Exploration

TGD & Quantum Hydrodynamics: General Ideas & Generation of Turbulence

Matti Pitkänen [1]

Abstract

This article is the first one in a series of 2 articles. The purpose of this is to consider possible applications of Topological Geometrodynamics (TGD) to hydrodynamics and quantum 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 $H = M^4 \times CP_2$. In the first article, the topics are general ideas of TGD inspired quantum hydrodynamics and generation of hydrodynamical and also magnetohydrodynamical turbulence. 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.

[1] Correspondence: Matti Pitkänen http://tgdtheory.fi/. Address: Rinnekatu 2-4 8A, 03620, Karkkila, Finland. Email: matpitka6@gmail.com.

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1 Introduction

This article is the first one in a series devoted to the question of what Quantum Hydrodynamics (QHD) could mean in the TGD framework. In this article basic ideas are introduced and the TGD based approach to hydrodynamic turbulence is discussed. 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. 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 [41]. Beltrami flow for classical Kähler field defines an integrable flow [34]. There is no dissipation classically and this can be interpreted as a correlate for a quantum coherent phase.

   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 [41].

2. Quantum hydrodynamics appears in TGD as an *exact* classical correlate of quantum theory [16]. Modified Dirac equation forces 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. This condition allows a considerable in understanding of the basic structure of quantum TGD [43].

3. Induced Kähler form J is the fundamental classical 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.

   The twistor lift of TGD strongly suggests that also M^4 possesses the analog of Kähler structure and its existence leads to a solution of longstanding problems of quantum TGD. M^4 Kähler form gives an additional contribution to the U(1) parts of electromagnetic and Z^0 fields, which could play key role in hydrodynamic systems at the magnetic body of the system carrying phases with large value of h_{eff}. Especially interesting possibility is Nottale's hypothesis $\hbar_{eff} = \hbar_{gr} = GMm/v_0$ finding support from hydrodynamic quantum analogs.

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.

   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.

   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.

5. 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 if the corresponding Killing vectors with proportionality factor constant along the projections of their flow lines [37]. 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. In the TGD framework, the braidings of flow lines correspond to the braidings of flux tubes and also 2-knots involving reconnections of flux tubes are possible.

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.

6. In zero energy ontology (ZEO) ordinary ("big") state function reductions (BSFRs) involve time reversal. This forces generalization of thermodynamics and leads to a new view about self-organization: at least some self-organization phenomena could correspond to dissipation in reversed time direction. The occurrence of time reversal at the MB of the hydrodynamical system could be essential for understanding the generation of turbulence as a self-organization phenomenon. The decay of turbulence could take place after the return of the original arrow of time.

Some key challenges related to the understanding of hydrodynamic turbulence 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.

2. 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).

3. 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.

4. 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 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 [4] (`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 [3] (`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 [4] (`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.

2.2 Super fluid flow 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 $D^2A \equiv \nabla^2 A - \nabla(\nabla \cdot A) = j$.

   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^2A 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.

2.3 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.

2.4 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 [23]. 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 [12].

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 [23], 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 [30, 33], 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

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

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

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

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

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

   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

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

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

   This would give

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

   This implies

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

   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

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

   From this one obtains

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

   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

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

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.

2.5 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.

2.5.1 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 must be a minimal surface. In this case electroweak gauge fields would vanish.

What is of central importance, is that this does not imply the vanishing of the induced Kähler gauge potential. 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.

2.5.2 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. 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, then the latter space-time sheets could contain a current creating magnetic field with non-mopole flux.

2.5.3 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 fluid implies that the velocities of the fluid 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 fluid. 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

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

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 presence of fluid with Z^0 charge density opposite to that of the fluid and having inertial mass density of the object. The spinning object would effectively correspond to a fluid with a Z^0 charge density opposite to that of the fluid.

   If the spinning object is Z^0 charged, it contributes to the density of the Z^0 charge and the size of the Magnus effect is changed. If the argument is correct, the Magnus effect for fluid vortices as cylindrical objects is predicted to be proportional to the difference of fluid densities inside and outside the vortex.

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 [19] [39], 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 [13, 11] 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. M^4 option

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.

2.5.4 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 A model for the generation 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.

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 [38] 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 [34].

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 $h_{eff} = h$ [38]. 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 [22] [29] 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 [27]. 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 [7], 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 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 [18, 21, 20, 17] could correspond to this phase.

3.2 Some examples about 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 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 a monopole flux tube 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 [9] 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 [8] 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. 1**) and **2**).

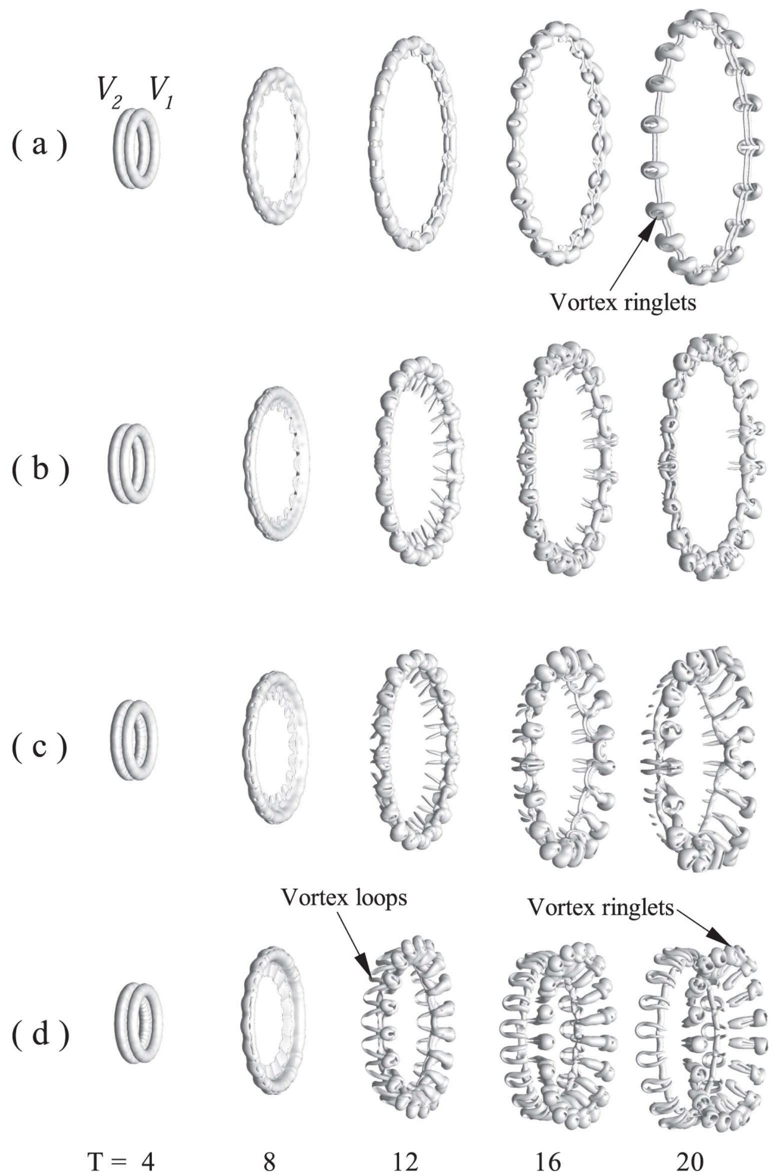

Figure 1: Illustrations of flow patterns resulting in a numerical simulation of a head-on collision of vortex rings with opposite circulations.

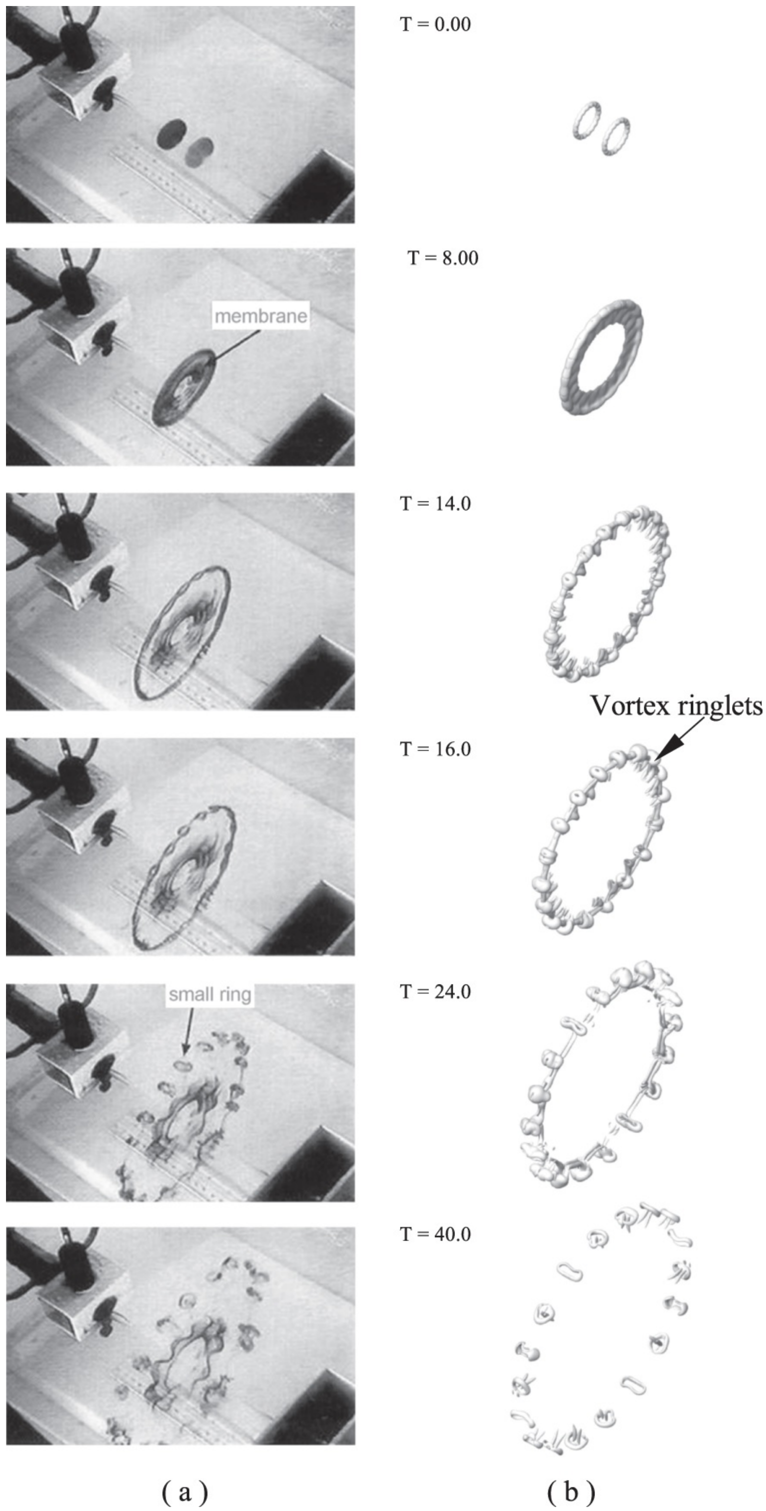

Figure 2: Illustrations of flow patterns resulting in a real head-on collision of vortex rings with opposite circulations.

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. 1**) illustrates the complexity of the resulting patterns. **Fig. 2**) 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. 1**) 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. 1**).

3.3 Breaking of the circulation theorem of Kelvin

This section was motivated by the article of Tobias et al [5] 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 [5].

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 citeGaloisTGD. 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 [32]. 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 $n\bar{h}_0$ 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 [31, 32] 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 [32].

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. In the core of the vortex, Beltrami flow implying the absence of classical dissipation, requires that that the CP_2 projection is 2-D.

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 [5], 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 $\Lambda_{gr} = GM/v_0$ [40, 39].

   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 [35].

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 [29, 22]. 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 [27].

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 electro-magnetic 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) RayleighTaylor instability (R-T) are instabilities of fluid flow.

1. Kelvin-Helmholz instability (K-H) (`https://cutt.ly/TENyKZO`) 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. RayleighTaylor 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 [1] (`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 [37].

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 [42].

3.5 Some comments about quantum hydrodynamics

In this section some questions related to TGD inspired quantum hydrodynamics for various quasiparticle 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 [2] (`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 $h_{eff}/h = n$?

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