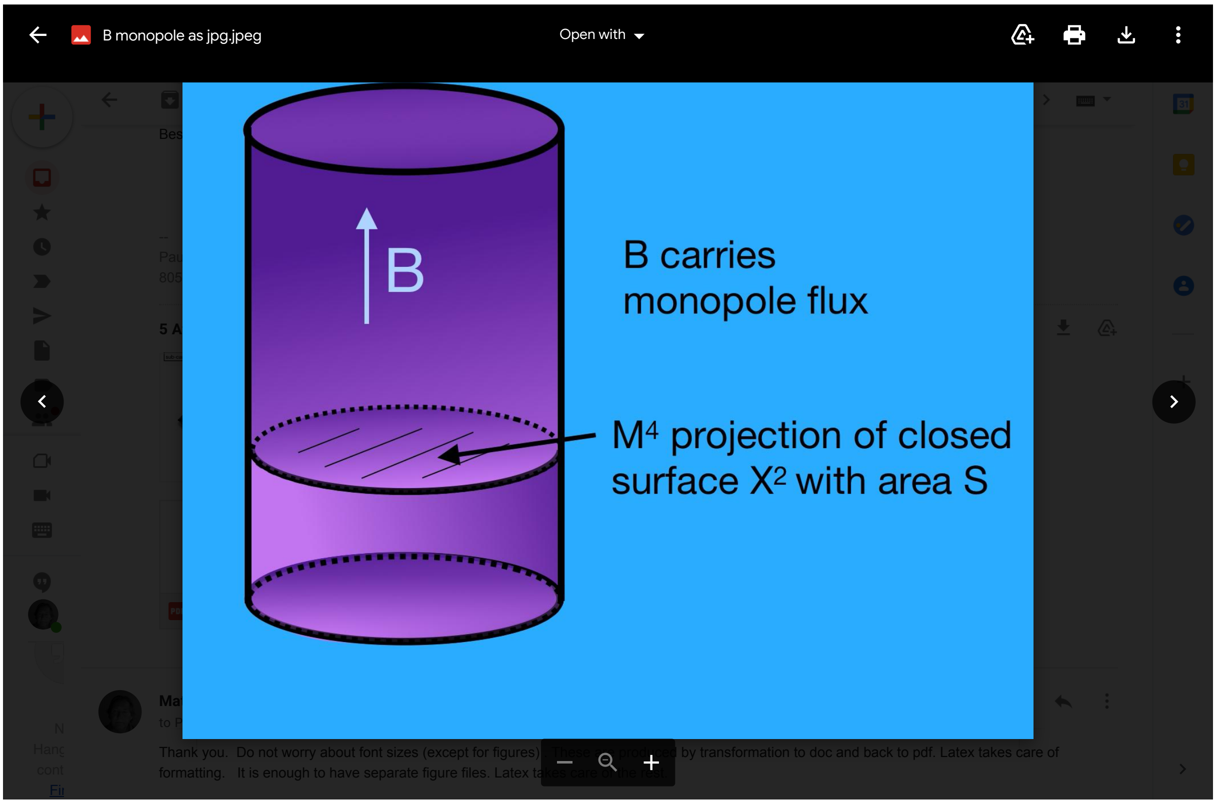

Figure 4: The M^4 projection of a closed surface X^2 with area S defining the cross section for monopole flux tube. Flux quantization $e\oint B\cdot dS = eBS = kh$ at single sheet of n-sheeted flux tube gives for cyclotron frequency $f_c = ZeB/2\pi m = khZ/2\pi mS$. The variation of S implies frequency modulation.

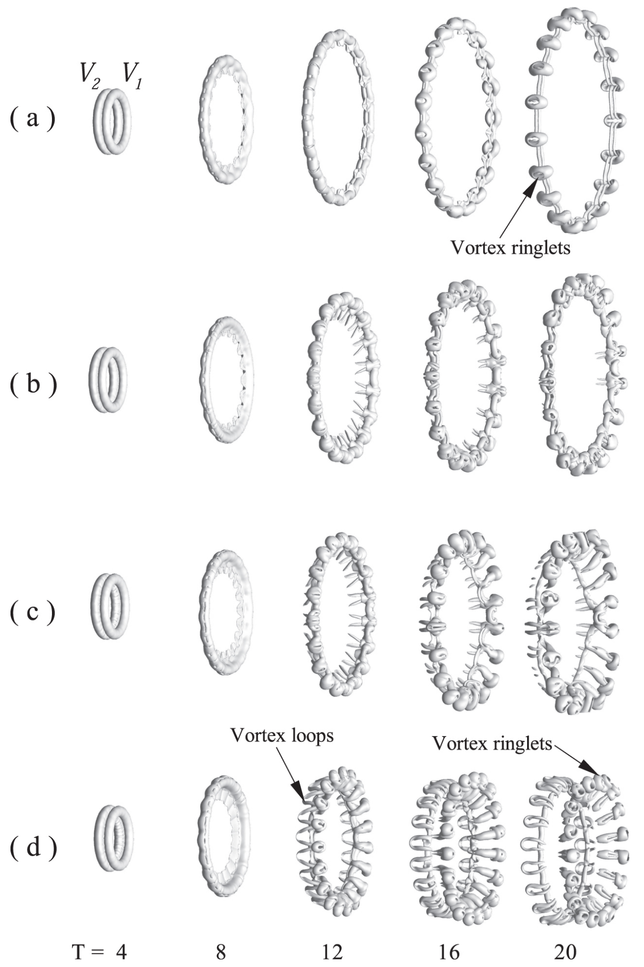

Figure 5: Illustrations of flow patterns resulting in a numerical simulation of a head-on collision of vortex rings with opposite circulations.

Figure 6: Illustrations of flow patterns resulting in a real head-on collision of vortex rings with opposite circulations.

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