About the Recent TGD Based View Concerning Cosmology and Astrophysics

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Abstract

This article is about various topics related to cosmology and to the physics of galaxies, stars and planets and was inspired by several inputs. The first section is about primordial cosmology and describes the TGD counterpart of inflation. The proposal is that the fluctuations of CMB background can be understood number-theoretically as being induced by the fluctuations of the effective Planck constant $h_{eff} = nh_0$ around $h_{eff} = h = n_0h_0$. This also suggests a solution of the problem posed by two different values of Hubble constants in terms of especially large local upwards fluctuation of the value of h_{eff} from $h_{eff} = h$.

The second section is about several important aspects of TGD inspired cosmology. The findings of JWST force us to ask which came first: supermassive blackholes of galaxies. The recently discovered weak lensing effects lend support for the very long cosmic strings, which represent a key notion in TGD inspired cosmology. Besides dark matter there is also the problem of missing baryonic matter: for some reason 30 per cent of baryons are missing. Furthermore, the quite recent finding of JWST related to supermassive blackhole challenges the GRT based notion of blackhole.

The third section is about the recent TGD view of the physics of stars and planets. The stimulus came from the discovery of a planet that should not exist: the planet has the mass scale of Neptune but the mass of the star is 1/9:th of the solar mass. TGD based model for the formation of galaxies, stars and planets is based on the notion of cosmic strings which produce monopole flux tubes provides and explanation for the finding and leads to considerably more detailed model for the evolution of stars making a rather dramatic prediction: the element abundances should depend only weakly on cosmic time: the first support for this prediction came already 20 years ago and JWST has provides additional support for it.

In the last section a model for planets and stars as gravitational oscillators inspired by the TGD variant of Nottale's proposal is discussed. It turns out that the radius of the core of Earth corresponds to the Bohr radius for the first orbital, which suggests that the core of Earth, and more generally of the inner planets and Mars corresponds to an S-wave ground state. For the Sun the $n = 1$ S-wave orbital is 1.5 times the solar radius. The model applies also to the outer planets. Also the rings of giant planets can be understood at a rough quantitative level.

In the last section a cosmic string model for the spiral galaxies predicting the branched spiral structure is considered. Also a quantum model for the galactic blackhole-like objects allowing to understand the weird properties of Sagittarius A* is discussed.

1 Introduction

This article is about various topics related to cosmology and to the physics of galaxies, stars and planets and was inspired by several inputs. The first section is about primordial cosmology and describes the TGD view of inflation that I have considered already 20 years ago in [L1] [K10]. The question of Marko Manninen forced me to realize that it is high time to update my views about inflation. This led to a proposal that the fluctuations of CMB background can be understood number-theoretically as being induced by the fluctuations of the effective Planck constant $h_{eff} = nh_0$ around $h_{eff} = h = n_0h_0$. This also suggests a solution of the problem posed by two different values of Hubble constants in terms of especially large local upwards fluctuation of the value of h_{eff} from $h_{eff} = h$.

The second section is about three important aspects of TGD inspired cosmology. The findings of JWST force us to ask which came first: supermassive blackholes of galaxies [E8]. The recently discovered weak lensing effects [**?**]end support for the very long cosmic strings, which represent a key notion in TGD inspired cosmology. Besides dark matter there is also the problem of missing baryonic matter: for some reason 30 per cent of baryons are missing. Furthermore, the quite recent finding of JWST related to supermassive blackhole challenges the GRT based notion of blackhole.

The third section is about the recent TGD view of the physics of stars and planets. The stimulus came from the discovery of a planet that should not exist [E9]: the planet has the mass scale of Neptune but the mass of the star is 1/9:th of the solar mass. TGD based model for the formation of galaxies, stars and planets is based on the notion of cosmic strings which produce monopole flux tubes provides and explanation for the finding and leads to considerably more detailed model for the evolution of stars making a rather dramatic prediction: the element abundances should depend only weakly on cosmic time: the first support for this prediction came already 20 years ago [E15] and JWST has provides additional support for it.

In the last section a model for planets and stars as gravitational oscillators inspired by the TGD variant of Nottale's proposal is discussed. Nottale's model [E5] for planetary systems suggests Bohr orbitals for planets with gravitational Plack constant $\hbar_{gr} = GMm/\beta_0$. The value of the velocity parameter $\beta_0 = v_0/c \leq 1$ is from the model of Nottale about 2^{-11} for the inner planets and possibly 1/5 times smaller for the outer planets. This might reflect the fact that originally the planets or what preceded them consisted of gravitationally dark matter or that the Sun itself consisted of gravitationally dark matter and perhaps still does so.

The model of stars and planets as gravitational harmonic oscillators turns out to be surprisingly successful. It turns out that the radius of the core of Earth corresponds to the Bohr radius for the first orbital, which suggests that the core of Earth, and more generally of the inner planets and Mars corresponds to an S-wave ground state. For the Sun the $n = 1$ S-wave orbital is 1.5 times the solar radius. The model applies also to the outer planets. Also the rings of giant planets can be understood at a rough quantitative level. One fascinating application is blackholes: for instance, could one one understand the weird properties of Sagittarius A* using Bohr quantization?

In the last section a cosmic string model for the spiral galaxies predicting the branched spiral structure is considered. Also a quantum model for the galactic blackhole-like objects allowing to understand the weird properties of Sagittarius A* is discussed.

2 About the TGD counterpart of the inflationary cosmology

The question of Marko Manninen related to the inflation theory (see this) inspired the following considerations related to the TGD counterpart of the inflationary period assumed to precede the radiation dominated phase and to produce ordinary matter in the decay of the inflaton fields. I have considered the TGD analog of inflation already 12 years ago [L1] [K10] and the recent discussion brings in the progress in the understanding that occurred during these years.

Recall that inflation theory was motivated by several problems of the standard model of cosmology: the almost constancy of the temperature of the cosmic microwave background; the nearly flatness of 3-space implying in standard cosmology that the mass density is very nearly critical; and the empirical absence of magnetic monopoles predicted by GUTs. The proposal solving these problems was that the universe had critical mass density before the radiation dominated cosmology, which forced exponential expansion and that our observable Universe defined by the horizon radius corresponds to a single coherent region of 3-space.

The critical mass density was required by the model and exponential expansion implying approximate flatness. The almost constant microwave temperature would be due to the exponential decay of temperature gradients and diluted monopole density. The model also explained the temperature fluctuations as Gaussian fluctuations caused by the fluctuations of the mass density. The generation of matter from the decay of the energy density of vacuum assigned with the vacuum expectation values of the inflaton fields was predicted to produce the ordinary matter. There was however also a very severe problem: the prediction of a multiverse: there would be an endless number of similar expanded coherence regions with different laws of physics.

A very brief summary of the recent view of the TGD variant of the inflation theory proposed earlier [L1] is in order before going into the details.

1. The TGD view is based on a new space-time concept: space-time surfaces are at the fundamental level identified as 4-D surfaces in $H = M^4 \times CP_2$. They have rich topologies and they are of finite size. The Eisteinian space-time of general relativity as a small metric deformation of empty Minkowski space M^4 is predicted at the long length scale limit as an effective description. TGD however predicts a rich spectrum of space-time topologies which mean deviation from the standard model in short scales and these have turned out to be essential not only for the understanding of primordial cosmology but also the formation of galaxies, stars and planets.

2. In TGD, the role of the inflaton fields decaying to ordinary matter is taken by what I call cosmic strings, which are 3-D extremely thin string-like objects of form $X^2 \times Y^2 \subset M^4 \times CP_2$, have a huge energy density (string tension) and decay to monopole flux tubes and liberate

ordinary matter and dark matter in the process. That cosmic strings and monopole flux tubes form a "gas" in $M^4 \times CP_2$ solves the flatness problem: M^4 is indeed flat!

TGD also involves the number theoretic vision besides geometric vision: these visions are related by what I call $M^8 - H$ duality, see for instance [L15, L16] for the odyssey leading to its recent dramatically simplified form [L38]. The basic prediction is a hierarchy of Planck constants $h_{eff} = nh_0$ labelling phases of ordinary matter behaving like dark matter: these phases explain missing baryonic matter whereas galactic dark matter corresponds to dark energy as the energy of monopole flux tubes.

Quantum coherence becomes possible in arbitrarily long scales and in cosmic scales gravitational quantum coherence replaces the assumption that the observed universe corresponds to an exponentially expanding coherence region and saves it from the multiverse. This solves the problem due to the constancy of the CMB background temperature.

3. In the TGD framework, cosmic strings thickened to monopole flux tubes are present in the later cosmology and would define the TGD counterpart of critical mass density in the inflationary cosmology but not at the level of space-time but in $M^4 \subset M^4 \times CP_2$. The monopole flux tubes are always closed: this solves the problem posed by the magnetic monopoles in GUTs. Monopole flux tubes also explain the stability of long range magnetic fields, which are a mystery in standard cosmology even at the level of planets such as Earth.

4. The fluctuations of CMB temperature would be due to the density fluctuations. In inflation theory they would correspond to the fluctuations of the inflaton field vacuum expectation values. In TGD, the density fluctuations would be associated with quantum criticality explaining the critical mass density ρ_{cr}. The fluctuations $\delta\rho_{cr}$ of the critical mass density for the monopole flux tubes would be due to the spectrum for the values of effective Planck constant h_{eff}: one would have $\delta T/T \propto \delta h_{eff}/h_{eff}$. This would give a direct connection between cosmology and quantum biology where the phases with large h_{eff} are in a fundamental role.

2.1 Some basic notions of TGD

2.1.1 Cosmic strings and monopole flux tubes

In the TGD Universe space-times are 4-D surfaces in $H = M^4 \times CP_2$.

1. Cosmic strings [K5, K10] are 3-D string like objects which have 2-D M^4 projection and do not have any counterpart in GRT. They are of the form $X^2 \times Y^2 \subset M^4 \times CP_2$, where X^2 is a string world sheet and Y^2 is a complex submanifold of CP_2, say geodesic sphere. They can be arbitrarily long and have length measured even in billions of light years. They are not possible in string models or in GUTs.

2. Cosmic string world sheets are unstable against the thickening of their 2-D M^4 projection making it 4-dimensional. This thickening creates what I call Einsteinian space-time. The thickening reduces the string tension and liberates energy as ordinary matter and the TGD counterpart of galactic dark matter. This decay process is the TGD counterpart of inflaton field decay.

   This process repeats itself as a similar process for monopole flux tubes but the liberated energy decreases. The recent accelerating period of expansion could correspond to this kind of phase transition. The thickening *need not* involve an exponential expansion of these space-time surfaces. This decay would lead from the cosmic string dominated phase to a radiation dominated phase and generate Einsteinian space-time and cosmology.

3. There is Quanta Magazine post (see this) telling about the evidence that dark energy is getting weaker found by DESI collaboration [E4]. This would mean that the values of the cosmological constant decreases. TGD predicts the analogy of cosmological constant and also its weakening in a sequence of phase transitions reducing the value of the string tension of the monopole flux tube analogous to string tension.

4. The energy of the cosmic strings generates a transversal $1/\rho$ gravitational field and cosmic strings orthogonal to galactic planes explain galactic dark matter yielding the flat velocity spectrum of stars in the galactic plane. No dark matter halo is needed as in ΛCDM model. Galactic dark matter as dark energy would not form a halo but a string-like structure. The prediction is that galaxies are formed as tangles of thickened cosmic strings along these very long cosmic strings. Zeldowich discovered these linear structures formed by galaxies decades ago [E18] but they have been "forgotten".

2.1.2 M^8-H duality

Before proceeding, one must say something about M^8-H duality.

1. In the earlier versions of M^8-H duality [L6, L7, L8, L15, L16, L31], the integer n appearing in $h_{eff}=nh_0$ corresponds to a dimension of an algebraic extension of rationals assignable to a single octonion polynomial $P(o)$ with integer coefficients defined in the space of complexified octonions O_c. The polynomials would have as roots possibly complex mass shells in $M^4_c\subset M^8_c$ and these would partially define the 3-D data of number theoretic holography in M^8.

2. It turns out that a correct spectrum of fluctuations is predicted if one has $n=n_1n_2$ where n_i are identical or nearly identical. One can consider several variants for the composition of n to a product of integers. For instance, for the polynomials defined as functional composites of polynomials P_i have dimension of extension which is product $\prod_i n_i$ of the dimensions n_i for the polynomials P_i. The decomposition of n to the product could physically correspond to various interactions.

   The factors in the product could also correspond to M^4 and CP_2 degrees of freedom and this option suggested by the recent view of M^8-H duality [L38]. As a matter of fact, I proposed this kind of decomposition in the beginning of M^8-H adventure but gave it up.

3. The most recent formulation of M^8-H duality [L38] is dramatically simpler than the earlier ones. Complexified octonsions $O_c=M^8_c$ are replaced with octonions O allowing naturally a Minkowskian number theoretic norm $Re(o^2)$ making O effectively M^8. The holography=holomorphy principle at the level of H together with M^8-H duality fixes the number theoretic holography at the level of M^8 (normal space of 4-surface is associative and contains 2-D commutative subspace there is no need to define number theoretic holography using polynomials $P(o)$ in M^8_c. It seems that all nice features of the earlier proposal apply also to this proposal.

   The vanishing of 2 holomorphic functions of 4 generalized complex coordinates of H defines 4-D space-time surfaces in H [L28, L35]. These holomorphic functions naturally form a hierarchy of pairs of polynomials P_i, $i=1,2,$ and one can assign toP_i an extension of rationals with dimension n_i, $i=1,2$. Could one identify $h=h_{eff}/h_0=n$ as the product $n=n_1n_2$? Note that n_1 and n_2 can also factorize to primes.

   Number theoretic vision forces the increase of algebraic complexity meaning the increase of h_{eff} during cosmic evolution. $h_{eff}=h_0$ would be the simplest option in the primordial phase, where things are as simple as possible.

2.1.3 Hierarchies of p-adic length scales and effective Planck constants

The number theoretic vision of TGD implies hierarchies of p-adic length scales labelled by powers of p-adic primes p. Each p-adic hierarchy is accompanied by a hierarchy of dark scales and a hierarchy of phases behaving like dark matter. p-Adic length scale hypothesis, motivated by p-adic mass calculations [K6, K3], states that primes near some powers of 2 are physically preferred p-adic primes strengthens this hypothesis.

1. For a given prime p there exists entire hierarchy of p-adic length scales $L_{p,n}=p^{(n-1)/2)}L_p$, where one has $L_p=sqrtpR$, where R equals to the radius of CP_2 apart from a numerical constant.

2. The hierarchy of Planck constants $h_eff = nh_0$, where h_0 is the minimal value of effective Planck constant defines a hierarchy of phases of ordinary matter behaving like dark matter. This hierarchy solves the missing baryon problem whereas the energy of cosmic strings explains the galactic dark matter. The dark scales are given by $L^{dark}_{p,n} = \hbar_{eff} L_{p,n}$.

3. These two hierarchies are not independent since a given extension of rationals determining $h_{eff}/h_0 = n$ as its dimension defines also a set of p-adic primes p as a ramified prime for a polynomial defining the extension. The largest p-adic prime p_{max} is in a special physical role. The phase transitions changing the extension of rationals and the value of h_{eff} are possible and change the length scale of the monopole flux tube. Reconnections of the flux tubes define their topological dynamics and are in a central role in TGD inspired quantum chemistry and explain the basic mysteries of biocatalysis. Simple calculations show that p_{max} can be exponentially larger than n_0 [L33].

4. The ramified primes are bounded if one assumes that the coefficients of polynomials P are smaller than their degrees and imply that the number of polynomials with a smaller degree is finite for a given degree: this forces a number theoretic evolution in a very strong sense.

2.1.4 Zero energy ontology

In the TGD framework, zero energy ontology (ZEO) [L14] [K14] is the central element of quantum measurement theory and provides additional insights to the situation.

1. ZEO ontology involves as a basic concept the notion of causal diamond (CD) [L32, L38] as an interaction of future and past directed light-cones. CD is characterized by its size identifiable as the distance between its tips. The sizes of CDs form scaling hierarchies labelled by $h_{eff}/h_0 = n$ and p-adic length scales L_p. At least L_p, $L_{p,2} = \sqrt{p}L_p$, and the dark scales nL_p and $nL_{p,2}$ are fundamental scales. The p-adic primes p correspond to the ramified primes assignable to the polynomials defining the extension and p_{max} is in a preferred position.

2. The interpretation of CD is as the perceptive field of a conscious entity: CD could correspond to the part of the Universe perceivable to corresponding conscious entity and CD size would serve as the analog for horizon radius. The size of CD would naturally define the scale of quantum coherence and would increase during the cosmic evolution as n increases. It could be however arbitrarily long already in the primordial phase if rational polynomials are allowed.

2.2 The TGD view of primordial cosmology

I have already considered primordial cosmology in the TGD framework [L1] [K10].

2.2.1 Primordial cosmology and the almost constant temperature of the CMB

Primordial cosmology preceding the radiation dominated phase corresponds in the TGD framework to a "gas" like phase formed by a network of cosmic strings, which could be arbitrarily long and are always closed. Reconnection is the basic topological reaction for them. This phase has no counterpart in Einstein's theory.

A natural assumption is that there is a quantum coherence along the string. This means a hierarchies of quantum coherence scales assignable to cosmic strings and monopole flux tubes, which in the number theoretic vision of TGD would correspond to p-adic length scales and to a hierarchy of dark scales assignable to the h_{eff} a hierarchy of phases behaving like dark matter.

1. The p-adic length scales L_p could characterize the thickness of the monopole flux tubes and, as it turns out, $L_{p,2}$ could characterize the lengths of strings and flux tubes.

2. The dark length scales $nL_{p,n}$, $n = h_{eff}/h_0$ would be associated with the dark variants of the strings and monopole flux tubes. p would correspond to a ramified prime for a polynomial P defining an extension of rationals with dimension n and there is a large number of polynomials of this kind. The maximal p-adic prime for given P and n is in a physical special role and defines the maximal thickness and length of the flux tube in this case.

What about the p-adic length scales associated with the primordial phase? Assume the holography=holomorphy vision [L35, L43] so that a pair of polynomials defines the space-time surface and these polynomials define extension rationals assignable to M^4 and CP_2 degrees of freedom.

One can consider two options.

1. The simplest option is that cosmic strings correspond to $p = 1$ for which the flux tube is infinitely thin and the extension of rationals is trivial ($n = 0$). This would mean that flux tubes would have the same minimal length defined by CP_2 radius R. Primordial quantum coherence would be possible only in CP_2 scale.

2. There is also a more complex option.

   (a) The transversal scale of the cosmic string corresponds to CP_2 length scale R and is minimal. The CP_2 projection Y^2 as a complex surface can however have several sizes. One could however argue that they do not correspond to p-adic length scales and $p = 1$ corresponding to linear polynomials of CP_2 coordinates allowing only a homologically non-trivial geodesic sphere is possible.

   (b) What about M^4 degrees of freedom? Could one allow the reduction of the polynomials of 4 four complex (or hypercomplex) variables to non-irreducible polynomials when 3 complex variables are fixed to rational values (say put equal to zero). These would also allow rational roots. If all roots are rational, $n = 0$ is true. Does it make sense to identify the ramified primes as prime factors of the determinant identified as the square of the product of root differences ($b^2 - 4ac$ for a second order polynomial). If so, one could have p-adic primes $p \geq 2$ also in the primordial phase. Strings could have arbitrary long lengths also in this phase but no dark phases would be present.

   For this option a primordial quantum coherence would be possible in arbitrarily long p-adic length scales. Only the dark phases would emerge during evolution. This option conforms with the recent view of TGD.

In ZEO causal diamond (CD=cd$\times CP_2$) defines the perceptive field of a conscious entity. cd is analogous to an empty cosmology as a big bang followed by big crunch.

1. What determines the size of the CD in the recent cosmology? The ratio of CP_2 radius to Planck length is in the range $10^3 - 10^4$ from p-adic mass calculations. Could the recent mean value $h_{eff} = h = n_0 h_0$ correspond to CP_2 length scale R perhaps identifiable as the length scale of M^4 projection of monopole flux tube? The value of n_0 is in the range $10^7 - 10^8$.

2. The scale defined as the geometric mean of Planck length and the length scale L defined by cosmological constant Λ defines the size scale of a large neuron around $L_m \sim 10^{-4}$ m. One can think that $_m$ is for "meso": L_m is the fundamental biological scale determined as a geometric mean of two scales: Planck length for microcosmos and Hubble radius for macroscosmos. The basic scale of biological systems would correspond to the geometric mean of horizons scale and Planck scale. The geometric mean property implies that L_m and L can be expressed as $L_n = xL_0$ and $L = x^2 L_0$ which strongly suggests that these scales are primary and secondary length scales for some prime p.

3. In the twistor lift of TGD [K12, K9] [L20, L21], the cosmological constant Λ appears as the coefficient of the 4-volume term in the dimensionally reduced Kähler action determining as its preferred extemals 6-D twistor space as 6-surface in the product of 6-D twistor spaces of M^4 and CP_2 having two-sphere S^2 as a fiber and the space-time surface $X^4 \subset H$ as the base space. The only spaces having a twistor space with Kähler structure are M^4 and CP_2 [A1] so that TGD is unique.

4. Twistor lift suggests that $L_m = xL_P$, $x \equiv L_m/L_P = \sqrt{L/l_P} \sim 10^{31}/1.65$, defines the maximal thickness of a typical monopole flux tube in the recent cosmos. The scale $x^2 L_P$ in turn could define the scaling factor giving the maximal length L of the cosmic string determining the size scale of the CD. The natural identification would be as Hubble length $\hbar/H_0$, which is determined by the cosmological constant Λ. There are two scales: do they

correspond to scales assignable to ordinary matter and dark matter at the highest possible level of the magnetic body of the system?

Could one understand the value of x number theoretically? Certainly it cannot correspond to the ratio $n_0 = h/h_0 \in [10^7 - 10^8]$. Much larger values are required.

1. Number theoretical approach predicts besides dark scales also p-adic length scales. The primary p-adic length scale L_p and secondary p-adic length $L_{2,p} = \sqrt{p}L_p$ and possibly also higher p-adic length scales forming a hierarchy in powers of $\sqrt{p}$. Could x and x^2 correspond to the dark primary length scale $nL_p \propto n\sqrt{p}R$ and to the dark secondary p-adic length scale $nL_{p,2} = npR$? p would be a ramified prime determined by the extensions of rationals determined by the value of h_{eff}.

   There are two options. In the recent universe either a) L_p or b) nL_p could correspond to a p-adic length scale assignable to neurons. For option a) nL_p would correspond to a scale in the range $10^3 - 10^4$ m. For option b) L_p would correspond to a length scale in the range $10^{-12} - 10^{-11}$ m (electron Compton length is 2.4×10^{-12} m).

   Secondary p-adic length scale $L_{2,p}$ would correspond to the horizon radius $\hbar/H_0$ and $nL_{2,p}$ to the radius of dark horizon assignable to the field body of cosmos perceivable to us.

2. During the primordial phase, the size of CD could correspond to Planck length or to CP_2 radius R. One could have $l_P = R$ for $h_{eff} = h_0$. In the recent situation one would $h = n_0 h_0$ and $R^2_{eff} = n_0 R^2 = n_0\sqrt{G}$, perhaps identifiable as the scale of the M^4 projection of cosmic string (see below). n_0 would correspond to the dimension of extension of rationals and the p-adic prime p to a ramified prime of extension. There would be at least two CD sizes defined by $L_m = xL_P$ and $L = x^2 L_P$, where one has $x = \sqrt{p/2}$ and p is a ramified prime of the extension of rationals considered.

2.2.2 Do quantum fluctuations replace the thermal fluctuations of inflation theory?

If long length scale quantum coherence is possible in the length scale of cosmic strings, one ends up with the following questions.

1. Does gravitational quantum coherence due to long cosmic strings explain the almost constant value of the CMB temperature? One has $\rho \propto T^4$, which gives $\delta\ T/T \propto 4\delta\ \rho/\rho$.

   One can imagine two options.

   (a) If arbitrarily long cosmic strings are possible in the primordial phase (rational polynomials are allowed), quantum coherence could be present in all scales already in the primordial phase with $h_{eff} = h_0$. This option conforms with the original proposal.

   (b) If the lengths of cosmic strings are bounded in the primordial phase so that they are proportional too h_{eff}, long cosmic strings must be created later by reconnection in phase transitions increasing the value of h_{eff} allowing larger p-adic primes defining p-adic lengths scales. These phase transitions would also increase the length of cosmic strings.

2. In the inflation model, the fluctuations of CMB temperature are due to the density fluctuations $\delta\ \rho/\rho$. Could these density fluctuations be reduced to the fluctuations of the density in the phase formed by the cosmic strings in the primordial phase and later in the phase formed by the monopole flux tubes (magnetic bodies) characterized by the value of h_{eff}?

3. Inflationary cosmology is critical in the sense that mass density $\rho_{cr} = 3H_0^2/8\pi G$, where H_0 is the Hubble constant, is critical. In the TGD framework, this formula holds true at the level of future light-cone $M^4_+ \subset M^4 \subset H = M^4 \times CP_2$ representing empty standard cosmology rather than at space-time level as in inflation theory. Therefore exponential expansion is not needed for this formula. The quantum criticality would naturally apply to the phase formed by ordinary particles at monopole flux tubes characterized by the values h_{eff}.

4. Quantum criticality means a spectrum of the values of $h_{eff} = nh_0$. How do the fluctuations of h_{eff} imply the density fluctuations?

   The dimension of G is $[L^2]/[h]$. In TGD the only dimensional parameter is CP_2 length scale R and this suggests the formula $G = R^2/\hbar$, which generalizes to the formula $G = R^2/\hbar_{eff}$. One must have $\hbar \sim (10^7 - 10^8)\hbar_0$ to explain CP_2 radius fixed by electron mass from p-adic mass calculations.

   Again one can consider several options.

   (a) R is a fundamental constant and the value of $G_{eff} = R^2/h_{eff}$ varies and is different in the dark phases and decreases with h_{eff}. This looks strange but since we cannot yet observe dark matter, one cannot exclude this option. For this option one would have for the dark matter $\rho_{cr} = 3H_0^2/4\pi G_{eff} = 3\hbar_{eff}H_0^2/4\pi R^2$. A natural assumption is that H_0 corresponds to a p-adic length scale that is $H_0 \propto 1/L_{p,2}$.

   (b) $G = R^2/\hbar_0$ is a fundamental constant and the effective radius squared $R_{eff}^2 = \hbar_{eff}R^2/\hbar_0$ of CP_2 varies. It could geometrically correspond to the size of the M^4 projection of the cosmic string, or more precisely the thickening of $Y^2 \subset CP_2$. CP_2 scale would correspond to the Planck scale. For this option one would have $\rho = 3\hbar_0 H_0^2/8\pi R_{eff}^2 = 3\hbar_{eff}/8\pi L_{p,2}^2$.

   (c) For both options the density of dark matter would increase with $\hbar_{eff}$. One can however consider also the possibility that H_0 corresponds to the inverse of the dark p-adic length scale $H_0 \propto 1/L_p(dark)$, $L_p(dark) = nL_p$. This would give $rho_{crit} \propto 1/nL_{p,2}^2$.

Consider now what quantum criticality predicts.

1. Criticality means that one has $\rho = \rho_{cr} = 3H_0^2/8\pi G$ so that the fluctuations would correspond to fluctuations of Hubble constant and $\hbar_{eff}$: $\delta\rho/\rho = \delta\hbar_{eff}/\hbar + 2\Delta H_0/H_0$. This means fluctuations and long range correlations since quantum coherence scales are typically proportional to h_{eff} and even h_{eff}^2 as in atomic physics.

2. Depending on option, one can write the fluctuations of H_0 in terms of fluctuations of p-adic length scale $L_{p,2}$ or of dark p-adic length scale $L_{p,2}(dark) = nL_{p,2}$.

   (a) For the $L_H = L_p$ option, one has $\Delta H_0/H_0 = \delta L_{p_2}/L_{p,2}$ which is extremely small in cosmic scales. This gives $\delta\rho/\rho \sim \delta\hbar_{eff}/\hbar = \delta n/n$.

   (b) For the $L_H = L_p(dark) = nL_p$ option one has $\Delta H_0/H_0 = -2\delta n/n + \delta L_{p_2}/L_{p,2} \simeq -2/\delta n/n$. This gives $\delta\rho/\rho \sim \delta - \hbar_{eff}/\hbar = -\delta n/n$.

   One therefore obtains $\delta H_0/H_0 \sim \epsilon\delta n/n$, where $\epsilon = \pm 1$ depending on option. The thermal fluctuations are induced by the fluctuations of $\hbar_{eff}/h_0 = n$ and depend extremely weakly on the polynomial defining the extension of rationals with dimension n.

   For the first option the scale $L_m \sim 10^{-4}$ m would correspond too L_p and for the second option to the scale $L_p(dark) = n_0 L_p$. In the latter case one would have $L_p \in [10^{-12}, 10^{-11}]$, the p-adic length scale $L_{M_{127}} \simeq \sqrt{5}L_c = 5.4 \times 10^{-12}$ m is highly suggestive. This would correspond to $n_0 \simeq 1.85 \times 10^7$.

What can one say about the p-adic prime p assignable to an extension as a ramified prime?

1. Suppose that $p = p_{max}(P_{|n})$, that is the largest ramified prime assignable to a polynomial P defining the extension of rationals with dimension n. Several extensions can have dimension n exist and several polynomials P could in principle define an extension with a given value of n and the same value of $p_{max} = p$.

2. For an extension with a given value of n, one can allow fluctuations defined by polynomials with different values of p_{max}. This gives a rough estimate $\delta H_0/H_0 = -(\delta n/n - dL_{p_{max}}/L_{p_{max}})$. The term $dL_{p_{max}}/L_{p_{max}} = \delta p_{max}/p_{max}$ is very small for large p-adic primes, and one would have $\delta H_0/H_0 \sim -\delta n/n$ giving $\delta H_0/H_0 \sim 1/n$ for $|\delta n| = 1$.

$$\frac{\delta T}{T} = \frac{1}{2}\frac{\delta\ \rho_{cr}}{\rho_{cr}} = 2\frac{\delta H_0}{H_0} = -2\ \frac{\delta n}{n}\ . \tag{2.1}$$

3. The temperature fluctuations of CMB would reveal the fluctuations of $n = \hbar_{eff}/h_0$ in turn inducing fluctuations of padic length scale $L_{p_{max},2}$ defining H_0.

The fluctuations of CMB would be a number theoretic phenomenon. Does this proposal conform with the observations?

1. Density fluctuations are in the range $\delta\ T/T \in [10^{-4}, 10^{-5}]$. The nominal value of $\delta\ T/T$ is $10^{-4}/3$ (see this). This corresponds to $\delta\ \rho_{cr}/\rho_{cr} = 4\delta\ T/T =\ 1.3 \times 10^{-4}$.

2. If the fluctuation corresponds to a single extension of rationals, or more generally, n is not a product of two or more statistically independent factors, one has $|\delta n| \geq 1$ and the $|\delta T|/T \sim\ (1/2)|\delta n|/n$. If one uses the estimate $n = R^2/G \in [10^7 - 10^8]$, one obtains $|\delta T|/T = (1/2)\sum_k p(|\delta|\ n = k)k/n$, which in the first approximation gives $|\delta T/T| = p(1)x/2$, $x \in [10^{-7}, 10^{-8}]$. The estimate is too small.

3. If one assumes that the decomposition $h_{eff}/h_0 = n_1 n_2$, where n_i are assumed to be statistically independent, one obtains $|\delta\ h_{eff}|/h_{eff} = |\delta n_1|/n_1 + |\delta n_2|/n_2$. If only $|\delta n_1| = 1$ and $|\delta n_2| = 1$ contribute significantly, and one has $|\delta|T/T = p(1)/n_1 + p(2)/n_2]/2$. Assuming $n_1 = n_2 \sim \sqrt{n} \in [10^{3.5}, 10^4]$, and $p_1 = p_2 = P$ one has very naive estimate $2P/\sqrt{n}$, $n \in [10^{-3.5}, 10^{-4}]$. The order of magnitude is correct.

4. The justification for the decomposition comes from the holography=holomorphy hypothesis, which implies that the two polynomials defining the space-time surface as a complex surface in generalized sense gives rise to two extensions of rationals with dimensions n_1 and n_2. These extensions can be assigned to M^4 degrees of freedom (string world sheets X^2) and to CP_2 degrees of freedom (partonic 2-surfaces Y^2). One can also consider the possibility that internal consistency requires the extensions to have the same dimension $n_1 = n_2$.

For the cold spot of CMB (see this), the temperature fluctuation of CMB is 70 μK and 4 times higher than on the average. Could one understand this number theoretically? For instance, could this could be due to $n_1 \rightarrow 8n_1$ and $n_2 = n_1 \rightarrow n_1/8$ in $n \rightarrow n_1 n_2 \sim n_1^2$ giving for $\delta\ n_1 = deltan_2 = 1$ the outcome $\delta\ n/n = 1/(8n_1) + 8/n_1 \simeq 8/n_1$ so that the fluctuation is 4 times larger.

2.2.3 About the problem of two Hubble constants

The usual formulation of the problem of two Hubble constants is that the value of the Hubble constant seems to be increasing with time. There is no convincing explanation for this. But is this the correct way to formulate the problem? In the TGD framework one can start from the following ideas discussed already earlier [K7].

1. Would it be better to say that the measurements in short scales give slightly larger results for H_0 than those in long scales? Scale does not appear as a fundamental notion neither in general relativity nor in the standard model. The notion of fractal relies on the notion but has not found the way to fundamental physics. Suppose that the notion of scale is accepted: could one say that Hubble constant does not change with time but is length scale dependent. The number theoretic vision of TGD brings brings in two length scale hierarchies: p-adic length scales L_p and dark length scale hierarchies $L_p(dark) = nL_p$, where one has $h_{eff} = nh_0$ of effective Planck constants with n defining the dimension of an extension of rationals. These hierarchies are closely related since p corresponds to a ramified prime (most naturally the largest one) for a polynomial defining an extension with dimension n.

2. I have already earlier considered the possibility that the measurements in our local neighborhood (short scales) give rise to a slightly larger Hubble constant? Is our galactic environment somehow special?

Consider first the length scale hierarchies.

1. The geometric view of TGD replaces Einsteinian space-times with 4-surfaces in $H = M^4 \times CP_2$. Space-time decomposes to space-time sheets and closed monopole flux tubes connecting distant regions and radiation arrives along these. The radiation would arrive from distant regions along long closed monopole flux tubes, whose length scale is L_H. They have thickness d and length L_H. d is the geometric mean $d = sqrt(l_P L_H)$ of Planck length L_P and length L_H. d is of about 10^{-4} meters and size scale of a large neuron. It is somewhat surprising that biology and cosmology seem to meet each other.

2. The number theoretic view of TGD is dual to the geometric view and predicts a hierarchy of primary p-adic length scales $L_p \propto \sqrt{p}$ and secondary p-adic length scales $L_{2,p} = \sqrt{p} L_p$. p-Adic length scale hypothesis states that p-adic length scales L_p correspond to primes near the power of 2: $p \simeq 2^k$. p-adic primes p correspond to so-called ramified primes for a polynomial defining some extension of rationals via its roots.

   One can also identify dark p-adic length scales

$$L_p(dark) = nL_p \ , \tag{2.2}$$

   where $n = h_{eff}/h_0$ corresponds to a dimension of extension of rationals serving as a measure for evolutionary level. h_{eff} labels the phases of ordinary matter behaving like dark matter explain the missing baryonic matter (galactic dark matter corresponds to the dark energy assignable to monopole flux tubes).

3. p-Adic length scales would characterize the size scales of the space-time sheets. The Hubble constant H_0 has dimensions of the inverse of length so that the inverse of the Hubble constant $L_H \propto 1/H_0$ characterizes the size of the horizon as a cosmic scale. One can define entire hierarchy of analogs of L_H assignable to space-time sheets of various sizes but this does not solve the problem since one has $H_0 \propto 1/L_p$ and varies very fast with the p-adic scale coming as a power of 2 if p-adic length scale hypothesis is assumed. Something else is involved.

One can also try to understand also the possible local variation of H_0 by starting from the TGD analog of inflation theory. In inflation theory temperature fluctuations of CMB are essential.

1. The average value of h_{eff} is $\langle h_{eff} \rangle = h$ but there are fluctuations of h_{eff} and quantum biology relies on very large but very rare fluctuations of h_{eff}. Fluctuations are local and one has $\langle L_p(dark) \rangle = \langle h_{eff}/h_0 \rangle L_p$. This average value can vary. In particular, this is the case for the p-adic length scale $L_{p,2}$ ($L_{p,2}(dark) = nL_{2,p}$), which defines the Hubble length L_H and H_0 for the first (second) option.

2. Critical mass density is given by $3H_0^2/8\pi G$. The critical mass density is slightly larger in the local environment or in short scales. As already found, for the first option the fluctuations of the critical mass density are proportional to $\delta n/n$ and for the second option to $-\delta n/n$. For the first (second) option the experimentally determined Hubble constant increases when n increases (decreases). The typical fluctuation would be $\delta h_{eff}/h \sim 10^{-5}$. What is remarkable is that it is correctly predicted if the integer n decomposes to a product $n_1 = n_2$ of nearly identical integers.

   For the first option, the fluctuation $\delta h_{eff}/h_{eff} = \delta n/n$ in our local environment would be positive and considerably larger than on the average, of order 10^{-2} rather than 10^{-5}. h_{eff} measures the number theoretic evolutionary level of the system, which suggests that the larger value of $\langle h_{eff} \rangle$ could reflect the higher evolutionary level of our local environment. For the second option the variation would correspond to $\delta n/n \leq 0$ implying lower level of evolution and does not look flattering from the human perspective. Does this allow us to say that this option is implausible? The fluctuation of h_{eff} around h would mean that the quantum mechanical energy scales of various systems determined by $\langle h_{eff} \rangle = h$ vary slightly in cosmological scales. Could the reduction of the energy scales due to smaller value of h_{eff} for systems at very long distance be distinguished from the reduction caused by the redshift.

Since the transition energies depend on powers of Planck constant in a state dependent manner, the redshifts for the same cosmic distance would be apparently different. Could this be tested? Could the variation of h_{eff} be visible in the transition energies associated with the cold spot.

3. The large fluctuation in the local neighbourhood also implies a large fluctuation of the temperature of the cosmic microwave background: one should have $\Delta T/T \simeq \delta n/n \simeq \delta H_0/H_0$. Could one test this proposal?

2.2.4 Is dark energy needed at all?

The year 2024 in comsmology and astrophysics have been full of surprises. The last surprise came afterthe Christmas. I received links to two very interesting ScienceDaily articles from Mark McWilliams. The first article (see this) discusses dark energy. The second article (see this) discusses Hubble tension. Both articles relate to the article "Cosmological foundations revisited with Pantheon+." published by Lane ZG et al in Notices of Royal Astronomical Society [E13] (see this).

On the basis of their larger than expected redshift supernovae in distant galaxies appear to be farther than they should be and this inspires the notion of dark energy explaining accelerated expansion. The argument proposes a different explanation based on giving up the Friedmannin cosmology and giving up the notion of dark energy. This argument would also resolve the Hubble tension discussed in the second popular article. The argument goes as follows.

(a) Gravitation slows down the clocks. The clocks tick faster inside large voids than at their boundaries where galaxies reside. When light passes through a large void it ages more than if it passed through the same region with an average mass density.

(b) As the light from distant supernovae arrives it spends a longer time inside the voids than in passing through galaxies. This would mean that the redshift for supernovae in distant galaxies appears to be larger so that they are apparently farther away. Apparently the expansion accelerates.

(c) This is also argued to explain the Hubble tension meaning that the cosmic expansion rate characterized by the Hubble constant, for the objects in the early Universe is smaller than for the nearby objects.

This looks to me like a nice argument and is claimed to also explain the Hubble tension. The model forces us to give up the standard Robertson-Walker cosmology. Qualitatively the proposal conforms with the notion of many-sheeted space-time predicting Russian doll cosmology defined by space-time sheets condensed on larger space-time sheets.

I have written two articles about what I call magnetic bubbles and used the term "mini big bang" [L29, L30]. Supernova explosion would be one example of a mini big bang. Also planets would be created in mini big bangs.

But what about the galactic dark matter? TGD predicts an analog of dark energy as Kähler magnetic and volume energy of cosmic strings and of monopole flux tubes generated as they thicken and generate ordinary matter in the process is identifiable as galactic dark matter. No dark matter halo is predicted, only the cosmic strings and the monopole flux tube with much smaller string tension appearing in all scales, even in biology.

It should be noticed that TGD also predicts phases of ordinary matter with non-standard value of Planck constant behaving like dark matter. The transformation of ordinary matter to these kinds of phases explains the gradual disappearance of baryonic (and also leptonic) matter. These phases are absolutely essential in TGD inspired quantum biology and reside at the field bodies of the organisms with a much larger size than the organism itself and their quantum coherence induces the coherence of biomatter.

2.2.5 Dark energy weakens?

Quanta Magazine post (see this) tells about the evidence, found by DESI collaboration (see this), that dark energy is getting weaker. These findings challenge the very notion of dark energy, which is also theoretically problematic. There is the problem whether the dark energy corresponds to a modification of the gravitational part of the action obtained by replacing the curvature scalar by adding a volume term or a modification of the matter part of the action corresponding to exotic particles, quintessence, with a negative pressure.

In Big Think (see this) there is an article discussing in detail the claim about the claimed weakening of dark energy (see this). The article describes in detail the constraints on the ΛCDM model. It becomes clear that standard cosmology is a good parametrization of huge amounts of data but has a lot of problems and that the notion of dark energy is far from being elegant. The basic empirical inputs are as follows.

1. Cosmic microwave background (CMB) provides information about the basic parameters of the standard cosmology such as its age, the value of Hubble constant characterizing the expansion rate, and density matter. This information allows us to identify several anomalies. For instance, the Hubble constant seems to have two slightly different values. It would seem that Hubble constant depends on length scale but the notion of scale is lacking from the standard cosmology.

2. The finding that the radiation from supernovae of type I is weaker than expected led to the conclusion that cosmic expansion is accelerating. Cosmological constant characterizing dark energy density would at least parametrix the acceleration expansion in the general relativistic framework.

3. Baryonic acoustic oscillations (BAO) provide information about the large scale structure of the Universe and BAO led in the recent study to the conclusion that dark energy is weakening. BAO has also led to the conclusion that the density of baryonic matter is decreasing: as if baryons were disappearing. Are these two phenomena different aspects of the same phenomenon?

In TGD, the new view of space-times as 4-D surfaces in $H = M^4 \times CP_2$, predicts the analogy of cosmological constant as well as its weakening. Only an analogy is in question and the optimistic expectation is that this analogy gives rise to GRT type description at the QFT limit of TGD when many-sheeted space-time is replaced with a single slightly deformed region of empty Minkowski space.

1. String tension characterizes the energy density of a magnetic monopole flux tube, a 3-D surface in $H = M^4 \times CP_2$. String tension contains a volume part (direct analog of Λ) and Kähler magnetic part and it is a matter of taste whether one identifies the entire string tension or only the volume contribution as counterpart of Λ. In the primordial cosmology [L40], cosmic string sheets have 2-D M^4 projection and 2-D CP_2 projection.

2. Cosmic strings are unstable against the thickening of their 2-D M^4 projection, which means that the energy density is gradually reduced in a sequence of phase transitions as thickenings of the cosmic string so that they become monopole flux tubes and give rise to galaxies and stars. The energy of cosmic strings is transformed to ordinary particles. This process is the TGD analog of inflation. No inflaton fields are required.

3. The string tension is gradually reduced in these phase transitions and in this sense one could say that dark energy is weakened. For instance, for hadronic strings it is rather small as compared to the original value of string tension during the primordial phase dominated by cosmic strings, at the molecular level the string tension of cosmic strings is really small.

4. The primordial string dominated phase was followed by a transition to the radiation dominated cosmology and emergence of Einsteinian space-time with 4-D M^4 projection so that general relativity and quantum field theory became good approximations explaining a lot of physics. Quantum field theory approximation cannot however explain the structures appearing in all scales and here monopole flux tubes are necessary.

5. TGD also predicts a hierarchy of effective Planck constants labelling phases of the ordinary matter behaving like dark matter in many respects. These phases would be quantum coherent in arbitrarily long scales. They would reside at the magnetic bodies consisting of monopole flux tubes and define a number theoretic complexity hierarchy highly relevant in quantum biology. The transformation of ordinary matter to this kind of dark matter would explain the observed apparent disappearance of baryons during cosmic evolution. In primordial cosmology cosmic strings as 4-D objects with 2-D M^4 projection would dominate: during this period one cannot speak of Einsteinian space-time as space-time surfaces with 4-D M^4 projection.

One can try to translate these analogies to a more detailed quantitative view of dark energy and dark matter.

1. The energy of the cosmic string contains two contributions: volume contribution and Kähler magnetic contribution. Their sum defines the galactic dark matter (see this), whose portion is about 26 percent of cosmic energy density, and it is concentrated at cosmic strings. Ordinary matter, about 5 percent of energy density emerges in the thickening of these cosmic strings as they form local tangles. The liberated energy transforms to ordinary matter. This is the TGD counterpart of inflation and cosmic strings carry the counterpart of matter assigned with the vacuum expectations of inflation fields.

2. What about the dark energy forming 85 percent of cosmic energy density? Does dark energy correspond to the energy associated with Minkowski space-time sheets as the energy associated with the volume action with Käher magnetic part being negligible. Could the volume contribution dominate or are the contributions of the same size scale? The cosmological constant would have a spectrum being inversely proportional to the p-adic length scale characterizing these space-time sheets. The value of the cosmological constant would not depend on time but on the scale of the space-time sheet and would decrease as a function of the scale. This might explain the latest findings if they are true.

3. One can ask whether only magnetic flux tubes and sheets are present at the fundamental level and whether cosmological constant corresponds to the energy assignable to large enough monopole flux tubes. Already flux tubes of the thickness of neuron size of about 10^{-4} m correspond to the extremely small value of cosmological constant deduced from cosmology. Also hadronic string tension corresponds to a particular value of cosmological constant.

3 Some important findings related to cosmology and astrophysics

3.1 Which came first: primordial supermassive blackhole or galaxies? Or was it something else?

The revolution initiated by the James Webb Telescope continues (see the popular article telling about the interpretation of the most reent findings proposed in the article "Which Came First: Supermassive Black Holes or Galaxies? Insights from JWST" [E8] by Joseph Silk et al published in The Astrophysical Journal Letters. The objects identified as gigantic primordial blackholes are introduced to explain the extremely fast formation of stars for a few million years after the Big Bang. After this period the formation of stars should have slowed down and the recent galaxies and galactic blackholes would evolve very slowly. The very existence of this kind of blackholes is in conflict with the standard general relativistic wisdom, which assumes that blackholes are formed as the final state of the development. The primordial blackholes should be formed directly from the concentrations of the primordial plasma without a formation of stars. Their presence would catalyze the rapid formation of stars and lead to formation of galaxies. These visions can be seen as part of the desperate battle of general relativity based cosmology in order to survive the empirical facts. In the TGD framework, space-time is replaced with a 4-surface in $H = M^4 \subset M^4 \times CP_2$: this predicts standard model symmetries and unifies gravitation and standard model. The choice of H is unique both mathematically and physically. GRT and standard model view follows at the QFT limit of TGD in long length scales. The TGD based space-time concept leads to a new view of cosmology involving cosmic strings (not those of GUTS) as string-like objects carrying monopole magnetic fluxes [L11, L12, L18, L29, L30]. Cosmic strings are extremely thin 4-surfaces with a huge string tension carrying energy having interpretation as analog of dark energy. They provide an explanation for the galactic dark matter involving only string tension as a parameter and solving the problems of ΛCDM and MOND. TGD also predicts a hierarchy of effective Planck constants giving rise to phases of ordinary matter behaving in many respects like dark matter: these phases explain the missing baryonic matter.

1. Cosmic strings dominated before the radiation dominated phase and their decay to ordinary matter was the TGD counterpart of inflation. Cosmic strings were unstable against the thickening of their 1-D M^4 projection to a 3-D flux tube. The string tension of the thickened portion of the flux tubes formed a tangle and the associated dark energy transformed to ordinary matter forming a galaxy around it. Also collisions of cosmic strings generated this kind of tangles.

2. This decay process as an analogy of inflation generated ordinary matter, galaxies and stars and generated the counterparts of the postulated primordial blackholes. During this period the formation of stars was extremely rapid and later slowed down as the findings of the JWT demonstrate.

3.2 Why the dark energy density is inversely proportional to the surface area of the volume studied?

Sabine Hossenfelder commented in her posting "Surprise Comeback: Dark Energy Could Be Holographic After All" (see this) the idea that the mysterious dark energy might not be real but an outcome of holography and assignable to the 3-D surface which in holography contains the information determining the dynamic in the interior of the space-time. The comments were inspired the the article "Evolution of perturbations in the model of Tsallis holographic dark energy" [E1] (see this) by Astashenok and Tepliakov.

The starting point observation is that the dark energy density is in a good approximation found to be proportional to $1/S$, where S is the surface area of a large sphere surrounding the region studied. By the way, Sabine makes a little mistake here: she talks about dark energy rather than dark energy density. The reader can check this from the article of Artyom et al. The model of Tsallis [E2, E16] has been given up long ago but the authors represent an argument that since dark energy is not ordinary cosmic fluid, ordinary perturbation theoretic analysis does not apply.

TGD suggests however a much simpler explanation of the finding. In TGD, dark energy is identifiable as a galactic dark matter and consists of magnetic and volume energy assignable to very long monopole flux tubes with a huge string tension. No galactic dark matter halo nor exotic dark matter particles are needed. The galactic velocity spectrum is correctly predicted from the string tension which is also predicted.

To see whether TGD can explain the finding that dark energy density is proportional to $1/S$, one must estimate the average density of dark energy in a large cylindrical volume around a long cosmic string. The dark energy is proportional to the length L of the string: $T = TL$. The volume is roughly $V = SL$, where S is the surface area of the cross section of the cylinder. Therefore one has that dark energy density satisfied $E/V = TL/SL = T/S$. Just as has been found.

3.3 Direct evidence for the TGD view of quasars

In a new paper in The Astrophysical Journal [E14] (see this), JILA Fellow Jason Dexter, graduate student Kirk Long, and other collaborators compared two main theoretical models for emission data for a specific quasar, 3C 273.

If the quasar were a blackhole, one would expect two emission peaks. If the galactic disk is at constant temperature, one would expect a redshifted emission peak from it. The second peak would come from the matter falling to the blackhole and it would be blue shifted relative to the first peak. Only a single peak was observed. Somehow the falling of the matter is prevented to the quasar is prevented. Could the quasar look like a blackhole-like object in its exterior but emit radiation and matter preventing the falling of the matter to it.

This supports the TGD view of quasars as blackhole-like objects are associated with cosmic strings thickened locally to flux tube tangles [L11, L18, L12, L29, L30]. The transformation of pieces of cosmic strings to monopole flux tube tangles would liberate the energy characterized by the string tension as ordinary matter and radiation. This process would be the TGD analog of the decay of the inflaton field to matter. The gravitational attraction would lead to the formation of the accretion disk but the matter would not fall down to the quasar.

3.4 Evidence for cosmic strings and monopole flux tubes

The evidence for cosmic strings and monopole flux tubes have been steadily increasing. The following represents some examples.

3.4.1 Evidence for cosmic strings from weak lensing

The cosmic plot is finally starting to unravel! For almost twenty years I have been trying to communicate a TGD-based theory for the galactic dark matter but in vain. Now empiria has come to rescue. There is now evidence for dark matter filaments from the detection of weak-lensing caused by them (see the popular article and the article "Weak-lensing detection of intracluster filaments in the Coma cluster" by HyeongHan et al in Nature Astronomy [E7]. This kind of dark filaments are a basic prediction of TGD and their classical energy corresponds to dark energy [L11, L12, L18, L29, L30]. Before radiation-dominated cosmology, the matter in the TGD Universe consists of extremely massive objects, cosmic strings. In TGD the spacetimes correspond to 4-surfaces $M^4 \subset M^4 \times CP_2$ and cosmic strings are string-like 3-surfaces. The monopole flux associated with these string-like objects stabilizes them against splitting. They are typically more or less perpendicular to the galaxies they have generated in a local decay process. Cosmic string create a gravitational field in the plane of the galaxy behaving like 1 over transversal distance. The string tension alone explains the constant velocity spectrum of the distant stars and the model avoids the problems of the ΛCDM and MOND. However, cosmic strings are unstable against decaying into ordinary matter by thickening, which reduces the string tension, and in this process galaxies are formed. In particular, the collisions of the cosmic strings trigger decay to ordinary matter as the TGD counterpart of inflation. The extremely fast star formation in the very early universe, recently observed by JWT, is a mystery for which an explanation is proposed in terms of giant black holes which, contrary to standard wisdom, were born before the galaxies and formed directly from plasma rather than as the end result of evolution (see this). The above picture explains the star formation in terms of the production of matter in the decay of cosmic string to monopole flux tubes. The above picture picture explains the rapid star formation in terms of the production of matter in the decay of cosmic string to monopole flux tubes.

3.4.2 The rotation of galaxies in the same direction in giga-ly scale as evidence for the TGD view of space-time and cosmic quantum coherence

Sabine Hossenfelder told in her Youtube video (see this) about the recent finding of Lior Shamir [E12] that galaxies have a clear tendency to rotate in the same direction in Giga light-year length scales. There is also a second popular article about this (see this). The following is the abstract of the article of Shamir.

JWST provides a view of the Universe never seen before, and specifically fine details of galaxies in deep space. JWST Advanced Deep Extragalactic Survey (JADES) is a deep field survey, providing an unprecedentedly detailed view of galaxies in the early Universe. The field is also in relatively close proximity to the Galactic pole. Analysis of spiral galaxies by their direction of rotation in JADES shows that the number of galaxies in that field that rotate in the opposite direction relative to the Milky Way galaxy is 50 per cent higher than the number of galaxies that rotate in the same direction relative to the Milky Way. The analysis is done using a computer-aided quantitative method, but the difference is so extreme that it can be noticed and inspected even by the unaided human eye. These observations are in excellent agreement with deep fields taken at around the same footprint by the Hubble Space Telescope and JWST. The reason for the difference may be related to the structure of the early Universe, but it can also be related to the physics of galaxy rotation and the internal structure of galaxies. In that case the observation can provide possible *explanations to other puzzling anomalies such as the tension and the observation of massive mature galaxies at very high redshifts.*

The popular article says that the fractions of the galaxies rotating to opposite directions with respect to the Milky Way are 2/3 and 1/3 and there is no doubt that the observation is real. The Doppler effect makes it possible to deduce the rotation direction for a given galaxy. Blueshift occurs in the opposite direction of rotation. The scale occurs in the scale of Giga light year. From the article of Shamir one learns that these kinds of observations have been made already earlier, as early as 1985. Already Zeldowich observed that galaxies are associated with long linear structures and tend to propagate in the same direction [E18]. I have proposed a TGD based explanation in terms of long cosmic strings whose tangles give rise to the generation of galaxies along them [L40].

Several explanations for the findings of Shamir have been proposed. The entire universe has been proposed to rotate. Also a fractal Universe has been proposed in which case the rotating structures would appear in all scales. TGD predicts that space-times are 4-surfaces in $H = M^4 \times CP_2$. This leads to the notion of many-sheeted space-time strongly suggesting the possibility of fractal structures in all scales [L40]. A fractal structure in a given scale would correspond to a quantum coherence region.

The realization that holography= holomorphy principle [L39, L28] reduces the extremely non-linear field equations of TGD to algebraic equations and led to the surprising conclusion that the fractality in question is a 4-D generalization of the fractality of Mandelbrot fractals and Julia sets [L45]. The number theoretic vision predicts a hierarchy of effective Planck constants and provides a precise formulation for what the long range quantum coherence means [L45].

Galaxies as 4-surfaces assignable with monopole flux tubes [L40], obtained by as tangles of thickened cosmic string and decaying to ordinary matter in a way similar to what occurs in inflation, are predicted to be organized along long string-like objects with 2-D M^4 projection, cosmic strings, and be highly correlated, for instance having correlated spin directions. This explains the findings of Zeldowich and quantum large scale coherence makes it possible to understand the more general findings about correlated rotation directions of galaxies. In the very early Universe cosmic strings with 2-D M^4 projection would have dominated and the Einsteinian space-time with 4-D M^4 projection would have emerged in the analog of inflation.

3.4.3 Could the new ANITA anomaly be due to dark cosmic rays?

ANITA, a balloon-borne radio detector flying over Antarctica was designed to detect neutrinos. Recently, it has however detected something totally unexpected: strange radio pulses rising from beneath the ice (see this). The strange radio waves detected by ANITA came from way below the ice, at angles so steep —like 30 degrees —that they should have traveled through thousands of kilometers of solid rock. Standard physics does not allow this. Pierre Auger Collaboration has carried out a search for the counterparts of events similar to those detected fy ANITA [**?**] (see this).

The first particle physics based guess would be that the radio wave pulses originated from a collision of ultrahigh energy neutrinos propagating through the Earth. The neutrino would have interacted with the condensed matter creating relativistic particles, which give rise coherent Cerenkov radiation (see this) at radio wave frequencies. A backwards directed cone at which the emission is maximal would be created. Sonic boom occurring as an object moves with a velocity larger than the sound velocity of the medium is a good analogy.

The Cerenkov radiation is created in condensed matter at energies, which correspond to the frequencies associated with core electronic transitions in condensed matter since the refractive index n is smaller than 1 below these frequencies so that the phase velocity $v_{ph} = c/n$ is smaller than c and therefore below the velocity of the particle. These frequencies correspond to radio frequencies so that the primary signals need not be at radio frequencies.

The interpretation of the events in terms of UHE neutrinos fails. The distance travelled by the neutrino inside the Earth should be 6000-7000 km. The interpretation in terms of ultra heavy neutrinos with energies in the range of .2 EeV ($.2 \times 10^{18} eV$) requires that the neutrino should have travelled 10-12 interaction lengths so that the probability of the events creating the shower by the resulting tau leptons is quite too small. New physics seems to be involved. Particle physicists would propose new extremely weakly interacting particles, perhaps dark matter particles decaying to ordinary particles.

TGD predicts the existence of a hierarchy of phases of ordinary matter with non-standard value of Planck constant h_{eff}, which can be very large so that these phases are quantum coherent in long length scales. These phases behave like dark matter and would reside at the field/magnetic bodies, which are the TGD counterpart for classical fields.

These new phases need not have anything to do with the galactic dark matter in the TGD framework: galactic dark matter would be analogous to dark energy and correspond to magnetic and volume energy associated with what I call cosmic strings [L40]. The observed disappearance of baryonic matter during the cosmic evolution could correspond to a gradual transformation of ordinary protons to dark protons at the field bodies. The $h_{eff} > h$ phases, in particular dark protons and dark photons, are the key players in the TGD inspired quantum biology [L22, L25, L34].

These (effectively) dark particles could propagate along the field (magnetic) body of the Earth and would have a scaled up interaction length proportional to $h_{eff}/h > 1$. Their transformation to ordinary particles with $h_{eff} = h$ would generate the shower. Also the transformation of dark photons to ordinary photons could create pairs of charged particles and lead to a generation of showers.

The identification of dark particles as dark variants of cosmic rays could also explain the unexpected finding of James Webb telescope of very distant galaxies [L40]. In standard cosmology, these galaxies should not be visible. Could the dark radiation arrive along monopole flux tubes connecting stars to the galactic center or even galactic blackhole?

This explanation is of course only the first guess and a lot of work is needed to check whether it works at a quantitative level.

3.5 A TGD based resolution of the clumpiness paradox and resolution of the tension between neutrino mass scale deduced from neutrino mixing and from gravitational lensing

I learned about very interesting findings related to neutrinos reported by DESI collaboration [E3] (see this). The 3 neutrino families are known to mix and from various experiments, also from those performed in the laboratory, one can deduce estimates for the analog of the CKM matrix describing the mixing. This also allows us to estimate the sum of the neutrino masses.

One can also deduce information about neutrino masses from cosmology. The information comes from gravitational lensing. The gravitational lensing increases with so called clumpiness which measures how the inhomogeneities of mass density are. If one assumes standard cosmology with cold dark matter, one expects that the larger the average neutrino mass scale is, the larger the effects of the neutrino mass density on the clumpiness of the universe is.

According to the popular article, DESI maps out cosmic structures to determine the expansion rate through an effect known as baryon acoustic oscillations, sound waves that imprinted circular patterns on the very early universe. By tracing those patterns at different points in the universe s history, scientists can track its growth, kind of cosmic tree rings are in question.

Combining the measurements of clumpiness from the cosmic microwave background and the expansion rate from DESI two things that neutrinos affect makes it possible for scientists to deduce estimates for the sum of neutrino masses. The upper limit turned out to be unexpectedly small, about .07 eV. This is very near to the lower bound for the sum, about .06 eV deduced from the neutrino mixing. There are even experiments suggesting an upper limit of .05 eV in conflict with neutrino mixing data.

The outcome suggests that something goes wrong with the standard cosmology. Could it be that neutrinos do not affect the clumpiness so much as believed? Could neutrinos be lighter in the early cosmology? Or is the view of how clumpiness is determined, entirely wrong? Could the mechanism behind the gravitational lensing be something different from what it is believed to be?

Clumpiness paradox is one of the many problems plaguing the cold dark matter scenario (see this). Clumpiness parameter (see this) is in principle deducible from the weak gravitational lensing caused by dark matter. In halo models it affects the annihilation rate of dark matter particles. Since the predicted rate is proportional to mass density squared, the annihilation rate increases for clumpy mass distribution.

If I understand correctly, the clumpiness paradox states that the clumpiness, which is determined by the size of dark matter clumps, depends on the scale in which observations are carried out. Clumpiness is smaller in long length scales, which means that the observed clumps are larger in long scales. In long scales, corresponding to recent cosmology, the sizes of clumps assignable are larger and the clumpiness parameter is .83. In shorter length scales corresponding to the age of the Universe about 380 thousand years the clumpiness parameter is smaller: .76.

In long length scales, a proposed explanation for the small value of clumpiness, i.e. a large size of clumps, is in terms of identification of dark matter as ultralight axions with very large Compton length determining the size scale of clumps.

This does not explain why the clumpiness depends on scale. Furthermore, clumps have been now observed in considerably smaller scales than earlier (see this). The strange looking conclusion is that cold dark matter is colder in short scales: the naive expectation would be just the opposite since it is the hot dark matter particles, which should form only small clumps. Something seems to go wrong.

The scale dependence of clumpiness suggests a fractal distribution of matter and dark matter. Indeed, in the TGD framework [L29, L30, L36], cosmic strings thickened to monopole flux tubes forming scale hierarchy would be responsible for the gravitational lensing and the thickness of the monopole flux tubes would characterize the lensing. The explanation for the large size of the clumps in long scales would be the large size of the Compton length proportional to effective Planck constant $h_{eff} = nh_0$. In the case of gravitational Planck constant $h_{eff} = h_{gr} = GMm/\beta_0$, β_0 a velocity parameter, assignable to the monopole flux tubes connecting pairs formed by a large mass M and small mass m, the gravitational Compton length is equal to $\Lambda_{gr} = GM/\beta_0 = r_s/2\beta_0$, r_s Schwartshild radius of mass M increasing with the size scale of structure (note that there is no dependence on m). The larger the scale of the studied astrophysical object, the larger Λ_{gr} as minimal gravitational quantum coherence length is, and the smaller the clumpiness in this scale.

This would predict the effect of neutrinos and also other particles on lumping and gravitational lensing is negligible. Cosmic strings would explain the lumping. The model would also explain why the upper bound for the sum of neutrino masses is inconsistent with the findings from neutrino mixing.

3.6 The connection of missing baryon number problem with the TGD view of evolution

The following argument relates the missing baryon problem to the TGD view of the evolution and also clarifies how the galactic dark matter differs from the dark matter as $h_{eff} \geq h$ phases (see this).

What is the problem of missing baryonic matter?

1. 1/7 of the matter of the Universe is dark matter in the sense of galactic dark matter. The identification of the dark matter is still a mystery. The proponenets of ΛCDM have decided dark matter to be some exotic particles forming halos around galaxies. MOND people have decided that Newtonian gravity is modified for weak fields.

2. Besides this 30 per cent of the ordinary matter, baryons, seems to be missing. This is known as the missing baryon problem (see this).

The prosaic explanation for the puzzle is that with the available technology we are not able to detect the missing part of ordinary matter and it has been argued that the missing baryonic matter can be assigned with long filamentary structures. This explanation might be correct.

What could one say about the missing baryonic matter in this framework? I have considered this question in more detail earlier [L5] [K2], and the following general comment explains why ordinary baryons should transform to dark ones during the cosmic evolution.

1. In the TGD Universe, the radiation dominated phase was preceded by cosmic string dominance [L1, L41] [K10]. Cosmic strings would have decayed to ordinary matter like inflaton fields and this would have led to the radiation dominated Universe.

2. The galactic dark matter could be actually dark energy assignable with long cosmic strings with a gigantic string tension. Monopole flux would make them stable. This dark energy would decay to ordinary matter since the cosmic strings are unstable against thickening

and the generation of flux tube tangles giving rise to ordinary galaxies and also stars and planets [L11, L18, L12, L29, L30].

This process would be the TGD counterpart of inflation (see this): inflaton fields would be replaced by cosmic strings. This view predicts the flat velocity spectra of galaxies using only string tension as a parameter and makes a long list of predictions allowing us to understand the anomalies of ΛCDM (see) and MOND (see).

3. TGD predicts also matter behaving like dark matter. This analog of dark matter is identifiable as $h_{eff} \geq h$ phases of ordinary matter. I have used to talk about dark matter but this matter need not be galactic dark matter, which could be mostly dark energy for cosmic strings. The $h_{eff} \geq h$ phases phases can have arbitrarily long quantum coherence scales and in the TGD view of quantum biology they play a fundamental role in living matter as controllers of ordinary matter. In TGD inspired biology dark protons identified as this kind of phase at monopole flux tubes play an essential role.

What could one say about the missing baryonic matter in this framework?

Could the missing baryonic matter correspond to $h_{eff} \geq h$ phases of the ordinary matter? Same would of course apply to other elementary particles and only the fact that baryons dominate the mass density motivates the attribute "baryonic". The intuitive view is that the density of dark protons is much smaller than the number of ordinary protons. Could this be true only in the regions containing high density of ordinary matter. The fraction of ordinary protons could be much larger than that of dark protons only in the regions where the visible matter is concentrated. Why would ordinary nucleons transform to dark nucleons? Evolution means the increase of complexity. In the TGD Universe this means the increase of h_{eff}, which corresponds to a dimension of algebraic extension of rationals characterizing polynomials which at the fundamental level characterize space-time regions. Number theoretic evolution would transform the ordinary matter to dark matter as $h_{eff} \geq h$ phases residing at the monopole flux tubes. Could 30 percent of ordinary matter have transformed to dark matter in this sense?

3.7 Are blackholes really what we believe them to be?

James Webb produces surprises at a steady rate and at the same time is challenging the standard view of cosmology and astrophysics. Just when I had written an article about the most recent findings, which challenged the basic assumption of these fields including those of general relativity and thought that I could rest for a few days, I learned from a new finding in FB. The title of the popular Youtube video (see this) was "James Webb Telescope Just Captured FIRST, Ever REAL Image Of Inside A Black Hole!" There is also a popular article describing a detection of light from behind the blackhole-like object (briefly BH) (see `https://cosmosmagazine.com/space/first-light-detected-from-behind-a-black-hole/`. One day after writing these lines, I learned that this kind of phenomenon had been observed already earlier 2 years ago by Connors et al: the finding is published in Astrophysics Journal [E6] (see this).

3.7.1 The findings

Gravitational lensing is the method used to gain information about these objects and it is good to start with a brief summary of what is involved. One can distinguish between different kinds of lensings: strong lensing, weak lensing, and microlensing.

1. In the strong lensing (see this), the lense is between the observer and the source of light so that the effect is maximized. For high enough mass of the lense, lensing causes multiple images, arcs or Einstein rings. The lensing object can be a galaxy, a galaxy cluster or a supermassive blackhole. Point-like objects one can have multiple images and for extended emissions rings and arcs are possible.

The galactic blackhole, SgrA*, at the center of the Milky Way at distance of 27,000 light-years was imaged in 2022 by the Event Horizon Telescope (EHT) Collaboration (see this) using strong gravitational lensing and radio telescope network in a planetary scale. The blackhole was seen as a dark region at the center of the image. The same collaboration observed the blackhole in the M87 galaxy at a distance of 54 million light years already in 2019.

2. In the weak lensing (see this), the lense is not between the observer and the source so that the effect is not maximized. Statistical methods can be however used to deduce information about the source of radiation or to deduce the existence of a lensing object. The lensing effect magnifies the image of (convergence effect) and stretches the image of the object (shear effect). For instance, weak lensing led quite recently to a detection of linear objects, which in the TGD framework could correspond to cosmic strings [L41] which are the basic objects in TGD based cosmology and model for galaxies, stars and planets.

3. In microlensing (see this) the gravitational lense is small such as planets moving between the observer and star serving as the light source. In this case the situation is dynamic. The lensing can create two images for point-like objects but these need not be distinguishable so that the lense serves as a magnifying glass. The effect also allows the detection of lense-like objects even if they consist of dark matter.

3.7.2 GRT based interpretation of the findings

The recent results of JWT the findings of JWT are about a supermassive blackhole located 800 million light years away. Consider first the GRT based interpretation of the findings.

1. What was observed by the strong lensing effect was interpreted as follows. The matter falling into the blackhole was heated and generated an X-ray corona. This X-ray radiation was reflected back from a region surrounding the blackhole. The reflection could be based on the same effect as the long wavelength electromagnetic radiation from the ionosphere acting as a conductor. This requires that the surface of the object is electrically charged, and TGD indeed predicts this for all massive objects and this electric charge implies quantum coherence in astrophysical scales at the electric flux tubes [L25], which would be essential for the evolution of life at Earth.

2. After this the radiation, which was reflected behind the blackhole should have ended up in the blackhole and stayed there but it did not! Somehow it got through the blackhole and was detected. It would seem that the blackhole was not completely black. This is not all the behavior of a civilized blackhole respecting the laws of physics as we understand them. Even well-behaving stars and planets would not allow the radiation to propagate through them. How did the reflected X ray radiation manage to get through the blackhole? Or is the GRT picture somehow wrong?

3.7.3 Could the TGD view of blackholes explain the findings?

Consider first the interpretation inspired by general relativity. Could the TGD view of BHs come to rescue?

1. In TGD, monopole flux tube tangles generated by the thickening of cosmic strings (4-D string-like objects in $H = M^4 \times CP_2$) and producing ordinary matter as the dark energy of the cosmic strings is liberated [L41] are the building bricks of astrophysical objects including galaxies, stars and planets. I have called these objects flux tube spaghettis.

   Einsteinian blackholes, identified as singularities with a huge mass located at a single point, are in the TGD framework replaced with topologically extremely complex but mathematically and physically non-singular flux tube spaghettis, which are maximally dense in the sense that the flux tube spaghetti fills the entire volume [L12]. The closed flux tubes would have thickness given by the proton Compton length. From the perspective of the classical gravitation, these blackholes-like objects behave locally like Einsteinian blackholes outside the horizon but in the interior they differ from the ordinary stars only in that the flux tube spaghetti is maximally dense.

2. The assumption, which is natural also in the TGD based view of primordial cosmology replacing the inflation theory, is that there is quantum coherence in the length scale of the flux tubes, which behave like elementary particles even when the value of h_{eff} is $h_{eff} = nh_0 = h$ or even smaller. What does this say is that the size of the space-time surface quite generally defines the quantum coherence length. The TGD inspired model for BHs suggests $h_{eff} = h$ inside the ordinary blackholes. The flux tubes would contain sequences of nucleons (neutrons) and would have a thickness of proton Compton length. For larger values of h_{eff}, the thickness would increase with h_{eff} and the proposal is that also stellar cores are volume filling black-hole like objects [L12].

   Besides this, the protons at the flux tubes can behave like dark matter (not the galactic dark matter, which in the TGD framework would be dark energy associated with the cosmic strings) in the sense that they can have very large value of effective Planck constant $h_{eff} = nh_0$, where h_0 is the minimal value of h_{eff} [L41]. This phase would solve the missing baryon problem and play a crucial role in quantum biology. In the macroscopic quantum phase photons could be dark and propagate without dissipation and part of them could get through the BH.

3. How could the X-rays manage to get through the supermassive black hole? The simplest option is that the quantum coherence in the length scale of the flux tube containing only neutrons allows photons to propagate along it even when one has $h_{eff} = h$. The photons that get stuck to the flux tube loops would propagate several times around the flux tube loop before getting out from the blackhole in the direction of the observer. In this way, an incoming radiation pulse would give rise to a sequence of pulses.

I have considered several applications of this mechanism.

1. I have proposed that the gravitational echoes detected in the formation of blackholes via the fusion of two blackholes could be due to this kind of stickind inside a loop [L4]. This would generate a sequence of echoes of the primary radiation burst.

2. The Sun has been found to generate gamma rays in an energy range in which this should not be possible in standard physics [L13]. The explanation could be that cosmic gamma rays with a very high energy get temporarily stuck at the monopole flux tubes of the Sun so that Sun would not be the primary source of the high energy gamma radiation.

3. The propagation of photons could be possible also inside the Earth along, possibly dark, monopole flux tubes, at which the dissipation is small. The TGD based model for Cambrian explosion [L10, L19, L27] proposes that photosynthesizing life evolved in the interior of Earth and bursted to the surface of Earth in the Cambrian explosion about 450 million years ago. The basic objection is that photosynthesis is not possible in the underground oceans: solar photons cannot find their way to these regions. The photons could however propagate as dark photons along the flux tubes. The second option is that the Earth's core [L24, L26] provides the dark photons, which would be in the same energy range as solar photons. The mechanism of propagation would be the same for both options.

3.7.4 A more precise view of monopole flux tubes

One can also consider other options to explain the findings: also these would be based on the propagation of photons along a monopole flux tube. First one must however develop a more detailed view of the monopole flux tubes.

1. Monopole flux tubes must be always closed. This is due to the conservation of monopole flux and the fact that boundary conditions do not allow cutting of flux tubes yielding opposite magnetic charges at the ends created in this way.

   There are also good reasons to argue that at least gravitons propagate from source A to the receiver B along pairs (a,b) of parallel flux tubes with opposite fluxes. The pairs (a,b) are naturally formed by reconnection of closed U-shaped flux tubes emating from A and B. The reconnection and its reversal are proposed to the basic mechanism of biocatalysis. The flux tube pair (a,b) is always a part of a closed flux tube loop. In the simplest situation the member a (b) of the loop would turn backwards inside A (B) and return back as b (a).

2. Also wormhole magnetic fields are possible. The members a and b of the tube pairs could also reside at parallel space-time sheets with distance about CP_2 size R scales of order 10^4 Planck lengths. The flux would move between the space-time sheets through wormhole contacts. Wormhole contact would like a magnetic dipole of size R. I have christened these structures as wormhole magnetic fields [K13] and elementary particles would be simplest configurations of this kind.

3. Since the flux tubes carrying opposite magnetic fields are extremely near to each other and since the space-time sheets cannot be resolved from each other, wormhole magnetic fields do not create any observable effects and have nothing to do with the observable magnetic fields.

   The flux tube pairs, in particular wormhole magnetic fields, can however mediate basic interactions by serving as channels for the propagation of associated elementary bosons. The distribution and direction of the flux tube pairs emanating from the surface of the source A must reflect the classical fields at the surface of A.

4. One can however argue that since one also has macroscopic magnetic fields even in cosmic scales (this is one of the mysteries of cosmology) that unpaired flux tubes are necessary.

   Could the magnetic fields of astrophysical objects correspond to unpaired flux tubes as single-sheeted objects? They would be closed but would not correspond to wormhole magnetic fields. A configuration consisting of unpaired monopole flux tubes could have a well-defined orientation, say parallel to the magnetic axis of BH. Monopole flux tubes would explain the existence of magnetic fields in cosmic scales not possible in the Maxwellian world and also the stability of the magnetic field of Earth [L3].

   The unpaired monopole flux tubes could form a network connecting various astrophysical objects, in particular stars, and light and gravitons could propagate also along them and would not be weakened with distance. This would give rise to effects not possible in the standard astrophysics. This could for instance explain why JWST has detected signals from "too distant" objects. Also the gravitational hum could be explained as a diffraction effect in a lattice-like network formed by the stars [L37].

3.7.5 Alternative explanations for the findings

Consider now an alternative explanation for the findings challenging our views of blackhole-like objects. This explanation does not exclude the explanation already discussed but leads to stronger predictions and would also explain why it is possible at all to see objects at such large distances.

1. If the light travels around the BH along unpaired monopole flux tubes like water flow around a spherical obstacle, the photons inside flux tubes are not "eaten" by the BH-like object. Magnetic fields and incompressible flow with constant density indeed obey the basic local equation stating that there are no magnetic charges. Note however that the flux tubes could also go through the BH since the photons propagating inside the monopole flux tubes are shielded against interactions with the surrounding matter inside BH.

2. The radiation from astrophysical object A would only reach observers B connected to it by unpaired monopole flux tubes or pairs of them. If the analogy with the simplest hydrodynamic flow around an obstacle makes sense, the effect would be observed only by observers in the direction of the monopole flux tubes defining the network and would be large since no attenuation is involved. The observers in the direction of the jets associated with the BH would satisfy this condition. One can of course consider more complex options in which several flux tubes emerge from the BH and connect it to astrophysical objects.

In the TGD framework, one must of course take the interpretation of the findings inspired by general relativity with a grain of salt. The object called supermassive blackhole-like could be something very different from a standard blackhole. If it is a thickened portion of a cosmic string, it emit particles instead of absorbing them in an explosion-like thickening of cosmic string transforming dark energy to matter and radiation (this would be TGD counterpart for the decay of inflation fields to matter [L29, L30, L41]. The matter bursting into the environment from a BH-like object would tend to fall back and could cause the observed phenomena in a way discussed above. Furthermore, the X-rays identified as the reflected X-rays could correspond to this kind of X-rays reflected back from the BH. I am not a specialist enough to immediately choose between these two options.

3.7.6 The blackhole that grew too fast

Marko Manninen asked for the TGD view concerning the recently found black-hole like object (BH), which seems to gobble the matter from the environment much faster than it should. The findings described in the popular article with title "'Fastest-feeding' black hole of the early universe found. But does it break the laws of physics?" (see this). The article [E10] about the discovery is published in Nature (see this).

This BH, cataloged as LID-568, found by the James Webb telescope, identified as dwarf blackhole, existed 1.5 billion years after the Big Bang. It should have gotten its mass of more than 7 million solar masses in 12 million years. The rate for its formation would have been 40 times too high.

General Relativity poses an upper limit for the rate with which a blackhole can consume matter, known as the Eddington limit (see this). The limit describes the balance between the rate of the infalling matter and the rate of the radiation produced by the infall that then pushes back on the accreting matter. At the limit the feedback shuts down the accretion.

Objects thought to be black holes often differ in many respects from the black holes of general relativity. In particular, the giant BHs of the very early universe and BHs associated with quasars and the cores of galaxies do so. Star-born BHs could be ordinary blackholes but the giant BHs might be something different. Also the dwarf backhole found by JWST might be different. The basic mystery is why the giant BHs can be so large in the very early Universe if they are formed in the expected way. Do the BHs always grow by gobbling up matter from the environment? Recently I learned of two astrophysical anomalies. The first anomaly was blackhole which grew 40 times too fast.

TGD leads to a view of BHs different from the GR view in many respects see for instance [L11, L12, L18] and more recent articles [L29, L30, L40, L44].

1. In TGD, BHs are not singularities containing their mass at a single point but correspond to portions of long cosmic strings (extremely thin string-like 3-surfaces), which have formed a tangle and thickened so that they fill the entire volume. The formation of this tangle could involve collision of two long cosmic strings. This could be the case for the spiral galaxies. BH property would mean that they are maximally dense.

2. The thickening of the cosmic string liberates part of the energy of the cosmic string and BHs would transform in an explosive way into ordinary matter, which is feeded into the environment. The accretion disk would not be associated with the inflowing matter, but would be formed by the outflowing matter as it slows down in the gravitational field and forms a kind of traffic jam. Radiation could however escape, especially if behaves like dark matter in the TGD sense meaning that it has non-standard value Planck constant h_{eff}, the hierarchy of which is predicted by the number theoretic view of TGD and plays a key role in the understanding of living matter. The situation would be in many respects similar to the standard picture where the outgoing radiation would be produced by the infalling matter. At the QFT limit of TGD, replacing many-sheeted space-time with a region of Minkowski space made slightly curved, the metric in the exterior region would be in a good approximation Schwartschild metric.

3. This kind of object would be more like a white hole-like object (WH). Zero-energy ontology indeed predicts objects resembling ordinary blackholes as the time reversals of WHs. Matter would really fall into them. One can make quite precise predictions about the mass spectrum of these objects [L44].

This vision leads to a model for the formation of galaxies and generation of ordinary matter from the dark energy assignable to the cosmic strings, which would dominate in the very early Universe [L40, L44].

1. The collisions of the cosmic strings during the primordial string dominated cosmology are unavoidable for topological reasons and would lead to their thickening and heating inducing the formation of WHs and their explosive decay to ordinary matter. This would generate a radiation dominated phase, perhaps when the temperature approaches the Hagedorn temperature as a maximal temperature for string-like objects. These WHs would be the TGD equivalent for the vacuum energy of inflaton fields of inflation theory to decay to the ordinary matter.

2. The energy of cosmic strings would have Kähler magnetic and volume parts and have interpretation as dark energy. There is now rather convincing evidence for a connection between dark energy and the giant blackholes (see this).

3. The galactic dark matter would be dark energy of a cosmic string transversal to the galactic plane and containing galaxies along it: this has been known for decades [E18]! There would be no dark matter halo nor exotic dark matter particles. This predicts without further assumptions the flat velocity spectrum of the distant stars rotating around galaxies associated with very long cosmic strings and also solves the many problems of the halo models and MOND [L42]. The gravitational force transforms from $1/r^2$ force created by the visible galactic matter to $1/\rho$ force created by the cosmic string at a critical radius. Under additional assumption this corresponds to a critical acceleration as in MOND [L42].

4. TGD also predicts dark matter-like macroscopically quantum coherent phases of ordinary matter for which the effective Planck constant h_{eff} is large. In particular, the gravitational *resp.* electric Planck constants associated with long range classical gravitational *resp.* electric fields can be very large. The generation of these phases at gravitational magnetic bodies, for example in biology, solves the problem of missing baryonic matter, that is why baryonic (and also leptonic) matter gradually disappears during the cosmic evolution. There is evidence for this process also in particle physics [L9].

Let's return to the question whether TGD can explain why the BHs in question grow so fast. They would not do so by gobbling the matter from the environment but receive it from the long cosmic string. The energy of the thickening string filament is converted into matter and generates a WH. This could happen much faster than the growth of a black hole in the usual way. At this moment it is not possible to estimate the rate of this process but it could also explain how the early Universe can contain these giant blackhole-like objects.

3.8 From blackholes to time reversed blackholes: comparing the views of time evolution provided by general relativity and TGD

The TGD inspired very early cosmology is dominated by cosmic strings. Zero energy ontology (ZEO) suggests that this is the case also for the very late cosmology, or that emerging after "big" state function reduction (BSFR) changing the arrow of time. Could this be a counterpart for the general relativity based vision of black holes as the endpoint of evolution: now they would also be starting points for a time evolution as a mini cosmology with reversed time direction. This would conform with the TGD explanation for stars and galaxies older than the Universe and with the picture produced by JWST.

First some facts about zero energy ontology (ZEO) are needed.

1. In ZEO space-time surfaces satisfying almost deterministic holography and having their ends at the boundaries of causal diamond (CD), which is the intersection of future and past directed light-cones and can have varying scale? The 3-D states at the passive boundary of CD are unaffected in "small" state function reductions (SSFRs) but change at the active boundary. In the simplest scenario CD itself suffers scaling in SSFRs.

2. In BSFRs the roles of passive and active boundaries of CD change. The self defined by the sequence of SSFRs "dies" and reincarnates with an opposite arrow of geometric time.

   The hierarchy of effective Planck constants predicted by TGD implies that BSFRs occur even in cosmological scales and this could occur even for blackhole-like objects in the TGD counterpart of evaporation.

Also some basic ideas related to TGD based astrophysics and cosmology are in order.

1. I have suggested that the counterpart of the GRT black hole in the TGD is a maximally dense volume-filling flux tube tangle [L12]. Actually an entire hierarchy of black-hole like objects with quantized string tension is predicted [L44] and ordinary BHs would correspond to flux tubes consisting of nucleons (they correspond to Mersenne prime M_{107} in TGD) and would be essentially giant nuclei.

   M_{89} hadron physics and corresponding BHs are in principle also possible and have string tension which is 512 higher than the flux tubes associated with ordinary blackholes. Surprisingly, they could play a key part in solar physics.

2. The very early cosmology of TGD corresponds to the region near the passive boundary of CD that would be cosmic string dominated. The upper limit for the temperature would be Hagedorn temperature. Cosmic strings are 4-D objects but their CP_2 projection is extremely small so that they look like strings in M^4.

   The geometry of CD strongly suggests a scaled down analog of big bang at the passive boundary and of big crunch at the active boundary as time reversal of big bang as BSFR. This picture should also apply to the evolution of BH? Could one think that a gas of cosmic strings evolves to a BH or several of them?

3. In ZEO, the situation at the active future boundary of the CD after BSFR should be similar to that at the passive boundary before it. This requires that the evaporation of the BH at the active boundary must occur as an analog of the big bang, and gives rise to a gas consisting of flux tubes as analog of cosmic string dominated cosmology. Symmetry would be achieved between the boundaries of the CD.

4. In general relativity the fate of all matter is to end up in blackholes, which possibly evaporate. What about the situation in TGD?: does all matter end up to a tangle formed by volume filling flux tubes which evaporates to a gas of flux tubes in an analog of Big Bang?

   Holography = holomorphy vision states that space-time surfaces can be constructed as roots for pairs (f_1, f_2) of analytic functions of 3 complex coordinates and one hypercomplex coordinate of $H = M^4 \times CP_2$. By holography the data would reside at certain 3-surfaces. The 3-surfaces at the either end of causal diamond (CD), the light-like partonic orbits, and lower-dimensional surfaces are good candidates in this respect.

   Could the matter at the passive boundary of CDs consist of monopole flux tubes which in TGD form the building bricks of blackhole-like objects (BHs) and could the BSFR leading to the change of the arrow of geometric time transform the BH at the active boundary of CD to a gas of monopole flux tubes? This would allow a rather detailed picture of what space-time surfaces look like.

Black hole evaporation as an analog of time reversed big bang can be a completely different thing in TGD than in general relativity. Let us first see whether a naive generalization of the GRT picture makes sense.

1. The temperature of a black hole is $T = \hbar/8\pi GM$. For ordinary hbar it would therefore be extremely low and the black hole radiation would therefore be extremely low-energy.

2. If hbar is replaced by GMm/β_0, the situation changes completely. We get $T = m/\beta_0$. The temperature of massive particles, mass m, is essentially m. Each particle in its own relativistic temperature. What about photons? They could have very small mass in p-adic thermodynamics.

3. If m=M, we get $T = M/\beta_0$. This temperature seems completely insane. I have developed the quantum model of the black hole as a quantum system and in this situation the notion of temperature does not make sense.

Since the counterpart of the black hole would be a flux tube-like object, the Hagedorn temperature T_H is a more natural guess for the counterpart of evaporation temperature and also blackhole temperature. In fact, the ordinary M_{107} BH would correspond to a giant nucleus. Also M_{89} BH can be considered.

1. The straightforward dimensionally motivated guess for the Hagedorn temperature is suggested by p-adic length scale hypothesis as $T_H = x\hbar/L(k)$, where x is a numerical factor. For blackholes as $k = 107$ objects this would give a temperature of order 224 MeV for $x = 1$. Hadron Physics giving experimental evidence for Hagedorn temperature about $T = 140$ MeV near to pion mass and near to the scale determined by Λ_{QCD}, which would be naturally related to the hadronic value of the cosmological constant Λ.

2. One can of course ask whether the BH evaporation in this sense is just the counterpart for the formation of a supernova. Could the genuine BH be an M_{89} blackhole formed as an M_{107} nuclear string transforms to an M_{89} nuclear string and then evaporates in a mini Big Bang? Could the volume filling property of the M_{107} flux tube make possible touching of string portions inducing the transition to M_{89} hadron physics just as it is proposed to do in the process which corresponds to the formation of QCD plasma in TGD [L44].

4 The planet that should not exist

The popular article in Futurism (see this) tells about a strange finding challenging the beliefs of the formation mechanism of planets. In the study published in Science, researchers out of Pennsylvania State described a surprising discovery: a Neptune-sized planet that's 13 times the mass of Earth, which is orbiting a tiny ultracool star that's with mass by a factor 1/9 smaller than the mass of the Sun.

According to the abstract of the article [E9] (see this) planets form in protoplanetary disks of gas and dust around young stars that are undergoing their own formation process. The amount of material in the disk determines how big the planets can grow. Stefansson et al. observed a nearby low-mass star using near-infrared spectroscopy. They detected Doppler shifts due to an orbiting exoplanet of at least 13 Earth masses, which is almost the mass of Neptune. Theoretical models do not predict the formation of such a massive planet around a low-mass star (see the Perspective by Masset). The authors used simulations to show that its presence could be explained if the protoplanetary disk were 10 times more massive than expected for the host star. To sum up, Neptune sized planets (mass is $17.1 M_E$ and radius $3.88 R_E$) should not exist around stars with mass $M_E/9$.

The analysis of these findings led to a considerably more detailed view of the formation of planets and also formation of stars.

4.1 TGD view of formation of planets and moons

The TDG based proposal for the formation of planets assumes that planets have condensed from spherical shells of dark matter produced by "mini big bangs" as explosions of the star [L29, L30]. These dark mass shells with a large value of h_{eff} would transform to ordinary matter around a seed giving rise to the core of the planet and the dark matter from the spherical shell would transform to ordinary matter and condense around this core. The seed region need not contribute much to the mass of the planet.

1. The basic difference with respect to the standard model would be that the disk is replaced with a spherical shell of dark matter. The open question is whether the mass of the shell condensing to form the planet can have a mass $\geq 13 M_E$ for a star with mass as small as $M_{Sun}/9$. The mass mass ΔM of the mass shell should have been of the order $10^{-4} M_{star}$ and gives $\Delta R/R_{Sun} \sim 10^{-4}/3$. The radius of the star is not very sensitive to its mass so

that $R_{star} = R_{Sun}$ is a reasonable estimate. Assuming $R_{star} \sim R_{Sun}$ and using $M_{Sun} = .333 \times 10^{-6} M_E$ and $R_{Sun} \sim 100 R_E$, one obtains the estimate $\Delta R \sim 75$ km.

2. For the Earth-Sun system the thickness of the layer would satisfy $\Delta R/R_{Sun} \sim 1.1 \times 10^{-4}$ and give $\Delta R \sim .64$ km.

4.2 How could stars form in the TGD Universe?

Also the mechanism for the formation of stars would be different in the TGD framework and is inspired by the predicted quantum coherence in astrophysical scales and the general view of TGD inspired view of what happens in state function reductions, which also leads to a theory of consciousness and life as universal phenomena present in all scales, even astrophysical.

1. According to the standard model, stars condense from the interstellar gas, possibly from a material of a spherical or a disk-like structure. In the TGD framework this cannot apply to the first generation stars. Rather, the mass of the first stars could have come from the transformation of the analog of dark energy to ordinary matter as the energy of a cosmic string transforms to matter in a process analogous to the decay of the inflaton field. The string tension of the resulting monopole flux tube is much smaller and the process can repeat itself. This mechanism could play some roles later.

2. The emerging matter could be mostly ordinary matter but can transform to a phase, which has a large effective Planck constant $h_{eff} > h$. These phases of ordinary matter would explain the missing baryonic mass [L5] and would have a key role in biology. Evolution as a gradual increase of h_{eff} serving as a measure of algebraic complexity conforms with this view.

   The galactic dark matter in turn would correspond to the dark energy assignable to the string tension of very long cosmic strings orthogonal to the galactic plane and creating a transversal $1/\rho$ gravitational field explaining the flat velocity spectrum of distant stars.

3. This model for the generation of stars should explain the fact that there are star generations: stars die as supernovae and are regenerated later. Zero energy ontology (ZEO) [L14] provides a possible solution to the problem. The end of the life of the star as supernova could correspond to "big" state function reduction (BSFR) (the TGD counterpart of the ordinary state function reduction) in astrophysical scale changing the arrow of time. This process would be highly analogous to a biological death involving a decay process identifiable as supernova explosion.

   After a supernova explosion the star would live a life with an opposite arrow of geometric time and reincarnate in the original time direction as a star which would partially consist of the decay products of the earlier star(s). The evolutionary age of the star increases steadily in this sequence of lives forth and back in geometric time although the cosmological age increases much slower. JWST has indeed discovered stars and galaxies older than the universe [L36].

The model should also explain how the core of the daughter star is generated.

1. The TGD based model is motivated by the problem caused by the fact that stellar fusion cannot produce elements heavier than iron plus the fact that the model for their production in supernova explosions has problems. Also the observed abundances of lighter elements are problematic. "Cold fusion", which is usually admitted as a real phenomenon, is the third problem [L2, L5, L17].

2. The TGD based model assumes that the dark "cold fusion" of dark nucleons produces nuclei with much smaller binding energy than that of normal nuclei and can occur at low temperatures. The potential energy wall preventing the occurrence of fusion is much lower if it scales as the inverse size scale of the dark nuclei. This predicts the formation of dark nucleon sequences which can transform to ordinary nuclei by the reduction of the value of h_{eff} and liberate in this process almost all ordinary nuclear binding energy. This process would lead to the generation of the core of the protostar and when the temperature is high enough, ordinary nuclear fusion reactions begin.

3. In this framework elements heavier than Fe would be formed outside stellar interiors during the period leading to the formation of the protostar. Also the formation of the cores of planets could involve this process but would not lead to the ignition temperature at which ordinary nuclear fusion begins. The seeds for the formation of stars could correspond to tangles of thickening cosmic strings producing ordinary matter as the energy of the string is liberated.

4.3 Are the abundances of elements independent of cosmic time?

The model predicts that effects of reprocessing, which are central in the standard model, would be weak and the abundances produced by the nuclear fusion itself inside the star should depend only weakly on cosmic time! The TGD Universe would be an expanding steady state Universe!

ZEO strengthens this prediction. The sequence of reincarnations leads to an asymptotic state: the abundances of the nuclei in the interstellar space should not depend on time: this was actually one of the first "almost-predictions" of the TGD inspired model of nuclei as string-like entities [K8]. Standard model makes different prediction: the abundances of the heavier nuclei should gradually increase as the nuclei are repeatedly re-processed in stars and blown out to interstellar space in a supernova explosion. What is the situation in real life?

Amazingly, there is empirical support for this highly non-trivial prediction of TGD [E15]. The 25 measured elemental abundances (elements up to $Sn(50,70)$ (tin) and $Pb(82,124)$ (lead)) of a 12 billion years old galaxy turned out to be very nearly the same as those for the Sun. For instance, oxygen abundance was 1/3 of that from that estimated for the Sun. Standard model would predict that the abundances should be .01-.1 from that for the Sun as measured for stars in our galaxy. The conjecture was that there must be some unknown law guaranteeing that the distribution of stars of various masses is time independent. The alternative conclusion would be that heavier elements are created mostly in the interstellar gas and dust.

The findings of JWST, in particular the discovery of stars and galaxies which seem to be older than the Universe, conforms with this picture.

4.4 Herbib-Haro stars and independence of abundances on time

The Youtube posting "The James Webb Space Telescope Has Just Made an Incredible Discovery about Our Sun! Birth of Sun"!" (see this) tells about Herbit Haro object HH211 located at a distance 1000 light years about which JWQST has provides a picture (I hope that the sensationalistic tone of the title does not irritate too much: it seems that we must learn to tolerate this style).

Herbig Haro luminous objects are associated with very young stars, protostars. Typically they involve a pair of opposite jets containing streams of matter flowing with a very high speed of several hundred km/s. The jets interact with the surrounding matter and generate luminous regions. HH211 was the object studied by JWT. The jets were found to contain CO, SiO, H_2.

Herbig Haro objects provide information about the very early states of star formation. As a matter of fact, the protostar stage still remains rather mysterious since the study of these objects is very challenging already because their distances are so large. The standard wisdom is that stars are born, evolve and explode as supernovae and that the remnants of supernovae provide the material for future stars so that the portion of heavy elements in their nuclei should gradually increase. The finding that the abundances of elements seem to depend only weakly on cosmic time seems to be in conflict with these findings and forces us to ask whether the vision about the protostars should be modified. Also JWT found that the galaxies in the very young Universe can look like the Milky Way and could have element abundances of recent galaxies which challenges this belief.

The association of the jets to Herbig Haro objects conforms with the idea that cosmic strings or monopole flux tubes formed from them are involved with the formation of a star. One can consider two options for how the star formation proceeds in the TGD Universe.

1. The seed for the star formation comes from the transformation of dark energy associated with the cosmic string or monopole flux tube to ordinary matter (it could also correspond to a large h_{eff} phase and behave like dark matter and. explain the missing baryonic matter). By the conservation of the magnetic flux the magnetic energy density per unit length of the monopole flux tube behaves like $1/S$ and decreases rapidly with its transversal area. The volume energy

density increases like area but its growth is compensated by the phase transition reducing the value of the analog of cosmological constant Λ so that on the average this contribution behaves as a function of the p-adic length scale. In the same way as magnetic energy per unit length. The energy liberated from the process is however rather small except for almost cosmic strings and this process might apply only to the formation of first generation stars.

2. The second option is that the process is analogous to "cold fusion" interpreted in the TGD framework as dark fusion [L5, L2, L17]) in which ordinary matter, say protons and perhaps even heavier nuclei, are transformed to dark protons at the monopole flux tubes having much larger Compton length (proportional to h_{eff}) that ordinary protons or nuclei. If the nuclear binding energy scales like $1/h_{eff}$ for dark nuclei nuclear potential wall, is rather low and the dark fusion can take place at rather low temperatures. The dark nuclei would then transform to ordinary nuclei and liberate almost all of their ordinary nuclear binding energy, which would lead to a heating which would eventually ignite the ordinary nuclear fusion at the stellar core. Heavier nuclei could be formed already at this stage rather than in supernova explosions. This kind of process could occur also at the planetary level and produce heavier elements outside the stellar cores.

   This process in general requires energy feed to increase the value of h_{eff}. In living matter the Pollack effect would transform ordinary protons to dark protons. The energy could come from solar radiation or from the formation of molecules, whose binding energy would be used to increase h_{eff} [L25]. This process could lead to the formation of molecules observed also in the jets from HH211. Of course, also the gravitational binding energy liberated as the matter condenses around the seed liberates and could be used to generate dark nuclei. This would also raise the temperature helping to initiate dark fusion. The presence of the dark fusion and the generation of heavy elements already at this stage distinguishes between this view and the standard picture.

   The flux tube needed in the process would correspond to a long thickened monopole flux tube parallel to the rotation axis of the emerging star. Stars would be connected to networks by these flux tubes forming quantum coherent structures [L37]. This would explain the correlations between very distant stars difficult to understand in the standard astrophysics. The jets of the Herbig Haro object parallel to the rotation axis would reveal the presence of these flux tubes. The translational motion of matter along a helical flux tube would generate angular momentum. They would make possible the transfer of the surplus angular momentum, which would otherwise make the protostar unstable. By angular momentum conservation, the gain of the angular momentum by the protostar could involve generation of opposite angular momentum assignable to the dark monopole flux tubes.

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Can one understand this time independence in the TGD framework? The association of the jets to Herbig Haro objects conforms with the idea that cosmic strings or monopole flux tubes formed from them are involved with the formation of a star. I have earlier considered two options for how the star formation proceeds in the TGD Universe.

4.4.1 Option I

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4.4.2 Option II

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4.4.3 Option III

The third view relies on the model of Sun [L44] could be seen as a fusion of these two options. The stimulus for the article was the article "Is the Sun a Black Hole?" by Nassim Haramein. The article describes a collection of various anomalies related to the physics of the Sun, which I have also considered from the TGD point of view. The most important anomalies are the gamma ray anomalies and the missing nuclear matter of about 1500 Earth masses. There is also evidence that the solar surface contains a solid layer: something totally implausible in the standard atomic physics. The idea that the Sun could contain a blackhole led in the TGD framework to a refinement of the earlier model for blackhole-like objects (BHs) as maximally dense flux tube spaghettis predicting also their mass spectrum in terms of Mersenne primes and their Gaussian counterparts. The mass of the Sun and the mass which is 4/3 times the mass of the Earth belong to this spectrum.

It however turned out that the TGD based model for the missing nuclear matter could assign the gamma ray anomalies to the magnetic body of the Sun consisting of monopole flux tubes. A magnetic bubble as a layer would cover the surface of the Sun and consist of closed monopole flux tube loops. One option is the analog of a dipole field containing flux tube portions along the magnetic axis from South to North and returning along the solar surface from North to South. Also the solar nucleus could contain M_{89} nucleons.

The flux tubes could carry M_{89} nucleons with a mass, which is 512 times the mass of the ordinary nucleon. They could be characterized by the gravitational Planck constant of the Sun with gravitational Compton length equal to $R_E/2$ for all particles (R_E refers to the Earth radius). Intriguingly, the Sunspot size is of the order of $R_E/2$. This flux tube structure, predicted to have a mass of order $1500M_E$, would correspond to one dark M_{89} nucleon per the Compton volume of the ordinary M_{89} nucleon so that the analog of supra phase with very large overlap between wave functions would be in question.

M_{89} nucleons at the monopole flux tubes at the surface of the Sun would produce in the decay to ordinary nuclei the solar wind and solar energy. In p-adic cooling, the splitting of the flux tubes to ordinary nucleons of the solar wind by reconnection would also liberate the radiation from the Sun.

The magnetic body carrying long strings of M_{89} nucleons could be seen as a 2-D surface variant of the TGD counterpart of blackhole, which is dark. This model conforms with the earlier model of the sunspot activity related to the reversal of the solar magnetic field.

An additional input is provided by the model for dark nucleons applied in the models of "cold fusion" and pre-stellar evolution. The conservative option is that the heating by the dark fusion ignites the ordinary nuclear reactions giving rise to the high temperature stellar core. The non-conservative option allowed by the role of the M_{89} layer is that, not only the convective zone but also solar core could consist of dark nuclei at temperature of order 10 keV and hot fusion is replaced by the scorned dark fusion.

A possible explanation for the gamma ray anomalies would be in terms of M_{89} and M_{79} mesons generated in the TGD counterpart for the formation of quark gluon plasma in a process analogous to high energy nuclear collision creating very high nuclear densities. The decay of M_{89} nucleons to ordinary nucleons of solar wind in p-adic cooling would generate anomalous gamma rays. $M_{G,79}$ mesons could be also generated in the touching of two M_{89} flux tubes, whose distance would be larger than 2 Compton lengths of M_{89} (M_{107}) nucleons.

The generation of M_{89} nucleons is necessary. The monopole flux tube network connecting stars to a network analogous to a blood circulation feeds the M_{89} nuclei burned to ordinary nuclei inside the Sun. This option looks plausible one. One cannot exclude the regeneration could be also p-adic heating as the reversal of the p-adic cooling. In zero energy ontology (ZEO) it could be associated with a "big" state function reduction (BSFR)in solar scale in which the arrow of time changes and the process can be seen as a decay process with a reversed arrow of time: the system would effectively extract energy from the surroundings. Also in TGD inspired quantum biology this kind of process takes place and makes homeostasis possible. That ordinary fusion could provide the needed metabolic energy seems implausible.

A dramatic modification of the views of the interior of the Sun is suggestive. The M_{89} surface layer of the Sun would produce both the solar wind and solar energy and feed energy to the interior of the Sun. The interior could be a quantum system at a relatively low temperature of order 10 keV. It would be a quantum criticality making possible dark fusion explaining the "cold fusion". The strong analogies with the TGD inspired quantum biology suggest that the M_{89} layer is analogous to the cell membrane and solar interior to a cell interior. The solar core could correspond to the solar nucleus carrying the solar genome. Stanislav Lem's Solaris is what comes into mind!

The quantum model leads also to a proposal for the generation of the inner planets and Mars via the explosion of the outer layer of the Sun consisting of M_{89} nuclei (dark M_{107} nuclei) to M_{107} nuclei. For the M_{89} option the conservation of baryon number dictates the mass of the structure form in this way to be at most of the order of $3M_E$. The explosion would give rise to the inner planets and cores of the outer planets, which would have got their gas envelopes by gravitational condensation. This model generalizes to a model for supernovas and generation of solar wind. The anomalies related to solar convection and solar neutrinos suggest that the standard model for solar interior must be replaced with a generalization of the nuclear shell model proposed already earlier.

This model explains naturally the observed weak time dependence of the observed compositions of the stars since the spectrum of the star is determined by the decay of the M_{89} layer at the surface of the Sun to ordinary nuclei. If the decomposition of the very long M_{89} is universal, the time independence of the composition follows as a consequence.

5 Could the TGD view of galactic dark matter make same predictions as MOND?

I learned about very interesting finding Kyu-Hyun Chae related to the dynamics of binaries of widely separated stars (see this). The dynamics seems to violate Newtonian gravitation for low accelerations, which naturally emerge at large separations and the violations are roughly consistent with the MOND hypothesis.

There is also a new contribution to the crisis of cosmology. ΛCDM scenario predicts that the Universe should become clumpier but the opposite seems to be true. Both MOND and TGD predict the opposite.

5.1 Basic fiends of Chae

The abstract of the research article [E11] (see this) summarizes the findings of Kyu-Hyun Chae.

A gravitational anomaly is found at weak gravitational acceleration $g_N \simeq 10^{-9}$ m/s^2 from analyses of the dynamics of wide binary stars selected from the Gaia DR3 database that have accurate distances, proper motions, and reliably inferred stellar masses. Implicit high-order multiplicities are required and the multiplicity fraction is calibrated so that binary internal motions agree statistically with Newtonian dynamics at a high enough acceleration of $\sim 10^{-8}$ ms^{-2}. The observed sky-projected motions and separation are deprojected to the 3D relative velocity v and separation r through a Monte Carlo method, and a statistical relation between the Newtonian acceleration $g_N \equiv GM/r^2$ (where M is the total mass of the binary system) and a kinematic acceleration $g \equiv v^2/r$ is compared with the corresponding relation predicted by Newtonian dynamics. The empirical acceleration relation at 10^{-9} ms^{-2} systematically deviates from the Newtonian expectation. A gravitational anomaly parameter $\delta_{obs-newt}$ between the observed acceleration at g_N and the Newtonian prediction is measured to be: $\delta_{obs-newt} = 0.034 \pm 0.007$ and 0.109 ± 0.013 at $g_N \sim 10^{-8.91}$ and $10^{-10.15}$ ms−2, from the main sample of 26,615 wide binaries within 200 pc. These two deviations in the same direction represent a 10 σ significance. The deviation represents a direct evidence for the breakdown of standard gravity at weak acceleration. At $g_N = 10^{-10.15}$ ms^{-2}, the observed to Newton-predicted acceleration ratio is $g_{obs}/g_{pred} = 10^{\sqrt{2}\delta_{obs-newt}} = 1.43 \pm 0.06$. This systematic deviation agrees with the boost factor that the AQUAL theory predicts for kinematic accelerations in circular orbits under the Galactic external field.

The findings lend strong support for a MOND type theory (see this) and for the notion of critical acceleration. The question is whether TGD and MOND could make the same prediction for the critical acceleration despite the fact the physical mechanism explaining the flat velocity spectrum of galaxies are completely different.

5.2 TGD view of the findings

How could one explain the findings in the TGD framework?

5.2.1 Basic ideas

The TGD inspired astrophysics and cosmology, actually the physics in all scales, relies crucially on the notions of cosmic string and monopole flux tube.

1. Cosmic strings as extremely thin 3-D surfaces would explain the flatness of the galactic rotation curve. They give rise to galaxies as local tangles involving thickening of the cosmic string to a monopole flux tube (MFT): the dark energy liberated in the reduction of the

string tension T (energy per unit length) would transform to ordinary galactic matter. The process is analogous to the decay of the inflaton field to ordinary matter [L40].

Also a second cosmic string at the galactic plane explaining the spiral structure could be involved and the galactic blackhole could have formed in the collision of cosmic strings as intersection.

The cosmic string would create a $1/\rho$ force orthogonal to the string and this would predict a constant velocity spectrum at large distances at which the ordinary gravitational force between the galactic matter and distant star can be neglected.

2. The gravitational acceleration due to the cosmic string would become visible at distances at which the ordinary gravitational acceleration caused by $1/r^2$ force becomes smaller than that caused by the $1/\rho$ force. This prediction deviates from the MOND prediction and does not require giving up the Newtonian dynamics.

3. The cosmic string itself would consist of dark energy rather than dark matter. TGD predicts a hierarchy of phases of ordinary matter labelled by the value of effective Planck constant. These phases behave like dark matter and would explain the missing baryonic matter and the growth of its portion in the cosmic evolution. This form of dark matter would play a key role in living matter [L40].

4. Also stars would correspond to thickened tangles of a MFT, or more naturally, of its thickened version with a lower string tension T. They would be arranged along cosmic strings. This would also predict anomalous correlations between the dynamics of stars associated with the same cosmic string.

5.2.2 Can one generalize the TGD based model for the galactic velocity spectrum to binary stars?

Could cosmic strings assignable to the stars of the binary explain the findings of Chae?

1. The stars of the binary could be associated with the MFTs from which they have emerged as local thickening transforming dark energy to ordinary matter and energy. The natural assumption is that they are orthogonal to the orbital plane of the binary. The MFTs associated with the stars of the binary could also be parts of the same closed MFTs. TGD indeed predicts that the nonopole flux tubes must be closed.

2. The gravitational force between either star of the binary system and the MFT of the companion star gives rise to an additional $1/\rho$ force just as in the interactions of the star with the galaxy and the galactic cosmic string.

   One expects that cosmic strings must be replaced with MFTs, which have considerably lower string tension than galactic strings. The value of T is expected to scale like the inverse of the radius of the MFT and therefore decrease rapidly.

3. The gravitational force between the associated cosmic strings behaving like $1/\rho$ would be very weak at short distances as compared to the $1/r^2$ force would be weak at short distances. At large enough distances it would exceed the acceleration predicted by the ordinary matter galactic matter. The critical acceleration is indeed weak. For a fixed value of T, the distance at which this occurs would depend on T with the cosmic string of the first star and the mass of the second star of the binary binary.

Consider now an order of magnitude estimate.

1. The acceleration caused by the string or monopole flux tube is

$$a = \frac{GkT}{\rho} \tag{5.1}$$

   and it produces by Kepler's law constant velocity $\beta_0 = \beta_0/c$ of rotation

$$\beta_0^2 = kTG \ . \tag{5.2}$$

Here k is a numerical constant, which disappears from the formulas).

2. The acceleration caused by the ordinary galactic matter (by the second star) is $a_{ord} = Gm/\rho^2$, where m is the ordinary galactic mass (mass of the star). By putting the accelerations caused by the cosmic string (monopole flux tube) associated with m and galactic matter equal, one obtains the estimate for the critical distance

$$\rho_{cr} = \frac{m}{T(m)k} = \frac{Gm}{\beta_0^2(m)} = \frac{r_s(m)}{2\beta_0^2(m)} \ , \tag{5.3}$$

where r_s is Schwartschild radius.

3. From the data, one can ne estimate the value of $T(m)$ for the binary system. One expects it to be much smaller than the value of $T(M)$ associated with galactic cosmic strings since it should correspond to a MFT, which has suffered several phase transition-like thickenings during cosmic evolution liberating the dark energy of the MFT identifiable as magnetic and volume energy.

4. From the estimate for the value of T deduced from β_0, one can deduce the value critical acceleration $a_{cr} = \beta_0^2/r_{cr}$ and it should have at least the same order of magnitude as derived in [E11]. The critical acceleration determined in the article for the binary system is roughly of the same order of magnitude as the critical acceleration in the galactic situation determined by the rotational speed about $\beta_0 = 2.2 \times 10^2$ km/s for distant stars around the galaxy and supports the MOND mechanism. In TGD, the mechanism is completely different and this provides a killer test.

5.2.3 Quantitave estimates

Consider now the estimate in the case of galaxies (Milky Way is taken as a representative example) and binaries.

1. Consider first an estimate for β_0^2 for the galaxy. Kepler's law for string-star system gives

$$\beta_0^2 = kTG \ . \tag{5.4}$$

This gives

$$r_{cr} = \frac{M}{kT} = \frac{GM}{\beta_0^2} = \frac{r_s}{2\beta_0^2} \ , \tag{5.5}$$

where r_s is the Schwarshild radius of the galaxy without counting the contribution of the dark mass. The mass of the Milky way is given by $M_{gal}/M_{Sun} = r_{s,gal}/r_{s,Sun} \in [1.2, 1.9] \times 10^{12}$. The value of $\beta_0 = v_0/c = \simeq .7 \times 10^{-3}$ gives an estimate for r_{cr} .

It should be noticed that the value of $\beta_0 \simeq 10^{-3}$ is of the same order of magnitude as the velocity parameter appearing in the formula $\hbar_{gr} = GMm/\beta_0$, $\beta_0 = v_0/c \leq 1$ for the gravitational Planck constant introduced by Nottale [E5] in the case of Sun. Could these two velocity parameters be identified? This need not make sense: for the Earth $\beta_0 \simeq 1$ is suggestive, which looks unrealistic as a velocity of rotation of something rotating around a monopole flux tube assignable to the Earth.

2. For the binary system the critical radius r_{cr} is of order $r_{cr} \sim 100$ pc ~ 326 ly $\sim 2.9 \times 10^{12}$ km. A reasonable estimate for the Schwarschild radius r_s of the stars of the binary is as solar Schwartschild radius equal to $r_s = 3$ km.

   The previous formula for r_{cr} gives an estimate for β_0^2

$$\beta_0^2 = \frac{Gm}{\beta_0^2} = \frac{r_s}{2r_{cr}} \quad . \tag{5.6}$$

   One obtains $\beta_0^2 \simeq 10^{-12}$ ($c = 1$), which could correspond to $\beta_0 = 2^{-20}$ (powers of 2 are suggested by number theoretical considerations). This in turn gives $\frac{T_{gal}}{T_{bin}} \sim 10^6$.

3. Consider now the critical accelerations a_{cr}. One has

$$a_{cr} = \frac{\beta_0^2}{\rho_{cr}} = \frac{kTG}{\rho_{cr}} \quad . \tag{5.7}$$

   There are two cases to consider: galactic and binary.

   The ratio of the critical accelerations is

$$\frac{a_{cr,gal}}{a_{cr,bin}} = (\frac{T_{gal}}{T_{bin}})^2 \frac{m_{bin}}{m_{gal}} = (\frac{\beta_{0,gal}}{\beta_{0,bin}})^4 \frac{m_{bin}}{m_{gal}} \quad . \tag{5.8}$$

   By feeding in the numbers the ratios of string tensions and masses and using reduces mass $m_{red} = m_{Sun}/2$, one obtains that the ratio is in the range $[1.3, 0.8]$ corresponding to the range for $M_{gal}/M_{Sun} \in [1.2, 1.9] \times 10^{12}$. The upper bound $a_{cr,bin} \sim 1.5 \times 10^{-10}$ m/s^2 for the estimate can be compared with the estimate $a_{cr,bin} \sim 10^{-9}$ m/s^2 of [E11] and the estimate $a_{cr,gal} \sim 1.9 \times 10^{-10}$ m/s^2 for the galactic critical acceleration. There is an order of magnitude discrepancy. The observations suggest $a_{cr,gal}/a_{cr,bin} \sim .7 \times 10^{-1}$ so that there would be discrepancy of an order of magnitude.

   The mass of the star of the binary system should be roughly $m_{bin} = .1 \times M_{Sun}$ to get rid of the discrepancy. It is however known that the probability of the star to belong to a binary increases with the mass of the star (see this). This hower increases the estimate for the value of $a_{cr,gal}/a_{cr,bin}$.

   Maybe, the assumption that the scaling law is exact over a mass scale range of 12 orders of magnitude is too much to hope for.

5.2.4 A scaling law implying that the predictions of TGD and MOND are identical

The predictions of TGD and MOND would be identical if the string tension $T(m)$ of the MFT assigned to an object with mass m (galaxy or star) satisfies the scaling law

$$\frac{T^2(m)}{m} = constant \quad . \tag{5.9}$$

The scaling law would have rather dramatic implications. There are two forms of this proposal depending on whether T is constant or depends on the position along the MFT.

1. If one one assumes that $T = constant$ along the MFT, the masses of objects (galaxies or stars) associated with it have the same mass and could be in the same evolutionary state.

   The dynamics of the MFT and objects associated with it would be in synchrony. This is an enormously powerful prediction but would conform with the predicted long range gravitational quantum coherence of the TGD Universe, for which the long MFTs would serve as correlates. This view involves the hierarchy of effective Planck constants $h_{eff} = nh_0$ labelling phases of the ordinary matter located at the field bodies (magnetic or electric), in particular gravitational magnetic bodies. Nottale's proposal [E5] for the gravitational Planck constant $\hbar_{gr} = GMm/\beta_0$, $\beta_0 = \beta_0/c \leq 1$ is part of the hypothesis [L22, L23] and its generalization would hold true for systems involving electric fields in long scales [L25]. One could in principle assign galaxies/stars having the same visible mass and evolutionary stage to the same MFT and one could in principle construct a flux tube map as a road map of the Universe.

2. The weaker, and probably more realistic, option is that the dynamics of objects and associated flux tubes are in synchrony only locally. T for the MFT can indeed vary along the flux tube. One could also say that MFTs could control the dynamics of galaxies/stars. This would be a scaled up variant for the vision that the magnetic body constings of MFTs (more generally field bodies) carrying dark matter has $h_{eff} = nh_0$ phases control the dynamics of the biological bodies (organisms). Universe would be analogous to a biological organism.

5.3 A new contribution to the crisis of cosmology

Sabine Hossenfelder has a Youtube video (see this) about the latest anomaly in cosmology [E17] (see this). This anomaly is very problematic from the point of view of the ΛCDM scenario of dark energy and possibly also from the point of view of general relativity. The MOND scenario is however consistent with the findings.

The ΛCDM scenario involves 6 parameters. Among them is Hubble constant. Depending on the measurement method one obtains two values for it: this creates Hubble tension. The two kinds of measurements correspond to short and very long scales and this might relate to the problem.

There is also so called sigma8 tension with significance larger than 4 sigmas, which is something very serious. ΛCDM predicts that the Universe should become clumpier as it evolves. This implies that the gravitational potential wells should become narrower with time. In shoret scales the clumpying rate is not as high as predicted. Also the new results from a dark energy survey based on gravitational lensing suggest that the gravitational valleys are shallower than they should be at large values of cosmic time of LambdaCDM.

1. What is measured is so-called Weyl potential $\Psi_W = (\Psi + \Phi)/2$ defined in terms of the space-time metric in cosmic scales having the expression

$$ds^2 = a^2(\tau)(1 + 2\Psi)d\tau^2 - (1 + 2\Phi)dx_3^2) \ .$$

Here τ and x_3 denote counterparts of linear Minkowski coordinates. For $Psi = \Phi = 0$ one has conformally flat metric. From the value of Psi_W one can deduce the clumpiness. The measurements are carried out for 3 widely differing values of cosmic time τ. The value of the Weyl parameter Ψ_W characterizing the clumping differs from the prediction of the ΛCDM scenario and is consistent with the increasing shallowness of the gravitational potentials of the mass distributions.

2. The significance of the finding is estimated to be 2-2.8 sigma, which is potentially significant. Since the same method is used for different cosmic times, it is not possible to claim that the discrepancy is due to the different methods.

MOND has no problems with the findings. What about TGD?

1. The TGD view of galactic dark matter as dark energy assignable to cosmic strings, which are 3-D extremely thin 3-surfaces with a huge density of magnetic and volume energy [L40]. String tension parametrizes the density of this energy and creates a $1/\rho$ gravitational potential which predicts flat velocity spectrum for distant stars rotating around the galaxy. No dark matter halo nor dark matter particles are needed.

2. The $1/rho$ gravitational potential created by cosmic strings makes the gravitational wells shallower than the sole $1/r^2$ potential due to visible galactic matter. Also the halo creates $1/r^2$ potential in long enough scales but the prediction is that the dark matter halo becomes more clumpy so that the gravitational wells should become sharper.

Cosmic strings are closed so that there is some scale above which this effect is not seen anymore since the entire closed cosmic strings become the natural objects. Therefore this effect should not be seen in long enough scales.

It is important to notice that the shallowing would be due to the shortening of the observation scale rather than due to the time evolution. The same interpretation applies to the Hubble constant. In the TGD framework, the finite size of space-time sheets indeed brings in a hierarchy of scales, which is not present in General Relativity.

3. How does this relate to MOND? The basic objection against MOND is that it is in conflict with mathematical intuition: for small accelerations Newtonian gravitation should work excellently. In TGD, the critical acceleration of MOND is replaced with a critical distance from the galactic nucleus at which the $1/\rho$ potential due to the cosmic string wins the $1/r^2$ potential. Under a suitable assumption discussed in [L42], this translates to a critical acceleration of MOND so that the predictions are very similar. Note that the cosmic strings also cause a lensing effect used in the survey and this gives an upper bound for their string tension.

6 Are planets and stars quantum gravitational harmonic oscillators?

I learned (thanks to Mark McWilliams and Grigol Asatiani) about a proposal that black-hole like stars, gravatars, could develop Russian doll-like nested structures, nestars (see this). Gravastar is a star proposed to replace blackhole. It has a thin layer of matter at the horizon and de-Sitter metric in the interior. Nestar would consist of nested gravastars.

This finding raised the question whether the layered structures of planets could be understood in the TGD framework and inspired what I call quantum gravitational harmonic oscillator model of star. The second input came from the observation of a planet which is too massive as compared to its mother star to exist [E9] (see this). Could the TGD based model for the formation of planets [L29, L30] be consistent with this finding? Quite surprisingly, the detailed considerations led to more detailed ideas about the evolution of stars explaining the old but forgotten paradoxical finding that the abundances of elements do not seem to depend on cosmic time as predicted by the standard model of star formation in which the decay products of supernovae are reprocessed. JWST has in fact confirmed this finding.

6.1 Could planets and stars have a layered structure in the TGD Universe?

The proposal is interesting from the TGD point of view because TGD raises the question whether stars, and astrophysical objects, in general could have a layered structure.

1. One of the early "predictions" of TGD for stars coming from the study of what spherically symmetric metrics could look like, was that it corresponds to a spherical shell, possibly a hierarchical layered structure in which matter is condensed on shells. p-Adic length scale hierarchy suggests shells with radii coming as powers of $2^{1/2}$.

2. Nottale's model [E5] for planetary systems suggests Bohr orbitals for planets with gravitational Plack constant $\hbar_{gr} = GMm/\beta_0$. The value of the velocity parameter $\beta_0 = v_0/c \leq 1$ is from the model of Nottale about 2^{-11} for the inner planets and $1/5$ times smaller for the outer planets. This might reflect the fact that originally the planets or what preceded them consisted of gravitationally dark matter or that the Sun itself consisted of gravitationally dark matter and perhaps still does so.

6.2 Nottale's model for solar and planetary interiors as gravitational harmonic oscillators

The Nottale model is especially interesting and one can look at what happens inside the Sun and planets, where the mass density is in a good approximation constant and gravitational potential is harmonic oscillator potential. Could particles be concentrated around the orbitals predicted by the Bohr model of harmonic oscillator with radii proportional to $n^{1/2}$, $n = 1, 2, 3, ...$ The lowest state would correspond to an S-wave concentrated around the origin, which is not realized as Bohr orbit. The wave function has nodes and would give rise to spherical layers of matter.

One can perform the simple calculations to deduce the energy values and the radii of Bohr orbits in the gravitational harmonic oscillator potential by using the Bohr orbit model.

The gravitational potential energy for a particle with mass m associated with a spherical object with a constant density would be $GmM(r)/r = GMmr^2/R^3$, where M is the mass of the Sun and R is the radius of the object. This is harmonic oscillator potential. The oscillator frequency is

$$\omega = (\frac{r_s}{R})^{1/2}/R \quad , \tag{6.1}$$

where $r_S = 2GM$ is the Schwartschild radius of the object, about 3 km for the Sun and 1 cm for Earth. The orbital radii for Bohr orbits are proportional to $n^{1/2}$ inside the star. By the Equivalence Principle, the radius does not depend on particle mass. One obtains

$$r_n = n^{1/2}(2\beta_0)^{-1/2}(\frac{r_s}{R})^{1/4} \times R \quad . \tag{6.2}$$

One must of course remember that in the recent Sun, Earth and other planets ordinary matter is probably not gravitationally dark: only the particles associated with the U-shaped monopole flux tubes mediating gravitational interaction could be gravitationally dark and would play an important role in biology. The situation could have been different when the planets formed. I have proposed a formation mechanism by an explosive generation of gravitationally dark magnetic bubbles ("mini big bangs"), which then condensed to planets [L29, L30]. This would explain why the value of β_0 for the Earth interior is the same as for the system formed by the interior planets and Sun and Mars. The simple calculations to be carried out suggest that for the outer planets only the core region emerged in this way and the gravitational condensation gave rise to the layer above it. The core should have the properties of Mars in order that it could correspond to an S-wave state.

The model of stars and planets as quantum gravitational harmonic oscillators turns out to be surprisingly successful. It turns out that the radius of the core of Earth corresponds to the Bohr radius for the first orbital, which suggests that the core of Earth, and more generally of the inner planets and Mars corresponds to an S-wave ground state. For the Sun the $n = 1$ S-wave orbital is 1.5 times the solar radius. The model applies also to the outer planets. Also the rings of giant planets can be understood at a rough quantitative level.

6.3 Application of the oscillator model to solar system

In this section the above simple model is applied to the solar system. Recall that the basic formula is

$$\frac{r_1}{R} = (2\beta_0)^{-1/2}(\frac{r_s}{R})^{1/4} \quad . \tag{6.3}$$

where R refers to the radius of the object.

6.3.1 Oscillator models for the Sun and Earth

Consider first the model for the Sun assuming that the value of $\beta_0 = 2^{-11}$ holds true for Sun and inner planets. One can of course argue that the value of β_0 need not be the same for pairs formed by particles inside Sun and Sun.

For the Sun one has $\frac{r_s}{R} = 4.3 \times 10^{-6}$. For $\beta_0 = 2^{-11}$ holding true for the inner planets one obtains $r_1 = 1.45R$ so that the solar interior would correspond to a ground state S-wave with smaller than the maximal radius. For $\beta_0 = 10^{-3}$ would give the maximal radius $r^1 \simeq R$. $\beta_0 = 1$ would give $r_1 = .032R$, which is considerably smaller than the radius of the solar core about $.2R$. $\beta_0 = 0.026$ would give $r_1 = .2R$. r_{25} would be near to the solar radius. The set of the nodes of a harmonic oscillator wave function would be rather dense: at the surface of the Sun the distance between the nodes would be .1R. Note that the convective zone extends to .7R.

What about the Earth?

1. One has $r_S = 1$ cm and $R = 6,378$ km. At the surface of Earth $\beta_0 = 1$ is the favoured value and would give $r_1 =\simeq 50.5$ km. The radius of the inner inner core is between 300 km and 400 km. $n = 36$ would correspond to 300 km and $n = 64$ to 400 km. β_0 scales like $(r_1/R_E)^2$. At the surface of Earth one would have $n = (R_E/r_1)^2 \sim 15996$ and the distance between two nodes would be $R_E/2n \simeq .197$ km.

   $\beta_0 \simeq 1$ should hold true above the surface of the Earth, which suggests that it characterizes the gravitational magnetic body of Earth. Gravitational magnetic bodies of the Sun and the Earth could combine to form a single entity.

2. One can write $\beta_0(r_1)$ as

$$\beta_0(r_1) = (\frac{50.5}{r_1})^2 \quad . \tag{6.4}$$

3. The value $\beta_0 = 2^{-11}$ for the inner planets would give $r_1 = .36R_E \simeq 2285$ km. This is equal to the radius $R_{Core} = .36R_E$ of the Earth's core (see this). Therefore the Earth's liquid core could correspond to the ground state S-wave for the gravitational harmonic oscillator and the mantle has gravitationally condensed above the core from the material coming from the environment.

   $n = 2$ orbit would correspond to the radius $.5R_E$, rather neat to the radius of Mars. The thickness of the mantle is about 45 per cent of the radius of Earth so that the crust of thickness 15-20 km might be associated with the $n < 8$ orbits. $n = 7$ would correspond to $.95R_E$ and to a depth of about 319 km. $n = 8$ would correspond to $1.018R_E$, which corresponds to 116 km above the Earth: the lower boundary of the ionosphere is at 80 km.

6.3.2 The radii of first Bohr orbits for planets modelled as gravitational harmonic oscillators

The above observations raise the question whether the value of β_0 for Sun and inner/outer planets is such that both the entire Sun or its core and the cores of at least some rocky planets correspond to the ground state S-waves for the value of the gravitational Planck constant assigned with the planet. The allowed $n \geq 1$ states could correspond to layers above the core.

Note that the Bohr orbital in plane corresponds to a wave function for Schrödinger equation localized to an orbital located near the orbital plane and that there are several orbitals for a given value of n. This state could have been the primordial dark matter state and the recent state could carry some information about this state.

The condition $r_1 \leq R_P$ requires

$$\frac{r_{S,P}}{R_P} \leq 4\beta_0^2(Sun, P) \quad . \tag{6.5}$$

Using M_E and R_E as units, this condition reads for inner planets as

$$\frac{r_{S,P}}{R_P} \leq 1 \tag{6.6}$$

and for outer planets as

$$\frac{r_{S,P}}{R_P} \leq K^2 \quad , \tag{6.7}$$

where one has $K = 1$ or $K = 1/5$ depending on what option is assumed.

1. The first option giving $K = 1$ assumes that the principal quantum numbers n are of the form $n = 5k$, $k = 1, 2, ..$ for the outer planets. This is possible although it looks somewhat un-natural.

2. The second option, proposed originally by Nottale [E5], is $\beta_0(outer) = K\beta_0(inner)$, $K = 1/5$.

Recall that the prediction for the radius of the first Bohr orbital is $\frac{r_1}{R_P} = (2\beta_0)^{-1/2}(\frac{r_s}{R_P})^{1/4}$. It is interesting to see whether the condition holds true (see this).

1. Rocky planets

Consider first the rocky planets, which include inner planets and Mars. For Mercury the ratio $\frac{r_1}{R}_M$ is $(R_E/R_{Mars})(M_{Mars}/M_E)^{1/4}(r_1(E)/R_E) \simeq .388$. For Venus and Earth with nearly equal masses, which suggests that Venus has also a core of nearly the same radius, which corresponds to $r_1 \sim .36R$.

For Mars, which is also a rocky outer planet, the condition for the $K = 1/5$ option gives the value of $\frac{r_1}{R}$ for Mars by a scaling the value .36 for the Earth by the factor $(1/K)^{1/2} \times (R_E/R_{Mars})(M_{Mars}/M_E)^{1/4} \simeq .931$ so that one $r_1 = .33R_{Mars}$. The situation for the mantle region would be very similar to that for the Earth. Note that the values of $r_1(P)/r_P$ are rather near to each other, which suggests that all are formed by the condensation of the mantle on top of the core.

Planet	$\frac{M_P}{M_E}$	$\frac{R_P}{R_E}$	$\frac{r_1}{R_P}$
Mercury	0.0553	0.383	.39
Venus	0.815	0.949	.35
Earth	1	1	0.36
Mars	0.107	0.532	.54

Table 1: Masses M_P and radii R_P for the inner planets and mass using mass M_E and radius R_E of Earth as units. The last column gives the ratio $\frac{r_1}{R_P}$ of the $n = 1$ Bohr orbit to the radius of planet

What is truly remarkable and raises hope that the proposed model has something to do with reality, that in the case of Earth r_1 is identifiable as the core radius.

The only rocky planets having moons are Earth and Mars.

1. For Earth, the harmonic oscillator orbit with a radius nearest to R_E corresponds to $n = 8$. The radius is $1.0188R_E$. The distance of the orbit from the Earth surface is 118.5 km, which corresponds to the thickness of the ionosphere. $n = 9$ corresponds to 512.2 km.

   The distance of the Moon is $60R_E$. For the harmonic oscillator model this would correspond to a rather large value $n = 2778$. The Bohr radius for gravitational Coulomb orbit is $a_{gr} =$ 20 km and the orbit of the Moon would correspond to $n = \sqrt{R_E/a_{gr}}$ giving $n = 138$. The interpretation as Coulomb orbit looks of course physically natural. Also Saturnus, Uranus, and Neptune have moons with large orbital radius and would naturally correspond to Coulombic moons (see this).

2. For Mars the oscillator orbit nearest to its radius has $n = 4$ and $1.08R_M$ and corresponds to a rather large distance of 943 km from the surface. Could this mean that Mars does not have the counterpart of the ionosphere, which seems to be essential for life in the TGD framework [L25]? Earth and Mars look clearly very different from each other.

   Mars has two moons: Phobos and Deimos. The radii for them are $2.76R_M$ and $6.91R_M$. In the harmonic oscillator model they would correspond in a good approximation to $n = 26$ and $n = 164$. The identification as Coulomb orbits would require much larger values of n of order 9.744×10^4 and 1.5418×10^5 and does not look natural.

2. Giant planets

The outer planets are gas giants apart from Mars and apart from Neptune, which is an ice giant.

1. The radii for $n = 1$ harmonic oscillator orbits The following table gives the ratios $r_1/R = (1/2\beta_0)^{1/2}(r_s(p)/R_P)^{1/4}$ for the first oscillator orbit. One can estimate the ratio $r_1(P)/R_P$ by scaling its value $r_1/R_E = .36$ for Earth. One has $r_r/R_P = K^{1/2}X \times .36$ where the scaling factor is $X = [(M_P/M_E) \times (R_E/R_P)]^{1/4}K^{1/2}$ and K is the scaling factor in $\beta_0 = 2^{-11}/K$. The model of Nottale indeed allows two options: either $K = 5$ or 1. The corrected calculations give for $K = 1/5$ $r_1/r_P \geq 1$ whereas $K = 1$ gives $r_1/R_P \leq 1$.

Planet	$\frac{M_P}{M_E}$	$\frac{R_P}{R_E}$	$\frac{r_1}{R_P}$
Jupiter	317.8	11.21	0.84
Saturn	95.2	9.45	0.64
Uranus	14.5	4.01	0.50
Neptune	17.1	3.88	0.52

Table 2: Masses M_P and radii R_P for outer planets using mass and radius of the Earth as units. The last column gives the ratio $\frac{r_1}{R_P}$ of the $n = 1$ Bohr orbit to the radius of planet assuming $K = 1$.

For $K = 5$ the values of r_1 for the giant planets are systematically somewhat larger than the orbital radius. The reason is that the value r_1 is proportional to $\sqrt{K}$. The second reason for this is that the large value of the mass of the planet increases like R_P^3 and makes $\hbar_{gr} \propto \frac{r_s}{R_P}$ large. Jupiter allows only $n = 1$ orbital as interior orbital and $n = 2$ orbital corresponds to radius $1.2R_J$. Saturn also allows $n = 2$ orbital as an interior orbital and $n = 3$ orbital has $r_3 = 1.1R_S$. Uranus allows $n = 4$ orbital with the radius of Uranus. One must of course take these rough estimates with caution: only simple estimates are in question.

The simplest model is obtained if $\beta \simeq 2^{-11}$ holds true also for the outer planets. The predictions for the radii of the cores or both inner and outer planets are in principle testable. The prediction $r_{Core} = r_1 < R_P$ can be also tested for exoplanets.

2. Do giant planets have a shell structure for a gravitational harmonic oscillator in some sense?

The above observations give $\frac{r_1}{R_P} \leq 1$ for the outer planets if one has $\beta_0 = 2^{-11}$. Giant planets would contain at least one orbit inside the planet. There are suggestions that giant planets could have a rocky core containing metals for which there is evidence (see this) with smaller mass.

1. A natural mechanism for the formation of the giant planet would be gravitational condensation of the matter from the environment around the core region, which according to TGD based proposal [L29] would have been generated in an explosion of Sun throwing out a mass shell of dark matter in TGD sense, which then condensed to planets (in Kuiper belt this did not happen).

2. The region outside the core would correspond in the first approximation to harmonic oscillator orbitals determined by the average density with radii given as $r_n = n^{1/2}R_{core}(P)$.

One can develop a more detailed model as follows.

1. One can apply Newton's law for circular Bohr orbits and quantization condition for angular momentum in the gravitational potential $V(R) = GmM(R)/R$, where M(R) is

$$M(R) = M(core) + M(layer) \times [(R/R_P)^3 - (R_{core}/R_P)^3) \quad . \tag{6.8}$$

Slightly below R(core) the force is harmonic force the interior R increases, the gravitational potential approaches to harmonic oscillator potential determined by M_P. For outer planets the average density is considerably smaller than the density of the core.

2. The first condition is

$$\frac{v^2}{R} = -\frac{dV(R)}{dR} = -\frac{d(GM(R)/R)}{dR} = \frac{GM(R)}{R^2} - G\frac{dM/dR)}{R} \ , \tag{6.9}$$

where one has

$$\frac{dM}{dR} = \frac{3R^2}{R_P^3} \ . \tag{6.10}$$

One obtains

$$v(R)^2 = \frac{1}{2} \times \frac{r_S(core)}{R} - 3r_S(layer) \times (\frac{R}{R_P})^3) \ . \tag{6.11}$$

3. The second condition corresponds to the quantization of the angular momentum

$$vR = \frac{GM(core)}{\beta_0} \ . \tag{6.12}$$

gives for R the condition

$$\frac{R}{R_E} = \frac{r_S(core)/R_E}{\beta_0 v(R)} \ . \tag{6.13}$$

Mars is the natural choice for the core. From these data the radii of the Bohr orbits can be calculated. Near the boundary of the core the radii would go like $n^{1/2}R_{Mars}$. For large enough radii one would obtain harmonic oscillator potential.

Jupiter serves as a representative example. One has $M_J = 317.8M_E$ and $R_J = 11.2R_E \simeq 22.4R_{Mars}$. The core has radius $.64R_J$. The density of Jupiter is fraction .22 of the density of Earth. Most of the mass of Jupiter would be generated by the gravitational condensation of gas from the atmosphere. At least the dark matter at the gravitational magnetic body would be at the harmonic oscillator orbitals.

3. Could one understand the rings of giant planets in terms of the oscillator model?

One can consider two alternative models for the rings of giant planets. One could try to model the rings in terms of Bohr orbits with a small principal quantum number n for a harmonic oscillator potential or using a Coulomb potential for the gravitational analog of hydrogen atom assuming the same gravitational Planck constant as for the harmonic oscillator model ($\beta_0 \simeq 2^{-11}$). In this case the Bohr radius $a_{gr} = \beta_0^{-2}r_S/2 \simeq 2^{10}r_S$ is much smaller than the planet radius so that the scale of the rings does not emerge naturally.

The assignment of the rings of the giant planets with the harmonic oscillator orbitals seems to make sense at the order of magnitude level at least (see this,this, this and this).

1. For Jupiter the halo ring has an average radius at $1.5R_J$ would be assigned with a $n = 3$ orbit with radius $1.45R_J$. The main ring has an average radius of $1.75R_J$ could correspond to a $n = 4$ ring with radius $1.7R_J$.

2. Saturn would allow a $n = 3$ orbit very close to the surface with radius $1.11R_S$: the smallest rings extend from $1.16R_S$ and could correspond to this orbit.

3. For Uranus the lowest ring has radius $1.48R_U$ which could correspond to $n = 9$ with radius $1.23R_U$ ($n = 4$ corresponds to the radius of Uranus).

4. For Neptune $n = 4$ orbital corresponds to $1.04R_N$. The $n = 12$ orbital could correspond to the lowest ring in this case.

4. Dwarf planets, Pluto, and some moons

One can also estimate the values of r_1 for some dwarf planets 3 known to be promising places for the evolution of organic life and the Moon and some moons of Jupter and Saturn. Table 3 gives the values of β_0 for some dwarf planets.

Object	M/M_E	R/R_E	$\frac{r_1}{R}$
Pluto	.00218	0.1818	.27
Eris	.0028	.182	.28
Ceres	1.57×10^{-4}	.2725	.17
Moon	.0123	.074	.17

Table 3: Masses M and radii R for Pluto, some dwarf planets and Moon using mass M_E and radius R_E of the Earth as units. The last column gives the ratio $\frac{r_1}{R}$ of the $n = 1$ Bohr orbit to the radius of the planet. The values $\beta_0 = 2^{-11}/5$ for outer planets and $\beta_0 = 2^{-11}$ for the Moon are used. In the case of Earth it this radius is identifiable as the core radius.

7 Cosmic strings and spiral galaxies

In the sequel a TGD based model for spiral galaxies as an outcome of two colliding cosmic strings, the first one transversal to the plane of the galaxy and the second one in the plane of the galaxy is considered. Also a TGD inspired quantum model of the blackhole-like object in the center of the Milky Way is discussed. The model explains the empirical findings challenging the interpretation as a blackhole.

7.1 A simple TGD based model for a spiral galaxy

The origin of the spiral structure of spiral galaxies is one of the poorly understood problems of astrophysics. Independent motions of stars around galaxy in $1/r^2$ central force leads very rapidly to a loss of original structure since angular velocities behave like $\omega \propto 1/r^2$. $1/\rho$ central forces caused by cosmic string orthogonal to the galactic plane gives $\omega \propto 1/\rho$. This suggests that there exists some pre-existing structure, which is much denser than the surrounding matter. The formation of stars would occur intensely in these regions and the decay of the dark energy of the cosmic string to ordinary matter would also generate stars rotating around the galaxy as effectively free objects. The spiral structure rotates slowly and in a good approximation keeps in shape so that the structure behaves somewhat like a rigid body.

This view differs from the density wave theory (see this) assumes that this structure is dynamically generated and due to self-gravitation. The density wave would be analogous to a traffic jam. The cars entering the traffic jam slow down and the jam is preserved. It can move but with a much slower velocity than the cars. Density wave theory allows us to understand why star formation occurs intensely in the spiral structure with a high density.

TGD suggests that the structure corresponds to a cosmic string in galactic plane, which has thickened to a monopole flux tube and produced ordinary matter.

1. One possibility is that the galaxy has formed in a topologically unavoidable collising of cosmic string (extremely thin 4-surfaces with 2-D M^4 projection). The cosmic string orthogonal to the galactic plane would contain the dark energy liberated in its thickening and giving rise to part of galactic dark matter and the galactic blackhole would be associated with it. It would create a $1/\rho$ gravitational expansion explaining the flat velocity spectrum of distant stars. The cosmic string in the galactic plane would in the same way give rise to the galactic matter at the spiral arms and outside the central region. The galactic bar could correspond to a portion of this string.

2. A simple model for the string world sheet assignable to the string in the galactic plane is as a minimal surface. In the first approximation, one can neglect the gravitational interaction with the second string and see whether it is possible to obtain a static string with a spiral structure with several branches and having a finite size. Th string carries monopole flux and should be closed and one can consider a shape which is flattened square like flux tube, which has changed its shape in the $1/\rho$ gravitational field of the long string ($\omega \propto 1/\rho$) and formed a folded structure. The differential rotation tends to lengthen the string and increase

its energy. Hence one expects that string tension slows down differential rotation to almost rigid body rotation.

7.1.1 A static model of the string world sheet neglecting the gravitational interactions

The simplest model is as a minimal stationary string world sheet.

1. By introducing cylindrical Minkowski coordinates $(m^0, m_1 = \rho cos(\phi), m_2 = \rho sin(\phi), m^3)$ and using $(m^0 = t, \phi)$ as coordinates also for the string world sheet, one can write that ansatz in the form $\rho = \rho(t,\phi)$. The metric of M^4 in the cylindrical coordinates is $m_{kl} \leftrightarrow (1, -1, -1, -\rho^2)$. The induced metric of X^2 in these coordinates has only diagonal components and can be written as

$$(g_{tt} = 1 - \rho_t^2, g_{\phi\phi} = -\rho^2 - \rho_\phi^2) \ . \tag{7.1}$$

2. For a static ansatz one has $\rho = \rho(\phi)$ so that the field equation reduces to an ordinary differential equation for ρ. Rotational invariance allows us to solve the equation as a conservation law for the angular momentum component parallel to the normal of the galactic plane. For as general infinitesimal isometry with Lie algebra generator j_A^k the conservation of corresponding charge reads as

$$\partial_\alpha (g^{\alpha\beta} m_\beta^k m_{kl} j_A^l \sqrt{-g_2}) = 0 \ . \tag{7.2}$$

The conservation laws of momentum and energy hold true and the conservation of angular momentum L_3 in direction orthogonal to the galactic plane gives

$$g^{\phi\phi}\rho^2\sqrt{-g_2} = \frac{1}{\rho_0} \ . \tag{7.3}$$

where ρ_0 is integration constant. This gives

$$x_\phi = \pm x\sqrt{x^2-1} \ , \quad x = \frac{\rho}{\rho_0} \ . \tag{7.4}$$

From this it is clear that the solution is well-defined only for $\rho \geq \rho_0$, which suggests that the branches of the spiral must turn back at $\rho = \rho_0$ $(x = 1)$. At the limit $x \to 1$, x_ϕ approaches zero so that the string is tangential to the circle $x = 1$.

3. The differential equation can be solved explicitly: one has

$$\int \frac{dx}{x\sqrt{x^2-1}} = \pm\phi + \phi_0 \ . \tag{7.5}$$

The elementary integral using the substitution $x = cosh(u)$ gives

$$\phi_\pm = \phi_0 \pm arctan(y) \ , \quad y = \sqrt{x^2-1} \ . \tag{7.6}$$

The argument of arctan is real only for $x \geq 1$. Could one define the solution for $x < 1$, where the argument is imaginary? $arctan(iy)$ for real argument y as $arctan(iy) = (i/2)ln((1 + x)/(1 - x))$. This would mean that ϕ is not real.

Consider now the general properties of the solution.

1. The solution has formally infinitely many branches $\phi_{\pm,n}$ differing by an integer multiple of π. However, for a fixed value of $\pm$, the branches differing by a $\Delta\phi = n2\pi$ coincide so that one obtains only 2 branches meeting at the $x = 1$ circle at points ϕ_0 and $\phi_0 + \pi$.

   $x \to 1$ corresponds to $\phi_{\pm,n} \to \phi_0 \pm n\pi$ and $x \to \infty$ corresponds to $\phi_\pm \to \phi_0 \pm \pi/2 \pm n\pi$. The variation of ϕ for a given branch is $\pi/2$.

2. What could be the physical interpretation? The probably correct interpretation is that the the string is tangential to the circle at this points. The two branches for a fixed sign factor $\pm$ meet $x = 1$ circle at tangles ϕ_0 and $\phi_0 + \pi$. Could galactic bar connect these points? Could the diverging value of $d\phi/dx$ at $x = 1$ mean that ϕ increases by ϕ at this point?

   It is now known that also in the case of the Milky Way there are only two branches. If this is the case then the two branches plus galactic bar could correspond to a single long cosmic string in the galactic plane which has collided with a transversal cosmic string. On the other hand, there is evidence that there are several structural components involved with the Milky Way.

   There is however no spiral structure involved, which suggests that this simple model cannot describe spiral waves.

7.1.2 How to take into account the gravitational interactions in the cosmic string model of spiral galaxy?

What has been neglected in the model is the presence of gravitational force.

1. The thickened string in the galactic plane acts with the cosmic string transversal to the galactic plane and with the matter formed by the decay of the cosmic string in the galactic plane to ordinary matter and reducing its string tension.

   The first guess is that this gives rise to a gravitational force, which in the first approximation is sum of the force $F_1 = d(GM(\rho)/\rho)$ and the force caused $F_2 = GT/\rho$ by the cosmic string.

   The non-relativistic Newton's equation for a point particle in this force field is $v^2 = \rho(F_1 + F_2) = d(GM(\rho)) + GM(\rho)/\rho + TG$. At short distances, the force caused by matter dominates and at long distances the force due to the long cosmic string dominates.

   One can however argue that if the mass $M(r)$ is generated by the decay of the cosmic string in the galactic plane, one should approximate the galaxy as a single thickened string, at least in the primordial state as a cosmic string.

2. If the planar cosmic string would consist of independent particles, it would decay very rapidly. String tension prevents this. One might however hope that in the first approximation string tension forces initial conditions preserving the identity of the string but that the points otherwise move independently. Note that by Equivalence Principle the decomposition to smaller masses does not depend on the size of the small mass.

3. The intuitive guess is that since the velocity of rotation increases towards the galactic nucleus, the gravitational force causes a differential rotation of the planar cosmic string. Since the velocity and therefore also angular velocity $\omega(\rho)$ increases towards the center of the galaxy, spiral structure is generated. At long distances the velocity of rotation is the same as for distant stars.

The system could be modelled by addition of the gravitational force to the equations of string world sheets as a minimum as an additional radial force. The model would generalize the ordinary Newtonian description of point-like particles in a gravitational field. One can deduce the equations of motion for the cosmic string in the galactic plane by modelling the effects of other masses in terms of a spherically symmetric gravitational potential $-GV$.

1. The interaction term in the action is given by the integral

$$L_{int} = T\int GV\sqrt{-det(g_2)}d^2x \ . \tag{7.7}$$

2. The minimal surface equation for the string world sheet are modified from $D_\alpha(g^{\alpha\beta}g^{m^k_\beta} = 0$ to

$$(1-GV)D_\alpha(g^{\alpha\beta}\partial_\beta m^k) = GP^{kl}\partial_l V \ . \tag{7.8}$$

Here P^{kl} is the projector to the normal space of the string world sheet and its presence guarantees that only the acceleration orthogonal to the string has physical effects (general coordinate invariance). The factor $1-GV$ can be transferred to $1/(1+GV)$ factor on the right hand side.

The above model suggests that convenient coordinates for the string world sheet are (t,ϕ) and the dynamical variable is the radial coordinate ρ along the rotating string as a function of (t,ϕ). Numerical modelling along these lines would give partial differential equations. Also now conservation of energy and angular momentum can be used. Could one imagine any elegant solution to the problem.

1. Physical intuition suggests that one should start from the solution without the gravitational force already considered since it looks realistic in some aspects. One should transform the static string to a string in a differential rotation determined by the gravitational forces and forcing only coherent initial conditions for the points of the string so that they all rotate with the velocity. One might even hope that Kepler's law can be used besides conservation laws.

2. Equivalence Principle suggests how one might achieve this at least approximately. Gravitational force is in the Einsteinian description a coordinate force describable in terms of Christoffel symbols. In TGD this force is force in H which can be approximated with M^4. Could one find a coordinate system of M^4 in which this coordinate force vanishes? Could a differentially rotating system be the system in which this is the case. This would generalize Einstein's freely falling elevator argument.

Could one obtain a coordinate system in which the gravitational acceleration vanishes by an analog of Lorentz boost in (t,ϕ) plane by a velocity $\beta(\rho) = v(\rho)/c$ and leaving ρ and z invariant? This transformation looks like Lorentz transformation for a given ρ but is a transformation to an accelerating system (acceleration is radial).

1. One could consider an infinitesimal variant of thef effective Lorentz boost and exponentiate it to get a flow restricting to the motion of the string defining the string world sheet. The infinitesimal boost would be

$$\begin{array}{l} dt = \gamma(dT-\beta\rho d\Phi) \ , \quad d\phi = \frac{1}{\rho}\gamma(\rho d\Phi - \beta dT) \ , \\ \gamma = \frac{1}{\sqrt{1-\beta^2}} \ . \end{array} \tag{7.9}$$

These equations define a flow in (T,ϕ) plane as an exponentiation of an infinitesimal Lorentz boost for a given value of radial coordinate ρ and one can solve (t,ϕ) as function of (T,Φ). The intuitive idea is that for ρ given by the static model but with (t,ϕ) replaced with (T,Φ) this flow reduces to the equations of the static string world sheet. This flow need not be integrable in the entire M^4. The points (T,ρ) for which Φ differs by a multiple of 2π could correspond to different turns of the spiral rotating around the origin.

This flow should be integrable in order that the flow lines have interpretation as coordinate lines. It should be possible to write the infinitesimal generator of the Lorentz boosts in (t,ϕ) plane for a given ρ as a product of scalar function and gradient: $j = \Psi d\Phi$ giving $d\Phi = j/\Psi$ so that Φ serves as a coordinate. Is it enough to satisfy this condition at the string world sheet at which the condition $\rho = \rho(\Phi,T)$ mildens it?

2. It is easy to find how this pseudo Lorentz boost affects the expression of M^4 metric $ds^2 = dt^2 - dz^2 - d\rho^2 - \rho^2 d\phi^2$ by writing the differentials $dt, d\phi$ and $d\rho$ explicitly:

$$ds^2 = dt^2 - dz^2 - d\rho^2 - \rho^2 d\phi^2 = (\gamma(dT - \beta\rho d\Phi)^2 - (\gamma(\rho d\Phi - \beta dT)^2 - d\rho^2 - dz^2 \ . \quad (7.10)$$

   Here $\rho(\Phi, T)$ corresponds to the orbits of the point of the string and must satisfy the field equations. Here $d\rho^2$ expressed in terms of $d\Phi$ and dT gives an additional contribution to the induced metric.

3. If only the gravitational force of the long cosmic string is taken into account one has $\beta = constant$ and the analogy with Lorentz books is even stronger.

The wishful conjecture is that these equation satisfy integrability conditions on string world sheet and that the gravitational force disappears from field equations using coordinates (T, Φ) when the velocity parameter corresponds to the expected solution in the external field in coordinate (t, ϕ).

7.2 Galactic blackhole-like object as a gravitational harmonic oscillator?

As described, in the TGD Universe blackhole-like objects are identified as monopole flux tube spaghettis and differ from the ordinary stars only in that for $h_{eff} = h$, the entire volume is filled by monopole flux tubes for which thickness is minimal and corresponds to a nucleon Compton length. For $h_{eff} > h$ also the flux tubes ordinary stars or star cores could fill the entire volume.

Just for fun, one can ask what the model of a gravitational harmonic oscillator gives in the case of Schwarzschild blackholes. The formula, $r_n = \sqrt{n} r_1$, $r_1/R = (r_s/sqrt2\beta_0)/times(r_s/R)^{1/4}$, gives for $R = r_s$ $r_1/r_s = 1/\sqrt{2\beta_0}$. $\beta_0 \leq 1/2$ gives $r_1/r_s \geq 1$ so that there would be no other states than the possible S-wave state ($n = 0$). $beta_0 = 1/2$ gives $r_1 = r_s$ and one would have just mass at $n = 0$ S-wave state and $n = 1$ orbital. For $\beta_0 = 1$ (the minimal value), one has $r_1/r_s = 1/\sqrt{2}$ and $r_2 = r_s$ would correspond to the horizon. There would be an interior orbit with $n = 1$ and the S-wave state could correspond to $n = 0$.

The model can be criticized for the fact that the harmonic oscillator property follows from the assumption of a constant mass density. This criticism applies also in the model for stars. The constant density assumption could be true in the sense that the mass difference $M(n+1) - M(n)$ at orbitals r_{n+1} and r_n for $n \geq 1$ is proportional to the volume difference $V_{n+1} - V_n$ proportional to $r_{n+1}^3 - r_n^3 = (n+1)^3 - n^3 = 3n^2 + 3n + 1$. This would give $M = m_0 + m(n_{max} + 1)^3$ leaving only the ratio of the parameters m_0 and m free. This could be fixed by assigning to the S-wave state a radius and constant density. This condition would give an estimate for the number of particles, say neutrons, associated with the oscillator Bohr orbits. If a more realistic description in terms of wave functions, this condition would fix the total amount of matter at various orbitals associated with a given value of n.

Sabine Hosssenfelder tells about the weird properties of the giant blackhole at the center of Milky Way known as Sagittarius A$*$ (see this). Sagittarius A* (briefly SA) is located at a distance of 26,700 ly and has mass about 4.1×10^{10} solar masses. Its Schwartschild radius $r_s = 2GM$ is 1.1×10^{11} km. Note that astronomical unit (the distance of the Earth from the Sun) 1.49597870700×10^8 km so that SA radius is almost 1000AU. The Schwartschild time $T_s = r_s/c$ is 41 s, about 2/3 minutes.

Hossenfelder lists six weird properties of SA.

1. SA is silent, one might say dead suggesting that no matter is falling inside it. There is however an accretion disk around it.

2. SA however shows signs of life by emitting periodically IR and X ray flares bursting huge amounts of energy as a radiation. Blackhole should not do this unless it absorbs matter but it is not at all clear whether anything is going inside SA!

3. 2019 SA showed a sudden gamma ray activity. The standard interpretation would be that it absorbed matter but now one saw this to happen.

4. SA is rotating extremely rapidly: the period τ of rotation is 10 minutes.

5. SA possesses a dozen of planet-like objects, so called G-objects, rotating around SA with a velocity which is 60 percent of the maximal rotation velocity allowed by the condition that the rotation velocity inside the blackhole does not exceed the light velocity. How these objects can exist in an extremely hostile environment of the blackhole where the matter from outside should be flowing to the blackhole is a mystery.

6. There is a blob of matter rotating around SA with a velocity, which is 30 percent of the velocity of light. The object emits gamma ray bursts with a period of 76 minutes. Rapidly rotating objects emit radiation mostly in forward direction and this burst would meet the Earth when the motion is towards Earth. This might relate to the mystery of gamma ray bursts.

Could one understand these properties of SA by regarding SA as a blackhole-like object in the TGD sense consisting of a maximally dense flux tube spaghetti which is a quantum system with gravitational Planck constant $\hbar_{gr} = GM/\beta_0$? Could one model SA as a quantum harmonic oscillator in the interior and using gravitational Coulomb potential in the exterior?

The reason for why matter is not falling inside SA could be the same as in the case of the hydrogen atom. Quantization would imply that the atom is a quantum system and does not dissipate so that the infrared catastrophe is avoided. Matter around it is at Bohr orbits of a central potential. The first guess would be Coulomb potential but also harmonic oscillator potential or something between these two could be considered.

1. The quantization of angular momentum gives for a central potential and circular orbits $r^2\omega = nGM/\beta_0$. The condition $v^2/r = \omega^2 r = -d(GM(r)/r)$ holds true also for a central force. Recall that for the harmonic oscillator this gives $\omega = 1/r_s$ $(c = 1)$and $r_n = \sqrt{n}r_1$, $r_1 = r_s/\sqrt{2\beta_0}$. The constancy of ω means that the system behaves like a rigid body. Note that one has $n > 0$. Note that there is also an S-wave state, which corresponds to $n = 0$ and can be described only by Schrödinger equation or its analog. The orbit with radius r_s correspond to a motion with light velocity. This conforms with the TGD view that horizons are quite generally light-like 3-surfaces.

2. For the Coulomb case one obtains $\omega = 2/n^3 r_s$ and $r_n = n^2 a_{gr}$, $a_{gr} = r_s/2\beta_0^2$. In the interior, $r_1 \leq r_s$ requires $\beta_0 \geq 1/2$. In the exterior, $a_{gr} \geq r_s$ requires $\beta_0 \leq \sqrt{1/2}$ and $r_1 \geq r_s$. This condition is not however absolutely necessary since the $n > 1$ follows from the condition that the orbital velocity is smaller than c, as will be found. The conditions therefore fix β_0 to the range $[1/\sqrt{2}, 1/2, 1]$. The quantization $\beta_0 = 1/n$ would select $\beta_0 \in \{1/2, 1\}$ giving $r_1 = (1, 1/\sqrt{2})r_s$ for the harmonic oscillator potential and $r_n \in \{2, 1/2\}n^2 r_s$ outside the blackhole.

   Orbital velocities in the exterior are given by $v_n = \beta_0/n$ and $v_n < c$ for all values of n requires $\beta_0 \leq 1$. For $\beta_0 = 1$ the allowed orbits have $n > 1$: the non-allowed orbit would have $r_1 = r_s/2$ and would be inside the BH.

3. The inner radius of the accretion disk for which one can find the estimate $r_{inner} = 30r_s$ (see this). Inside the accretion disk, the harmonic oscillator model could be more appropriate than the Coulomb model. The inner edge of the accretion disk would correspond to $(r_8 = 32r_s, r_5 = 25r_s, r_4 = 32r_s)$ for $\beta_0 \in \{1, 1/\sqrt{2}, 1/2\}$.

Could one understand the findings about SA in this picture?

1. The silence of SA would be completely analogous to the quantum silence of atoms. Note that $\beta_0 = 1$ $v < c$ condition would prevent $n = 1$ orbit, which would have radius $r_s = 1/2$ and be inside the blackhole.

2. The periodically occurring X-ray flares could be analogs of atomic transitions leading to the emission of photons. They could due to the internal excitations of the matter from lower to higher energy state. For $\beta_0 = 1$ one has a maximal number of the harmonic oscillator states corresponding to the principal quantum number $n = 0, 1, 2$ and the $n = 2$ state would correspond to the horizon. Also transition to states which could be modelled as states in Coulomb potential are possible. $n = 2$ Coulomb orbital would be the first allowed state $\beta_0 = 1$. The prediction is that the total X-ray energy is quantized.

3. Could one understand the rotation of SA in terms of the harmonic oscillator model predicting $\omega = 1/r_s$ giving $\tau = 2\pi r_s$. The estimated mass of the black hole gives $\tau = 4.2$ minutes and by a factor too small. Harmonic oscillator model assumes a constant density of matter inside the blackhole and that matter is at harmonic oscillator Bohr orbits: this logical conflict could explain the failure.

   One can argue that the rotation at the surface of the BH can be regarded as a Keplerian motion in the gravitational field of the inner mass shells. This could increase τ at the surface of the blackhole.

4. G-objects could be understood as gravitational analogs of the atomic electrons orbiting SA at radii with small values of n. The orbital radii are predicted to be proportional to n^2. The orbitals allowed by $v/c \leq 1$ condition would correspond to $(2 \leq n \leq 8, 1 \leq n \leq 5, 1 \leq n \leq 5)$ for $\beta_0 \in \{1, 1/\sqrt{2}, 1/2\}$.

5. The mysterious blob of matter rotating around SA with velocity $v = 3c/10$ could correspond to a Coulombic Bohr orbit with a small value of n: for $\beta_0 = 1$, $n = 3$ orbit gives $v/c = .33$ and $v/c = 3/10$ is obtained for $\beta_0 = 9/10$ and $n = 3$.

In an article related to the determination of the magnetic field of Sagittarius A (SA) (see) it is concluded that the so called spin parameter for it is $s = J/GM^2 = .94$. The inclination angle as the angle between the magnetic axis at SA and the line of sight of the observer was estimated to be 150$\circ$.

1. With an inspiration coming from Equivalence Principle, I have proposed that it is possible to assign to even astrophysical objects, or at least to BHs, a value of $\hbar_{gr}$ as $\hbar_{gr} = GM^2/beta_0$.

   Could the generalization of the quantization of angular momentum hold true for all BHs and perhaps even for more general stellar objects? Could SA be a spin 1 object with respect to $\hbar_{gr}$ having $J_z/\hbar_{gr} = 1$? This condition would give $\beta_0 = 1/.94 \simeq 1.03 \geq$ for the value of s used: this is not quite consistent with $\beta_0 \leq 1$.

   If one replaces M with $M/.94 = 1.03M$, one obtains $\beta_0 = 1$ and $J_z/\hbar_{gr} = 1$. According to Wikipedia, the mass of Sagittarius A is ~ 4.1 million solar masses so that this correction is with what is known of the value of M. Also smaller values of β_0 are possible but require a larger value of M.

2. On the other hand, the model for SA as quantum object and the discovery of a blob of matter rotating around it with velocity $v = c/3$ led to the conclusion that $\beta_0 = 9/10 = .9$: the error is only 1 per cent. This value is consistent with the uncertainties in the mass value.

3. Sagittarius A is a weird object in the sense that its rotation axis points to the Earth rather than being orthogonal to the galactic plane. This is consistent with the above discussed proposal that the Milky Way is formed in the collisions of a cosmic string orthogonal to the plane of the Milky Way and cosmic string in the plane of the Milky way assignable to its spiral structure. That the direction of the magnetic axis is related to the local the direction of the line of sight would conform with the propagation of the radiation along the monopole flux tubes forming a spiral structure to the Earth (for the implications of the monopole flux tube network connecting astrophysical objects see for instance [L37]). The inclination angle as the angle between line of sight and magnetic axis is reported to be 150 degrees.

4. For a spin one object the angle $sin(\theta)$ between the projection J_z and total angular momentum vector J is semi-classically quantized and for $J_z = -1$ equal to $1/\sqrt{2}$, which correspond to an angle of 135 degrees. Could this angle relate to the inclination angle of 150$\circ$ reported in the article: the local direction of the magnetic field would correspond to the direction of J and measured J would correspond to J_z as in standard quantum theory?

These arguments suggest that the evolution of a galactic BH from the quasar state involves a sequence of state function reduction gradually reducing the value of J and J_z. There would be transitions emitting angular momentum assignable to the emitted radiation but preserving the value of β_0 put perhaps also transitions increasing the value of β_0 towards its maximal value $\beta_0 = 1$, which would corresponds to a dead state of BH. If the same applies also to the evolution of small BHs, the evolution of the solar system to BH should increase β_0 from $\beta_0 \simeq 2^{-11}$ to $\beta_0 = 1$.

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