TGD View of the Engine Powering Jets from Active Galactic Nuclei

M. Pitkänen,

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Email: matpitka6@gmail.com.
http://tgdtheory.com/public_html/.
Postal address: Rinnekatu 2-4 A 8, 03620, Karkkila, Finland. ORCID: 0000-0002-8051-4364.

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Abstract

The identification of the energy source (central engine) explaining the energy loss associated with the jets from active galactic nuclei (AGNs) is a long-standing problem of astrophysics. In the model of Blandford and Znajek (BZ model) for the central engine as a blackhole, the Penrose process would provide the energy. The energy would come basically from the blackhole mass.

Empirical support for the BZ model emerges from the study of the supermassive blackhole associated with a galaxy known as Messier 87 (M87). The finding is that the magnetic field associated with the jet structure is tightly wound helical structure and so strong that it would control the dynamics of the matter from falling to blackhole except by occasional leakages. Electron-positron pairs created in the annihilation of photons would accelerate in the force-free helical electromagnetic field having also an electric component.

The TGD based model involves several aspects of the new physics predicted by TDG. TGD leads to a model of galaxies and other astrophysical structures. Inflaton decay is replaced with the thickening of cosmic strings to flux tubes liberating as ordinary matter. Hierarchy of Planck constants $h_{eff} = nh_0$, in particular Nottale's hypothesis predicts quantum coherence in the exterior of in scales at least of order Schwartschild radius of the blackhole-like entity. Zero energy ontology (ZEO) predicts that the arrow of time changes in ordinary state function reductions. TGD replaces black-holes with blackhole-like entities (BHs) and white-holes with their time reversals (WHs) allowed in ZEO.

BH (WH) would be a volume filling flux tube but with a relatively small value of h_{eff}. In the case of WH, it would provide "metabolic energy" for jets and take care that the value of h_{eff} is preserved (the analogy with living systems is very strong). The jets would be analogous to laser beams/supracurrents with a huge value of $h_{eff} = h_{gr}$. The model would also explain the ultrahigh energy cosmic rays. The force-free fields would be generalized Beltrami fields associated with flux tubes and identifiable as minimal surfaces in the Minkowskian regions of space-time surface. The absence of classical dissipation would be a correlate for the absence of dissipation for supra-currents and dark photon laser beams.

1 Introduction

This work was inspired by a Quanta Magazine article "Physicists Identify the Engine Powering blackhole Energy Beams" (`https://cutt.ly/dQtDK7Q`) telling about an empirical support for the model of Blandford and Znajek (BZ model in the sequel) [E8] for the central engine providing energy for jets from active galactic nuclei (AGNs). In the BZ model (`https://cutt.ly/9QtDOkK`) AGN is identified as a blackhole and the Penrose process would provide the energy of the jets emerging from the blackhole. The energy would come basically from the blackhole mass. The empirical support is found by studying the supermassive blackhole associated with a galaxy known as Messier 87 (M87).

The basic problem is the identification of the central engine of the active galactic nuclei (AGNs) (`https://cutt.ly/eQtFyib`) providing the huge energy feed to the the jets.

1.1 Typical properties of active galactic nuclei

The power emitted by active galactic nuclei (AGNs) is typically of the order of 10^{38} W corresponding to a transformation of a mass of 10^{22} kg per second to energy. The typical radius of the AGN is $R \simeq 2$ AU for the active region.

One must distinguish between magnetic fields associated with the interior of the central objects, the region near its surface, and the jet region with the scale of visible jets about 10^5 ly. According to the estimate of [E3] (`https://cutt.ly/DQtFzD3`), the magnetic field is about 10 Gauss in the jet region. About $10^6 - 10^7$ Gauss near horizon. Also near-horizon magnetic fields in the range $10^8 - 10^{11}$ Tesla have been proposed for some AGNs.

Quasars are examples of AGNs and also M87 central region idenfied as a blackhole is such. In this case the mass is $6.5 \times 10^9 M_{Sun}$ and Scwartschild radius is about 2×10^{10} km $= 1.3 \times 10^3$ AU. For M87 central object the magnetic field in the jet region is that of refrigerator magnet and about 100 Gauss. For Sagittarius A has a in the center of the Milky Way the radius of the central object .4 AU.

One can pose some general conditions on the central engine serving as the energy source for the jets. The time scale Δt for the luminosity fluctuations in the power should satisfy $\Delta t < R$. For M87 one has $\Delta t \leq 10^4$ s. The gravitational force is assumed to be balanced by the radiation pressure of the outward radiation.

Consider now the observations about the M87 blackhole-like entity (`https://cutt.ly/dQtDK7Q`).

1. The mass of the M87 black-hole-like entity is about $6.5 \times 10^9 M_{Sun}$.

2. There are two 5,000 ly long white hot plasma jets travelling in opposite time directions with emitted power of 3×10^{36} W. They have blobs at their ends. Synchrotron radiation is emitted at radio wavelengths in the magnetic field, which according to the popular article has the strength of a refrigerator magnet, so that one would have $B \sim 100$ Gauss. Both the intensity of B and the size of the emitting region contribute to the intensity of the energy flow.

3. There are two alternatives for the BZ process that have been developed and explored in hundreds of computer simulations in recent decades. They have acronyms MAD and SANE.

   For the SANE option B is weak: charged matter dominates over B. For the MAD option B is strong, has a spiral structure and acts as a "boss" of the matter. The tight spiral structure forms a sleeve around the jet preventing charges from entering the central object. This inspires a critical question: doesn't the object look more like a whitehole.

   The strongly polarized light in the Event Horizon Telescope's new photo suggests strong magnetic fields, and supports the MAD version. B has a strength of about 100 Gauss, that is 200 times the strength of the Earth's magnetic field with the nominal value $B_E \simeq .5$ Gauss. The polarization pattern for the radio waves is found to be stripy and the polarization in a plane locally: this allows us to conclude that the magnetic field is indeed helical and non-random.

1.2 Central engine as a Penrose process?

In the BZ model, the central object is assumed to be a blackhole and Penrose process would provide the energy feed to the jets of length about 5000 ly. Note that the Milky Way is about 1,0000 ly thick.

1. The blackhole is surrounded by an accretion disk from which the matter ends down to the BH.

2. Kerr solution of Einstein-Maxwell field equations [B2, B6] (`https://cutt.ly/sQuKXth`) involving magnetic field is the starting point. Matter falling into the Kerr blackhole rotates and the magnetic field lines are twisted to helical shape. By Faraday law, an electric field along field lines is generated by the rotation of the flux lines. Electrons and positrons created in the annihilation photons emitted as the particles fall to the region near the blachole, start to flow along the field lines of the electric field in opposite directions and generate the jets.

3. The model assumes that the electromagnetic field is force free so that it does not dissipate and Lorentz force vanishes. At a single particle level this implies the condition $E + qv \times B = 0$. Vanishing dissipation requires $v \cdot E = 0$. This helical structure would be in the direction of the jet.

4. The basic question has been whether it is accretion disk or magnetic field that controls the dynamics. The first option, known as SANE, corresponds to weak and incoherent magnetic fields. The second option, known as MAD, corresponds to strong and coherent magnetic fields.

5. MAD is favoured by the recent observations. Magnetic field would form a sleeve around the jet and the synchrotron radiation pressure would prevent matter from falling into the blackhole. Matter can only occasionally leak to blackhole.

   One can however wonder whether it makes sense to talk about blackhole anymore! Doesn't this look more like white hole as a time reversal of blackhole feeding energy and matter to the environment?

1.3 TGD inspired view of the central engine

In the TGD framework the model of the central engine as a Penrose process is replaced by the following picture. The key concepts are following:

1. Space-time is identified as a 4-D minimal surface in $H = M^4 \times CP_2$ [L26] or as an algebraic surface in complexified M^8 having octonionic interpretation [L14, L15, L20]. These descriptions are related by $M^8 - H$ duality analogous to momentum-position duality, which does not generalize from wave mechanics to quantum field theory (QFT). Therefore the points or M^8 are 8-momenta.

   The classical dissipation is absent for the generalized Beltrami fields and the proposal [L26] is that minimal surfaces (apart form singularities defining dynamically generated frame for space-time surfaces as analog of a soap film) define locally generalized Beltrami fields.

2. Zero energy ontology (ZEO) [L12, L23, L21] predicts that time reversal occurs in the TGD counterparts of ordinary state function reductions ("big" SFRs) but not in "small" SFRs (SSFRs).

3. The hierarchy of effective Planck constants predicts a hierarchy of phases of ordinary matter labelled by the values of effective Planck constant $h_{eff} = nh_0$. The phases with different values of h_{eff} behave in many respects like dark matter with respect to each other. The findings of Randell Mills suggest $\hbar/\hbar_0 = 6$ [L3] but also larger values for this ratio can be considered [L22]. In [L22] it is proposed that the $\hbar_0/\hbar$ is equal to the ratio l_P/R of Planck length l_P to CP_2 radius R.

   As a special case, one obtains gravitational Planck constant satisfying $h_{eff} = h_{gr} = GMm/\beta_0$, where $\beta_0 = v_0/c$ and $\beta_0 < c$ has dimensions of velocity, as a generalization of Nottale's hypothesis [E1]. The gravitational Compton length $\lambda_{gr} = \hbar_{gr}/m = GM/\beta_0$ does not depend on m and is equal to Schwartschild radius r_s for $\beta_0 = 1/2$. Also the cyclotron energy spectrum $E_c = nGMqB/\beta_0$ is independent of the mass of the charged particle.

   The hierarchy of Planck constants, the notion of $\hbar_{gr}$, and coupling constant evolution are discussed in detail in [L22].

Consider now the key elements of the model.

1. TGD leads to a general model for the formation of galaxies, stars, planets,... in terms of cosmic strings thickening to flux tubes [L9, L10, L11]. The energy of the flux tube, which consists of a volume energy and Kähler magnetic energy, is transformed to ordinary matter as the string tension is reduced in a sequence of phase transitions reducing the length scale dependent cosmological constant Λ.

   This process is analogous to the decay of an inflaton field to matter. The model (there are actually several basic variants of it) explains the flat velocity spectra associated with the spiral galaxies. For the first option, a long cosmic string normal to the galactic plane causes the gravitational field explaining the flat velocity spectrum of spiral galaxies. For galaxies formed around closed flux loops the velocity spectrum is not flat. There is no dark matter halo although it is possible that the galactic plane contains cosmic strings parallel to the plane.

2. ZEO (ZEO) [L12, L23, L21], which predicts that the TGD counterparts of ordinary state function reductions (SFRs) involve time reversal, is involved in an essential way. TGD predicts both blackhole-like objects (BH) and whitehole-like objects (WH) as the time reversals of BHs. The seed of the galaxy, active galactic nucleus (AGN), involves WH. Quasars are cases of AGNs as WHs [L9, L10].

3. In the TGD framework, the Kerr blackhole [B2, B6] is replaced with a whitehole-like object (WH). Kerr blackhole indeed has an opposite arrow of time reversal as the distant environment. The WH is time reversal of BH and feeds matter and energy to the environment. This serves as an analog of the Penrose process in the TGD based model.

4. The TGD analog for the rotation of spacetime and the twisting of the magnetic field lines near the Kerr blackhole is very concrete. Space-time is a 4-surface and the flux tubes carrying monopole flux are pieces of 3-space as a 3-surface. They quite concretely rotate and get twisted in the process. Analogous process occurs in the Sun with a period of 11 years ending as reconnections untwist the flux tubes.

5. WH would correspond to a tangle of a long cosmic string in the direction of the jet thickened to a flux tube but still carrying an extremely strong magnetic field. The helical magnetic field in the exterior of the jet would not represent return flux of this field as one might first think. There is a current ring associated with the equator of Earth, which carries a parallel magnetic field analogous to the helical magnetic field.

   The magnetic field in the exterior of WH is associated with a space-time surface, which is many-sheeted with respect to CP_2 rather than M^4 so that either CP_2 or cosmic string world sheet $M^2 \times S^2 \subset M^4 \times CP_2)$ would serve as the arena of physics rather than M^4, which is quantum coherent flux tube bundle analogous to BE-condensate. M^4 coordinates as functions of CP_2 or $M^2 \times CP_2$ coordinates would be many-valued rather than vice versa. This picture is very natural if one accepts $M^8 - H$ duality [L14, L15, L20].

   Cosmic strings dominate during the primordial cosmology in TGD Universe, and the analog of the inflationary period corresponds to the transition to a phase in which the Einsteinian space-time with M^4 as the arena of physics is a good approximation. Hence the $M^2 \times CP_2$ option looks more plausible.

6. The force-free em fields appearing in the BZ model [E8] correspond to space-time surfaces as minimal surfaces realizing a 4-D generalization [K5, K6, K2] of 3-D Beltrami fields [B1, B5, B3, B4], which do not not dissipate classically [K1]. The interpretation of the non-dissipating Kähler currents is as classical correlates for supracurrents [L17]. The prediction is that charged particles flow without dissipation that is as supra currents: not only Cooper pairs but also charged fermions. Also the analogs of laser beams of dark photons are expected.

7. The hierarchy of Planck constants [K9] [L22] is an important piece of the picture emerging from adelic physics [L6, L7]. From $\hbar_{gr} = GMm/\beta_0$ realizing Equivalence Principle, the gravitational Compton length $\lambda_{gr} = r_s/2\beta_0$ is universal and equals to r_S for $\beta_0 \equiv \beta_0 = 1/2$.

   All astrophysical objects are predicted to be quantum coherent in the scale of $\lambda_{gr} = r_s/2\beta_0$ at least. The quantum coherence would be at the level of magnetic body (MB) [L11, L10]. WH/BH as a thickened flux tube tangle would not have large h_{eff} but would be accompanied by a large scale quantum object.

   The astroscopic quantum coherence would be associated with the helical magnetic field surrounding the long cosmic string having BH or WH as a tangle.

8. Also the cyclotron energy spectrum is universal and does not depend on the mass of the charged particles so that all charged particles rather than only electrons are expected to form supracurrents. Dark matter would flow along flux tubes and form the dark core of the jet, perhaps extending over cosmic distances to other galaxies identified as tangles of the one and the same cosmic string.

   Stars and even planets would be parts of this fractal network. Dark cyclotron states have huge energies for $h_{eff} = h_{gr}$ serving also as a measure for algebraic complexity and, in the TGD inspired theory of consciousness, also for intelligence and scale of quantum coherence. The analogy with a cosmic nervous system is obvious.

9. The decay of quantum coherent states to ordinary states takes place by the loss of quantum coherence in which $h_{eff} = h_{gr}$ is reduced. This would create the visible jets and blobs at their ends. For M87, which is elliptical for which the velocity spectrum is not flat, the flux tubes would be closed in a relatively short scale. Their length scale could be that of the jets in the case of ellipticals. The thickening of the cosmic string at the core leads to the reduction of mass of WH and gives rise to the flow of mass and energy to the environment. One could see this process as a time reversal for the generation of BH and perhaps also as an analogy for the evaporation of BH.

10. $M^8 - H$ duality [L14, L15, L20] and adelic physics [L7] help to understand the decoherence process geometrically. The reduction of h_{eff} and thus of the length scale of quantum coherence, allows a number theoretic description at the level of M^8. An irreducible polynomial, which depends on parameters, reduces to a product of polynomials for some critical values of the parameters. This gives rise to a set of disjoint space-time surfaces, which are not correlated. This means decoherence. This includes as a special case the description of catastrophic changes in catastrophe theory of Thom [A1]. The maximal decoherence produces a product of first order polynomials with rational roots.

    At the level of H this corresponds to a decay of coherent flux tube bundle to disjoint uncorrelated flux tubes.

2 TGD based model for the formation of galaxies and other astrophysical structures

TGD leads to a rather detailed picture about the formation of galaxies and other basic astrophysical structures [L9, L10, L11].

2.1 Brief description of the model for for the formation of galaxies and stars

TGD based cosmology predicts that the primordial cosmology was dominated by cosmic strings identified as 4-surfaces having 2-D M^4 projection in $H = M^4 \times CP_2$. CP_2 projection is a complex surface of CP_2. The dimension of M^4 projection is unstable against perturbations and during cosmological evolution the M^4 projection thickens. This leads to a model for the formation of galaxies as tangles along cosmic strings in turn containing stars and even planets as sub-tangles [L10, L9, L11].

1. Twistor lift of TGD [L2] predicts that cosmological constant Λ at the level of space-time surface (to be distinguished from that associated with GRT limit of TGD) is length scale dependent. This solves the basic problem caused by the huge value of cosmological constant in the very early Universe. In ZEO length scale dependent Λ having spectrum coming as some negative powers of 2 characterizes the space-time sheets assignable to individual system and the corresponding causal diamond (CD) and is determined by its p-adic length scale.

   For instance, Sun has its own cosmological constant predicted by the model solving the puzzle due to larger abundances obtained in solar-seismological determinations than in spectroscopic and meteoritic determinations. Dark nuclear states of nuclei inside solar core contribute also to the nuclear abundances [L11].

2. The energy of flux tubes consists of Kähler magnetic energy and volume energy. Quantum classical correspondence strongly suggests that this energy is identifiable as dark matter even for minimal value of h_{eff}.

3. Phase transitions reducing the value of cosmological constant are possible. Cosmic strings (or rather their M^4 projections) start to thicken and lose magnetic energy by transforming to ordinary matter. This is analogous to the decay of the inflaton field to matter. This generates Einsteinin space-time with space-time surfaces having large and increasing 4-D M^4 projection. Flux tubes and cosmic strings are however still present.

   The expansion of flux tubes in phase transitions reducing Λ gives rise to a jerk-wise accelerated expansion at the level of astrophysical objects. For given phase transition the accelerated expansion eventually stops since the expansion increases volume energy. The expansion periods however repeat being induced by phase transitions reducing length scale dependent quantized cosmological constant Λ associated with the volume action coming as powers of 2 and making flux tubes unstable against thickening and transformation of magnetic energy to ordinary matter.

   The recent accelerated expansion corresponds to this kind of period being thus analogous to inflation and is predicted to stop since volume energy increases. The expansion rate is predicted to oscillate so that the expansion takes place as jerks and there is evidence for this [E9] (see (http://tinyurl.com/oqcn2hp) discussed from TGD point of view in [K4].

4. In particular, the TGD counterpart of inflation would have led from cosmic string dominated primordial cosmology in which Einsteinian space-time does not make sense to a radiation dominated phase in which Einsteinian space-time makes sense. Expanding Earth model [L8, L25], which allows to understand Cambrian Explosion is one application of TGD based quantum cosmology.

2.2 The notion of length scale dependent cosmological constant

TGD predicts that cosmological constant Λ characterizing space-time sheets is length scale dependent and depends on p-adic length scale. Furthermore, expansion would be fractal and occur in jerks. This is the picture that twistor lift of TGD leads to [L2].

Quite generally, cosmological constant defines itself a length scale $R = 1/\Lambda^{1/2}$. $r = (8\pi)^{1/4}\sqrt{Rl_P}$ - essentially the geometric mean of cosmological and Planck length - defines second much shorter length scale r. The density of dark energy assignable to flux tubes in TGD framework is given as $\rho = 1/r^4$.

In TGD framework these scales corresponds two p-adic length scales coming as half octaves. This predicts a discrete spectrum for the length scale dependent cosmological constant Λ [L2, K7, K10] . For instance, one can assign to ..., galaxies, stars, planets, etc... a value of cosmological constant. This makes sense in many-sheeted space-time but not in standard cosmology.

Cosmic expansion is replaced with a sequence of fast jerks reducing the value of cosmological constant by some power of 2 so that the size of the system increases correspondingly. The jerk involves a phase transition reducing Λ by some negative power of 2 inducing an accelerating period during which flux tube thickness increases and magnetic energy transforms to ordinary matter. Thickening however increases volume energy so that the expansion eventually halts. Also the opposite process could occur and could correspond to a "big" state function reduction (BSFR) in which the arrow of time changes.

An interesting question is whether the formation of neutron stars and super-novas could involve BSFR so that these collapse phenomena would be kind of local Big Bangs but in opposite time direction. One can also ask whether blackhole evaporation could have as TGD analog BSFR meaning return to original time direction by a local Big Bang. TGD analogs of blackholes are discussed in [L9].

Evidence for the anisotropy of the acceleration of cosmic expansion has been reported (see http://tinyurl.com/rx4224f). Anisotropy of cosmic acceleration would fit with the hierarchy of scale dependent cosmological constants predicting a fractal hierarchy of cosmologies within cosmologies down to particle physics length scales and even below. The phase transitions reducing the value of Λ for given causal diamond would induce accelerated inflation like period as the magnetic energy of flux tubes decays to ordinary particles. This would give a fractal hierachy of accelerations in various scales.

2.3 Some examples

Consider now some representative examples to see whether this picture can be connected to empirical reality [L10].

1. Cosmological constant in the length scale of recent cosmology corresponds to $R \sim 10^{26}$ m (see http://tinyurl.com/k4bwlzu). The corresponding shorter scale $r = (8\pi)^{1/4}\sqrt{Rl_P}$ is identified essentially as the geometric mean of R and Planck length l_P and equals to $r \sim 4 \times 10^{-4}$ m: the size scale of large neuron. This is very probably not an accident: this scale would correspond to the thickness of monopole flux tubes.

2. If the large scale R is solar radius about 7×10^8 m, the short scale $r \simeq 10^{12}$ m is about electron Compton length, which corresponds to p-adic length scale $L(127)$ assignable to Mersenne prime $M_{127} = 2^{127} - 1$. This is also the size of dark proton explaining dark fusion deduced from Holmlid's findings [L4, L5]: this requires $h_{eff} \sim 2^{12}$!

Remark: Dark proton sequences could be neutralized by a sequence of ordinary electrons locally. This could give rise to analogs of atoms with electrons being very densely packed along the flux tube.

The prediction of the TGD based model explaining the 10 year old puzzle related to the fact that nuclear abundances in solar interior are larger than outside [L11] (http://tinyurl.com/y38m54ud) assumes that nuclear reactions in Sun occur through intermediate states which are dark nuclei. Hot fusion in the Sun would thus involve the same mechanism as "cold fusion" [L5, L16]. The view about cosmological constant and TGD view about nuclear fusion lead to the same prediction.

3. If the short scale is p-adic length $L(113)$ assignable to Gaussian Mersenne $M_{G,113} = (1+i)^{113} - 1$ defining nuclear size scale of $r \sim 10^{-14}$ m, one has $R \sim 10$ km, the radius of a typical neutron star (see http://tinyurl.com/y5ukv2wt) having a typical mass of 1.4 solar masses.

   A possible interpretation is as a minimum length of a flux tube containing sequence of nucleons or nuclei and giving rise to a tangle. Neutron would take volume of about nuclear size - size of the magnetic body of neutron? Could supernova explosions be regarded as phase transitions scaling the stellar Λ by a power of 2 by making it larger and reducing dramatically the radius of the star?

4. Short scale $r \sim 10^{-15}$ m corresponding to proton Compton length gives R about 100 m. Could this scale correspond to quark star (see http://tinyurl.com/y3n78tjs)? The known candidates for quark stars are smaller than neutron stars but have considerably larger radius measured in few kilometers. Weak length scale would give large radius of about 1 cm. The thickness of flux tube would be electroweak length scale.

Starting from this picture, one ends up to rather detailed picture making correct predictions about minimum radii of blackholes and neutron stars.

1. The idea about ordinary stars as blackhole-like objects in generalized sense emerges naturally since flux tubes are universal objects in TGD Universe and could be also inspired by the fashion of dualizing everything to blackholes.

2. The standard blackhole thermodynamics is replaced by two thermodynamics. The first thermodynamics is assignable to the flux tubes as string like entities having Hagedorn temperature T_H as maximal temperature.

   The second thermodynamics is assignable to the gravitational flux tubes characterized by the gravitational Planck constant h_{gr}: Hawking temperature T_B is scaled up by the ratio $\hbar_{gr}/\hbar$ to $T_{B,D}$ and is gigantic as compared to the ordinary Hawking temperature but the intensity of dark Hawking radiation is extremely low.

   The condition $T_H = T_{B,D}$ for thermodynamical equilibrium fixes the velocity parameter $\beta_0 = v_0/c$ appearing in the Nottale formula for $\hbar_{gr}$ and suggests $\beta_0 = 1/h_{eff}$ for the dark nuclei at flux tubes defining star as blackhole like entity in TGD sense.

   This also predicts the Hagedorn temperature of the counterpart of blackhole in GRT sense to to be hadronic Hagedorn temperature assignable to the flux tube containing dark nuclei as dark nucleon sequences so that there is a remarkable internal consistency. In ZEO (ZEO) quasars and active galactic nuclei can be seen as white-hole like objects (WHs) and time reversals of blackhole-like objects (BHs).

3. The cosmological time anomalies such as stars older than the Universe can be understood. In ZEO the time evolution for the zero energy states associated with causal diamonds (CDs) by sequences of small state function reductions (weak measurements) gives rise to conscious entity, self. Self dies and re-incarnates with an opposite arrow of time in big (ordinary) state function reduction reversing the arrow of time. These reincarnations define kind of universal Karma's cycle. If the Karma's cycle leaves the sizes of CDs bounded and their position in M^4 unaffected, quantum dynamics reduces to a local dynamics inside CDs defining sub-cosmologies. In particular, the age distributions and properties of stars depend only weakly

on the value of cosmic time - stars older than the Universe become possible in standard view about time.

4. The flux tube picture about galaxies and larger structures explains the flat velocity spectrum of spiral galaxies if they correspond to tangles of long cosmic strings in which string thickens to flux tube. For elliptical galaxies the cosmic string would be relatively short that the velocity spectrum would not be flat. There would be no dark matter halo except possibly due to the presence of cosmic strings in galactic plane. Some anomalies strongly suggesting the presence of quantum coherence in scales of even billion light years. This could be due to the presence of long quantum coherent structures consisting of flux tube bundles.

5. The presence of dark matter in TGD sense having huge effective Planck constant $h_{eff} = h_{gr} = GMm/\beta_0$ provides a general solution of the well-known angular momentum problem. As the energy associated with thickening cosmic string is transformed to ordinary matter, it must start to rotate around the string to avoid falling back to the cosmic string. This is consistent with angular momentum conservation only if cosmic string generates an opposite angular momentum by developing a helical structure [L18] such that dark matter flows along string and rotates at the same time. This solves the well-known angular momentum of the GRT based models.

6. The general model suggests that at least quasars and perhaps all AGNs are actually white-hole like objects as time reversals of blackhole-like objects. The TGD counterpart of BZ model support this view.

2.4 Is James Webb telescope forcing a revolution in cosmology?

The first preliminary findings of the James Webb telescope, the successor of the Hubble telescope, are in conflict with the standard view of the formation of galaxies. The YouTube video (`https://cutt.ly/OZc4lV7`) "James Webb Found Galaxies That Sort of Break Modern Theories" gives a good summary of these findings. The findings are also summarized in an article in Nature [E11] (`https://cutt.ly/lZc4clq`) with the title "Four revelations from the Webb telescope about distant galaxies".

2.4.1 The official story

The official story of the formation of galaxies goes roughly as follows.

1. Around 3 minutes of cosmic time, the cosmic microwave background emerged as the first atoms formed and radiation decoupled from matter.

2. When the age of the Universe was more than about .1 billion years, the first stars were formed. They lived their life and exploded as supernovas and yielded interstellar hydrogen gas. Galaxies started to form. One can see this process as a gravitational condensation. What is essential is that this process went from long to short scales, just as the formation of stars in the earlier phase.

3. The model gives a stringent upper bound for the age of the galaxies. They should be younger than the oldest observed stars. This limit gives an upper bound for the distance of the galaxy, that is for its redshift.

2.4.2 The findings of James Webb telescope

The first, preliminary, observations of the James Webb telescope were galaxies with redshifts up to 16. Even redsshift extending to 20 have been speculated in arXiv papers. Redshift 16 would correspond to the age of 250 million years and redshift of 20 to the age of 200 million years. They are too far to fit into the official picture. To get some perspective, note that the estimate for the age of the Universe is 13.8 billion years.

The ages of these galaxies were few hundred million years and of the same order as the estimated ages of about 100 million years of the hypothetical population III stars (`https://cutt.ly/`

eZc4mr1), which are thought to be the oldest stars but have not not (yet?) detected. The criterion for the age of the star is its metal content: the first stars should have contained only hydrogen and Helium and "metal" here means anything heavier than Helium.

The suggestive conclusion is that there was a significant population of star forming galaxies in the early universe. This challenges the standard view stating that stars came first and led to the formation of galaxies.

Scientific American has an article with title "JWST's First Glimpses of Early Galaxies Could Break Cosmology" (https://cutt.ly/R0hqYLW), which provide a nice summary of the first findings of the telescope. This gave an opportunity to sharpen the somewhat fuzzy view of how the findings of James Webb telescope relate to TGD.

What was found first, was a galaxy dubbed as "GLASS-z13". It was found by Rohan Naidu and led to an article published within a few days. The discovery of the GLASS-z13 was followed by a discovery by numerous even more distant galaxies. The very existence and the properties of these galaxies came as a total surprise.

1. From the redshift of about $z = 13$, the GLASS-z13 was dated back 300 million years after the big bang that is thought to have occured 13.8 billion years ago. According to the standard view of galaxy formation (so called Lambda CDM model involving dark matter as exotic particles), galaxies with such a large distance are not expected to even exist. According to the standard model, the formation of galaxies should have begun at the cosmic age of about 400 million years. The galaxy found by Naidu would have emerged more than 70 millions years too early.

2. The images of the galaxies from so early era were expected to be extremely dim. The galaxies discovered were however anomalously bright.

3. The large size of the galaxies came as a total surprise. The age of the galaxies increases with its age and the conclusion was that the galaxies had to be much more mature than the standard model for the formation of galaxies allows. This leads to a paradox since the first galaxies should be very young.

2.4.3 The TGD view of the formation of galaxies

TGD proposes an unofficial view of the formation of galaxies [L9, L10, L24].

1. In the very beginning the Universe was dominated by cosmic strings, which were space-time surfaces in $H = M^4 \times CP_2$ having 2-dimensional M^4 projection. They were not "Einsteinian" space-time surfaces with 4-D M^4 projection and have no counterpart in general relativity.

2. Cosmic strings were unstable against thickening of the M^4 projection to 4-D one. Phase transitions thickening the cosmic strings occurred and increased their thickness and reduced string tension so that part of their energy transformed to ordinary matter. This is the TGD counterpart for inflation.

   This process led to radiation dominated Universe and the local description of the Universe as an Einsteinian 4-surface became a good approximation and is used in standard cosmology based on the standard model as a QFT limit of TGD.

   At this moment the thickness of the thickened strings would be around 100 micrometers, which corresponds to a length scale around large neuron size. Water blob with this size has mass of order Planck mass. The connection with biology is suggestive [L28, L30, L13].

3. The liberated dark energy (and possible dark matter, dark in the TGD sense) assignable to cosmic strings produced quasars, which in the TGD framework are identified as time reversals of the ordinary galactic blackholes. They did not extract matter from the environment but feeded darl energy as matter to the environment as jets. Jets are observed and explained in terms of the magnetic field due to the rotation of the galaxy.

   The jets are somewhat problematic in the GRT based cosmology since the simplest, non-rotating Schwarzschild blackholes do not allow them. The rotating blackholes identifiable as

Kerr-Newman blackholes [B2, B6] accompanied by magnetic fields, also have some interpretational problems. For instance, the arrow of time can be said to be different in the nearby and faraway regions and closed time-like geodesics are possible. In TGD, this could have an interpretation in terms of zero energy ontology (ZEO). The matter from the jets would have eventually led to the formation of atoms, stars, and galaxies.

4. What is essential is that the formation of galaxies proceeds from short to long scales rather than vice versa as in the standard cosmology. A second essential point is that the dark energy (and possible dark matter) concentrated at cosmic strings was added to the ordinary matter predicted by the standard model to be present in the radiation dominated cosmology. This led to the formation of galaxies. Therefore this picture is consistent with the standard story as far as the formation of atoms and emergence of CMB is considered.

The possibility considered in [L9, L10, L24] is that quasars are time reversed black-holes (this property can be formulated precisely in zero energy ontology (ZEO), which forms the basis of TGD based quantum measurement theory) [L12, L27] [K11]. Note that the time reversal property would hold true in long time scales at the magnetic body (MB) defined by the monopole flux tubes produced by the thickening of the cosmic strings. For ordinary matter, the scale for the time spent with a given arrow of time is very short but MB with a large gravitational Planck constant can force ordinary matter to effectively behave like its time reversed version.

There is indeed quite recent support for the proposal that quasars are time reversals of blackhole-like objects identified in the TGD framework as monopole flux tube tangles. The Hubble telescope detected a dwarf galaxy at a distance of 30 million light years for which the number of stars is about 10 per cent for that in the Milky Way [E10]. Its center contains a blackhole-like object (`https://cutt.ly/kZc77B1`), which did not extract matter from the environment but did just the opposite by jets, which gave rise to a formation of stars.

The observations challenging the basic dogma of blackhole physics are not new and during writing of the article [L24] I got the impression that one of the basic challenges is to explain why some blackholes do just the opposite of what they should do.

This picture leads to ask whether blackhole evaporation could have a counterpart in TGD. The "death" of blachole-like object (BHO) could mean a macroscopic "big" state function reduction (BSFR) in which the arrow of time changes. Since the time reversal occurs at the level of MB, one can observe the behavior of time reversed BHO at the new geometric past of the BHO and finds that BHO feeds matter to the environment and can produce stars. Biological death (and also falling asleep) would correspond to BSFR. Could the time reversed history for BHO correspond to the evaporation of the ordinary blackhole? Could an analog of the decay of a dead organism occur after the geometric time at which time reversal for BHO took place.

2.4.4 TGD based explanation for the three paradoxical findings

One can indeed understand the 3 paradoxical findings described in Scientific American article in the TGD view of galaxy formation.

1. According to the standard model, these galaxies were formed quite too early. The standard mechanism of formation is a gravitational condensation of stars and interstellar to form galaxies. Dark matter halo plays a key role in the process. The model is however plagued by several contradictions. As a matter of fact, empirical facts suggest that there is no dark halo. The MOND model explains many of the anomalies but is in conflict with the Equivalence Principle and in conflict with standard Newtonian gravitation. The TGD based model replaces dark matter halo with long cosmic strings carrying dark energy and possibly also dark matter. One does not lose either Equivalence Principle or Newtonian gravitation.

   The TGD based view of galaxy formation is diametrically opposite to the standard view, being analogous to the generation of ordinary matter via the decay of the inflation field in the inflationary cosmology. Ordinary matter would have been created by the decay of the energy of cosmic strings to ordinary matter as they formed tangles. This led to a thickening of cosmic strings to monopole flux tubes and to a reduction of string tension so that energy was liberated as ordinary matter. In particular, galactic dark matter and the flat velocity spectrum of distant stars find an elegant explanation.

In this view galaxies started to emerge already during the TGD analogue of the inflationary period.

2. The high apparent luminosity of these galaxies is the second mystery. Are the galaxies indeed so luminous as they seem to be? Or could it be that the standard view of how light emitted by galaxies is distributed is somehow wrong?

   In the TGD framework, the space-time of general relativity is replaced with a fractal network of nodes defined by various structures including galaxies, stars, planets,... Monopole magnetic flux tubes connect the nodes and the light propages as beams of dark photons (in the TGD sense) along these flux tubes. A light beam travelling along a flux tube is not attenuated at all if the cross section of the flux tube stays constant. Therefore the intensity of the light beam is not reduced with distance. In GRT it would be reduced since there would be no splitting to beams. This would explain why the apparent luminosities of the galaxies are anomalously high.

3. The unexpectedly large size of the galaxies implies a long age if one believes in the standard view of galactic evolution. This paradox finds a solution in zero energy ontology (ZEO), which defines the ontology of quantum TGD. ZEO solves the basic paradox of quantum measurement theory and is forced by the holography implied in the TGD framework by 4-D general coordinate invariance.

   In ZEO, the arrow of time changes in ordinary quantum jumps ("big" state function reductions, BSFRs). The repeated change of the arrow of time in the sequence of BSFRs implies that the system can be said to live forth and back in geometric time. Aging does not correspond to "center of mass motion" in time direction but this forth and back motion. In the TGD inspired biology, BSFR is analogous to death or falling asleep.

   In "small" SFRs (SSFRs) the arrow of time is not changed and they are counterparts of weak measurements introduced by quantum opticians. They generalize the quantum measurements associated with the Zeno effect, in which a system is frozen and its state does not change. Now the sequence of SSFRs would define a conscious entity, self.

   In TGD, gravitational quantum coherence is possible in all scales and galaxies would be astrophysical quantum systems performing BSFRs. Even astrophysical objects such as galaxies would live forth and back in time. This would give rise to galaxies and stars older than the Universe if one tries to explain their age using the standard view of the relationship between experienced time and geometric time.

3 The findings of the James Webb telescope concerning very early Universe

The list of the discoveries of the James Webb telescope is rather impressive (`rb.gy/8gjh2`). There is also a popular article "12 amazing James Webb Space Telescope discoveries across the universe" (`rb.gy/rdj0c`). The list includes discoveries related to galaxies and globular star clusters in the very early universe, star formation, exoplanets, in particular hot Jupiters, protoplanets, and brown dwarfs.

The Youtube video (see `rb.gy/j52ux`) in LAB360 with the title "James Webb Telescope Detects more than 700 Galaxies at the Edge of Our Universe" summarizes some of the basic findings of the James Webb telescope concerning the very early Universe.

The preliminary paradoxical findings of the James Webb telescope have been affirmed and now there is much more detailed picture available about galaxies and stars in the very early Universe challenging the standard cosmology.

I have considered the findings of James Webb telescope from the TGD point of view in [L29, L24]). The TGD view of cosmology and astrophysics is discusse in articles [L9, L10, L24, L31, L32].

3.1 Summary of the findings of the James Webb telescope

The existence of more than 700 galaxies a few hundred million years after BB is in sharp conflict with the standard Big Bang Model although it is consistent with the cosmic expansion. Distance measurements indeed use cosmic redshift to deduce the distances of the galaxies. In any case, the James Webb telescope is profoundly shaking the foundations of cosmology. It seems that one can safely forget the standard story about the formation of stars and galaxies and also inflation as the generally accepted story of what happened before that.

In the standard picture, the epoch of reionization starts 1 billion years after the BB as the fog of gas is cleared by reionization so that photons can propagate. No signals hould arrive from the epoc preceding reionization. These 700 galaxies should not be there since they are too young, existing 370-500 million years after BB.

The mass of the galaxy serves as a measure for the age of the galaxy but 6 galaxies with age .5 Gy and 10 times bigger than the Milky Way have been found! This makes one wonder, what will be found when one goes farther back in time?

JW can see galaxies as extended objects with visible structures and this provides a lot of additional information about the composition of these too-early birds.

1. Complex organic molecules, found also in smoke/fog, were found [E7]: this is 1 billion years too early! These molecules, polycyclic aromatic hydrocarbons (PAHs) (`rb.gy/cx75l`), are big molecules, containing hundreds of atoms. What adds to the mystery, is that PAHs were found in regions where there are no stars or star formation but not in regions where stars are forming! PAH world hypothesis states that PAHs have played a key role in prebiotic life leading the emergence of RNAs (`rb.gy/z6vma`).

2. Also the locations of these molecules can be determined by JW in terms of their spectra. The distribution of the molecules is not uniform as one might expect. These galaxies can have the same mass as the Milky Way. The mass serves as a measure for the age of the galaxy but the age of these galaxies, according to standard cosmology, is only 10 percent of that of the Milky Way. This creates a paradox.

3. One particular galaxy, GN-z11 (`rb.gy/gx9fh`) is observed as it existed 13.3 Gy ago.

   (a) GN-z11 is found to contain an exceptionally high proportion of nitrogen and abundance of stars.

   (b) Birth of globular star clusters (`rb.gy/xezay`) have been found in GN-z11. This finding is especially paradoxical since they are regarded as very old objects! The compositions of O,N, Na, and Al vary inside globular clusters. These anomalies have been known for a long time `rb.gy/8rdew`). One however expects that the stars of the cluster should have the same origin and age in the early universe.

   (c) Also supermassive stars (`rb.gy/o0y36`), having masses of few hundred solar masses, have been found in globular clusters. Multiple globular clusters have been found.

3.2 What theoretical implications the discoveries might have?

The findings of the James Webb telescope could be fatal for the fashionable theories related to standard cosmology. Inflationary scenario is the predecessor of radiation dominated cosmology which was once thought to be understood and it is difficult to think that it could survive if the cosmic evolution at the later period differs dramatically from the expectations.

One of the possible victims of the mass extinction of theories is ΛCDM model of cold dark matter, which has been the guiding cosmology for decades. Professor Boylan-Kolchin's paper, "Stress testing ΛCDM with high-redshift galaxy candidates" published in Nature Astronomy [E6] (`https://www.nature.com/articles/s41550-023-01937-7`) discusses the constraint posed by the James Webb findings. The problem is that both the stellar and galactic masses are limited by the baryonic reservoir and the detected unexpectedly large number of massive stars and galaxies is at the very edge of these limits.

3.3 TGD explanation of the paradoxical findings of the James Webb telescope about very early Universe

What goes wrong with the standard cosmology? Could TGD inspired cosmology suggest an answer?

3.3.1 Zero energy ontology

Consider first zero energy ontology (ZEO) and the TGD view of dark matter. TGD suggests that the prevailing view about the notion of time is wrong. TGD forces a new ontology of quantum theory, which I call zero energy ontology (ZEO) [L12].

1. Causal diamond (CD) as a state-determined and dynamical quantization volume has two boundaries and zero energy states are in fermionic degrees of freedom superpositions of pairs of 3-D states asociated with these two.

2. Zero energy states corresponds also to superpositions of space-time surfaces connecting the two boundaries of CD. By the almost deterministic holography implied by the 4-D general coordinate invariance, the space-time analogs 4-D analogs of Bohr orbits of particles as 3-D surfaces. In ZEO, subjective time and geometric time are not the same thing but are strongly correlated. This new ontology solves the basic paradox of quantum measurement theory.

3. There are two kind of state functions reductions (SFRs): "Small" SFRs (SSFRs) corresponding to repeated measurements in Zeno effect and "big" SFRs (BSFRs) corresponding to ordinary SFRs. CD has two kind of boundaries; active and passive. In SSFRs, the active boundary and states at it change whereas the passive boundary and the states at it remain unaffected. This is the counterpart of the Zeno effect: the state changes slighty but the arrow of time is preserved. SSFRs also correspond to weak measurements in quantum optics.

   In BSFRs the arrow of time changes. BSFR occurs when the set of observables measured in SSFR a the active boundary of CD does not commute with those measured earlier at the passive boundary of CD. CD increases in size in a statistical sense during the sequence of SSFRs since the active boundary drifts farther from the passive one. This gives rise to the correlation of subjective time a sequence of SSFRs with geometric time a distance between the tips of CD.

3.3.2 Hierarchy of dark matters as $h_{eff} = nh_0$ phases of ordinary matter

TGD also predicts quantum coherence in arbitrarily long scales and gravitational quantum coherence corresponds to the longest, even astrophysical, coherence scales since gravitational interaction has infinite range and is unscreened [L28]. The gravitational Planck constant introduced by Nottale [E1] characterizes the monopole flux tubes connecting astrophysical objects. Along these flux dark gravitons mediating gravitational interaction and also other dark particles propagate. This has important implications in TGD inspired biology since the gravitational magnetic bodies of Sun, planets and perhaps even Moon become key plaryes in TGD inspired quantum biology.

TGD leads also to a view of dark energy identified as classical energy assignable to string like objects that I call cosmic strings. Their thickening to monopole flux tubes lead to vision about the formation of galaxies, stars and planets differing in many respects dramatically from the standard view [L9, L10, L24, L31, L32]. In particular, galactic dark matter would be associated with long cosmic strings formed as thickenings of the cosmic strings to monopole flux tubes.

The change of arrow of time in BSFR implies dramatic effects even in astrophysical scales. Even astrophysical objects can live forth and back in geometric time. The ageing in the physical sense occurs in both directions of geometric time so that the physical age is total time spent in this moving forth and back. Since the passive boundary is stationary, the physical ageing in ZEO is faster than ageing in the standard ontology.

3.3.3 TGD view of the anomalies

Consider now a slightly more detailed the explanation of the various anomalies.

1. Time anomalies

Consider first the time anomalies.

1. ZEO explains stars and galaxies older than the Universe.

2. ZEO also predicts the variation of the ages of galaxies and stars in the very early Universe. Since galaxies and stars can be born at different periods in this life forth and back in geometric time, they can have different ages in the sense of ZEO. This explains why the abundances of atoms associated with the stars of star clusters are found to vary. The life forth and back in time also explains the appearance of globular star clusters, which are very old and are not possible in standard cosmology.

2. PAHs in the very early Universe

What about PAHs, which appear in the regions where star formation does not occur and do not appear in the region containing stars?

1. The TGD view of nuclear physics, originally inspired by the findings about "cold fusion", and based on the notion of dark nuclei, identified scaled up analogs of ordinary nuclei, leads to a model of prestellar evolution based on dark fusion (explaining also "cold fusion" [L11, L5, L16]).

   "Dark" means that the nucleons of these nuclei have non-standard values of Planck constant $h_{eff} = nh_0$. In the number theoretic vision of TGD, integer n has interpretation as the dimension of extension of rationals associated with the polynomial with integer coefficients, which defines the space-time region [L14, L15, L33].

2. Dark fusion generates dark nuclei as sequences of dark protons at monopole flux tubes having size scale of electron Compton length. Their binding energy is much smaller than the binding energy of the ordinary nuclei. Dark nuclei can therefore transform to ordinary nuclei and liberate most of the nuclear binding energy in the process, this give rise to "cold fusion". The temperature of the dark fusion region increases in the process and eventually reaches the temperature at which ordinary nuclear fusion can start.

   Even chemistry and complex molecules can emerge before the ordinary nuclear fusion is ignited. This could explain the presence of PAHs, in particular their presence in regions, where there is no star formation or stars.

3. James Webb telescope has also found complex organic molecules, such as methanol and ethanol, in pre-stellar ice in the molecular cloud Chamaeleon I located 630 light year away (`rb.gy/d3q0s`). Contrary to expectations, this finding suggests that many star and planetary systems developing in Chamaeleon I contain molecules in a fairly advanced chemical state. This would indicate that the presence of precursors to prebiotic chemicals in planetary systems is a typical outcome of star formation rather than a peculiarity of our solar system.

   In the TGD framework, dark fusion could produce heavier elements before the ignition of the ordinary nuclear fusion and lead also to a development of complex chemistry [L5, L16]. This could resolve some mysteries related to the abundances of nuclei such as the origin of nuclei heavier than Fe and also the anomalous abundances of some lighter nuclei. Also objects like brown dwarfs (`rb.gy/41kp5`), called planets , which failed to become stars, could have emerged in this way. James Webb has also identified numerous protostars, which have not yet reached the ignition temperature (`rb.gy/6hsax`): they could be similar objects. TGD however suggests that planets could have formed by an explosion throwing out an outermost layer of the stellar magnetic body as a magnetic bubble consisting of monopole flux tubes carrying dark matter, which would then transform to ordinary matter in a process starting with dark fusion [L31, L32].

3. Why signals from the period preceding the reionization are possible at all?

One reason is that there was a reionization. TGD also allows us to consider the possibility that the signals arrive as dark photons along monopole flux tubes of a cosmic flux tube network acting as an analog of the nervous system. Also in the TGD based model of the brain, dark photon signals propagating between the central nervous system and magnetic body play a key role.

I have considered the findings of James Webb telescope from the TGD point of view in [L29, L24]). The TGD view of cosmology and astrophysics is discussed in various articles [L9, L10, L24, L31, L32].

3.4 About the identification of the Schrödinger galaxy

The latest mystery related created by the observations of James Webb telescope is so called Schrödinger galaxy [E2] (see this and this).

It has been found that the determination of the redshift $1+z=a_{now}/a_{emit}$ gives two possible space-time positions for the Schrödinger galaxy CEERS-1749 a_{now} *resp.* a_{emit} corresponds to the scale factor for the recent cosmology *resp.* cosmology when the radiation was emitted. Note that for not too large distances the recession velocity β satisfies the Hubble law $\beta = HD$. The nickname "Schrödinger galaxy" comes from the impression that the same galaxy could have existed in two different times in the same direction.

Accordingly, CHEERs allows two alternative identifications: either as an exceptionally luminous galaxy with $z \sim 17$ or as a galaxy with exceptionally low luminosity with $z \sim 5$. Both these identifications challenge the standard view about galaxy formation based on ΛCDM cosmology.

1. The first interpretation is that CHEERS is very luminous, much more luminous than the standard cosmology would suggest, and has the redshift $z \sim 17$, which corresponds to light with the age of 13.6 billion years. The Universe was at the moment of emission $t_{emit} = 220$ million years old.

   In the TGD framework, the puzzlingly high luminosity might be understood in terms of a cosmic web of monopole flux tubes guiding the radiation along the flux tubes. This would also make it possible to understand other similar galaxies with a high value of z but would not explain their very long evolutionary ages and sizes. Here the zero energy ontology (ZEO) of TGD could come in rescue [L34, L31, L32].

2. Another analysis suggest that the environment of the CHEERS contains galaxies with redshift $z \sim 5$. The mundane explanation would be that CHEERS is an exceptionally dusty/quenched galaxy with the redshift $z \sim 5$ for which light would be 12.5 billion years old.

   Could TGD explain the exceptionally low luminosity of $z \sim 5$ galaxy? Zero energy ontology (ZEO) and the TGD view of dark matter and energy predict that also galaxies should make "big" state function reductions (BSFRs) in astrophysical scales. In BSFRs the arrow of time changes so that the galaxy would become invisible since the classical signals from it would propagate to the geometric past. This might explain the passive periods of galaxies quite generally and the existence of galaxies older than the Universe. Could the $z \sim 5$ galaxy be in this passive phase with a reversed arrow of time so that the radiation from it would be exceptionally weak.

TGD seems to be consistent with both explanations. To make the situation even more confusing, one can ask whether two distinct galaxies at the same light of sight could be involved. This kind of assumption seems to be unnecessary but one can try to defend this question in the TGD framework.

1. In the TGD framework space-times are 4-surfaces in $M^4 \times CP_2$. A good approximation is as an Einsteinian 4-surface, which by definition has a 4-D M^4 projection. The scale factor a corresponds to the light-cone proper time assignable to the causal diamond CD with which the space-time surface is associated. a is a very convenient coordinate since it has a simple geometrical interpretation at the level of embedding space $M^4 \times CP_2$. The cosmic time t assignable to the space-time surface is expressible as $t(a)$.

2. Astrophysical objects, in particular galaxies, can form comoving tessellations (lattice-like structures) of the hyperbolic space H^3, which corresponds to $a = constant$, and thus $t(a)$ constant surfaces. The tessellation of H^3 is expanding with cosmic time a and the values of the hyperbolic angle η and spatial direction angles for the points of the tessellation do not depend on the value of a. The direction angles and hyperbolic angle for the points of the tessellation are quantized in analogy with the angles characterizing the points of a Platonic solid and this gives rise to a quantized redshift.

   A tessellation for stars making possible gravitational diffraction and therefore channelling and amplification of gravitational radiation in discrete directions, could explain the recently observed gravitational hum [L35], These tessellations could also explain the mysterious God's fingers [E4], discovered by Halton Arp, as sequences of identical look stars or galaxies of hyperbolic tessellations along the line of sight [L26, K8]. Maybe something similar is involved now.

This raises two questions.

1. Could two similar galaxies at the same line of sight be behind Schrödinger galaxy and correspond to the points of scaled versions of the tessellation of H^3 having therefore different values of a and hyperbolic angle η? The spatial directions characterized by direction angle would be the same. Could one think that the tessellation consists of similar galaxies in the same way as lattices in condensed matter physics? The proposed explanation for the recently observed gravitational hum indeed assumes tessellation form by stars and most stars are very similar to our Sun [L35].

   The obvious question is whether also the neighbours of the $z \sim 5$ galaxy belong to the scaled up tessellation. The scaling factor between these two tessellations would be $a_5/a_{17} = 17/5$. Could it be that the resolution does allow to distinguish the neighbors of the $z \sim 17$ galaxy from each other so that they would be seen as a single galaxy with an exceptionally high luminosity? Or could it be that the $z \sim 5$ galaxy is in a passive phase with a reversed arrow of time and does not create any detectable signal so that the signal is due to $z \sim 17$ galaxy.

2. Could one even think that the values of hyperbolic angles are the same for the two galaxies in which case the $z \sim 5$ galaxy could correspond to $z \sim 17$ galaxy but in the passive phase with an opposite arrow of time? The ages of most galaxies are between 10 and 13.6 billion years so that this option deserves to be excluded. Could the hyperbolic tessellation explain why two similar galaxies could exist at the same line of sight in a 4-dimensional sense?

   This option is attractive but is actually easy to exclude. The light arriving from the galaxies propagates along light-like geodesics. Suppose that a light-like geodesic connects the observer to the $z \sim 17$ galaxy. The position of the $z \sim 5$ galaxy would be obtained by scaling the H^3 of the older galaxy by the ratio $a(young)/a(old)$. Geometrically it is rather obvious that the geodesic connecting it to the observer cannot be lightlike but becomes space-like. If one approximates space-time with M^4 this is completely obvious.

Consider now more precisely the conditions posed by the light-likeness of the geodesic representing the arriving photon.

1. Let us assume that the light from the distant galaxy moves along a light-like geodesic of X^4. The equation for the light-like geodesic line reads as $dt^2 - a^2(t)sinh^2(\eta)d\eta^2 = 0$. From this one can solve $cosh(\eta)$ as

$$cosh(\eta) - 1 = 2sinh^2(\eta/2) = \int_{t_{emit}}^{t_{now}} dt/a(t)) \quad .$$

2. It is convenient to look at what happens when the space-time surface X^4 is approximated with M^4. This gives $a = t$ and the differential equation can be solved:

$$sinh(\eta/2) = \sqrt{ln(\sqrt{\frac{a_{now}}{a_{emit}}})} \quad .$$

   The quantized value of η for the point of the tessellation fixes the ratio a_{now}/a_{emit} and therefore of a_{emit}. Already this is highly non-trivial. Since the functions appearing on both sides are monotonically increasing, only a single value of a_{emit} is possible for a given value of η. Therefore the strong option cannot be true as already the intuitive argument made clear.

3. During the matter dominated era lasting from $t_0 = 47,000$ years to $t_{end} = 9.8$ billion years, the condition

$$a(t) = a_{end}(\frac{t}{t_{end}})^{2/3} \quad .$$

After that standard model assumes de Sitter Universe with an accelerating expansion with

$$a(t) \propto a_{end}exp(H_0(t-t_{end}) \quad .$$

Here one has $H_0 = \sqrt{\Lambda/3}$, where Λ is cosmological constant and $H_0 \simeq 70.88$ kms^{2}Mpc^{-1} is the Hubble constant. Hubble time corresponds to $t_H = H_0/c \simeq 13.79$ billion years. Therefore the ratio t_{now}/t_H equals to 1 with percent accuracy. This gives $a(t) \simeq a_{end}exp((t-t_{end})/t_{now})$.

4. One obtains for the value of $sinh(\eta/2)$ the expression

$$sinh(\eta/2) = \sqrt{X_{md}+X_{dS}} \quad , X_{md} = \frac{3}{4}t_{end}^{2/3}(t_{end}^{1/3}-t_{emit}^{1/3}) \quad , X_{dS} \simeq \frac{1}{2}\frac{t_{now}}{a_{end}}(1-exp[-1+\frac{t_{end}}{t_{now}}]) \quad .$$

A cautious TGD inspired conclusion is that TGD cannot select between $z \sim 17$ and $z \sim 5$ interpretations but that most naturally only one of them is realized. Certainly it is not possible to identify the two galaxies as time= constant snapshots of the same galaxy such that $z \sim 5$ galaxy has a reversed arrow of time and corresponds to the same point of an expanding tessellation of H^3. The identification of the galaxies as different points of an expanding tessellation with different quantized values of the hyperbolic angle η is not excluded but has no explanatory power. One could try to check whether the two galaxies can be identified as scaled variants of some hyperbolic tessellation having a different value of the η.

4 TGD counterpart of BZ model for central engine

The best manner to explain the TGD variant of BZ model inspired by the Penrose process is to start from the abstract of the original article [E8] (`https://cutt.ly/9QtDOkK`).

"It is shown that if the magnetic field and angular momentum of a Kerr blackhole are large enough, the vacuum surrounding the hole is unstable because any stray charged particles will be electrostatically accelerated and will radiate, with the radiation producing electron-positron pairs so freely that the electromagnetic field in the vicinity of the event horizon will become approximately force-free.

Equations governing stationary force-free electromagnetic fields in Kerr spacetime are derived, and it is found that energy and angular momentum can be extracted from a rotating blackhole by a purely electromagnetic mechanism.

The present concepts are applied to a model of an active galactic nucleus containing a massive blackhole surrounded by an accretion disk."

4.1 Beltrami field as the TGD counterpart of force-free field

1. Force free field corresponds in TGD to a generalized Beltrami field conjectured to define very general solutions of field equations [L17]. Beltrami fields are analogous to the solutions of Maxwell's equations in the sense that they are dissipation free. This corresponds to the vanishing of the Lorentz force giving $\rho E + j\times B = 0$ and vanishing dissipation giving $j\cdot E = 0$. Therefore the covariant divergence of the energy momentum tensor vanishes and it is plausible that Einstein's equations hold true at the field theory limit.

2. If Beltrami fields correspond to minimal surfaces and at the same time extremals of Kähler action (this requires what I call Hamilton-Jacobi structure as a generalization of ordinary complex structure), the analogs of massless field equations are satisfied as for Maxwell action.

3. The topologies of Beltrami fields are extremely composite and represent knotting and linking of field lines [B1, B5, B3, B4]. Helical flux tubes with electric fields parallel to the flux tubes are excellent candidates for Beltrami fields. Configurations of magnetic field, electric field and current such that all three are mutually orthogonal, are suggestive.

   Quantum classical coherence together with the absence of dissipation suggests that supracurrents proportional to j are present.

4.2 Whitehole-like object as the TGD counterpart of Kerr blackhole

Kerr blackhole is used as a model for a rotating blackhole with magnetic field [B2, B6] (`https://cutt.ly/sQuKXth`) has besides horizon an outer surface known as ergosphere. At ergosphere light-moving around light-like geodesics is stationary from the point of view of a very distant stationary observer.

In the TGD framework, Kerr blackhole is replaced with a white-hole like object (WH) as a time reversal of a blackhole-like object (BH). This is possible in ZEO (ZEO) [L12, L23]. WH is a portion of a tangle of a cosmic string, which has thickened to a flux tube. This reduces string tension as energy per unit length and the system emits energy as ordinary matter to the environment leading to the creation of the galaxy. The process is analogous to the decay of the inflaton field.

4.3 Are secondary objects with quantum coherence scale of order λ_{gr} possible?

All BHs and could be seen as gravitionally quantum coherent objects. For $\beta_0 = 1/2$ quantum gravitational coherence length is at least r_s. If $\beta_0 \leq 1/2$ holds true, r_S is the smallest possible quantum gravitational coherence length.

However, Nottale's hypothesis would assign quantum gravitational coherence length of at least $\lambda_{gr} = GME/v_0$ also to objects which are not BHs. As a matter of fact, TGD leads to a generalization of the notion of BH as a model for the final state of the star [L10].

The following intriguing observations inspire the question whether $r_s/2\beta_0$ could define the scale of quantum gravitational coherence also for the secondary objects associated with the astrophysical objects with mass M rather than only WHs and BHs.

1. For Sun λ_{gr} is rather near to the radius of Earth for $\beta_0 \simeq 2^{-11}$ for the 4 inner planets. Could this be interpreted in terms of quantum coherent structure formed by parallel flux tubes such that planets correspond to tangles associated with them?

2. The central engines of AGNs have typical size about 2AU, where AU is the distance of Earth from the Sun and size of the inner planetary system [L17]. For the blackhole in the center of Milky Way the radius is about .4 AU.

   Is this a mere coincidence or could the important size scales of stellar systems correspond at some level to quantum gravitionally coherent objects with gravitational Compton length determined by AGN? This could be the case if flux tube flux tube bundle from AGN with $h_{eff} = \hbar_{gr}(AGN)$ extends to the galactic plane and forms stellar systems as sub-tangles.

3. One could see the central engine as a provider of metabolic energy to the quantum coherent system formed by the flux tube bundle analogous to a laser beam. The energy feed is necessary to preserve the value of $\hbar_{gr}$ since it tends to be reduced spontaneously. For instance, flux tubes can separate from the bundles as tubes with $h_{eff} = h$. In the terminology of TGD inspired quantum biology, the flux tube bundle would be the magnetic body of the AGN.

4.4 The TGD counterpart of the Penrose process

A popular description of the Penrose process is as follows. Outside the Kerr blackhole a piece of mass split to two pieces. One piece falls to the blackhole and the other piece goes outside (one can imagine that a rocket accelerates outwards and the fuel from a rocket falls into the blackhole). The blackhole piece can be said to have negative energy. By energy conservation this means that one obtains energy from the blackhole. Also the angular momentum of WH is reduced.

One can say that the 3-space around Kerr blackhole is captured into a rotating motion. This applies also to magnetic fields so that the flux lines get twisted and helical patterns are generated. The matter associated with flux lines generates angular momentum.

1. In the TGD framework, the matter from WH forms gravitationally bound states and must rotate in order to avoid falling back to WH. Angular momentum conservation, which is exact in TGD and forces the twisting of the flux tubes so that linear motion forces rotational motion and the system develops classical angular momentum. Also the charged particles flowing along the helical flux tube contribute to the angular momentum. For space-time surfaces, the notion of space-time being captured to rotation is very concretely realized.

2. Also electric field is generated along the helical flux tube to guarantee vanishing of the Lorentz force. In the recent case there is however no accelerated motion. Rather, the flow is dissipation free and gives rise to analog of a supracurrent and/or laser beam. The natural guess for the radius of the helix is as the Schwartschild radius. Quantum gravitational coherence would result from $\hbar_{gr} = GM/\beta_0$ at least in the scale defined by $\lambda_{gr} = r_s/2\beta_0$ equal to Schwartschild radius for $\beta_0 = v_0/c = 1/2$

4.4.1 The magnetic fields associated with the central object and jets

I have considered the identification of BH/WH as a volume filling tangle of a cosmic string thickened to a flux tube and having an ordinary value or relatively small value of $\hbar_{eff}$ much smaller than $\hbar_{gr}$ [L10, L11].

The flux tube outside BH/WH could form a flux tube bundle of parallel flux tubes having interpretation as manysheeted space-time with respect to CP_2 or more plausibly $M^2 \times S^2$, serving therefore as the arena of physics instead of M^4. The $\hbar_{gr}/h_0$ would correspond to parallel flux tubes forming a quantum coherent structure.

This helical quantum coherent flux tube structure would be parallel to cosmic string but could have much larger size that the jet length of order 5000 ly. Both would be closed. The tangles of the cosmic string could give give rise to other galaxies, stars, and even planets as suggested [L10, L11]. Cyclotron energy in the quantum coherent be however proportional to $\hbar_{gr}$.

In the case of spiral galaxies, this cosmic string would be very long and could connect galaxies: the recent findings suggest that the surrounding structure rotates. This leads to the proposal that the angular momentum of dark matter associated witht this structure compensates for that of ordinary matter [L18]: this would solve the well-known angular momentum problem of GRT based cosmology. For elliptical galaxies about which M87 is an example, the velocity spectrum is not flat and the flux tube bundles should close in a relatively short scale.

In the WH/BH region there would be much thinner volume filling flux tube - flux tube spaghetti with relatively small value of h_{eff}. The total flux for a single strand of tangle would be that for the cosmic string itself. There are analogous systems in biology. Proteins consist of parts, which are random coils, helical regions, and planar tangles. These geometries would be induced by the underlying flux tube parallel to the protein. In the recent case, the tangles would be 3-D and have cylindrical geometry in the simplest situation.

Consider now a more detailed model for the magnetic field of M87. The central region is expected to have very strong magnetic field whereas the surrounding region would have much weak magnetic field consisting of parallel flux tubes forming a quantum coherent structure with the length of quantum coherence larger than λ_{gr} identified as parallel space-time sheets but with respect to CP_2 rather than M^4.

Consider first the quantum coherent flux tube structure outside WH surrounding the jet like glove.

1. Suppose that the magnetic field (see the figure of `https://cutt.ly/dQtDK7Q`) external to the central region corresponds to that for a tangle formed by a cosmic string thickened to a flux tube. $\hbar_{gr}$ would be the number of the parallel flux tubes of the tangle. Many-sheetedness holds true with respect to CP_2 - one can say that CP_2 or $M^2 \times S^2$ serves as the arena of physics instead of M^4.

2. The estimate for the radius of the flux tube obtained by dividing the area πr_s^2 with $\hbar_{gr}/\hbar \simeq 10^{24}$ is of order 2 m so that the helical flux tube structure outside the central object cannot

correspond to the observed stripy structure for the magnetic field seen in the polarization patterns. Could the observed stripes correspond to sub-bundles with $\hbar_{eff} \leq \hbar_{gr}$? Or could the quantized monopole flux for the flux tube proportional to the area of the flux tube be large?

3. A reasonable working hypothesis is that the strength of B outside the central region is not more than 100 Gauss in the recent case. Second working hypothesis is that the entire B outside WH is a monopole flux field.

   For $\beta_0 = 1/2$, the gravitational cyclotron energy is $E_{c,gr} \simeq 10^{10}$ GeV: this is by an order of magnitude smaller than the minimal energy scale of ultrahigh energy (UHE) cosmic rays, which is by definition larger than 10^{11} GeV. This supports $\beta_0 = 1/2$ as also the fact that λ_{gr} is equal to r_S, which is a good guess form the minimal value of λ_{gr}

   In the case of M87, quantum coherent emission - whatever it actually means - should take place in a region of size scale about r_s. The length of visible jets is about 5,000 ly Could this scale correspond to the length scale of the helical flux tube tangle in the vertical direction outside the central object?

According to the earlier model [L10] the central region corresponds to a volume filling monopole flux tube tangle formed from a cosmic string by thickening and having much narrower flux tubes and by flux conservation with much stronger field strength.

1. The field strength in the central region identified as WH could have considerably higher values. Active galactic nuclei (AGNs) (`https://cutt.ly/DQtFhH3`), which include quasars, emit jets and the emitted power is typically 10^{38} W to be compared with 3×10^{36} W for M87. The typical radius of the central region is $R \simeq 2$ AU for the active region and about 3 orders of magnitude larger than in the case of M87.

2. The estimate of [E3] (`https://cutt.ly/DQtFzD3`) gives a magnetic field $B \sim 10$ Gauss in the jet region whereas the field strength in the horizon is estimated to be in the range $10^6 - 10^7$ Gauss. Also near-horizon magnetic fields in the range $10^8 - 10^{11}$ Tesla have been proposed for AGNs.

One obtains a rough estimate for the radius r of the flux tube assuming that inside WH the tangle fills the volume.

1. Assume that the particles inside the flux tube are protons with $h_{eff} = h$ and with an average distance equal to the radius of the flux tube. The number N of protons is $N = V/v = (r_s/r)^3$ from which $r = (r_s^3/N)^{1/3}$. One can also express N as M/m_p so that one has $r = ((2G)^3 M^2 m_p)^{1/3} \propto M^{2/3}$ so that r increases with the mass of the central object. For M87 one obtains $r \simeq 10^{-12}$ m, which is of the order electron Compton length. This would suggest that the protons are dark with the value of $h_{eff}/h \simeq m_p/m_e \simeq 2^{11}$. The TGD based model for "cold fusion" leads to the value of h_{eff} [L5, L1, L16].

2. By flux conservation, a single unit of flux would correspond to a flux tube with radius equal to Compton length L_c of electron. If L_c equals to the magnetic length $L_B = \sqrt{\hbar/eB}$, one has from $L_B(Tesla) = 26nm$, that the $B \simeq 10^4$ Tesla. If the unit of quantization for magnetic flux is scaled up to $\hbar_{eff}$, the field strength is scaled by $mp_{/}m_e \simeq 2^{11}$ to 2×10^7 Tesla. This option is more natural.

To get some perspective, one can estimate r also for a blackhole with solar mass.

1. From the ratio $M(M87)/M_{Sun} \sim 6.5 \times 10^9$ one obtains that r for a blackhole with solar mass is roughly $.3 \times 10^{-6}$ times smaller than for M87 so that one would have $r \simeq .3 \times 10^{-18}$ m, which is by a factor $.2 \times 10^{-3}$ shorter than proton Compton length 1.3×10^{-15} m.

2. This suggests that the particles are not protons but particles with a higher mass $m = xm_p$. In this case the above estimate is scaled up $r \rightarrow x^{1/3}$. p-Adic length scale hypothesis, which is a central element of TGD, indeed predicts scaled up versions of hadron physics assignable to Mersenne primes and their Gaussian counterparts.

3. Ordinary hadron physics would correspond to Mersenne prime $M_{107} = 2^{107} - 1$ M_{89} defines a second candidate for hadron physics with mass scale scaled up by $2^{(107-89)/2} = 2^9$. This would scale up r by a factor $2^{9/3} = 2^3$ to 2.4×10^{-17} m to be compared with the Compton wavelength 2.6×10^{-18} m of M_{89} nucleon so that the interpretation of the flux tubes as having ordinary value of h_{eff} seems to make sense. $\hbar$ would characterize the magnetic body of the BH like object. Note that the model discussed in [L10] led to a proposal that the particles at the flux tubes of BH are ordinary nucleons.

4. In this case the magnetic field strength of 2×10^7 Tesla would be scaled by factor 2^{18} to $.5 \times 10^{13}$ Tesla.

4.4.2 The identification of the energy source

Typical radius R of AGN is 2 AU which suggests that the size scale of AGN defines the size of the typical solar system as gravitational Compaton length λ_{gr}. Sagittarius A in the center of Milky way has radius .4 AU, which is the distance of Mercury from Sun. Could solar system be quantum coherent system with respect to Milky Way like Earth with respect to Sun?

One can start from the BZ model [E8] of the central object of M87 as a Kerr blackhole. In the TGD framework, blackhole *resp.* whitehole is replaced with a blackhole-like (BH) *resp.* whitehole-like object (WH). WH and BH are time reversals of each other [L9, L10, L11].

1. For BZ model, the matter falling into the blackhole would provide the "metabolic" energy feed to the jet and one would have a Penrose process. However, in general relativity the presence of the magnetic field requires Kerr blackhole. However, the arrow of time for Kerr solution is opposite to that of the environment at long distances, which suggests an interpretation as a whitehole having WH rather than BH as its TGD counterpart.

2. WH would have a time direction opposite to that of BH. The energy would come from dark energy and matter of cosmic string (or bundle of cosmic strings) thickening in standard time direction defined by the environment. WH as a quantum coherent object would receive this energy and emit it as jets in opposite directions along the flux tube carrying Beltrami field with electric component. The emission of the energy from thickening cosmic string is analogous to the decay of the inflaton field generating ordinary matter.

   This option looks more plausible and will be considered in the sequel.

In the case of M87 WH, one can estimate the rate of mass loss as the energy radiated as jets. The mass of M87, one would have $M(WH) = 6.5 \times 10^9 M_{Sun}$, $M_{Sun} = 2.2 \times 10^{57}$ J. The mass loss is $dM/dt = 3 \times 10^{36}$ J/s. This gives $dM/dt = -M/\tau$, $\tau = .7 \times 10^{14}$ y. The proportionality $\hbar_{gr} \propto M$ would mean that the rate for the reduction of quantum coherence scale and algebraic complexity defined as $\hbar_{gr}/dt/\hbar_{gr} = 1/\tau$ is slow. This process is analogous to blackhole evaporation as a time reversal for the formation of a blackhole.

One can consider three mechanisms for the energy emission creating a beam along cosmic string possibly thickened to flux tube also outside the WH.

1. The reduction of $\hbar_{gr}$ involves the splitting of the flux tubes from the quantum coherent flux tube bundle as they become ordinary flux tubes so that the number of dark flux tubes decreases. This splitting could give rise to a radiation associated with the jets. This includes synchrotron radiation in $B \sim 100$ Gauss. WH would lose energy as ordinary particles.

2. If the flux tube structure is of size of order of the length of jets about 5000 ly, the emission of closed flux tube bundles by reconnection could be second mechanism. This process would be analogous to the emission of closed flux tubes from the magnetic field of the solar wind. Also now $\hbar_{gr}$ should be reduced.

   The mysterious ultrahigh energy (UHE) cosmic rays could be produced in this process creating the analog of solar wind so that they could be seen as a support for the $\hbar_{gr}$ hypothesis. This process could be regarded as quantum coherent emission with the rate proportional N^2 rather than N, where $N = \hbar_{gr}/h_0$ is the number of flux tubes. The length $L \sim 5000$ ly could be interpreted as the size of the quantum coherent region and would be considerably larger than $\lambda_{gr} \sim 2 \times 10^{-3}$ ly.

3. Dark cyclotron particles and dark cyclotron photons could form an analog of laser beam as a quantum coherent flux tube structure extending to large distances although it forms a closed flux tube. This beam would be quantum analog of solar wind.

   The dark particles could transform in the interactions with ordinary matter to dark particles with a smaller value of $h_{eff}/\hbar_0 = n$ identifiable as the number of flux tubes of the associated sub-bundle. Eventually the beam would decay to ordinary photons with energies which are multiples of E_c. The occurrence of this kind of process in atmosphere could explain the cosmic ray showers due to UHE cosmic rays.

4.5 Nottale's hypothesis and universal cyclotron energies

The non-relativistic approximation for cyclotron energies does not make sense in the recent case so that a relativistically invariant formula $\hbar_{gr} = GME/\beta_0$ [L22] is needed.

1. An approximate formula for cyclotron energy in thew relativistic case is obtained from the d'Alembertian equation

$$(E^2 - p_z^2 - m^2 - (p_T - qA)^2)\Psi = \Psi \quad . \tag{4.1}$$

   The part depending on p_T and vector potential for a constant magnetic field gives the spectrum of non-relativistic harmonic oscillator $n\hbar_{gr}\omega_c$ Hamiltonian multiplied by $2m$. For a given value of n the are $2n+1$ angular momentum eigenstates states with spin in the range $|m| \leq n$. This gives for the energy eigenvalues

$$E_c^2 = m^2 + p_z^2 + n\hbar_{gr}\frac{qB}{m} = m^2 + p_z^2 + n\frac{GM}{\beta_0}qB \quad . \tag{4.2}$$

   p_z satisfies is given by

$$p_z = k\frac{\hbar_{gr}}{L} = \frac{r_s}{L}\frac{m}{2\beta_0} \quad . \tag{4.3}$$

   If the length L of the closed flux tube is of order 5000 ly, $p_z/m = (r_s/L)(1/2\beta_0)$ is very small one neglect p_z^2 and also m^2. This gives

$$E_c = n \times 2\frac{GM}{\beta_0} \quad . \tag{4.4}$$

   The relativistic formula differs from the non-relativistic naive guess only by the factor 2.

2. $\beta_0 = 1/2$ gives $\lambda_{gr} = r_s$ and is therefore favored value in the vicinity of WH/BH. In the case of M87 WH with mass $M = 6.5 \times 19^9 M_{Sun}$ this gives the estimate $E_c = 10^{10}$ GeV, which corresponds to the highest energy for cosmic rays. Could these quanta propagate to Earth and interact with the nuclei of atmosphere to create cosmic ray showers with highest energies about 10^{11} GeV? Note that the proportionality to magnetic field B and $1/v_0$ allows to consider even higher energies.

4.5.1 Two simple models for cyclotron states in generalized Beltrami fields

To get some idea about the solutions of d'Alembertian for a generalized Beltrami field, consider a constant magnetic field at a straight flux tube parallel to the z-axis.

Assume that the constant velocity v corresponds to a rotation around the z-axis. Beltrami condition gives a constant electric field $E = v \times B$ in the radial direction with electric potential

$\phi = qvB\rho$. Note that v corresponds to a parameter of Beltrami flow rather than being identified as a single particle operator $v = p_\phi/m = \partial_\phi/\rho m$.

The minimal substitution $p_\mu \rightarrow p_\mu - eA_\mu$ in the d'Alembertian gives

$$(E - qBv\rho)^2 - p_z^2 - m^2 - (p_T - qA)^2)\Psi = 0 \ . \tag{4.5}$$

One can write the equation in the form analogous to the non-relativistic Schrödinger equation:

$$\begin{aligned} (H_1 + H_2)\Psi &= \frac{1}{2m}(m^2 + p_z^2 - E^2)\Psi \ , \\ H_0 &= (p_T - qA)^2)\Psi \ , \\ H_1 &= \frac{(qBv)^2}{2m}\rho^2 - \frac{EqBv}{m}\rho \ . \end{aligned} \tag{4.6}$$

For $v \leq\leq c$, H_1 can be treated as a perturbation. For $H_0 = (p_T - qA)^2$, eigenstates of p_z, L_z and harmonic oscillator Hamiltonian can be solved exactly in the symmetric gauge $A = B \times \rho$, $\rho = (x, y)$. H_0 reduces to commuting harmonic oscillator Hamiltonians for energy and angular momentum L_z with operators x, ∂_x and y, ∂_y expressed as linear combinations of oscillator operators a^{dagger}, a and $b^\dagger, b$ which commute with each other (`https://cutt.ly/iQtFaPR`)

ρ^2-term in H_1 can be expressed as bilinear of these operators involving only terms formed from $a^\dagger$ and a *resp.* $b^\dagger$ and b. This term could be included in H_0 and one can hope that Bogoliubov transformation makes it possible to diagonalize the resulting Hamiltonian. ρ is a square root of ρ^2 and this produces problems. Since this term contains also c-number terms from the commutators $[a^{dagger}, a]$ and $[b^{dagger}, b]$, one can expand this term as a power series and treat it perturbatively. One can also use harmonic ordinary oscillator basis for H_0 and treat the situation perturbatively. Note that H_1 commutes with L_z so that one obtains degeneracy of states with respect to L_z also now.

If one had an ordinary gauge invariance, one could consider a gauge in which Kähler gauge potential A is of form $(A_x, A_y) = (0, Bx)$ (`https://cutt.ly/iQtFaPR`). This situation is of course interesting as such also in the TGD context and could provide a TGD based model for Hall effect.

For $v = (v_x, v_y, v_z)(0, v, 0)$, the electric part of the Kähler gauge potential is $\phi = vBx$. The effective Hamiltonian contains part $H_0 = (p_y - qBx)^2/2m$ and $H_1 = -(E - qvBx)^2/2m$. p_y commutes with both of them so that one can assume eigenstates of p_y. The sum $H_0 + H_1$ reduces to the following form:

$$H_0 + H_1 = \frac{k_1(x - x_0)^2}{2m} - \frac{k_1 x_0^2}{2} \ , \tag{4.7}$$

where one has

$$k_1 = \hbar^2\omega_1^2 \ , \quad \omega_1 = \sqrt{1 - v^2}\omega_c = \sqrt{1 - v^2}\frac{qB}{m} \ , \quad x_0 = \frac{Ev - p_y}{m}\frac{1}{\omega_1} \ . \tag{4.8}$$

The outcome is a harmonic oscillator Hamiltonian for cyclotron energy scale E_c scaled by factor $\sqrt{1 - v^2}$. The origin is shifted from $x = 0$ to $x_0 = (Ev - p_y)qB/m$. Besides this there is a constant term $-\sqrt{1 - v^2}(qB^2x_0^2/m)/2$.

For $p_y/E = v$ stating that the motion of particles occurs with velocity v, one has $x_0 = 0$ and no shift occurs for energy and the energy spectrum is only scaled by $\sqrt{1 - v^2}$ factor.

4.6 TGD view of jets

There are may questions to be answered.

What is the central engine causing the jets? How does it function? Where does the energy come from? One must also understand the transversal emission: otherwise the jets would be invisible.

BZ proposal is that he jets are naturally in the direction of flux tube along cosmic string of length about 5000 ly. Motion would be along helical orbits and transversal synchrotron radiation would make the jets visible.

There are also questions related to the TGD proposal.

1. Do the synctrotron states as such define the radiation of jet. Both charged dark particles and dark photons indeed have longitudinal momentum along the helix as required by the requirement that they carry angular momentum.

   Are also N-bosons and N-fermions, whose existence is proposed in the TGD based model of dark genetic codes [L36, L19] based on dark photons and dark protons, involved.

2. Could also quantum coherent cyclotron transitions give rise to dark photons with $h_{eff} = h_{gr}$ possibly also in directions transversal to the jet? Do all charged particles emit dark cyclotron radiation in synchrony or is this the case only for the charged particles with the same mass m as the fact that cyclotron frequencies depend on m suggests? Could the huge radiation power be due to quantum coherence: the radiation would be proportional to N^2 instead of N?

3. Could transversal synchrotron radiation with small value of h_{eff} take place for invidual flux tubes or sub-bundles forming a higher level flux tube? The value of $\hbar_{eff}$ would be smaller than $\hbar_{gr}$ for the sub-bundle. Could ordinary synchrotron radiation involve a separation of single flux tube from the condensate and reduction of $\hbar_{gr}$ to $\hbar$?

4. Could the helical flux tube loop also generate dark matter carrying closed flux tubes by reconnection just as occurs in the solar wind of the Sun? These flux tubes could carry cyclotron states and generate synchrotron radiation in transverse directions. This option is not plausible for long cosmic strings.

4.6.1 A model of jets based on Beltrami fields

The helical structure of the magnetic fields and the fact that the generalized Beltrami fields [B1, B5, B3, B4] could represent very general preferred extremals in the TGD framework suggest the following picture.

1. The helical structure of the magnetic field is forced by angular momentum conservation in the thickening of a cosmic string to a flux tube liberating energy as matter. Both the classical energy of the helical flux tubes and the motion of particles along the helical flux tube generates angular momentum compensating the angular of matter feeded into environment, which starts to avoid falling into WH.

2. Assume that longitudinal electric field is present inside flux tubes and induced by the rotation of the flux tube and that the classical em field is force-free and therefore a generalized Beltrami field. At single particle level this would mean that Lorenz force vanishes $E = v \times B$.

3. By quantum-classical correspondence, one expects non-dissipative supra current along the helical flux tube. There would be no dissipation by radiation in the ideal situation. One could have analogs of supra currents and laser beams along cosmic string in cosmic scales.

4. The analogs of supracurrents and laser beams would decay to dark particles with a smaller value of $h_{eff}/\hbar_0$ identifiable as the number of flux tubes of the associated sub-bundles. Eventually the beam would decay to ordinary photons. This kind of process occurring in atmosphere could explain ultra-high energy cosmic rays. This process could involve reconnection.

   The transversal synchrotron radiation could be created as $h_{eff} = h_{gr}$ for a particle decreases and photon with much smaller value of h_{eff} leaks out from the dark flux tube?

5. The quantum coherence along jet decreases gradually if its h_{eff} decreases. The WH associated defining a tangle of the cosmic string would however serve as a source of metabolic energy so that the value of $\hbar_{gr}$ would not be reduced. The situation would be very much like in TGD inspired biology except that the life in question would be in cosmological scales. The value of $\hbar_{gr}$ for AGNs would be huge as compared for that for Earth based life.

There is clearly an analog with the evaporation of blackholes and one can ask whether blackhole evaporation is induced by the change of the arrow of time for BH transforming it to WH.

4.6.2 How do the jets shine?

Jets shine, which means that photons and other particles are emitted in directions nearly parallel to the particle motion. One expects synchrotron radiation - possibly dark but with relatively small h_{eff}- in the plane orthogonal to the flux tube. According to the BZ proposal, particles rotating along the helical flux tubes in the direction of jet axis could emit the radiation as synchrotron radiation in directions roughly tangential to the helical orbit. How could this mechanism be realized in the TGD framework?

The synchrotron radiation could be seen as a leakage of particles from the helical flux tubes occurring directions near the tangential direction. This process could relate closely to the reduction of quantum coherence scale as flux tubes are separated in the quantum coherent flux tube bundle to a flux tube with ordinary value of Planck constant. For $\hbar_{gr}/\hbar \sim 8.1 \times 10^{24}$ (electron) and area πr_s^2 of the cylinder determined by $r_s \sim 19.5 \times 10^9$ km, the transversal area of single flux tube would be about 2.4π m^2. Cyclotron energy scale 5×10^{-7} eV corresponds to 2 meter wavelength for a radiowave photon.

One could also consider a splitting to quantum coherent sub-bundles of flux tubes with h_{eff} proportional to the number n of split flux tubes and cyclotron frequency scaled up accordingly.

4.6.3 UHE cosmic rays as a quantum gravitational effect?

The origin of ultra high energy (UHE) cosmic rays is poorly understood in the standard physics framework. The reader can consult a Wikipedia article about UHE cosmic rays (`https://cutt.ly/7QtFc7h`) and there is also Quanta Magazine article about the topic (`https://cutt.ly/ZQtFnff`).

Could the huge dark cyclotron energies for quantum gravitational cyclotron states make it possible to understand the origin of UHE cosmic rays? The following proposal is perhaps the simplest mechanism that one can imagine in TGD framework.

Assume that the monopole part $B_{end}(M87)$ of the magnetic field of M87 WH is equal to the magnetic field $B(M87) \sim 100$ Gauss: $B_{end}(M87) = B(M87)$.

For electron with $h_{eff} = h$ in $B_{end} = .2$ Gauss associated to Earth by the model for the findings of Blackman and others [J1] gives $E_c(e) = 4.96 \times 10^{-7}$ eV. For $B_{end}(M87) = B(M87) \simeq 100$ Gauss $B_{end} = .2$ Gauss is scaled up by factor 500. $\hbar$ is scaled up by $\hbar_{gr}/\hbar \simeq 8.1 \times 10^{24}$. The relativistic formula $E_c(M87) = 2GMQB/\beta_0$ for the cyclotron energy scales gives for $\beta_0 = 1/2$ $E_c(M87) = 2(\hbar_{gr}/\hbar)(B_{end}) \simeq 10^{10}$ GeV . This is extremely high energy: note that 10^{10} GeV corresponds to the lower bound for UHE cosmic rays with energies of order 10^{11} GeV.

All charged particles have this energy scale independently of their mass. What could happen to dark photons emitted in cyclotron transitions and dark charged particles with energy about 10^{10} GeV if they are emitted from WH?

Is there any separate emission process or do the dark particles in cyclotron states travel along the direction of jet as an analog of laser beam?

1. If the laser beam option is realized, dark cyclotron photons and particles (this includes charged particles with large range of masses) could travel to Earth as such. The interaction with the atomosphere would make this dark cosmic ray observable. This process would involve reduction of $\hbar_{gr}$ to $\hbar$.

2. Is the direct transformation to single photon possible as in the case of the decay of dark photons to biophotons? This would conform with the interpretation as ordinary UHE cosmic ray - say proton.

3. TGD suggest also the decay to large number of photons with smaller values of h_{gr} and the flux tube bundle picture suggests that the sum of the integers n_i characterizing $h_{eff,i}$ and the number of flux tubes in the sub-bundle associated satisfies $\sum n_i \simeq \hbar_{gr}/\hbar_0$. For $n_i = 1$ the outcome would be a bunch of ordinary radiowave photons with $E_c \simeq 5 \times 10^{-7}$ eV. A natural expectation is that the decay process occurs as a cascade in which sub-bundles decay to smaller sub-bundles or transform to single ordinary photon with energy $n_i E_c$. Irrespective

of the details of the decay process, the total energy of the cosmic ray show would correspond to $8.1 \times 10^{24} E_c$.

4. If the formula from the d'Alembertian is a good approximation, most of the energy of dark cyclotron particle parallel to the flux tube bundle, in particular the energy of photon, would be in transversal degrees of freedom in cyclotron motion at flux tube although the particle is by its huge energy massless in an excellent approximation.

   The synchrotron particles would propagate very slowly in the direction of the jet although the are massless: $p_z/E \leq\leq 1$. In fact, TGD based view about particle massivation relies on zitterbewung so that all particles are predicted to massless in short enough scales. This does not conform with the properties of MEs for which the longitudinal momentum is light-like although transversal degrees of freedom are present.

4.6.4 Steady state Universe or TGD Universe?

The title of the popular article "Universe is Not Expanding After All, Controversial Study Suggests" (`https://cutt.ly/OOnAjoy`) is quite provocative. The article tells about the findings of Lerner *et al* described in the article "UV surface brightness of galaxies from the local universe to z $\simeq$ 5" [E5] (`https://cutt.ly/6OnAvVT`).

Luminosity P is the total power of electromagnetic radiation emitted by the source per time. The total power $dP/d\Omega\Delta\Omega$ measured by an instrument spanning a solid angle $\Delta\Omega$ weakens as function of distance d like $1/d^2$. Bolometric surface brightness (SB) refers to the total radiation power per area at source and is $SB = d^2P/dSd\Omega$, that is $dP/d\Omega$ divided by the area S of the source.

The general relativity (GRT) based cosmology predicts that SB decreases as $(1+z)^{-4}$ and therefore very rapidly. One factor of $(1+z)^{-1}$ comes time dilation reducing the emission rate. Second $(1+z)^{-1}$ comes from the cosmic redshift. A factor of $(1+z)^{-2}$ comes from the fact that the apparent size as the area spanned by the source has decreased since the emission by cosmic expansion so that the apparent size is now by a factor $(1+z)^2$ larger at the moment of emission. If the cosmic redshift is caused by some other mechanism instead of expansion so that one has steady state cosmology, one has much weaker $(1+z)^{-1}$ dependence.

The findings of Lerner *et al* [E5] however suggest that SB for identical spiral galaxies defined as the emitted radiation power per area and solid angle depends only weakly on the distance of the source. In the Einsteinian Universe this favors steady state Universe. This is in conflict with the recent view of cosmology having a strong empirical support.

In the TGD Universe, galaxies are nodes of a network formed from cosmic strings thickened to flux tubes [L9, L10]. The article at "TGD view of the engine powering jets from active galactic nuclei" [L24] provides a model for how galactic jets would correspond to this kind of flux tube connections. The light from the galaxy from A to B travels only along the flux tubes connecting the source to the receiver. These flux tubes can stretch but the amount of light arriving B remains the same irrespective of distance. In the Einsteinian space-time this kind of channeling would not happen and the intensity would decrease like $1/d^2$.

This mechanism would give rise to a compensating factor $(1+z)^2$ so that the dependence of the BS on redshift would be $(1+z)^{-2}$, while the BS in the static Einsteinian Universe would be $(1+z)^{-1}$. For $z \simeq 5$, the TGD prediction for BS is by by a factor of 1/6 smaller than for static Universe whereas the GRT prediction is by a factor 1/196 smaller.

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