TGD and Astrophysics

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Abstract

Astrophysics in TGD Universe is the basic topics of this chapter. The topics discussed are following.

1. p-Adic length scale hypothesis can be applied also in astrophysical length scales, and some examples of possible applications are discussed. One of the most interesting implications of p-adicity is the possibility of series of phase transitions changing the value of cosmological constant behaving as $\Lambda \propto 1/L^2(k)$ as a function of p-adic length scale characterizing the size of the space-time sheet.

2. A model for the solar magnetic field as a bundle of topological magnetic flux tubes is constructed and a model of Sunspot cycle is proposed. This model is also shown to explain the mysteriously high temperature of solar corona and also some other mysterious phenomena related to the solar atmosphere. A direct connection with the TGD based explanation of the dark energy as magnetic and Z^0 magnetic energy of the magnetic flux tubes containing dark matter as ordinary matter, emerges. The matter in the solar corona is simply dark matter leaked from the highly curved portions of the magnetic flux tubes to the space-time sheets where it becomes visible. The generation of anomalous Z^0 charge caused by the runoff of dark neutrinos in Super Nova could provide a first principle explanation for the avoidance of collapse to black-hole in Super Nova explosion.

   The recent view about fermions is based on the condition that spinor modes have well-define em charge predicts that induced spinor fields are in the generic case localized to 2-D surfaces at which the classical W field vanishes as does also Z^0 field above weak scale (proportional to effective Planck constant h_{eff}). Hence fermions would feel weak Z^0 field only if they are at space-time sheets with large h_{eff}.

3. One section is devoted to some astrophysical and cosmological anomalies such as the apparent shrinking of solar system observed by Masreliez, Pioneer anomaly and Flyby anomaly.

4. The astrophysics of solar system involves also an anomaly related to the precession of equinoxes suggesting that Sun might have a companion. TGD suggests a model for anomalies as being due to interaction magnetic flux tube connecting Sun to its companion.

5. The TGD variant of the model of Nottale involved gravitational Planck constant h_{gr} is discussed in detail. Also further indications for large values of Planck constant are discussed and also the argument that $h_{gr} = GMm/v_0 = h_{eff} = n \times h$ holds true at least microscopiall. If so, the dependence of the effective Planck constant on particle mass can be predicted.

1 Introduction

The concept of 3-space in TGD is considerably more general than in the conventional theories. According to the original picture 3-space is not any more connected but can have arbitrary many disjoint components. Even macroscopic boundaries would be allowed: macroscopic bodies are interpreted as 3-surfaces having outer boundary. This picture has been modified. Space-time is a surface inside causal diamond (CD) and decomposes to Minkowskian and Euclidian regions. The boundaries of Minkowskian/Euclidian regions (to be called parton orbits in the sequel) are light-like 3-surfaces and replace the genuine boundaries. Hence closed 3-surfaces at the ends of CD can be seen as double coverings of with sheets glued together along boundaries of sheets.

There are strong indications that 3-space has a hierarchical fractal structure: 3-surfaces topologically condensed on 3-surfaces condensed on..., where topological condensation means that "small" 3-surface is "glued" to a larger 3-surface by connected sum operation.

The original hypothesis was that preferred extremals of Kähler action are absolute minima of Kähler action. This hypothesis is natural only in Euclidian regions of the space-time surface. Furthermore, zero energy ontology (ZEO) means that pairs of space-like 3 surface located at the opposite boundaries of CD or the unions of these with parton orbits become basic objects. In this case the the attribute "preferred" might be possessed by any extremal and space-time surface could be unique apart from gauge symmetries defined by Kac-Moody type algebras respecting the light-likeness of parton orbits. The non-determinism of Kähler action suggests tht this is true in given measurement resolution only. The recent view about preferred extremals is as critical extremals for which a large number of deformations exist with a vanishing second variation of Kähler action: critical deformations correspond to Kac-Moody type conformal algebra. The number n of conformal equivalence classes of 4-surfaces corresponds to the integer defining the effective value of Planck constant $h_{eff} = n \times h$ and also characterizes the breaking of conformal symmetry: only the sub-algebras of conformal algebra with conformal weights divisible by n acts as gauge symmetries. These algebras form fractal inclusion hierarchies bringing strongly in mind those for the hyperfinite factors.

Gravitational fields are always accompanied by long range electro-weak gauge fields with Kähler charge, which in the astrophysical scales is apart from a small but non-vanishing numerical factor equal the mass of particle using Planck mass as unit. In shorter length scales the Kähler charge can be larger and reflects the development of long range classical Z^0 fields. Also long ranged classical color fields with U(1) holonomy are present.

The long ranged W fields are not experienced by induced spinor fields if one requires that em charge for the modes of induced spinor field is well-defined. This forces the localization of the modes to 2-D surfaces - string world sheet and possibly partonic 2-surfaces at which induce W field vanish. One can require also the vanishing of induced Z^0 field - at least above weak scale proportional to h_{eff}. Under this assumption no large parity breaking effects are predicted for ordinary value of Planck constant associated with ordinary matter. For dark matter with large h_{eff} the situation is different.

Topological field quantization is a central concept: the presence of Kähler charge implies that 3-surface has outer boundary unless one replaced it with double covering: the larger the charge the smaller the size of the 3-surface. This makes it possible to relate the size of the 3-surface (topological field quantum) to the Kähler charge of a typical particle in the condensate. The formation of macroscopic quantum systems, such as super conductors, corresponds to the formation of bonds between the boundaries of the neighboring topological field quanta. They could correspond in either flux tubes connecting partonic 2-surfaces and having Euclidian signature or to flux tubes connecting double coverings. A possible astrophysical example is neutron star: join along boundaries bonds are formed between neutrons so that single giant nucleus results.

1.1 P-Adic Length Scale Hypothesis And Astrophysics

Various levels of the topological condensate obey effective p-adic topology and form p-adic hierarchy ($p_1 < p_2$ can condense on p_2). Physically interesting length scales should come as square roots of powers of 2: $L_e(k) \simeq 2^{\frac{k}{2}} l$, $l = 1.288 \cdot 10^4 \sqrt{G}$ and various considerations suggest that prime powers are especially interesting values of k. For astrophysical applications interesting prime values of n are: $n = 229, 233, 239, 241, 251, 257, 263...$ and it is of considerable interest to find whether these length scales correspond to astro-physically interesting length scales.

The combination of p-adic length scale hierarchy idea with the concepts of topological evaporation and condensation, join along boundaries bond and long ranged weak and color forces, is an exciting challenge. In this chapter these concepts are applied in astrophysical length scales. The identification of the prime power length scales as fundamental astrophysical length scales is proposed and the identification of the fundamental cosmological length scale identified by Einasto *et al* [E40] as a p-adic length scale is proposed. One of the most interesting implications of p-adicity is the possibility of series of phase transitions changing the value of cosmological constant behaving as $\Lambda \propto 1/L^2(k)$ as a function of p-adic length scale characterizing the size of the space-time sheet.

1.2 Quantum Criticality, Hierarchy Of Dark Matters, And Dynamical $\hbar$

Quantum criticality is the basic characteristic of TGD Universe and quantum critical superconductors provide an excellent test bed to develop the ideas related to quantum criticality into a more concrete form.

1.2.1 Quantization of Planck constants and the generalization of the notion of imbedding space

The recent geometric interpretation for the quantization of Planck constants is based on Jones inclusions of hyper-finite factors of type II_1 [K10]. The following generalization is only one possibility and might involve too strong assumptions such as the decomposition of the integer n in $h_{eff} = n \times h$ to a product of integers associated with M^4 and CP_2.

1. One can argue that different values of Planck constant correspond to imbedding space metrics involving scalings of M^4 *resp.* CP_2 parts of the metric deduced from the requirement that distances scale as $\hbar(CP_2)$ *resp.* $\hbar(M^4)$. Denoting the Planck constants by $\hbar(M^4) = n_a\hbar_0$ and $\hbar(CP_2) = n_b\hbar_0$, one has that covariant metric of M^4 is proportional to n_b^2 and covariant metric of CP_2 to n_a^2.

   This however leads to difficulties with the isometric gluing of CP_2 factors of different copies of H together. Kähler action is however invariant under over-all scaling of H metric so that one can scale it down by $1/n_a^2$ meaning that M^4 covariant metric is scaled by $(n_b/n_a)^2$ and CP_2 metric remains invariant and the difficulties in isometric gluing are avoided. This means that if one regards Planck constant as a mere conversion factor, the effective Planck constant scales as n_a/n_b.

   In Kähler action only the effective Planck constant $\hbar_{eff}/\hbar_0 = \hbar(M^4)/\hbar(CP_2)$ appears and by quantum classical correspondence same is true for Schödinger equation. Elementary particle mass spectrum is also invariant. Same applies to gravitational constant. The alternative assumption that M^4 Planck constant is proportional to n_b would imply invariance of Schrödinger equation but would not allow to explain Bohr quantization of planetary orbits and would to certain degree trivialize the theory.

2. M^4 and CP_2 Planck constants do not fully characterize a given sector $M^4_\pm \times CP_2$. Rather, the scaling factors of Planck constant given by the integer n characterizing the quantum phase $q = exp(i\pi/n)$ corresponds to the order of the maximal cyclic subgroup for the group $G \subset SU(2)$ characterizing the Jones inclusion $\mathcal{N} \subset \mathcal{M}$ of hyper-finite factors realized as subalgebras of the Clifford algebra of the "world of the classical worlds". This means that subfactor $\mathcal{N}$ gives rise to G-invariant configuration space spinors having interpretation as G-invariant fermionic states.

3. $G_b \subset SU(2) \subset SU(3)$ defines a covering of M^4_+ by CP_2 points and $G_a \subset SU(2) \subset SL_e(2, C)$ covering of CP_2 by M^4_+ points with fixed points defining orbifold singularities. Different sectors are glued together along CP_2 if G_b is same for them and along M^4_+ if G_a is same for them. The degrees of freedom lost by G-invariance in fermionic degrees of freedom are gained back since the discrete degrees of freedom provided by covering allow many-particle states formed from single particle states realized in G group algebra.

4. Phases with different values of scalings of M^4 and CP_2 Planck constants behave like dark matter with respect to each other in the sense that they do not have direct interactions except at criticality corresponding to a leakage between different sectors of imbedding space glued together along M^4 or CP_2 factors. In large $\hbar(M^4)$ phases various quantum time and length scales are scaled up which means macroscopic and macro-temporal quantum coherence. In particular, quantum energies associated with classical frequencies are scaled up by a factor n_a/n_b which is of special relevance for cyclotron energies and phonon energies (superconductivity). For large $\hbar(CP_2)$ the value of $\hbar_{eff}$ is small: this leads to interesting physics: in particular the binding energy scale of hydrogen atom increases by the factor $(n_b/n_a)^2$.

1.2.2 Preferred values of Planck constants

Number theoretic considerations favor the hypothesis that the integers corresponding to Fermat polygons constructible using only ruler and compass and given as products $n_F = 2^k \prod_s F_s$, where $F_s = 2^{2^s} + 1$ are distinct Fermat primes, are favored. The reason would be that quantum phase $q = exp(i\pi/n)$ is in this case expressible using only iterated square root operation by starting from rationals. The known Fermat primes correspond to $s = 0, 1, 2, 3, 4$ so that the hypothesis is very strong and predicts that p-adic length scales have satellite length scales given as multiples of n_F of fundamental p-adic length scale. $n_F = 2^{11}$ corresponds in TGD framework to a fundamental constant expressible as a combination of Kähler coupling strength, CP_2 radius and Planck length appearing in the expression for the tension of cosmic strings, and the powers of 2^{11} seem to be especially favored as values of n_a in living matter [K6].

1.2.3 How Planck constants are visible in Kähler action?

$\hbar(M^4)$ and $\hbar(CP_2)$ appear in the commutation and anti-commutation relations of various super-conformal algebras. Only the ratio of scalings of M^4 and CP_2 metrics appears in Kähler action. The most natural assumption at the level of hyper-octonion space $HO = M^8$ is that M^4 metric is proportional to n_b^2 and E^4 metric to n_a^2. For $H = M^4 \times CP_2$ the assumption that CP_2 metric is proportional to n_a^2 however leads to mathematical difficulties and to a rather weird looking prediction that CP_2 can have arbitrarily large size. Hence the most natural conclusion is that the scaling of CP_2 metric is universal [K10]. This is achieved elegantly by performing over-all scaling of scaled up H metric allowed by the invariance of Kähler action in this scaling so that a scaling of M^4 covariant metric by $(n_b/n_a)^2$ results and effective Planck constant as a mere conversion factor is scaled by n_a/n_b.

This implies that Kähler function through its dependence on n_a/n_b codes for radiative corrections to the classical action, which makes possible to consider the possibility that higher order radiative corrections to functional integral vanish as one might expect at quantum criticality. For a given p-adic length scale space-time sheets with all allowed values of Planck constants are possible. Hence the spectrum of quantum critical fluctuations could in the ideal case correspond to the spectrum of $\hbar$ coding for the scaled up values of Compton lengths and other quantal lengths and times. If so, large $\hbar$ phases could be crucial for understanding of quantum critical superconductors, in particular high T_c superconductors.

1.2.4 Phase transitions changing the level in dark matter hierarchy

The identification of the precise criterion characterizing dark matter phase is far from obvious. TGD actually suggests an infinite number of phases which are dark relative to each other in some sense and can transform to each other only via a phase transition which might be called de-coherence or its reversal and which should be also characterized precisely.

A possible solution of the problem comes from the general construction recipe for S-matrix. Fundamental vertices correspond to partonic 2-surfaces representing intersections of incoming and outgoing light-like partonic 3-surfaces.

1. If the characterization of the interaction vertices involves all points of partonic 2-surfaces, they must correspond to definite value of Planck constant and more precisely, definite groups G_a and G_b characterizing dark matter hierarchy. Particles of different phases could not appear in the same vertex and a phase transition changing the particles to each other analogous to a de-coherence would be necessary.

2. If transition amplitudes involve only a discrete set of common orbifold points of 2-surface belonging to different sectors then the phase transition between relatively dark matters can be described in terms of S-matrix. It seems that this option is the correct one. In fact, also propagators are essential for the interactions of visible and dark matter and since virtual elementary particles correspond at space-time level CP_2 type extremals with 4-dimensional CP_2 projection, they cannot leak between different sectors of imbedding space and therefore cannot mediate interactions between different levels of the dark matter hierarchy. This would suggest that the direct interactions between dark and ordinary matter are very weak.

   If the matrix elements for real-real partonic transitions involve all or at least a circle of the partonic 2-surface as stringy considerations suggest [K2]. then one would have clear distinction between quantum phase transitions and ordinary quantum transitions. Of course, the fact that the points which correspond to zero of Riemann Zeta form only a small subset of points common to real partonic 2-surface and corresponding p-adic 2-surface, implies that the rate for phase transition is in general small. On the other hand, for the non-diagonal

S-matrix elements for ordinary transitions would become very small by almost randomness caused by strong fluctuations and the rate for phase transition could begin to dominate.

1.2.5 Transition to large $\hbar$ phase and failure of perturbation theory

A further idea is that the transition to large $\hbar$ phase occurs when perturbation theory based on the expansion in terms of gauge coupling constant ceases to converge: Mother Nature would take care of the problems of theoretician. The transition to large $\hbar$ phase obviously reduces gauge coupling strength α so that higher orders in perturbation theory are reduced whereas the lowest order "classical" predictions remain unchanged. A possible quantitative formulation of the criterion is that maximal 2-particle gauge interaction strength parameterized as $Q_1Q_2\alpha$ satisfies the condition $Q_1Q_2\alpha \simeq 1$.

A justification for this picture would be that in non-perturbative phase large quantum fluctuations are present (as functional integral formalism suggests). At space-time level this would mean that space-time sheet is near to a non-deterministic vacuum extremal. At parton level this would mean that partonic surface contains large number of CP_2 orbifold points so that S-matrix elements for the phase transition becomes large. At certain critical value of coupling constant strength one expects that the transition amplitude for phase transition becomes very large.

1.2.6 Dark matter as large $\hbar_{gr}$ phase

D. Da Rocha and Laurent Nottale have proposed that Schrödinger equation with Planck constant $\hbar$ replaced with what might be called gravitational Planck constant $\hbar_{gr} = \frac{GmM}{v_0}$ ($\hbar = c = 1$). v_0 is a velocity parameter having the value $v_0 = 144.7 \pm .7$ km/s giving $v_0/c = 4.6 \times 10^{-4}$. This is rather near to the peak orbital velocity of stars in galactic halos. Also subharmonics and harmonics of v_0 seem to appear. The support for the hypothesis coming from empirical data is impressive.

Nottale and Da Rocha believe that their Schrödinger equation results from a fractal hydrodynamics. Many-sheeted space-time however suggests astrophysical systems are not only quantum systems at larger space-time sheets but correspond to a gigantic value of gravitational Planck constant. The gravitational (ordinary) Schrödinger equation would provide a solution of the black hole collapse (IR catastrophe) problem encountered at the classical level. The resolution of the problem inspired by TGD inspired theory of living matter is that it is the dark matter at larger space-time sheets which is quantum coherent in the required time scale. Schrödinger equation need not be involved. Rather, Bohr orbitology could reflect the fact that dark matter is in anyonic phase and confined by charge fractionization at large partonic 2-surfaces with a gigantic value of Planck constant. These surfaces could have complex topologies involving flux tubes around planetary orbits connected by radial spokes to a spherical surface associated with Sun.

1.2.7 Prediction for the parameter v_0

TGD predicts correctly the value of the parameter v_0 assuming that cosmic strings and their decay remnants are responsible for the dark matter. The harmonics of v_0 can be understood as corresponding to perturbations replacing cosmic strings with their n-branched coverings so that tension becomes n^2-fold: much like the replacement of a closed orbit with an orbit closing only after n turns. $1/n$-sub-harmonic would result when a magnetic flux tube split into n disjoint magnetic flux tubes. v_0 has dimensions of velocity and the identification as typical rotation or orbital velocity is natural first guess. In next chapter it will be found that this identification rather non-trivial but correct prediction and leads to the identification $h_{gr} = h_{eff}$ in elementary particle, and atomic length scales at least. This leads to a rather strong predictions in TGD inspired quantum biology where quantum gravitation in TGD sense becomes a key player.

The planetary mass ratios can be produced with an accuracy better than 10 per cent assuming ruler and compass phases, and the dependence of v_0 on p-adic length scale characterizing the space-time sheets carrying the planet-Sun gravitational force might relate to the discrepancies.

1.2.8 Further predictions

The study of inclinations (tilt angles with respect to the Earth's orbital plane) leads to a concrete model for the quantum evolution of the planetary system. Only a stepwise breaking of the rotational symmetry and angular momentum Bohr rules plus Newton's equation (or geodesic equation) are needed, and gravitational Shrödinger equation holds true only inside flux quanta for the dark matter.

1. During pre-planetary period dark matter formed a quantum coherent state on the (Z^0) magnetic flux quanta (spherical cells or flux tubes). This made the flux quantum effectively a single rigid body with rotational degrees of freedom corresponding to a sphere or circle (full SO(3) or SO(2) symmetry).

2. In the case of spherical shells associated with inner planets the $SO(3) \rightarrow SO(2)$ symmetry breaking led to the generation of a flux tube with the inclination determined by m and j and a further symmetry breaking, kind of an astral traffic jam inside the flux tube, generated a planet moving inside flux tube. The semiclassical interpretation of the angular momentum algebra predicts the inclinations of the inner planets. The predicted (real) inclinations are 6 (7) resp. 2.6 (3.4) degrees for Mercury resp. Venus). The predicted (real) inclination of the Earth's spin axis is 24 (23.5) degrees.

3. The $v_0 \rightarrow v_0/5$ transition allowing to understand the radii of the outer planets in the model of Da Rocha and Nottale can be understood as resulting from the splitting of (Z^0) magnetic flux tube to five flux tubes representing Earth and outer planets except Pluto, whose orbital parameters indeed differ dramatically from those of other planets. The flux tube has a shape of a disk with a hole glued to the Earth's spherical flux shell.

   It is important to notice that effectively a multiplication $n \rightarrow 5n$ of the principal quantum number is in question. This allows to consider also alternative explanations. Perhaps external gravitational perturbations have kicked dark matter from the orbit or Earth to $n = 5k$, $k = 2, 3, ..., 7$ orbits: the fact that the tilt angles for Earth and all outer planets except Pluto are nearly the same, supports this explanation. Or perhaps there exist at least small amounts of dark matter at all orbits but visible matter is concentrated only around orbits containing some critical amount of dark matter and these orbits satisfy $n \ mod \ 5 = 0$ for some reason.

4. A remnant of the dark matter is still in a macroscopic quantum state at the flux quanta. It couples to photons as a quantum coherent state but the coupling is extremely small due to the gigantic value of $\hbar_{gr}$ scaling alpha by $\hbar/\hbar_{gr}$: hence the darkness.

   The rather amazing coincidences between basic bio-rhythms and the periods associated with the states of orbits in solar system suggest that the frequencies defined by the energy levels of the gravitational Schrödinger equation might entrain with various biological frequencies such as the cyclotron frequencies associated with the magnetic flux tubes. For instance, the period associated with $n = 1$ orbit in the case of Sun is 24 hours within experimental accuracy for v_0.

1.3 Dark Matter As A Source Of Long Ranged Weak And Color Fields

Long ranged classical electro-weak and color gauge fields are unavoidable in TGD framework. The smallness of the parity breaking effects in hadronic, nuclear, and atomic length scales does not however seem to allow long ranged electro-weak gauge fields. The problem disappears if long range classical electro-weak gauge fields are identified as space-time correlates for massless gauge fields created by dark matter. The identification explains chiral selection in living matter and unbroken $U(2)_{ew}$ invariance and free color in bio length scales become characteristics of living matter and of bio-chemistry and bio-nuclear physics. An attractive solution of the matter antimatter asymmetry is based on the identification of also antimatter as dark matter.

1.4 The Topics Of The Chapter

The following topics discussed in the chapter are following.

1. p-Adic length scale hypothesis can be applied in astrophysical length scales, too and some examples of possible applications are discussed. One of the most interesting implications of p-adicity is the possibility of series of phase transitions changing the value of cosmological

constant behaving as $\Lambda \propto 1/L^2(k)$ as a function of p-adic length scale characterizing the size of the space-time sheet.

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3. One section is devoted to some astrophysical and cosmological anomalies such as the apparent shrinking of solar system observed by Masreliez, Pioneer anomaly and Flyby anomaly.

4. The astrophysics of solar system involves also an anomaly related to the precession of equinoxes suggesting that Sun might have a companion. TGD suggests a model for anomalies as being due to interaction magnetic flux tube connecting Sun to its companion.

5. The TGD variant of the model of Nottale involved gravitational Planck constant h_{gr} is discussed in detail. Also further indications for large values of Planck constant are discussed. A rather recent result (2014) is that $h_{gr} = GMm/v_0$ hypothesis might be needed only for microscopic objects with small mass m since gravitational acceleration and gravitational Compton length do not depend on particle mass. This allows also the identification $h_{eff} = h_{gr}$ leading to powerful predictions in the TGD based model of living matter.

The appendix of the book gives a summary about basic concepts of TGD with illustrations. Pdf representation of same files serving as a kind of glossary can be found at `http://tgdtheory.fi/tgdglossary.pdf` [L1].

2 P-Adic Length Scale Hypothesis At Astrophysical And Cosmological Length Scales

p-Adic length scale hierarchy gives quantitative contents for the idea about fractal many-sheeted cosmology and therefore deserves a brief discussion.

2.1 List Of Long P-Adic Length Scales

There are not very many p-adic lengths scales $L(k)$ ($p \simeq 2^k$, k power of prime) between 1 meter and 10^{11} light years as the approximate density $\Psi(n) \simeq \frac{1}{ln(n)}$ of prime numbers as function of n shows. Therefore the length scale hypothesis is nontrivial and the attempt to identify physically the length scales is perhaps worth of the trouble although detailed identifications are not attempted in the following. If physics is indeed p-adic below length scale L_p at level p, one expects p-adic fractality, when length scale resolution is smaller than L_p. Length scales $L(k)$ coming as twin pairs corresponding to primes k and $k+2$ seem to define particularly interesting biological length scales. Therefore it is of interest look whether something similar might happen in astrophysical context. L_p is the infrared cutoff scale for p-adic field theory limit of TGD but the idea that quantum effects might be important in astrophysical length scales looks admittedly rather wild.

The length scales can contain some overall factor r of order order one. If this factor is chosen so that the length scale $L_e(151)$ is the thickness of the cell membrane, one must multiply p-adic length scales of the table by a factor $r \simeq 1.1$ to obtain $\hat{L}_e(k) = r * L_e(k)$.

Table 1: p-Adic length scales $L_e(k) = 2^{(k-127)/2}L_e127$, $p \simeq 2^k$, k prime, $L_{127} \equiv \sqrt{5+Y}\pi/m_e$, $Y \simeq .0317$ possibly relevant to astrophysics. The definition of the length scale involves an unknown factor r of order one and the requirement $L_e(151) \simeq 10^{-8}$ meters, the thickness of the cell membrane, implies that this factor is $r \simeq 1.1$.

k	227	229	233	239	241
$L_e(k)$	$2.3E+3$	$4.6E+3$	$1.9E+4$	$1.5E+5$	$3.0E+5$
k	251	257	263	269	271
$L_e(k)/m$	$.96E+7$	$7.7E+7$	$6.0E+8$	$4.8E+9$	$.9E+10$
k	277	289	293	307	311
$L_e(k)$	$7.7E+10$	$5.0E+12$	$2.0E+13$	$2.5E+15$	$1.0E+16$
k	313	317	329	331	337
$L_e(k)/ly$	2.2	$5.4E+2$	$1.0E+3$	2.2E+3	$8.4E+3$
k	347	349	353	359	367
$L_e(k)ly$	$2.8E+5$	$5.6E+5$	$2.2E+6$	$1.8E+7$	$2.9E+8$
k	373	379			
$L_e(k)/ly$	$2.2E+9$	$1.9E+10$			

1. $L_e(227) \sim 2.3$ kilometers, $L_e(229) \sim 4.6$ kilometers (twin pair) and $L_e(233) = 19.0$ kilometers. It would be interesting to find whether these length scales could be identified as geo-physically important length scales or/and length scales relevant to the internal structure of stars or planets. $L_e(233)$ is the order of magnitude for the size of neutron star.

2. $L_e(239) \simeq 1.5E+5$ m and $L_e(241) \simeq 3.0E+5$ m form a twin pair and could represent geophysically/astrophysically interesting length scales.

3. $L_e(251) = .96E+7$ m and $L_e(257) = 7.7E+7$ m. The radii of the planets are of this order of magnitude.

4. $L_e(263) = 6.0E+8$ m is of same order of magnitude as solar radius ($\sim 6.96E+8$ m). Note that $\hat{L}(263) \simeq 6.6E+8$ m is considerably nearer to the solar radius. $L_e(269) \simeq 4.8E+9$ meters and $L_e(271) \simeq .9E+10$ meters form a twin pair. Titius-Bode law for planetary distances reads as $r = r_0 + r_1 2^n$ AU, $r_0 = .4$ and $r_1 = .3$. A(stronomical) U(nit) corresponds to distance between Earth and Sun: $r_1 \simeq .3AU \simeq 4.5E+10m \sim 2^2 L_e(271)$ holds in a reasonable approximation. $2^2\hat{L}_e(271) \simeq 4.4E+10$ m is quite near to r_1! $L_e(271)$ is a member of twin pair and it might be that length scales corresponding to twin primes lead to approximate 2-adicity of the mass distribution. If primordial mass distribution is 2-adic and of form $((r-r_0)/r_1)^n$ it has peaks at $r - r_0 = r_1 2^k$ and Titius-Bode law is natural consequence. If this is the case then the planetary distance ratios might be universal!

5. For $k = 277, 289 = 17^2, 293, 307$, $L_e(k)$ varies between $7.7E+10$ m and about $2.5E+15$ m. $L_e(277)$ is of same order as the distance from Earth to Sun. The size of the solar system is about $L_e(289)$. $L_e(311) \simeq 1.0$ ly and $L_e(313) \simeq 2.0$ ly form a twin pair. Could these distances have a tendency to appear as distances between binaries? Or could the distances have a tendency to come as powers $2^n L_e(313)$?

6. $L_e(329) \simeq 1.0E+3$ and $L_e(331) \simeq 2.0E+3$ light years form a twin pair. Sizes for the galactic nuclei are of this order of magnitude. The very powerful energy sources in the nuclei of the galaxies are associated with regions of this distance. A suggested explanation is black hole in the region between the object and also TGD allows galactic black holes. $L_e(337) \simeq 8.4 \cdot 10^3$ light years corresponds to the size of the central region of the galaxy. $L_e(353) \simeq 2.2 \cdot 10^6$ light years corresponds to a typical size scale of the galaxy [E33].

7. $L_e(367) \simeq 2.2 \cdot 10^8$ light years is same order of magnitude as the size of the large voids and perhaps corresponds to the length scale identified by Einasto.

2.2 P-Adic Evolution Of Cosmological Constant

One of the most fascinating outcomes of the new view about gravitational energy is the resolution of the most gigantic failure in the art of order magnitude estimates. The naive estimate for the cosmological constant predicted also by TGD is by a factor 10^{120} larger than its value deduced from the accelerated expansion of the Universe. The resolution comes naturally from the p-adic fractality predicting that cosmological constant is reduced by a factor of 2 in a step wise manner in phase transitions occurring at times $T(k) \propto 2^{k/2}$, which correspond to p-adic time scales. On the average $\Lambda(k)$ behaves as $1/a^2$, where a is the light-cone proper time. This predicts correctly the observed value of Λ.

p-Adic length scale hypothesis plus the detailed study of membrane like vacuum extremals lead to the hypothesis that cosmological constant depends on p-adic length scale $\Lambda/R^2 \propto 1/R^2L^2(k) \propto 2^{-k}$. Amazingly, the recent value of the cosmological constant suggested by the accelerated expansion of the Universe comes out as a correct prediction!

Cosmological expansion at a particular space-time sheet becomes a TGD counterpart for a sequence of periods of increasingly slow inflation which a reduction of Λ by a factor of 2 at each time when the size of space-time sheet exceeds a p-adic length scale. It must be however emphasized that Kähler action determines the classical dynamics and it is by no means clear that exponential expansion is involved. What certainly occurs is liberation of gravitational energy, which means that the difference of inertial energy densities for matter and antimatter is reduced in a phase transition like manner. Maybe the interpretation in terms of annihilation of matter and antimatter is appropriate. Perhaps particles with masses of order p-adic length scale become non-relativistic and annihilate to lighter particles, most naturally those corresponding to the next p-adic length scale.

2.3 Evidence For A New Length Scale In Cosmology

There is evidence [E40] for a cubic lattice structure in the length scale of the large cosmic voids containing matter near their boundaries. Single void having galaxies on its boundaries would be the basic unit of this structure. This means a characteristic length scale of order 1.2 Megaparsecs, which in light years makes $7.8E+8$ light years. As noticed in the paper, these observations do not fit with the prediction of the cold dark matter scenarios predicting random distribution of galaxies and galaxy clusters at long length scales.

The first task is to find whether one could understand the length scale of order 1.2 Megaparsecs p-adically. In TGD, the cosmological evolution means the gradual emergence of longer and longer p-adic length scales, that is space-time sheets with size of order not too many p-adic length scales $L(p)$, where p is assumed to be near prime power of two by experience with the p-adic mass calculations: $p \simeq 2^k$, k power of prime. These regions (3-surfaces with outer boundaries!) do not expand any more but move like comoving particles in the expanding background (surface of larger p-adic prime).

There are not too many physically interesting p-adic primes near prime powers of two and the p-adic length scale associated with the prime $p \simeq 2^k$, $k = 367$ is $\hat{L}(367) \simeq 3.2E+8$ light years, whereas the length scale $L(Einasto) = 7.8E+8$ light years, deduced by Einasto *et al* is roughly *two times* this length scale. The two nearest length scales correspond to $p \simeq 2^k$, $k = 359$ with 16 times smaller length scale and $k = 373$ with 8 times larger length scale so that identification is unique. Therefore, it seems that p-adic length scale hypothesis might work even in the cosmological length scales.

The problem is to understand the origin of the lattice like structure. The least radical suggestion mentioned in [E40] is that some kind of acoustic waves during the early cosmology have left their trace in the background and caused the periodicity. Also a new physics in the inflation period has been speculated.

A priori, one can consider in TGD framework two alternative scenarios for the origin of the lattice structure. Either the structure is created during the very early cosmology and during cosmic expansion its size has gradually increased to its recently measured value. Or the structure is created later. TGD inspired cosmology is based on the hypothesis that new p-adic length scales emerge in the topological condensate during the cosmic evolution. Therefore one can consider the possibility that the large voids are structures, which have appeared later rather than having been present all the time. Of course, nothing excludes the possibility that the voids have expanded until they have reached the critical p-adic size for which the expansion has ceased.

The mechanism creating lattice structure could be based on so called p-adic fractals and be a consequence of the effective p-adic topology rather than result from some delicate dynamical mechanism. Already the existence of the p-adic length scales implies one kind of fractality. There is however also a second kind of fractality associated with a given value of the p-adic prime p. This latter kind of fractality, p-adic fractality for short, might provide an explanation for the lattice like structures as the following argument suggests.

p-Adic fractality for the real mass density ρ_R means that the density can be regarded as a map

$$\rho_R = I^{-1} \circ \rho \circ I \ \ ,$$

where ρ is the p-adic valued mass density in p-adic space-time and I denotes the so called *canonical identification*,

$$I : \sum_n x_n p^n \rightarrow \sum_n x_n p^{-n} \ \ ,$$

mapping p-adics to reals and inducing a map from real space-time region to p-adic space-time region. Thus, given a p-adically analytic mass density function ρ, the map $\rho_R = I \circ \rho \circ I^{-1}$ induces real density function ρ_R, which turns out to be a fractal as the numerical study of simple examples for small values of p shows.

This lattice structure of the p-adic fractals follows directly from the basic properties of the canonical identification mapping p-adics to reals. The point is that canonical identification in range $[0, p)$ for the real numbers induces discontinuities of the real density $\rho_R = I \circ \rho \circ I^{-1}$ at the points $x = k = 0, 1, ...p - 1$. Same occurs in each interval $[n, n + 1)$ at $x = n + kp$, k integer, which are mapped to the reals in the interval $[n, n + 1)$ and so on ad infinitum. Therefore the powers $p^{k/2}$ of the basic length scale are preferred scales for this structure. In higher-dimensional case one clearly obtains lattice like structure for the discontinuities. The lattice structure is not quite obvious in the illustrations of the 2-dimensional p-adic fractals represented in the first part of the book. If one plots p-adic fractal of the planar coordinates using different colors for different value ranges of the function, the cubic structure becomes manifest and one obtains extremely beautiful pictures.

2.4 Sunspot Cycle

To begin with, consider the general properties of the solar magnetic fields and Sunspots [E46].

1. The average magnetic field of the Sun is dipole field and reverses its polarity with a period of eleven years. The actual solar magnetic field consists of the discrete elements (flux tubes) and all element sizes and magnetic field strengths seem to be possible. The appearance of the discrete structures is not in accordance with the naive magnetohydrodynamics expectations [E46]: the stability argument (magnetic pressure plus the plasma pressure inside the flux tube equals to the plasma pressure outside the flux tube) gives a lower bound of about 0.1 T for the magnetic field of a stable flux tube and smaller field strengths have been observed.

2. The short time scales associated with the dynamics of the magnetic structures are not in accordance with the magnetohydrodynamics expectations [E46]: in magnetohydrodynamics diffusion determines the time scale for the change of the magnetic fields and the time scale for changes in length scale L is of the order of $T \simeq L^2/\sigma$, where σ is the conductivity of the plasma. For the changes taking place in the length scale of Sun the time is of the order of $T \simeq 10^{10}$ years: dipole field changes its direction during a year! For Sunspots having typically the size of the order of $L \simeq 10^7$ m, the corresponding time is of the order of $T \simeq 10^6$ years.

3. The appearance of the Sunspots is related to the change of the polarity of the Solar magnetic field. Sunspots appear first at latitudes ± 40 *degrees* and gradually the region, where new Sunspots appear, drifts to the direction of the equator. Sunspot magnetic field is bipolar and the field strength is typically about 0.1 T. The magnetic pole is referred to as p or f pole depending on whether the pole in question precedes or follows in the solar rotation (the

western pole is by definition the leading pole). The polarity of the leading spots is same (Hale-Nicholson law) for all Sunspots in a given hemisphere and for a given solar cycle. The polarity of the p spot is opposite for the two hemispheres and for two successive cycles. The opposite polarity of the southern and northern p spots guarantees the dipole field nature of the average magnetic field. The change of the polarity in the beginning of the solar cycle (implying the change of the polarity of the dipole field) is however not well understood in the present models.

4. Sunspots seem to be related to the convective motion of the matter. There is a net outward and inward flow of the matter with a velocity of order $\beta \simeq 10^{-5}$ at p and f poles of the Sunspot respectively so that Sunspots take part in the convection. There are also indications that the fibril like structures on the penumbra of p pole are convective rolls [E46]. These features suggest that Sunspots are magnetized helical vortices.

5. The appearance of the Sunspots is accompanied by a reduction of the solar constant: a possible explanation is that part of the solar energy is stored as a kinetic energy of the fluid motion associated with the Sunspots and as a magnetic field energy [E46].

2.5 Sunspots As Helical Vortices

TGD suggests an explanation of the discrete magnetic structures as a direct manifestation of the CP_2 geometry. The TGD inspired model for the Sunspot is motivated by the general ideas described earlier and by the basic features of Sunspots. For the reader's convenience only the general ideas are described and calculational details are left later.

1. In accordance with the ideas about the generation of hydrodynamical turbulence as spontaneous Z^0 magnetization, it is assumed that the structures of the solar magnetic field correspond to Z^0 magnetized domains, i.e. vortices of some kind.

2. The TGD based concept of the 3-space suggests strongly that vortices correspond to topological field quanta, that is 3-surfaces of a finite size and with outer boundary, glued to a background 3-space. The outer boundary corresponds to the critical radius for the imbedding of the Z^0 magnetic field created by the moving matter. The requirement that the critical radius of the magnetic flux tube is of the order of Sunspot size or smaller, implies that the values of the vacuum quantum numbers associated with the Sunspots must be considerably smaller than those associated with the background 3-space.

3. Also the background space is a carrier of a Z^0 magnetic field (which can be weak) and helical vortex interacts with this field by Z^0 magnetic dipole interaction, which explains the motion of the ends of the helical vortex in the Sunspot cycle.

4. The simplest (Z^0) magnetized domains are vortex like structures and Sunspots are identified as helical vortices, one of whose functions, besides maximizing Kähler function, is the convective transport of heat. This function explains why the ends of the Sunspot are at the surface of the Sun and why the main part of the structure is beneath the surface of the Sun, possibly at the bottom of the convective zone. It should be emphasized that Sunspots are not the only structures of this type: also smaller structures are possible and the radius of the vortex is determined by the value of the fractal quantum number m and magnetic quantum numbers. The small size of these structures however makes them invisible.

5. The velocity field of the vortex serves as a source of Z^0 magnetic field:

$$\nabla \times \bar{B}_Z = NK_Z\bar{v} \ , \tag{2.1}$$

where $N \equiv \rho_m/m_p$ denotes nucleon density and $K_Z = \epsilon_1 10^{-19} = g_Z/\sqrt{\epsilon_Z}$ describes the strength of the Z^0 force. By neutrino screening, the average Z^0 charge density is expected to be much smaller than the density of the nuclei. It has been assumed that neutrinos do not participate in the rotational motion so that nucleons serve effectively as the source of the Z^0 magnetic field. This means that ϵ_Z appearing in the formula refers to the Z^0 gauge flux coming from the "previous" condensate level. For the condensate level at which the elementary particles feed their Z^0 charges, one has therefore $\epsilon_Z = 1$. At the astrophysical scales ϵ_1 is smaller than one.

6. The magnetic field of the Sunspot is generated, when the integers n_i change so that their ratio differs from the value $n_1/n_2 = \omega_1/\omega_2$ guaranteeing the vanishing of the electromagnetic fields. This process implies that Z^0 magnetic line dipole becomes also an ordinary magnetic line dipole and therefore visible, when the ends of the vortex are at the surface of the Sun. This mechanism implies also that magnetic and Z^0 magnetic fields are parallel to each other.

7. Magnetohydrodynamic stability conditions are satisfied if the magnetic field of the Sunspot is parallel with the electric current so that the Lorentz force vanishes: $\nabla \times \bar{B} = \bar{v} \propto \bar{B}_{em}$ [E46]. This condition holds true also for the Z^0 magnetic field. If the magnetic field is generated by changing the values of the magnetic quantum numbers n_1 and n_2, then Z^0 magnetic and magnetic fields are parallel so that also Z^0 magnetic and velocity fields are parallel:

$$\bar{B}^Z \propto \bar{v} \ . \tag{2.2}$$

Helical vortices are the simplest objects allowing this kind of structure. A more detailed model for the helical vortices is postponed to the last subsection.

2.6 A Model For The Sunspot Cycle

Consider now a simplified model of the Sunspot cycle in terms of the helical vortices.

1. Sunspots correspond to helical vortices, whose main part is parallel to the surface of the Sun and whose ends are vertical vortices. In accordance with the idea that 3-space is a hierarchical condensate of 3-surfaces of various sizes, it is assumed that helical vortices correspond to topological field quanta condensed to the background 3-space. Also the background 3-space is a carrier of Z^0 magnetic field B_Z, which might be identified as the "average" or "self consistent" magnetic field created by the other topological field quanta.

   Helical vortices possess a definite Z^0 magnetic moment $d\bar{\mu}_Z/dl$ per unit length in the direction of the vortex: magnetic moment is due to the rotational motion of the matter inside the helical vortices. Therefore the vortices interact with the average Z^0 magnetic field of the Sun by the usual dipole interaction. Observations suggests that the poles of the Sunspot behave like independent dynamical objects so that in the first approximation the constraint forces can be neglected the ends of the vortex and vortices suffer a force per unit length given as the gradient of the dipole interaction energy per unit length

$$\frac{d\bar{F}}{dl} = \nabla(\frac{d\bar{\mu}_Z}{dl} \cdot \bar{B_Z}) \ . \tag{2.3}$$

   At the beginning of the Sun spot cycle only the radial component of the magnetic field contributes to the force since p and f poles of the Sunspot are to a good approximation at the same latitude. The force is in the direction of the meridian. Since the sign of $d\bar{\mu}/dl$ is opposite for p and f poles they begin to move in opposite directions. The contribution of B_r to the force changes its sign at equator and this motivates the assumption that the p end of the Sunspots oscillates between the latitudes $+40$ and -40 degrees.

   The nice feature of the proposal is that the force is indeed in the right direction at the beginning of the solar cycle and the forces on p and f have opposite directions. The details of the force are not important for the estimate of the duration of solar cycle. It is the latitude at which the Sunspot formation begins, which depends on the detailed properties of the force.

2. The motion of poles and in particular, differential rotation of the Sun implies the stretching of the vortex. If the flow is incompressible the volume of the vortex remains constant (V_0) so that the area (S) of the vortex decreases as $1/L$ as function of the vortex length L:

$$L = L_0 \frac{S_0}{S} . \tag{2.4}$$

Typical initial values of S and L are $S_0 \simeq \pi \cdot 10^{12}\ m^2$ and $L_0 \simeq 10^7\ m$. The decrease of the cross sectional area implies that the Sunspot becomes invisible after having reached some critical radius.

3. After having reached a certain critical radius of the order of the radiation length $L_{rad} \simeq 3 \cdot 10^4\ m$, vortex becomes unstable against pinch and splits to two pieces. The reason is that vortex must be cooler than its surroundings by the magnetic equilibrium conditions ($B^2/2 + nkT_{in} = nT_{out}$) and this is not possible if the radius of the vortex is too small since the radiation flux of the Sun destroys all temperature gradients in the length scales smaller than $L_{rad} \simeq 3 \cdot 10^4\ m$. The critical length of the vortex is therefore given by $L_f \sim L_0 S_0/S_f \simeq 4 \cdot 10^{11}\ m$.

4. Since the stretching of the vortex results mainly from the differential rotation of the Sun (rotation period is $T_{rot} = 25\ d(ays)$ and $T_{rot} = 30\ d$ on poles and equator respectively). This means that the upper bound for the time required to achieve instability is of the order of $T_{cycle} \leq (L_f/R_{Sun})T_{rot} \simeq 4 \cdot 11$ years ($R_{Sun} \simeq 8 \cdot 10^8\ m$) and of the same order of magnitude as the period of the Sunspot cycle (recall that the naive magnetohydrodynamic estimate is about 10^{10} years!). The actual value is smaller since in the beginning of the cycle the effect of the differential rotation is considerably smaller than at the end of the cycle.

5. The stretched magnetized vortices give the dominant contribution to the average dipole field of the Sun and the entanglement of the dipole field lines resulting from the freezing of the magnetic field lines to differentially rotating matter corresponds to the stretching of the co-rotating vortices. The dipole nature of the average solar magnetic field requires that p type poles must have same polarity on the given hemisphere and that the polarities of p type poles are opposite for Southern and Northern hemispheres.

6. The vortices started from the latitude of 40 (-40) degrees achieve critical length at the latitude -40 (40) degrees begin to split to pieces. The resulting pieces achieve their equilibrium volume V_0 by increasing their transverse size from the critical size S_f to S_0 implying the increase of the radius by a factor of order $10^{3/2}$. The pieces are observed as new Sunspots and the gradual splitting starting from the end explains why the Sunspot active region proceeds gradually to the direction of equator. The mysterious reversal of p type polarity results from the opposite polarities of p poles at Northern and Southern hemispheres. This in turn implies the change of polarity of the solar magnetic field at each Sunspot cycle.

7. The energy needed to generate the magnetic field of the thickened vortex and the kinetic energy of the vortex motion is provided by the energy production in the interior of the Sun and the process explains the decrease of the Solar constant.

2.7 Helical Vortex As A Model For A Magnetic Flux Tube

The detailed model of the magnetic flux tube as a helical vortex is based on the following physical picture.

1. The velocity field of the vortex serves as source of Z^0 magnetic field

$$\begin{aligned} \nabla \times \bar{B}^Z &= K_Z N \bar{v} \ , \\ K_Z &= -\frac{g_Z^2}{4\sqrt{\epsilon_Z}} \frac{A-Z}{A} \ . \end{aligned} \tag{2.5}$$

where $N \equiv \rho_m/m_p$ denotes nucleon density and K_Z describes the strength of Z^0 force. $\epsilon_1 \leq 1$ measures the relative strength of Z^0 and gravitational forces. For the gravitational interaction to dominate over Z^0 force the condition $\epsilon_Z > 10^{36}$ must hold true.

2. The magnetic field is generated, when the integers n_i change so that their ratio differs from the value $n_1/n_2 = \omega_1/\omega_2$ guaranteeing electrovac property. This mechanism implies that magnetic and Z^0 magnetic fields are parallel to each other.

3. Magnetohydrodynamic stability conditions are satisfied if the magnetic field of the Sunspot is parallel with the electric current so that the Lorentz force vanishes: $\nabla \times \bar{B} = \bar{v} \propto \bar{B}_{em}$ [E46]. If the magnetic field is generated by changing the values of the magnetic quantum numbers n_1 and n_2 then Z^0 magnetic and magnetic fields are parallel so that also Z^0 magnetic and velocity fields are parallel:

$$\bar{B}^Z \propto \bar{v} \ . \tag{2.6}$$

Helical vortices are the simplest objects allowing this kind of structure and cylindrical symmetry fixes the structure of the helical vortex almost completely.

The helical vortex possesses cylindrical symmetry in the sense that Z^0 magnetic field and velocity field have only z and ϕ components, which depend on the cylindrical coordinate ρ only, so that one has

$$\begin{aligned}
\Phi &= \omega_1 t + k_1 z + n_1\phi \ , \\
\Psi &= k\Phi = \omega_2 t + k_2 z + n_2\phi \ , \\
r &= tan(X(u)) \ , \\
X(u) &= ln((k+u)/C)\epsilon/2 \qquad u = u(\rho) \ , \\
\frac{\omega_2}{\omega_1} &= \frac{k_2}{k_1} = \frac{n_2}{n_1} \ .
\end{aligned} \tag{2.7}$$

The relationship between the velocity field and Z^0 magnetic field is dictated by the condition that matter flow serves as source of the Z^0 magnetic field.

The expressions for the non-vanishing components of the induced Z^0 magnetic field are given by

$$\begin{aligned}
B_z^Z &= -\frac{3}{(3+p)} n_1 sin^2 X \frac{\partial_\rho u}{\rho} \ , \\
B_\phi^Z &= -\frac{3}{(3+p)} k_z sin^2 X \frac{\partial_\rho u}{\rho} \ .
\end{aligned} \tag{2.8}$$

The requirement $\nabla \times \bar{B^Z} \propto \bar{B^Z}$ implies the condition

$$\frac{\partial_\rho B_z^Z}{\partial_\rho B_\phi^Z} = -\frac{B_\phi^Z}{\rho^2 B_z^Z} \ . \tag{2.9}$$

Using the explicit representation as an induced gauge field one obtains the differential equation

$$\begin{aligned}
\partial_\rho Y &= \frac{(1-(\rho/\rho_1)^2)}{(1+(\rho/\rho_1)^2)\rho} Y \\
Y &= sin^2 X \partial_\rho u \ , \\
\rho_1 &= \frac{n_1}{k_z^1} \ ,
\end{aligned} \tag{2.10}$$

which gives

$$\begin{aligned} \partial_\rho Y &= \frac{(1-(\rho/\rho_1)^2)}{\rho(1+(\rho/\rho_1)^2)} Y \ , \\ Y &= sin^2 X \partial_\rho u \ . \end{aligned} \tag{2.11}$$

By integrating this equation, one obtains

$$\begin{aligned} B_z^Z &= -\frac{3}{(3+p)}\frac{n_1}{[(1+(\rho/\rho_1)^2)\rho_0^2]} \ , \\ B_\phi^Z &= \frac{k_z^1}{n_1}\rho^2 B_z^Z \ , \end{aligned} \tag{2.12}$$

where ρ_0 is an integration constant possessing the dimension of length.

The magnitudes of the velocity components β_z and β_ϕ are

$$\begin{aligned} \beta_z &= \frac{2k_z^1}{NK_Z\rho_0^2}\frac{p}{2(3+p)}\frac{1}{(1+(\frac{\rho}{\rho_1})^2)} \ , \\ \beta_\phi &= \frac{\rho}{\rho_1}\beta_z \ . \end{aligned} \tag{2.13}$$

Stability requirements for helical vortices [E60] suggest that the value of n_1/k_z^1 is of the same order as critical radius. Notice that the vortex rotates like a rigid body near the z-axis and that the longitudinal velocity is also approximately constant near the z-axis.

The above described imbedding of the helical Z^0 magnetic field fails at the critical radius $\rho = \rho_{cr}$, which corresponds to the value of $r = \infty$. The expression for the critical radius in present case is obtained from the condition $r = \infty$ and reads as

$$\begin{aligned} \rho_{cr} &= \rho_1\{exp[4(\frac{\rho_0}{\rho_1})^2(u_0+k)exp(-\frac{2\pi m}{\epsilon})X_0] - 1\}^{1/2} \ , \\ &\simeq 2\rho_0 exp(-\frac{m\pi}{\epsilon})[(u_0+k)X_0]^{1/2} \ , \\ X_0 &= \frac{(2+\epsilon^2)exp(\frac{\pi}{\epsilon})+\epsilon^2}{1+\epsilon^2} \ , \end{aligned} \tag{2.14}$$

where it has been assumed that the value of the exponent is small. It will shortly found that the assumption is physically well founded. Notice that the critical radius depends extremely sensitively on the value of the "fractal" quantum number m and that the critical radii are related by a power of a discrete scaling transformation in the approximation used.

If one requires that Z^0 magnetic flux is quantized with n_1 multiple of some integer n, one has simpler condition

$$\begin{aligned} \frac{3}{3+p}2(u_0+k)exp(-2\pi m/\epsilon)X_0 &= \frac{1}{n} \ , \\ \rho_{cr} &= \rho_1\{exp[2\frac{\rho_0^2}{n\rho_1^2}] - 1\}^{1/2} \ . \end{aligned} \tag{2.15}$$

If one requires flux quantization without any conditions on n_1, one must assume $n = 1$.

Vortex carries also radial Z^0 electric field: the magnitude of this field is given by

$$|E^Z| = |B_\phi^Z|(\omega_1\rho/n_1) \ . \tag{2.16}$$

The parameterization $\omega_1 = \sqrt{\epsilon_Z}x$, $x \sim 1$ is expected to hold true for ω_1.

2.8 Estimates For The Vacuum Parameters Of Magnetic Flux Tube

Consider next the values of the various vacuum parameters appearing in the embedding of the helical vortex.

2.8.1 An estimate for the quantum number ω_1

From the requirement that gravitational interaction is stronger than Z^0 force in long length scales one obtains $\omega_1 \leq 1/R \sim 10^{-4} m_{Planck}$ and $\epsilon_Z > 10^{38}$. The other extreme correspond to the condensate level $n = n_Z$ with $\epsilon_Z(n_Z) \sim 10^{20}$. One must however remember that neutrinos are not expected to serve as the source of Z^0 magnetic field and therefore $\epsilon_Z(n-1)$ appears in the expression of the magnetic field at level n and at level n_Z the total unscreened nuclear charge serves therefore as the source of B_Z. Lorentz invariance implies that the value of k_z^1 is given by

$$k_z^1 \simeq \omega_1 \beta_z \ . \tag{2.17}$$

2.8.2 An estimate for the quantum number n_1

The requirement that angular momentum density is of correct order of magnitude gives an estimate for the value of the parameter n_1. The expression of the conserved angular momentum current in the z-direction is given by

$$J^\alpha = T^{\alpha\beta} \partial_\beta m^k m_{kl} j^l \ , \tag{2.18}$$

where j^k denotes the vector field associated with an infinitesimal rotation and $T^{\alpha\beta}$ denotes energy momentum tensor. For the angular momentum density one obtains in the cylindrical M^4 coordinates for X^4 the expression

$$\begin{aligned} J^t &= T^{t\phi}\rho^2 \ , \\ T^{\alpha\beta} &= \frac{1}{16\pi G} G^{\alpha\beta} \ , \end{aligned} \tag{2.19}$$

where the second equation is Einstein's equation.

Case a:

If the contribution of CP_2 curvature to the curvature tensor is not dominating the leading order contribution to $G^{t\phi} = R^{t\phi} - g^{t\phi}R/2$ comes from the non-vanishing of the metric component $g_{t\phi}$:

$$g_{t\phi} = s_{\Phi\Phi}^{eff}\omega_1 n_1 = -\frac{R^2}{4}(cos^2(X)(k+u)^2 + 1 - u^2)sin^2(X)\omega_1 n_1 \ , \tag{2.20}$$

and one obtains the order of magnitude estimate

$$J^t \simeq -T^{tt} g_{t\phi} \simeq \rho_m \frac{R^2}{4}\omega_1 n_1 \ . \tag{2.21}$$

In order to obtain a correct order of magnitude for the angular momentum density associated with rotational flow one must have

$$\frac{R^2}{4}\omega_1 n_1 \sim \rho\beta(\rho) \ , \tag{2.22}$$

which implies

$$\begin{aligned} n_1 &\simeq \frac{L}{R^2\omega_1}\beta \sim \frac{10^{19}}{\sqrt{\epsilon_Z}x}\frac{L}{R}\beta \ , \\ \omega_1 &\equiv x\sqrt{\epsilon_Z}m(proton) \ , \end{aligned} \tag{2.23}$$

where L and β are typical scale and velocity associated with the flow and $x \sim 1$ is expected to hold true. If L is taken to be the radius of the vortex ($L \sim 10^7\ m$) and $\beta_\phi \sim 10^{-5}$ the rotation velocity of the vortex, one obtains: $n_1 \sim \frac{10^{55}}{x\sqrt{\epsilon_Z}}$. If L is taken to be the radius of the Sun and β, the rotation velocity of the Sun the value of n_1 is about hundred times larger. The order of magnitude for E^Z is

$$E^Z \sim a\frac{B^Z}{\beta_{rot}} \ ,$$

with

$$a = x\sqrt{\epsilon_Z}Gm_p\omega_1 << 1 \ ,$$

and is consistent with the assumption that the density of Z^0 charge is much smaller than the density of the nucleons.

Case b:

If Z^0 field is strong as compared to the gravitational field, the dominating contribution to $G^{t\phi}$ comes from the contribution of the CP_2 curvature to $R^{t\phi}$ and is proportional to the quantity $J^t{}_\rho J^{\rho\phi}$: in this case the previous estimate doesn't hold anymore and one obtains the estimate

$$\frac{n_1}{\omega_1} \simeq \beta L \ . \tag{2.24}$$

Since Z^0 field is strong inside the Sunspots one must use this estimate for n_1/ω_1 and one obtains the estimate

$$E^Z \sim \frac{B^Z}{\beta_{rot}} \ .$$

The result would mean that the density of Z^0 charge is of same order of magnitude as the density of the nucleons and by the presence neutrino screening this is not possible. Therefore case 1) is closer to the actual physical situation.

2.8.3 An estimate for the radius ρ_0

An estimate for the radius ρ_0 is obtained by substituting the estimate of k_z to the general expression of β_z at z-axis and one obtains the condition

$$\begin{aligned} \rho_0 &\sim [10^{19}\frac{p}{(3+p)}\frac{1}{\sqrt{G}N\epsilon_1}]^{1/2} \\ &\sim (\frac{1}{\epsilon_1})^{1/2}10^{11}\ m \ , \\ \epsilon_1 &\equiv K_Z 10^{19} \ , \end{aligned} \tag{2.25}$$

where the estimate $N \sim 10^{30}/m^3$ for the nucleon density has been used.

2.8.4 An estimate for the fractal quantum number m

En estimate for the value of the fractal quantum number m is obtained from the condition that the exponent appearing in the expression of the critical radius is small:

$$4(\frac{\rho_0}{\rho_1})^2 exp(-2m\pi\epsilon)[(u_0+k)X_0] \ll 1 \ . \tag{2.26}$$

Since one has $\rho_0 \simeq \sqrt{1/\epsilon_1}10^{11}\ m$ and $\rho_1 \sim \rho_{cr} \sim 10^6\ m$, one obtains an order of magnitude estimate $exp(-2m\pi/\epsilon) \ll 10^{-10}\epsilon_1/(u_0+k)$ so that the value of m must be rather large unless the value of the parameter $u_0+k = u_0+n_2/n_1$ is very small or the value of ϵ_1 is sufficiently large: the value $\epsilon_1 \geq 10^5$ implies that m is of order 2: a rather natural looking value unlike the large values implied by $\epsilon - 1 \sim 1$.

2.8.5 Estimate for the magnetic field

If the magnetic field is generated by the change of n_1 so that the condition $\omega_1/\omega_2 = n_1/n_2$ ceases to hold true one obtains the following approximate expression for the magnetic field at the z-axis

$$B_z^{em} \simeq \frac{\Delta n_1(3+p)}{\rho_0^2} . \tag{2.27}$$

The requirement that the magnetic field is of the order of $B_{em} = 10^3\ Gauss$ gives the estimate $\delta n_1 \simeq 10^{36}/\epsilon_1$ so that the relative change of n_1 is given by $\Delta n_1/n_1 = 10^{-19}x\sqrt{\epsilon_Z}/\epsilon_1 << 1$ for alternative 1) in which n_1 is very large. The argument related to the destruction of the super fluidity by the generation of Z^0 magnetic fields suggests the range $\epsilon_Z \in (10^{20} - 10^{22})$ at the condensation level level n_Z, at which elementary particles feed their Z^0 gauge fluxes for ϵ_Z (recall that $1/\sqrt{\epsilon_Z(n)}$ tells which fraction of total nuclear Z^0 charge the unscreened Z^0 charge is at the condensate level n and therefore flows to level $n+1$ via the # throats located near the boundaries of level n surface). This number corresponds to $\epsilon_1(n_Z) = 10^{19}g_Z/\sqrt{\epsilon_Z} \in (10^8 - 10^9)$. Quite strong Z^0 magnetic fields are possible: the strength of the Z^0 magnetic field at the level $n = n_Z + 1$ is below $10^4\ Tesla$ for $\epsilon_Z(n_Z) = 10^{22}$ and $\rho_{cr} \sim 10^6\ m$!

3 Explanation For The High Temperature Of Solar Corona

The mysterious feature of the solar corona is its high temperature $T \sim 10^6\ K$, as compared with the temperature of the chromosphere of order $10^4\ K$ [E46] (the book of Zirin provides excellent introduction to the physics of Sun). The temperature rises very rapidly to $10^6\ K$ at height $h \sim 2 \cdot 10^6\ m$ from the surface of Sun. The problem is to identify the mechanism leading to the heating of the particles of the solar wind after leaving solar surface: no convincing mechanism has been identified and this suggests that many-sheeted space-time concept might be involved in an essential manner. Indeed, the high temperature matter in the solar corona can be interpreted as a dark matter leaked from the highly curved portions of magnetic flux tubes to the space-time sheets where it becomes visible.

3.1 Topological Model For The Magnetic Field Of Sun

The basic observation is that solar corona cannot behave like single homogenous object possessing high temperature $T \sim 10^6$ K: the effective black body temperature deduced from the net radiation flux is not larger than 7000 K [E46] corresponding energy density is more than 10^{-9} times smaller than the energy density associated with T. This suggests the existence of local high temperature regions giving rise to characteristic spectral lines in X ray region serving as a signature of the high temperature.

It is also known that the dynamics of the solar atmosphere and convective zone is very strongly correlated with magnetic fields, which from Zeeman splitting are known to have typical magnitudes of order .3 Tesla [E46]. Furthermore, only those stars which have convective zone, possess corona and the size and shape of corona varies during the sunspot cycle.

Also solar constant is found to vary during sunspot cycle, which is difficult to understand in the standard picture about solar energy transfer. Solar wind is known to be associated with the non-closed magnetic fields lines and with the coronal holes in which temperature is lower than in the surroundings. High temperature regions in corona in turn correspond to regions at which field lines tend to be tangential to the surface and temperature. This suggests that magnetic fields provide the basic mechanism of convective energy transfer and that magnetic fields somehow make it possible to heat the solar corona locally.

These considerations suggests that magnetic flux tubes realized as tube like space-time sheets having radius $\rho \geq \rho_0 = \sqrt{1/eB}$ provide a TGD based topological realization for the convective energy transfer. This hypothesis reduces the problem to microscopic level and rather precise quantitative predictions should become possible. Protons and electrons can topologically condense at the magnetic flux tubes and move along them. It is assumed that in good approximation all protons, electrons and also heavier elements are condensed at the magnetic flux tubes.

The magnetic field of the flux tube confines charged particles and in transversal degrees of freedom they behave quantum mechanically like 2-dimensional harmonic oscillators with wave functions localized around Landau orbits with radius of order $\sqrt{n}\rho_0$, $n = 0, 1, 2..$ whereas in longitudinal degrees of freedom they behave like free particles locally. If n is sufficiently large, classical description as continuous matter should become possible. In the classical description charged particles are confined around magnetic lines of force and rotate with frequency $\omega = eB/E$, where E is total relativistic energy. The radius of the orbit is $\rho = \beta/\omega$, where β is rotational velocity. For sufficiently small values of β the radius of orbit is so small that particle is confined inside the flux tube. The dominant component of velocity is along the direction of flux tube.

In magneto-hydrodynamical description the basic equations state the conservation of magnetic flux, of various particle numbers (electron and proton numbers for magnetic flux tubes and neutron and neutrino numbers for Z^0 magnetic flux tubes) and conservation of momentum and energy along the flow lines. Energy density contains the energy density σT^4 of from black body radiation, kinetic energy density $\rho v^2/2$ of the macroscopic motion, pressure contribution p and the density $B^2/2$ of the magnetic energy. Gravitation is assumed to couple to the size and shape of the flux tube rather than to individual particles inside the flux tube so that gravitational energy density does not contribute to energy conservation conditions. If the particles slow down somewhat as they approach to the highly curved portions of the flux tubes, the increase of the temperature along the flux tube is implied by the conservation of energy $\sigma T^4 + \rho v^2/2 \simeq constant$. This explains why the local temperature of the corona is higher than the temperature at the surface of Sun and why the temperature is lowest and streaming velocity highest at the coronal holes with non-closed magnetic field lines extending to interplanetary space. The leakage of the particles to other space-time sheets at the highly curved portions of the flux tubes could in turn cause local heating of the matter.

Since the particles entering the closed flux tubes have some kinetic energy and since most of them return to the convective zone, there must be a momentum transfer from particles to the flux tube and flux tube must receive momentum. In equilibrium this force and gravitational force affecting the shape and size of the entire flux tube cancel each other. This is nothing but a topological representation for the freezing of magnetic field lines to moving matter. In this picture it is possible to understand the mysterious looking ability of the solar prominences to defy the force of gravity. Solar wind corresponds to particles glued to open flux tubes or closed flux tubes formed via the recombination of flux lines in solar atmosphere and having velocity larger than the escape velocity.

The model predicts correctly the basic qualitative properties of the solar wind [E46].

1. The highest velocity streams come from the coolest part of corona, coronal holes: these regions correspond to open magnetic field lines extending into interplanetary space. This follows from the energy conservation and from the fact that temperature is lower for coronal holes so that kinetic energy must be larger.

2. The velocity of the solar wind protons is found to decrease with the increasing density of electrons at the base of Corona [E46]. By charge neutrality inside flux tubes also proton density is reduced and conservation law for energy requires the increase of the velocity of protons. Streaming velocity is also found to increase with the electron temperature at the base of the corona [E46]. Assuming thermal equilibrium this means that the radiative contribution to energy is reduced so that kinetic energy density must increase.

If flux tube is closed, particles return to the convective zone and one can indeed speak about convective motion also in solar atmosphere. The confinement of radiative energy to the closed magnetic flux tubes (space-time sheets actually!) might explain why solar constant depends on the phase of the sunspot cycle being smallest at sunspot maximum when the number of closed field lines is maximum. Neutrinos and neutrons are expected to suffer topological condensation on Z^0 magnetic flux tubes and the obvious explanation for the solar neutrino deficit is that some fraction of neutrinos is confined to these tubes returns back to Sun. The reduction of the neutrino flux is possible even without absolute confinement inside flux tubes: already the dispersion of the neutrino flux caused by the change in the direction of motion during the travel inside the flux tube reduces neutrino flux from the solar core.

3.2 Quantitative Formulation

Magnetic flux tubes are assumed to have fractal "flux tubes inside flux tubes" structure and decompose ultimately into microscopically thin flux tubes. Furthermore that protons and electrons are assumed to suffer magnetic confinement inside these flux tubes. Classical rotational motion around field lines occurs with frequency $\omega = eB/m$ and the rotational velocity satisfies $\beta = \omega\rho$. For small values of rotational velocity the particle remains confined inside the flux tube. The observed Zeeman splitting suggests that B is of order .1 Tesla. Quantum mechanically the confined particle is essentially equivalent with a harmonic oscillator with frequency ω in transversal degrees of freedom and behaves like free particle in longitudinal degrees of freedom. $B \simeq .3$ Tesla gives in case of proton the estimate $\omega \sim 10^{-7}$ eV for the frequency ω serving as the energy unit of the harmonic oscillator in question. Clearly, quasi-continuous spectrum is in question. The width of the ground state Gaussian wave function is $\rho_0 = \sqrt{\frac{1}{eB}}$ giving $\rho_0 \sim 10^{-8}$ meters for $B \sim .3$ Tesla. This gives the constraint $\rho > \rho_0$ to the thickness of the flux tube.

Higher Landau levels correspond to the radii $\rho_n = \sqrt{n}\rho_0$, $n = 1, 2, ...$ with energy spectrum given by $E_{n,m} = (n + m/2)\omega$, with angular momentum quantum number m varying in the range $-2n \leq m \leq 2n$. Transversal excitations with energies up to thermal energy must be allowed and this allows excitations up to $n = 10^7$ and thermal stability against the transfer of proton to larger space-time sheets requires $\rho > 10^{-5}$ meters. Since rather large values of n are excited thermally, it is possible to treat the matter inside flux tubes as continuous matter obeying hydrodynamic equations and ordinary Boltzmann statistics (rather than behaving as degenerate Fermi gas). The dominant component of the velocity is along the flux tube. The requirement that the Compton wavelength of the thermal photon is smaller than ρ gives $\rho > 10^{-8}$ meters for $T \sim 10^2\ eV$.

The effective black body temperature for the radiation from corona determined from the entire energy flux is not larger than 7000 K and corresponding energy density is roughly a fraction 10^{-9} of black body radiation temperature associated with the real temperature of order $T \sim 10^6$ K. Near the solar surface the density of matter is roughly 10^9 times that in corona [E46]. In the approximation that the matter density inside flux tubes is same in the corona and at the solar surface these observations suggest that the matter inside the magnetic flux tubes behaves as a dark matter and that the matter visible in the corona corresponds to a fraction 10^{-9} of dark matter leaked out from the magnetic flux tubes to space-time sheets where it becomes visible. This interpretation is consistent with the TGD based explanation of dark energy and dark matter in terms of magnetic energy of magnetic and Z^0 magnetic flux tubes and particles residing inside them (see the chapter "Cosmic Strings").

The particle density in the corona is of order $10^{14}/m^3$ particles [E46]. This implies a density of order $10^{23}/m^3$ particles (protons dominate in the mass density) inside flux tubes in corona. The density of solar wind particles is roughly $10^6/m^3$ at the solar surface [E46] and forms a fraction of order 10^{-17} of the density of matter at solar surface. If all solar wind particles are condensed at magnetic flux tubes, this means that only a fraction 10^{-17} of all magnetic flux tubes runs out of Sun! If flux tube structure is described as ordinary classical magnetic field one would say that most of magnetic energy resides in turbulent magnetic fields.

The basic equations of the model state the conservation of magnetic flux, particle number, energy and momentum. The requirement that the magnetic flux is conserved implies that the magnitude of BS, where S is the transverse area of the flux tube, is constant along the flux tube. Together with the conservation of particle number this gives the conditions

$$\begin{aligned} BS &= B_0S_0 \ , \\ n_pvS &= n_p^0v_0S_0 \ . \end{aligned} \tag{3.1}$$

Since the flux tubes turns back to the solar surface in corona, the vertical component of v is reduced at the corona whereas the tangential component increases by energy conservation. If the particle density inside the flux tubes were much smaller at the solar surface than in corona, the fraction of volume occupied by the magnetic flux tubes at solar surface would be larger than one so that the changes of ρ and v must be rather small.

The conservation of energy, assuming that gravitational force couples to the flux tube geometry rather than the matter inside flux tube, gives

$$\sigma T^4 + \frac{1}{2}\rho v^2 + \frac{1}{2}B^2 + p = constant \ . \tag{3.2}$$

Here one has $\sigma \simeq 51.95/2\pi^2 \sim 3$. The pressure term associated with matter is in a good approximation negligible as compared to the energy density of the kinetic energy since the thermal velocity of proton at corona is about $10^{-3-1/2}$. The dominating part in the energy density at solar surface corresponds to the density of kinetic energy which is roughly 10^2 times larger than the thermal energy density of photons at corona and 10^4 times larger than the density of the magnetic energy. If one assumes that the thickness of the flux tubes does not change, magnetic energy remains constant and one has $\rho v = \rho_0 v_0$, and energy conservation gives

$$\sigma\Delta(T^4) = -\frac{1}{2}\rho_0 v_0 \Delta v \ ,$$

which gives

$$\frac{\Delta v}{v_0} = -\frac{2\sigma\Delta(T^4)}{\rho_0 v_0^2} \ . \tag{3.3}$$

For $T = 10^2$ eV and $v_0 = 10^{-2}$ [E46] and $\rho_0 = 10^{23} m_p/m^3$ this gives $|\Delta\rho/\rho| = |\Delta v/v_0| = 6\cdot 10^{-2} \ll 1$ so that the scenario is internally consistent. The slowing down of the particles as they approach the highly curved portion of the flux tube inside corona is natural.

As such the matter inside flux tubes is invisible and the high temperature matter in the corona results from a partial leakage of the particles from the magnetic flux tubes to other space-time sheets. The leakage of a fraction 10^{-9} would be caused by the large centrifugal acceleration at the highly curved portion of the flux tube. This would also explain why coronal holes are cooler than other regions of the corona.

The conservation of momentum together with the assumption that (most) matter flowing around flux tube returns back to the Sun implies that the matter topologically condensed at the flux tube feeds momentum in the degrees of freedom characterizing the size and shape of the flux tube and this must give rise to over all cm motion of the flux tube. The net force acting on the flux tube is obtained by integrating the divergence of the energy momentum tensor over the entire flux tube. Assuming that the velocity of matter at the return end is not considerably reduced, the contributions from the two ends are roughly identical and the expression for the resulting force acting on the cm of the flux tube reads as

$$F \simeq 2\rho_0 v_0^2 A \ , \tag{3.4}$$

where A is the transverse area of the flux tube. Also gravitational force acts on the cm motion of the flux tube and in equilibrium the two forces must cancel each other.

$$GM(Sun)L\langle\frac{\rho}{(R(Sun)+h)^2}\rangle = \rho_0 v_0^2 \ , \tag{3.5}$$

where h is the height from the surface of Sun and brackets denote averaging along the length of the flux tube of length L.

It can quite well happen that the momentum feed is so large that equilibrium is not possible and flux tube rises gradually and, if recombination of the flux tube ends giving rise to a closed flux tube occurs, runs away. This effect is enhanced by the fact that at large values of distance from Sun, where gravitational force is weakest, the mass density of the flux tube is largest. From the dependence of the gravitational force on height h it is clear that the eruption should occur when the height of prominence is same order of magnitude as solar radius: solar prominences have indeed the mysterious looking property of being unstable against upwards rather than downwards perturbations.

4 A Quantum Model For The Formation Of Astrophysical Structures And Dark Matter?

D. Da Rocha and Laurent Nottale, the developer of Scale Relativity, have ended up with an highly interesting quantum theory like model for the evolution of astrophysical systems [E31] (I am grateful for Victor Christianito for informing me about the article). In particular, this model applies to planetary orbits. I learned later that also A. Rubric and J. Rubric have proposed a Bohr model for planetary orbits [E59] already 1998.

The model is simply Schrödinger equation with Planck constant $\hbar$ replaced with what might be called gravitational Planck constant

$$\hbar \quad \rightarrow \quad \hbar_{gr} = \frac{GmM}{v_0} \quad . \tag{4.1}$$

Here I have used units $\hbar = c = 1$. v_0 is a velocity parameter having the value $v_0 = 144.7 \pm .7$ km/s giving $v_0/c = 4.6 \times 10^{-4}$. The peak orbital velocity of stars in galactic halos is 142 ± 2 km/s whereas the average velocity is 156 ± 2 km/s. Also sub-harmonics and harmonics of v_0 seem to appear.

v_0 could quite generally correspond to some rotational velocity associated with the two particle system and h_{gr} can be assigned with flux tubes mediating gravitational interactions: massless extremals topologically condensed at the flux tubes are natural candidates for the analogs of Alfwen waves mediating gravitational interaction.

There are several alternative interpretations for v_0.

1. One could assume single value of v_0 for all planets and sub-harmonics $v_0 \rightarrow v_0/n$ could actually correspond to the scaling of the principal quantum number (also denoted by n - hopefully this does not cause confusion) for Bohr orbits by n.

2. One could also assume that all orbits correspond to $n = 1$ orbits and that but for varying parameter $v = v_0/n$ replacing v_0 identified as rotation velocity $v = v_0/n$ for the Bohr orbit. This does not reduce the hypothesis a mere parameterization since the basic prediction in TGD framework is macroscopic quantum coherence in astrophysical scales at flux tubes mediating gravitational interaction.

Some further general comments are in order.

1. The proposal generalizes also to electromagnetic interactions - maybe even color interactions inside hadrons - with h_{gr} replaced with $h_{em} = |Z_1Z_2|\alpha/v_0$ [K16, K17] with critical value $n = h_{em}/h = 1$. Systems involving large charge separations such as plasmas and living matter would be excellent candidates for carrying dark matter with $h_{eff} = h_{em}$. In the electromagnetic case second system is most naturally microscopic since EP does not hold true and Compton lengths depend on the mass of the particle.

2. It took long time to realize that Equivalence Principle (EP) implies that it is enough to assume that the notion of h_{gr} makes sense at microscopic level [K25, K17]. The reason is that the acceleration does not depend on the mass of particle. This obviously favors quantum coherence in absence of forces for which accelerations are different for various particles. EP also means that gravitational Compton length of particle is independent of particle's mass.

   Direct calculation [K25] shows that for planets the predicted gravitational Compton length varies has order of magnitude varying from one to two gravitational Compton lengths suggesting that at the level of dark matter planets could be quantum systems. For elementary particles and atom sized objects the values of h_{gr} are in the same range as $h_{eff} = n \times h$ proposed with motivation coming from quantum biology [K10, K17, K6]. $h_{gr} = h_{eff}$ is a natural proposal at least in microscopic scales.

3. The natural assumption is that the astroscopic quantum coherence holds true only for dark matter at the gravitational flux tubes. If dark matter serves as a template for the formation of planets from ordinary matter, the Bohr rules for dark matter apply in reasonable approximation to the visible matter too.

4. One can also consider a model using only Bohr orbitology: in TGD framework the analogs of Bohr rules are expected to hold true at space-time level so that this approach is theoretically justified. If astroscopic quantum coherence due to large values is realized then one can think that planetary space-time sheets correspond to wormhole throats for which M^4projection has astroscopic size. In this framework description in terms of Schrödinger equation need not be appropriate.

The model makes fascinating predictions which hold true. For instance, the radii of planetary orbits fit nicely with the prediction of the hydrogen atom like model. The inner solar system (planets up to Mars) corresponds to v_0 and outer solar system to $v_0/5$.

The predictions for the distribution of major axis and eccentrities have been tested successfully also for exoplanets. Also the periods of 3 planets around pulsar PSR B1257+12 fit with the predictions with a relative accuracy of few hours/per several months. Also predictions for the distribution of stars in the regions where morphogenesis occurs follow from the gravitational Schödinger equation.

What is important is that there are no free parameters besides v_0. In [E31] a wide variety of astrophysical data is discussed and it seem that the model works and has already now made predictions which have been later verified. In the following I shall discuss Nottale's model from the point of view of TGD.

4.1 TGD Based Estimates For The Parameter v_0

One of the basic questions is the origin of the parameter v_0.

1. The original guess was that v_0 [E31] might be a constant of Nature.
2. Second possibility is that v_0 can be deduced from the rotational velocity assignable to the 2-particle system in question by Bohr quantization rule for angular momentum: this is possible using hydrogen atom Bohr rules expressing quantization for angular momentum and mechanical equilibrium. One obtains $v/c = \sqrt{v_0/c}/2\pi n$. For spherical stellar objects one could consider the identification of v_0 with the rotation velocity v of the object obtained quantization of angular momentum and condition $mvR = n\hbar_{gr}$ and $R = k\hbar_{gr}/M$, $k > 0$ integer, to give $v_0/c = v/c = n/k$ and $R = GMk^2/n$.

It was already noticed that the first option could explain the data in solar system assuming Bohr quantization for hydrogen atom but assuming different value of n for inner and outer planets. There are many alternative scenarios however. The following argument was inspired by the idea that v_0 might be a constant of Nature.

One of the first applications of cosmic strings in TGD sense was an explanation of the velocity spectrum of stars in the galactic halo in terms of dark matter which could consists of cosmic strings. Cosmic strings could be orthogonal to the galactic plane going through the nucleus (jets) or they could be in galactic plane in which case the strings and their decay products would explain dark matter assuming that the length of cosmic string inside a sphere of radius R is or has been roughly R [K3]. The predicted value of the string tension is determined by the CP_2 radius whose ratio to Planck length is fixed by electron mass via p-adic mass calculations. The resulting prediction for the v_0 is correct and provides a working model for the constant orbital velocity of stars in the galactic halo.

The parameter $v_0 \simeq 2^{-11}$, which has actually the dimension of velocity unless on puts $c = 1$, and also its harmonics and sub-harmonics appear in the scaling of $\hbar$. v_0 corresponds to the velocity of distant stars in the model of galactic dark matter. TGD allows to identify this parameter as the parameter

$$\begin{aligned} v_0 &= 2\sqrt{TG} = \sqrt{\frac{1}{2\alpha_K}}\sqrt{\frac{G}{R^2}} \ , \\ T &= \frac{1}{8\alpha_K}\frac{\hbar_0}{R^2} \ . \end{aligned} \tag{4.2}$$

Here T is the string tension of cosmic strings, R denotes the "radius" of CP_2 ($2R$ is the radius of geodesic sphere of CP_2). α_K is Kähler coupling strength, the basic coupling constant strength of TGD, whose evolution as a function of p-adic length scale is fixed by quantum criticality. The condition that G is invariant in the p-adic coupling constant evolution and number theoretical arguments predict

$$\begin{aligned} \alpha_K(p) &= k\frac{1}{log(p)+log(K)} \ , \\ K &= \frac{R^2}{\hbar_0 G} = 2\times 3\times 5\times 7\times 11\times 13\times 17\times 19\times 23 \ , \quad k\simeq \pi/4 \ . \end{aligned} \tag{4.3}$$

The predicted value of v_0 depends logarithmically on the p-adic length scale and for $p \simeq 2^{127}-1$ (electron's p-adic length scale) one has $v_0 \simeq 2^{-11}$.

4.2 Model For Planetary Orbits Without $v_0 \rightarrow V_0/5$Scaling

Also harmonics and sub-harmonics of v_0 appear in the model of Nottale and Da Rocha. For instance, the outer planets (Jupiter, Saturn, ...) correspond to $v_0/5$ whereas inner planets correspond to v_0. Quite generally, it is found that the values seem to come as harmonics and sub-harmonics of v_0: $v_n = nv_0$ and v_0/n, and the argument [E31] is that the different values of n relate to fractality. This scaling is not necessary for the planetary orbits in TGD based model.

Effectively a multiplication $n \rightarrow 5n$ of the principal quantum number is in question in the case of outer planets. If one accepts the interpretation that visible matter has concentrated around dark matter, which is in macroscopic quantum phase around Bohr orbits, this allows to consider also the possibility that $\hbar_{gr}$ has the same value for all planets.

1. Some gravitational perturbation has kicked dark matter from the region of the asteroid belt to $n \simeq 5k$, $k = 2,..,6$, orbits. The best fit is obtained by using values of n deviating somewhat from multiples of 5 which suggests that the scaling of v_0 is not needed. Gravitational perturbations might have caused the same for the visible matter. The fact that the tilt angles of Earth and outer planets other than Pluto are nearly the same suggests that the orbits of these planets might be an outcome of some violent quantum process for dark matter preserving the orbital plane in a good approximation. Pluto might in turn have experienced some violent collision changing its orbital plane.

2. There could exist at least small amounts of dark matter at all orbits but visible matter is concentrated only around orbits containing some critical amount of dark matter.

4.2.1 How to understand the harmonics and sub-harmonics of v_0 in TGD framework?

Also harmonics and sub-harmonics of v_0 appear in the model of Nottale and Da Rocha. In particular, the outer planets (Jupiter, Saturn, ...) correspond to $v_0/5$ whereas inner planets correspond to v_0 in this model. As already found, TGD allows also an alternative explanation.

Quite generally, it is found that the values seem to come as harmonics and sub-harmonics of v_0: $v_n = nv_0$ and v_0/n, and the argument [E31] is that the different values of n relate to fractality. This quantization is a challenge for TGD since v_0 certainly defines a fundamental constant in TGD Universe.

1. Consider first the harmonics of v_0. Besides cosmic strings of type $X^2 \times S^2 \subset M^4 \times CP_2$ one can consider also deformations of these strings defining their multiple coverings so that the deformation is n-valued as a function of S^2-coordinates (Θ, Φ) and the projection to S^2 is thus an $n \rightarrow 1$ map. The solutions are higher dimensional analogs of originally closed orbits which after perturbation close only after n turns. This kind of surfaces emerge in the TGD inspired model of quantum Hall effect naturally [K23] and $n \rightarrow \infty$ limit has an interpretation as an approach to chaos [K21].

   Using the coordinates (x, y, θ, ϕ) of $X^2 \times S^2$ and coordinates m^k for M^4 of the unperturbed solution the space-time surface the deformation can be expressed as

Table 2: Table represents the experimental average orbital radii of planets, the predictions of Titius-Bode law (note the failure for Neptune), and the predictions of Bohr orbit model assuming a) that the principal quantum number n corresponds to best possible fit, b) the scaling $v_0 \rightarrow v_0/5$ for outer planets. Option a) gives the best fit with errors being considerably smaller than the maximal error $|\Delta R|/R \simeq 1/n$ except for Uranus. R_M denotes the orbital radius of Mercury. T-B refers to Titius-Bode law.

	Exp.	T-B	Bohr$_1$	Bohr$_2$
Planet	R/R_M	R/R_M	$[n, R/R_M]$	$[n, R/R_M]$
Mercury	1	1	[3, 1]	
Venus	1.89	1.75	[4, 1.8]	
Earth	2.6	2.5	[5, 2.8]	
Mars	3.9	4	[6, 4]	
Asteroids	6.1-8.7	7	[(7, 8, 9), (5.4, 7.1, 9)]	
Jupiter	13.7	13	[11, 13.4]	[2×5, 11.1]
Saturn	25.0	25	[3×5, 25]	[3×5, 25]
Uranus	51.5	49	[22, 53.8]	[4×5, 44.4]
Neptune	78.9	97	[27, 81]	[5×5, 69.4]
Pluto	105.2	97	[31, 106.7]	[6×5, 100]

$$
\begin{aligned}
m^k &= m^k(x,y,\theta,\phi) \ , \\
(\Theta,\Phi) &= (\theta, n\phi) \ .
\end{aligned} \tag{4.4}
$$

The value of the string tension would be indeed n^2-fold in the first approximation since the induced Kähler form defining the Kähler magnetic field would be $J_{\theta\phi} = nsin(\Theta)$ and one would have $v_n = nv_0$. At the limit $m^k = m^k(x,y)$ different branches for these solutions collapse together.

2. Consider next how sub-harmonics appear in TGD framework. Cosmic strings are predicted to decay to magnetic flux tube structures by absolute minimization of Kähler action (, which of course is only one possible identification for what it is to be a preferred extremal). The Kähler magnetic flux $\Phi = BS$ is conserved in the process but the thickness of the M^4 projection of the cosmic string increases field strength is reduced. This means that string tension, which is proportional to B^2S, is reduced (so that also Kähler action is reduced). The fact that space-time surface is Bohr orbit in generalized sense means that the reduced string tension (magnetic energy per unit length) is quantized.

The task is to guess how the quantization occurs. There are two options.

1. The simplest explanation for the reduction of v_0 is based on the decay of a flux tube resembling a disk with a hole to n identical flux tubes so that $v_0 \rightarrow v_0/n$ results for the resulting flux tubes. It turns out that this mechanism is favored and explains elegantly the value of $\hbar_{gr}$ for outer planetary system. One can also consider small-p p-adicity so that n would be prime.

2. Second explanation is more intricate. Consider a magnetic flux tube. Since magnetic flux is quantized, the magnetic field strengths are quantized in integer multiples of basic strength: $B = nB_0$ and would rather naturally correspond to the multiple coverings of the original magnetic flux tube with magnetic energy quantized in multiples of n^2. The idea is to require internal consistency in the sense that the allowed reduced field strengths are such that the spectrum associated with B_0 is contained to the spectrum associated with the quantized field strengths $B_1 > B_0$. This would allow only field strengths $B = B_S/n^2$, where B_S denotes the field strength of the fundamental cosmic string and one would have $v_n = v_0/n$. Flux conservation requires that the area of the flux tube scales as n^2.

Sub-harmonics might appear in the outer planetary system and there are indications for the higher harmonics below the inner planetary system [E31]: for instance, solar radius corresponds to $n = 1$ orbital for $v_3 = 3v_0$. This would suggest that Sun and also planets have an onion like structure with highest harmonics of v_0 and strongest string tensions appearing in the solar core and highest sub-harmonics appearing in the outer regions. If the matter results as decay remnants of cosmic strings this means that the mass density inside Sun should correlate strongly with the local value of n characterizing the multiple covering of cosmic strings.

One can ask whether the very process of the formation of the structures could have excited the higher values of n just like closed orbits in a perturbed system become closed only after n turns. The energy density of the cosmic string is about one Planck mass per $\sim 10^7$ Planck lengths so that $n > 1$ excitation increasing this density by a factor of n^2 is obviously impossible except under the primordial cosmic string dominated period of cosmology during which the net inertial energy density must have vanished. The structure of the future solar system would have been dictated already during the primordial phase of cosmology when negative energy cosmic string suffered a time reflection to positive energy cosmic strings.

4.2.2 Nottale equation is consistent with the TGD based model for dark matter

TGD allows two models of dark matter. The first one is spherically symmetric and the second one cylindrically symmetric. The first thing to do is to check whether these models are consistent with the gravitational Schödinger equation/Bohr quantization.

1. Spherically symmetric model for the dark matter

The following argument based on Bohr orbit quantization demonstrates that this is indeed the case for the spherically symmetric model for dark matter. The argument generalizes in a trivial manner to the cylindrically symmetric case.

1. The gravitational potential energy $V(r)$ for a mass distribution $M(r) = xTr$ (T denotes string tension) is given by

$$V(r) = Gm\int_r^{R_0} \frac{M(r)}{r^2}dr = GmxTlog(\frac{r}{R_0}) \ . \tag{4.5}$$

   Here R_0 corresponds to a large radius so that the potential is negative as it should in the region where binding energy is negative.

2. The Newton equation $\frac{mv^2}{r} = \frac{GmxT}{r}$ for circular orbits gives

$$v = xGT \ . \tag{4.6}$$

3. Bohr quantization condition for angular momentum by replacing $\hbar$ with $\hbar_{gr}$ reads as $mvr = n\hbar_{gr}$ and gives

$$\begin{aligned} r_n &= \frac{n\hbar_{gr}}{mv} = nr_1 \ , \\ r_1 &= \frac{GM}{vv_0} \ . \end{aligned} \tag{4.7}$$

   Here v is rather near to v_0.

4. Bound state energies are given by

$$E_n = \frac{mv^2}{2} - xTlog(\frac{r_1}{R_0}) + xTlog(n) \ . \tag{4.8}$$

   The energies depend only weakly on the radius of the orbit.

5. The centrifugal potential $l(l+1)/r^2$ in the Schrödinger equation is negligible as compared to the potential term at large distances so that one expects that degeneracies of orbits with small values of l do not depend on the radius. This would mean that each orbit is occupied with same probability irrespective of value of its radius. If the mass distribution for the stars does not depend on r, the number of stars rotating around galactic nucleus is simply the number of orbits inside sphere of radius R and thus given by $N(R) \propto R/r_0$ so that one has $M(R) \propto R$. Hence the model is self consistent in the sense that one can regard the orbiting stars as remnants of cosmic strings and thus obeying same mass distribution.

2. Cylindrically symmetric model for the galactic dark matter

TGD allows also a model of the dark matter based on cylindrical symmetry. In this case the dark matter would correspond to the mass of a cosmic string orthogonal to the galactic plane and traversing through the galactic nucleus. The string tension would the one predicted by TGD. In the directions orthogonal to the plane of galaxy the motion would be free motion so that the orbits would be helical, and this should make it possible to test the model. The quantization of radii of the orbits would be exactly the same as in the spherically symmetric model. Also the quantization of inclinations predicted by the spherically symmetric model could serve as a sensitive test. In this kind of situation general theory of relativity would predict only an angle deficit giving rise to a lens effect. TGD predicts a Newtonian $1/\rho$ potential in a good approximation.

Spiral galaxies are accompanied by jets orthogonal to the galactic plane and a good guess is that they are associated with the cosmic strings. The two models need not exclude each other. The vision about astrophysical structures as pearls of a fractal necklace would suggest that the visible matter has resulted in the decay of cosmic strings originally linked around the cosmic string going through the galactic plane and creating $M(R) \propto R$ for the density of the visible matter in the galactic bulge. The finding that galaxies are organized along linear structures [E69] fits nicely with this picture.

4.2.3 MOND and TGD

TGD based model explains also the MOND (Modified Newton Dynamics) model of Milgrom [E54] for the dark matter. Instead of dark matter the model assumes a modification of Newton's laws. The model is based on the observation that the transition to a constant velocity spectrum seems in the galactic halos seems to occur at a constant value of the stellar acceleration equal to $a_0 \simeq 10^{-11}g$, where g is the gravitational acceleration at the Earth. MOND theory assumes that Newtonian laws are modified below a_0.

The explanation relies on Bohr quantization. Since the stellar radii in the halo are quantized in integer multiples of a basic radius and since also rotation velocity v_0 is constant, the values of the acceleration are quantized as $a(n) = v_0^2/r(n)$ and a_0 correspond to the radius $r(n)$ of the smallest Bohr orbit for which the velocity is still constant. For larger orbital radii the acceleration would indeed be below a_0. a_0 would correspond to the distance above which the density of the visible matter does not appreciably perturb the gravitational potential of the straight string. This of course requires that gravitational potential is that given by Newton's theory and is indeed allowed by TGD.

The MOND theory (see `http://tinyurl.com/qt875`) [E54] and its variants predict that there is a critical acceleration below which Newtonian gravity fails. This would mean that Newtonian gravitation is modified at large distances. String models and also TGD predict just the opposite since in this regime General Relativity should be a good approximation.

1. The $1/r^2$ force would transform to $1/r$ force at some critical acceleration of about $a = 10^{-10}$ m/s^2: this is a fraction of 10^{-11} about the gravitational acceleration at the Earth's surface.

2. The recent empirical study (see `http://tinyurl.com/ychyy3z3`) [E48] giving support for this kind of transition in the dynamics of stars at large distances and therefore breakdown of Newtonian gravity in MOND like theories.

In TGD framework critical acceleration is predicted but the recent experiment does not force to modify Newton's laws. Since Big Science is like market economy in the sense that funding is more important than truth, the attempts to communicate TGD based view about dark matter [K10, K18, K14, K19, K3] have turned out to be hopeless. Serious Scientist does not read anything not written on silk paper.

1. One manner to produce this spectrum is to assume density of dark matter such that the mass inside sphere of radius R is proportional to R at last distances [K3]. Decay products of and ideal cosmic strings (see `http://tinyurl.com/y8wbeo4q`) would predict this. The value of the string tension predicted correctly by TGD using the constraint that p-adic mass calculations give electron mass correctly [K13].

2. One could also assume that galaxies are distributed along cosmic string like pearls in necklace. The mass of the cosmic string would predict correct value for the velocity of distant stars. In the ideal case there would be no dark matter outside these cosmic strings.

   (a) The difference with respect to the first mechanism is that this case gravitational acceleration would vanish along the direction of string and motion would be free motion. The prediction is that this kind of motions take place along observed linear structures formed by galaxies and also along larger structures.

   (b) An attractive assumption is that dark matter corresponds to phases with large value of Planck constant is concentrated on magnetic flux tubes. Holography would suggest that the density of the magnetic energy is just the density of the matter condensed at wormhole throats associated with the topologically condensed cosmic string.

   (c) Cosmic evolution modifies the ideal cosmic strings and their Minkowski space projection gets gradually thicker and thicker and their energy density - magnetic energy - characterized by string tension could be affected

TGD option differs from MOND in some respects and it is possible to test empirically which option is nearer to the truth.

1. The transition at same critical acceleration is predicted universally by this option for all systems-now stars- with given mass scale if they are distributed along cosmic strings like like pearls in necklace. The gravitational acceleration due the necklace simply wins the gravitational acceleration due to the pearl. Fractality encourages to think like this.

2. The critical acceleration predicted by TGDr depends on the mass scale as $a \propto GT^2/M$, where M is the mass of the object- now star. Since the recent study considers only stars with solar mass it does not allow to choose between MOND and TGD and Newton can continue to rest in peace in TGD Universe. Only a study using stars with different masses would allow to compare the predictions of MOND and TGD and kill either option or both. Second test distinguishing between MOND and TGD is the prediction of large scale free motions by TGD option.

TGD option explains also other strange findings of cosmology.

1. The basic prediction is the large scale motions of dark matter along cosmic strings. The characteristic length and time scale of dynamics is scaled up by the scaling factor of $\hbar$. This could explain the observed large scale motion of galaxy clusters - dark flow (see `http://tinyurl.com/ckfg25`) [E3] - assigned with dark matter in conflict with the expectations of standard cosmology.

2. Cosmic strings could also relate to the strange relativistic jet like structures (see `http://tinyurl.com/2x5od6`) [E17] meaning correlations between very distant objects. Universe would be a spaghetti of cosmic strings around which matter is concentrated.

3. The TGD based model for the final state of star (see `http://tinyurl.com/yantmeot`) [K22] actually predicts the presence of string like object defining preferred rotation axis. The beams of light emerging from supernovae would be preferentially directed along this lines- actually magnetic flux tubes. Same would apply to the gamma ray bursts (see `http://tinyurl.com/csd2an`) [E6] from quasars, which would not be distributed evenly in all directions but would be like laser beams along cosmic strings.

4.3 The Challenge Of Six Planets

NASA has published the first list of exoplanets found by Kepler satellite. In particular, the NASA team led by Jack Lissauer reports a discovery of a system of six closely packed planets (see `http://tinyurl.com/66vn9k9`) [E2] around a Sun-like star christened as Kepler-11_a located in the direction of constellation Cygnus at distance of about 2000 light years. The basic data about the six planets Kepler-11_i, $i = b, c, d, e, f, g$ and star Kepler-11_a can be found in Wikipedia (see `http://tinyurl.com/y8exe44b`). Below I will refer to the star by Kepler-11 and planets with label $i = b, c, d, e, f, g$. Lissauer regards it as quite possible that there are further planets at larger distances. The fact that the radius of planet g is only.462AU together with what we know about solar system suggests that this could be be the case. This leaves door for Earth like planet.

4.3.1 The conclusions from the basic data

Let us list the basic data.

1. The radius and mass and surface temperature of Kepler-11 are very near to those of Sun.

2. The orbital radii using AU as unit are given by

$$(.091, .106, .159, .194, .250, .462) \ .$$

   The orbital radii can be deduced quite accurately from the orbital periods by using Kepler's law stating that the squares of periods are proportional to cubes of orbital radii.The orbital periods of the five inner planets are between 10 and 47 days whereas g has a longer period of 118.37774 days (note the amazing accuracy). The orbital radii of e and f are.194 AU and.250 AU so that the temperature is expected to be much higher than at Earth so that life as we know it is not expected to be there. The average temperature of the radiation from Kepler-11 scaling as $1/r^2$ would be 4 times the temperature at Earth. The fact that gas forms a considerable fraction of the planet's mass could however mean that this does not give a good estimate for the temperature of the planet.

3. The mass estimates using Earth mass as unit are

$$(4.3, 13.5, 6.1, 8.4, 2.3, \leq 300) \ .$$

   There are considerable uncertainties involved here, of order factor of 1/2.

4. The estimates for the radii of the planets using the radius of Earth as unit are

$$(1.97, 3.15, 3.43, 4.52, 2.61, 3.66) \ .$$

   The uncertainties are about 20 per cent.

5. From the estimates for the radii and mass estimates one can conclude that the estimates for the densities of the planets are considerably lower than those for Earth. Density of (e, f) is about $(1/8, 1/4)$ of that for Earth. The surface gravitation for e and f is roughly 1/2 of that at Earth. For g it is same as for Earth if g has mass roughly $m(g) \simeq 15$. The upper bound $m(g) \leq 300$ implies that surface gravity is weaker than $20g$ for g.

The basic conclusions from the Wikipedia data are following. One cannot exclude the possibility that the planetary system could contain Earth like planets. Furthermore, the distribution of the orbital radii of the planets differs dramatically from that in solar system.

4.3.2 How to understand the tight packing of the inner planets?

The striking aspect of the planetary system is how tightly packed it is. The ratio for the radii of g and b is about 5. This is a real puzzle for model builders(see `http://tinyurl.com/y7xtog56`). TGD suggests three phenomenological approaches.

1. Titius-Bode law (see `http://tinyurl.com/3cum7h7`)

$$r(n) = r_0 + 2^n r_1$$

is supported by p-adic length scale hypothesis. Stars would have onion-like structure consisting of spherical shells with inner and outer radii of the shell differing by factor two. The formation of planetary system involves condensation of matter to planets at these spherical shells. The preferred extremals of Kähler action describing stationary axially symmetric system corresponds to spherical shells containing most of the matter. A rough model for star would be in terms of this kind of spherical shells defined an onion-like structure defining a hierarchy of space-time sheets topologically condensed on each other. The value of the parameter r_0 could be vanishing in the initial situation but subsequent gravitational dynamics could make it positive reducing the ratio $r(n)/r(n-1)$ from its value 2.

2. Bohr orbitology suggested by the proposal that gravitonic space-time sheets assigned with a given planet-star pair correspond to a gigantic value of gravitational Planck constant given by

$$\hbar_{gr} = \frac{GMm}{v_0} \ ,$$

where v_0 has dimensions of velocity and actually equal to the orbital velocity for the lowest Bohr orbit. For inner planets in solar system one has $v_0/c \simeq 2^{-11}$.

The physical picture is visible matter concentrates around dark matter and in this matter makes it astroscopic quantum behavior visible. The model is extremely predictive since the spectrum of orbital radii would depend only on the mass of the star and planetary systems would be much like atoms with obvious implications for the probability of Earth like systems supporting life. This model is consistent with the Titius-Bode model only if the Bohr orbitology is a late-comer in the planetary evolution.

3. The third model is based on same general assumptions as the second one but only assumes that dark matter in astrophysical length scales associated with anyonic 2-surfaces (with light-like orbits in induced metric in accordance with holography) characterized by the value of the gravitational Planck constant. In this case the hydrogen atom inspired Bohr orbitology is just the first guess and cannot be taken too seriously. What would be important would be genuinely quantal dynamics for the formation of planetary system.

Can one interpret the radii in this framework in any reasonable manner?

1. Titius-Bode predicts

$$\frac{r(n) - r(n-1)}{r(n-1) - r(n-2)} = 2 \ ,$$

which works excellently for c, f, and g. For b, d and e the law fails. This suggests that the four inner planets a, b, c, d, whose radii span single 2-adic octave in good approximation (!) correspond to single system which has split from single plane or will fuse to single planet distant future.

2. Hydrogenic Bohr orbitology works only if g corresponds to $n = 2$ orbit. $n = 1$ orbit would have radius.116AU. From the proportionality $r \propto \hbar_{gr}^2 \propto 1/v_0^2$, one obtains that the value one must have

$$R \equiv \frac{v_0^2(Kepler)}{v_0^2(Sun)} \simeq 3.04 \ .$$

This would result as in reasonable approximation for $v_0(Kepler)/v_0(Sun) = 7/4$ (the values of Planck constant are predicted to integer multiples of the standard value) giving $R = 7/4^2 \simeq 3.06$.

Note that the planets would correspond to those missing in Earth-Sun system for which one has $n = 3, 4, 5$ for the inner planets Mercury, Venus, Earth.

One could argue that Bohr orbits result as the planets fuse to two planets at these radii. This picture is not consistent with Titius-Bode law which predicts three planets in the final situation unless $n = 2$ planet remains unrealized. By looking the graphical representation of the orbital radii (see `http://tinyurl.com/y8exe44b`) of the planet system one has tendency to say that b, c, d, e, and f form a single subsystem and could eventually collapse to single planet. The ratio of gravitational forces between g and f is larger than that between f and e for $m(g) \geq 6m_E$ so that one can ask whether f could be eventually caught be g in this case. Also the fact that one has $r(g)/r(f) \leq 2$ mildly suggests this.

5 Further Indications For Dark Matter

The notion of many-sheeted space-time (see **Fig.** `http://tgdtheory.fi/appfigures/manysheeted.jpg` or **Fig.** 9 in the appendix of this book) has been continually receiving qualitative support from various anomalies. In the following some candidates for anomalies are summarized briefly.

5.1 Some Anomalies

5.1.1 New dark matter anomaly

One of the most radical parts of quantum TGD is the view about dark matter as a hierarchy of phases of matter with varying values of Planck constant realized in terms of generalization of the 8-D imbedding space to a book like structure. The latest blow against existing models of dark matter is the discovery of a new strange aspect of dark matter discussed in New Scientist popular article "Galaxy study hints at cracks in dark matter theories" [E61]. The original article in Nature is titled as *Universality of galactic surface densities within one dark halo scale-length* [E42]. I glue here a short piece of the New Scientist article.

A galaxy is supposed to sit at the heart of a giant cloud of dark matter and interact with it through gravity alone. The dark matter originally provided enough attraction for the galaxy to form and now keeps it rotating. But observations are not bearing out this simple picture.

Since dark matter does not radiate light, astronomers infer its distribution by looking at how a galaxy's gas and stars are moving. Previous studies have suggested that dark matter must be uniformly distributed within a galaxy's central region - a confounding result since the dark matter's gravity should make it progressively denser towards a galaxy's centre.

Now, the tale has taken a deeper turn into the unknown, thanks to an analysis of the normal matter at the centres of 28 galaxies of all shapes and sizes. The study shows that there is always five times more dark matter than normal matter where the dark matter density has dropped to one-quarter of its central value.

In TGD framework both dark energy and dark matter are assumed to correspond to dark matter but with widely different values of Planck constant. The point is that very large value of Planck constant for dark matter implies that its density is in an excellent approximation constant as is also the density of dark energy. Effective value of Planck constant is indeed predicted to be gigantic at the space-time sheets mediating gravitational interaction. It must be however emphasized that the huge value of the gravitational Planck constant h_{gr} suggests that it can have different origin that that associated with the hierarchy of Planck constant: I have discussed this possibility in [K18].

The appearance of number five as a ratio of mass densities sounds mysterious. Why the average mass in a large volume should be proportional to $\hbar$ if $\hbar$ is not too large? Intriguingly, number five appears also in the Bohr model for planetary orbits. The value of the gravitational Planck constant $\hbar_{gr} = GMm/v_0$ assignable to the space-time sheets mediating gravitational interaction between planet and star is gigantic: $v_0/c \simeq 2^{-11}$ holds true inner planets. For outer planets v_0/c is by a factor 1/5 smaller so that corresponding gravitational Planck constant is 5 times larger. Do these two fives represent a mere coincidence?

1. In accordance with TGD inspired cosmology suppose that visible matter and also the matter which is conventionally called dark matter has emerged from the decay and widening of

cosmic strings to magnetic flux tubes. Assume that the string tension can be written as $k \times \hbar/G$, k a numerical constant.

2. Suppose that the values of $\hbar$ come as pairs $\hbar = n \times \hbar_0$ and $5 \times \hbar$. Suppose also that for a given value of $\hbar$ the length of the cosmic string (if present at all) inside a sphere or radius R is given by $L = x(n)R$, $x(n)$ a numerical constant which can depend on the pair but is same for the members of the pair $(\hbar, 5 \times \hbar)$. This assumption is supported by the velocity curves of distant stars around galaxies.

3. These assumptions imply that the masses of matter for a pair $(\hbar, 5 \times \hbar)$ corresponding to a given value of $\hbar$ in a volume of size R are given by $M(\hbar) = k \times x(\hbar) \times \hbar \times R/G$ and $M(5 \times \hbar) = 5 \times M(\hbar)$. This would explain the finding if visible matter corresponds to $\hbar_0$, and $x(n)$ is much smaller for pairs $(n > 1, 5 \times n)$ than for the pair $(1, 5)$.

4. One can explain the pairing in TGD framework. Let us accept the earlier hypothesis that the preferred values of $\hbar$ correspond to number theoretically maximally simple quantum phases $q = exp(i2\pi/n)$ emerging first in the number theoretical evolution having a nice formulation in terms of algebraic extensions of rationals and p-adics and the gradual migration of matter to the pages of the book like structure labeled by large values of Planck constant. These number theoretically simple quantum phases correspond to n-polygons drawable by ruler and compass construction. This predicts that the preferred values of $\hbar$ correspond to a power of 2 multiplied by a product of Fermat primes $F_k = 2^{2^k} + 1$. The list of known Fermat primes is short and given by $F_k, k = 0, 1, 2, 3, 4$ giving the Fermat primes $3, 5, 17, 257, 2^{16} + 1$. This hypothesis indeed predicts that Planck constants $\hbar$ and $5 \times \hbar$ appear as pairs.

5. Why the pair $(1, F_1 = 5)$ should be then favored? Could the reason be that $n = 5$ corresponds also to the smallest integer making possible universal topological quantum computer: the quantum phase $q = exp(i2\pi/5)$ characterizes the braiding coding for the topological quantum computer program. Or is the reason simply that this pair corresponds to the number theoretically simplest pair which must have emerged first in the number theoretic evolution?

6. This picture supports the view that ordinary matter and most what is usually called dark matter are characterized by Planck constants $\hbar_0$ and $5 \times \hbar_0$, and that the space-time sheets mediating gravitational interaction correspond to dark energy because the density of matter at these space-time sheets must be constant in an excellent approximation since Compton lengths are so gigantic.

7. Using the fact that 4 per cent of matter is visible this means that $n = 5$ corresponds to 20 per cent of dark matter in standard sense. Pairs $(n > 1, 5n)$ should contribute the remaining 2 per cent of dark matter. The fractal scaling law $x(n) \propto 1/n^r$ allowing pairs defined by all Fermat integers not divisible by 5 would give for the mass fraction of conventional dark matter with $n > 1$ the expression

$$p = 6 \times \sum_k 2^{-kr}[2^{-r} + \sum n_F^{-r}] \times \frac{4}{100} = \frac{24}{100} \times \frac{1}{1 - 2^{-r}} \times [2^{-r} + \sum n_F^{-r}] \ .$$

Here n_F denotes a Fermat integer which is product of some Fermat primes in the set $\{3, 17, 257, 2^{16} + 1\}$. The contribution from $n = 2^k$, $k > 0$, gives the term not included to the sum over n_F. $r = 4.945$ predicts $p = 2.0035$ and that the mass density of dark matter would scale down as $1/\hbar^{r-1} = 1/\hbar^{3.945}$.

8. The prediction brings in mind the scaling $1/a^{r-1}$ for the cosmological mass density. a^{-4} scaling for radiation dominated cosmology is very near to this scaling. $r = 5$ (sic!) would predict $p = 1.9164$ which is of course consistent with the data. This inspires the working hypothesis that the density of the dark matter as function of $\hbar$ scales just like the density of matter as function of cosmic time during particular epoch. In matter dominated cosmology with mass density behaving as $1/a^3$ one would have $r = 4$ and $p = 4.4502$ and in asymptotic cosmology with mass density behaving as $1/a^2$ (according to TGD) one would have $r = 3$ and $p = 11.68$.

9. Living systems would represent a deviation from the "fractal thermodynamics" for $\hbar$ since for the typical values of $\hbar$ associated with the magnetic bodies in living systems (say $\hbar = 2^{44}\hbar_0$ for EEG to guarantee the energies of EEG photons are above the thermal threshold) the density of the dark matter would be extremely small. Bio-rhythms are assumed to come as powers of 2 in the simplest model for the bio-system: the above considerations raise the question whether these rhythms could be accompanied by 5-multiples and perhaps also by Fermat integer multiples. For instance, the fundamental 10 Hz alpha frequency could be accompanied by 2 Hz frequency and the 40 Hz thalamocortical resonance frequency by 8 Hz frequency.

This model is an oversimplification obtained by assuming only singular coverings of CD. In principle both coverings and factor spaces of both CD and CP_2 are possible. If singular covering of both CP_2 and M^4 is involved and if one has $n = 5$ for both then the ratio of mass densities is 1/25 or about 4 per cent. This equals to the experimental ratio of about 4 per cent of the density of visible matter to the density of ordinary, dark matter and dark energy. I interpret this as an accident: dark energy can correspond to dark matter only if the Planck constant is very large and a natural place for dark energy is at the space-time sheets mediating gravitational interaction.

Some further observations about number five are in order. The angle $2\pi/5$ relates closely to Golden Mean appearing almost everywhere in biology. $n = 5$ makes itself manifest also in the geometry of DNA (the twist per single nucleotide is $\pi/5$ and aromatic 5-cycles appear in DNA nucleotides). Could it be that electron pairs associated with aromatic rings correspond to $\hbar = 5\times\hbar_0$ as I have proposed? Note that DNA as topological quantum computer hypothesis plays a key role in TGD inspired quantum biology.

5.1.2 The planet that should not exist

There is an interesting news story about an exoplanet that should not exist [E24]. The exoplanet is so called hot-Jupiter and so close to its Sun that it should have been torn by pieces by tidal forces and spiralled long ago to the Sun. For some reason this has not happened. The abstract of the article gives a more quantitative view about the discovery.

The "hot Jupiters" that abound in lists of known extrasolar planets are thought to have formed far from their host stars, but migrate inwards through interactions with the proto-planetary disk from which they were born, or by an alternative mechanism such as planet-planet scattering. The hot Jupiters closest to their parent stars, at orbital distances of only approximately 0.02 astronomical units, have strong tidal interactions and systems such as OGLE-TR-56 have been suggested as tests of tidal dissipation theory. Here we report the discovery of planet WASP-18b with an orbital period of 0.94 days and a mass of ten Jupiter masses (10 M Jup), resulting in a tidal interaction an order of magnitude stronger than that of planet OGLE-TR-56b. Under the assumption that the tidal-dissipation parameter Q of the host star is of the order of 106, as measured for Solar System bodies and binary stars and as often applied to extrasolar planets, WASP-18b will be spiralling inwards on a timescale less than a thousandth that of the lifetime of its host star. Therefore either WASP-18 is in a rare, exceptionally short-lived state, or the tidal dissipation in this system (and possibly other hot-Jupiter systems) must be much weaker than in the Solar System.

The finding brings in mind more than hundred year old problem: why the electron orbiting atom did not spiral into atomic nucleus? The solution of the puzzle was provided by the discovery of quantum theory. The postulate was that electron moves on Bohr orbits and can make only transitions between the Bohr orbits emitting light in these transitions. There is minimum value for the radius of Bohr orbit. Later wave mechanism emerged from Bohr model.

TGD view about dark matter suggests an analogous solution to the astrophysical variant of this puzzle. Planets correspond to Bohr orbits but for a gigantic value of Planck constant whose value is dictated by Equivalence Principle to high degree. This Planck constant could be assigned to the space-time sheet mediating gravitational interaction or even with matter. This means astroscopic quantum coherence and the interpretation is that astroscopic quantum coherence is associated with dark matter around which visible matter condenses and makes in this manner visible the quantum character of dark matter. That the planet does not spiral to the star means smallness of dissipation and this is guaranteed by the large value of $\hbar$. The naive estimate is that dissipation rate is proportional to the inverse of $\hbar$ and anomalously small dissipation in astrophysical scales is basic prediction of quantum astrophysics. Also Mars-Phobos forms a similar mysterious system and the explanation would be the same.

A more refined view about the situation is in terms of light-like 3-surfaces, which are basic dynamical objects in quantum TGD. At elementary particle level their size is about CP_2 size (about 10^4 Planck lengths). Also macroscopic and even astroscopic sizes are possible and this would be the case for dark matter for which Planck constant and thus also quantum scales are scaled up. Note that light-like 3-surfaces are boundaries between regions of space-time with Euclidian and Minkowskian signature of metric. The recent TGD inspired vision about Universe is as a kind of Indra's net formed by light-like 3-surfaces appearing in all length scales and having extremely complex topology. Quantum Hall Effect is described in terms of macroscopic light-like 3-surfaces in [K15] and it is suggested that this kind of anyonic phases are realized also in astrophysical scales for dark matter. In this framework it is not necessary to Bohr rules are replaced by quantization rules for the light-like 3-surfaces satisfied by the preferred extremals of Kähler action and expressing quantum criticality.

Amusingly, the counterpart of Planck length scaling as $(\hbar G)^{1/2}$ is apart from numerical constant equal to $v_0^{-1/2}GM$ ($2GM$ is Schwarschild radius) if one assumes that $\hbar = GM^2/v_0$ is associated with an astrophysical system with mass M: $v_0/c \simeq 2^{-11}$ holds true for the gravitational space-time sheets mediating gravitational interaction between inner planets and Sun in the solar system. Planck length would be few orders of magnitude larger than Schwartscild radius so that Planck scale physics would be scaled up to astrophysical length scale. Black-hole entropy which is proportional to $1/\hbar$ is of order unity and would be extremely small for the ideally dark black-hole if this picture is correct. This looks strange. If one accepts the proposal that the hierarchy of Planck constants is implied by the basic TGD so that only covering spaces of $CD \times CP_2$ are possible [K14, K10], the natural interpretation of the scaled down blackhole entropy is as the entropy for single sheet of the covering. The total entropy would be given by the standard formula since the number of sheets is given by $\hbar/\hbar_0 = n_a n_b$. This would suggest that entropy serves as a control variable in the sense that when it exceeds the threshold value, the partonic 2-surfaces at the ends of CD split to a surfaces in the covering. Second law suggests the increase of the Planck constant not only for blackholes but quite generally. One the other hand, large values of Planck constant mean failure of second law below the time scale defined by the Planck constant so that the increase of entropy and evolution would accompany each other.

5.1.3 First dark matter galaxy found?

The propose model for dark matter suggests an existence of dark matter planets and even dark matter galaxies. Therefore the news about finding of the first dark galaxy in New Scientist [E5] came as a pleasant surprise. The galaxy is located at a distance of 10^7 light years. It contains 1 per cent hydrogen gasand99 per cent dark matter and is identified by 21 cm hydrogen line: hence the name VIRGOH21. The amount of dark matter counts as 10^8 average stars.

5.1.4 Anomalous chemical compositions at the surface of Sun as evidence for dark matter

Physics in Action, February 2005 contained the popular article "Chemical Controversy at the Solar Surface" by J. Bahcall in Physics in Action [E50]. The article describes the problems created by results reported in the article "The Solar Chemical Decomposition" by M. Asplund, N. Grevesse, J. Sauval [E21]. The abundances of C, N, O, Ne, Ar at the solar surface are about 30-40 per cent less than predicted by the standard solar model. If these abundances are fed into the standard solar model as input the predictions change in the range $.45R - .73R$ of distances from solar interior (R is solar radius). In particular, sound velocity is predicted incorrectly. Interestingly, these abundances are consistent with the abundances in the gaseous medium in the neighborhood of our galaxy.

In TGD framework a possible solution of the paradox comes from already old model of solar corona and solar magnetic field. Part of matter resides as dark matter at magnetic and Z^0 magnetic flux tubes of Sun (dark energy) and enters to the solar corona along these. That also gaseous medium in the neighborhood of our galaxy contains same abundances suggests that the formation of Sun has proceeded by a transformation of part of dark matter to a visible matter by leakage to space-time sheets visible to us. This is indeed what TGD inspired model for the formation of solar system based on quantal dark matter suggests.

5.1.5 Does Sun have a solid surface?

$n = 1$ Bohr orbit corresponds in a reasonable approximation to $L(276)/9 \simeq L(270)$ and thus to solar radius. This raises the question whether solar surface could contain spherical shell representing a topological condensate of dense matter around dark matter, kind of spherical preform of planet below the photosphere.

Recently new satellites have begun to provide information about what lurks beneath the photosphere. The pictures produced by Lockheed Martin's Trace Satellite and YOHKOH, TRACE and SOHO satellite programs are publicly available in the web. SERTS program for the spectral analysis suggest a new picture challenging the simple gas sphere picture [E55]. The visual inspection of the pictures combined with spectral analysis has led Michael Moshina to suggests that Sun has a solid, conductive spherical surface layer consisting of calcium ferrite. The article of [E55] [E55] provides impressive pictures, which in my humble non-specialist opinion support this view. Of course, I have not worked personally with the analysis of these pictures so that I do not have the competence to decide how compelling the conclusions of Moshina are. In any case, I think that his web article [E55] deserves a summary.

Before SERTS people were familiar with hydrogen, helium, and calcium emissions from Sun. The careful analysis of SERTS spectrum however suggest the presence of a layer or layers containing ferrite and other heavy metals. Besides ferrite SERTS found silicon, magnesium, manganese, chromium, aluminum, and neon in solar emissions. Also elevated levels of sulphur and nickel were observed during more active cycles of Sun. In the gas sphere model these elements are expected to be present only in minor amounts. As many as 57 different types of emissions from 10 different kinds of elements had to be considered to construct a picture about the surface of the Sun.

Moshina has visually analyzed the pictures constructed from the surface of Sun using light at wave lengths corresponding to three lines of ferrite ions (171, 195, 284 Angstroms). On basis of his analysis he concludes that the spectrum originates from rigid and fixed surface structures, which can survive for days. A further analysis shows that these rigid structures rotate uniformly.

The existence of a rigid structure idealizable as spherical shell in the first approximation could by previous observation be interpreted as a spherical shell corresponding to $n = 1$ Bohr orbit of a planet not yet formed. This structure would already contain the germs of iron core and of crust containing Silicon, Caandother elements.

There is also another similar piece of evidence [E57]. A new planet has been discovered orbiting around a star in a triple-star system in the constellation Cygnus. The planet is a so-called hot Jupiter but it orbits the parent star at distance of.05 AU, which much less that than allowed by current theories of planetary formation. Indeed, the so called migration theory predicts that the gravitational pull of the two stars should have stripped away the proto-planetary disk from the parent star. If an underlying dark matter structure serves as a condensation template for the visible matter, the planetary orbit is stabilized by Bohr quantization.

There is however a problem: ordinary iron and also ordinary iron topologically condensed at dark space-time sheets, becomes liquid at temperature 1811 K at atmospheric pressure. Using for the photospheric pressure p_{ph}, the ideal gas approximation $p_{ph} = n_{ph}T_{ph}$, the values of photospheric temperature $T_{ph} \sim 5800$ K and density $\rho_{ph} \sim 10^{-2}\rho_{atm}$, and idealizing photosphere as a plasma of hydrogen ions and atmosphere as a gas of O_2 molecules, one obtains $n_{ph} \sim .32n_{atm}$ giving $p_{ph} \sim 6.4p_{atm}$. This suggests that calcium ferrite cannot be solid at temperatures of order 5800 K prevailing in the photosphere (the material with highest known melting temperature is graphite with melting temperature of 3984 K at atmospheric pressure). Thus it would seem that dark calcium ferrite at the surface of the Sun cannot be just ordinary calcium ferrite at dark space-time sheets.

The following explanation for the solid surface is perhaps the simplest one found hitherto. Since the atomic energy spectrum is unaffected it seems that $n_a = n_b = 1$ holds true and the radii of Bohr orbitals are scaled up by the factor $n_a^2/n_b = n_a$. If the density of dark matter is roughly the same as that of ordinary matter, the larger size of atoms suggests that melting temperature must be higher than for ordinary matter. Ordinary photons would result via dark-visible phase transition from dark photons emitted by these atoms. Quite generally, spectral lines of molecules in environments in which they should not be thermally stable, would serve as a signature of dark matter with $n_a/n_b = 1$.

5.1.6 How to create dark matter in laboratory...

The creation of dark matter at laboratory is of course the crucial test. The hints for what to do come already from the findings of Tesla, which did not fit completely with Maxwell's electrodynamics (, which, using M-theory inspired jargon, had become "the only known classical theory of electromagnetism") and were thus forgotten.

To transform visible matter to dark matter in laboratory one might try to generate conditions in which visible matter leaks to larger space-time sheets. What one could try is to generate pulsed current of electrons. For instance, current could flow to a circuit component acting as a charge reservoir. When the circuit is opened, and current cannot leave the charge reservoir, a situation analogous to a traffic jam occurs and some electrons might leak to larger space-time sheets via flux tubes generated in the process. Di-electric breakdown along larger space-time sheet would be in question. Recoil effects and zero point kinetic energy liberated as ionizing radiation would serve as a signature of the process. The production of dark matter might occur also in the usual di-electric breakdown and lead to the appearance of electrons in much larger volume after it partially re-enters original space-time sheets. The change of zero point kinetic energy would be liberated as radiation and would cause formation of plasma. Tesla detected dramatic effects of this kind in experiments utilizing sharp pulses.

5.1.7 ..or has it already been done?

In their article "Investigation of high voltage discharges in low pressure gases through large ceramic super-conducting electrodes", Modanese and [H2] [H1] report a fascinating discovery suggesting that some new form of radiation is generated in the di-electric breakdown of a capacitor at low temperature and having super-conductor as a second electrode. This radiation induces oscillatory motion of test penduli but, and this is very strange, its intensity is not reduced with distance.

The TGD based explanation [K7] would be in terms of either "topological light rays" or what I call in honor of Tesla "scalar wave pulses" (much like a capacitor moving with velocity of light predicted by TGD but not allowed by Maxwell's ED). This radiation would induce the formation of flux tubes between atomic and larger space-time sheets and part of electrons from penduli would leak to larger space-time sheets and their motion would result as a recoil effect. The radiation would have only the role of control signal and this would explain why its intensity is not weakened.

From the point of view of single sheeted space-time an over-unity device would be in question since the zero point kinetic energy would be transformed to kinetic energy. The transformation of visible matter to dark matter is in TGD Universe the basic mechanism of metabolism predicting universality of metabolic energy currencies and living matter in TGD Universe has developed a refined machinery to recycle the dropped charges back to the atomic space-time sheets to be used again. Combined with time mirror mechanism (see **Fig.** `http://tgdtheory.fi/appfigures/timemirror.jpg` or **Fig. ??** in the appendix of this book) this makes, not a perpetuum mobile, but an extremely flexible mechanism of metabolism.

5.2 Anti-Matter And Dark Matter

The usual view about matter anti-matter asymmetry is that during early cosmology matter-antimatter asymmetry characterized by the relative density difference of order $r = 10^{-9}$ was somehow generated and that the observed matter corresponds to what remained in the annihilation of quarks and leptons to bosons. A possible mechanism inducing the CP asymmetry is based on the CP breaking phase of CKM matrix.

The TGD based view about energy [K22, K19] forces the conclusion that all conserved quantum numbers including the conserved inertial energy have vanishing densities in cosmological length scales. Therefore fermion numbers associated with matter and antimatter must compensate each other. Therefore the standard option as such is definitely excluded in TGD framework although CKM matrix might well relate to the generation of matter antimatter asymmetry as discussed in [K11].

An early TGD based scenario explains matter antimatter asymmetry by assuming that antimatter is in topological vapor phase. This requires that matter and antimatter have slightly different topological evaporation rates with the relative difference of rates characterized by the parameter r. A more general scenario assumes that matter and antimatter reside at different space-time sheets.

The reader can easily guess the next step. The strict non-observability of antimatter finds an elegant explanation if matter and anti-matter are dark relative to each other. For instance, the masses of particles of antimatter could be scaled down so that antimatter could be practically everywhere without appreciably affecting the density of gravitational mass.

The matter antimatter asymmetry should be generated during cosmic evolution already before the formation of nucleons during the primordial synthesis of matter and antimatter. The number theoretical model for topological condensation based on formation of # contacts between space-time sheets of opposite time orientations (and thus opposite signs for energies) leads to a more detailed view about what might happen.

contacts can be modeled as CP_2 type extremals which simultaneously topologically condense to the two space-time sheets with Minkowskian signature of induced metric. The resulting two causal horizons are carriers of elementary particle quantum numbers and are identifiable as partons. The # contacts with vanishing net quantum numbers could be generated spontaneously and the splitting of # contact would create positive particle and negative energy particle at the two space-time sheets involved. The requirement that the net quantum numbers of Universe vanish is consistent with this kind of pairing of positive and negative energy space-time sheets.

Number theoretical vision [K11, K20] leads to a vision in which elementary particles correspond to infinite primes, perhaps also integers, or even rationals which in turn can be mapped to finite rationals. To infinite primes, integers, and rationals is is possible to associate a finite rational $q = m/n$ by a homomorphism. q defines an effective q-adic topology of space-time sheet consistent with p-adic topologies defined by the primes dividing m and n ($1/p$-adic topology is homeomorphic to p-adic topology).m and n are exchanged by super-symmetry and the primes dividing m (n) correspond to space-time sheets with positive (negative) time orientation. The largest prime dividing m (n) determines the mass scale of the space-time sheet in p-adic thermodynamics. Two space-time sheets characterized by rationals having common prime factors can be connected by a $\#_B$ contact and can interact by exchange of particles characterized by divisors of m or n. Thus fundamental topological selection rules would be coded by the hierarchy of infinite primes.

A possible interpretation is that particle (in extremely general sense that even entire universe can be regarded as a particle) corresponds to a pair of positive and negative energy space-time sheets labeled by m and n characterizing the p-adic topologies consistent with $m-$ and n-adicities. This looks natural since Universe has necessary vanishing net quantum numbers. Unless one allows the non-uniqueness due to $m/n = mr/nr$, positive and negative energy space-time sheets can be connected only by # contacts so that positive and negative energy space-time sheets cannot interact via the formation of $\#_B$ contacts and would be therefore dark relative to each other. Negative energy antiparticles would also have different p-adic mass scales. If the rate for the creation of # contacts and their CP conjugates are slightly different, say due to the presence of electric components of gauge fields, matter antimatter asymmetry could be generated primordially.

6 Explanations Of Some Astrophysical And Cosmological Anomalies

In the sequel some astrophysical and cosmological anomalies such as the apparent shrinking of solar system observed by Masreliez, Pioneer anomaly, Flyby anomaly and new anomalies in cosmic microwave background.

6.1 Apparent Shrinking Of Solar System

6.1.1 The findings of Masreliez

There are two means of determining the positions of planets in the solar system [E68, E58]. The first method is based on optical measurements and determines the position of planets with respect to the distant stars. Already thirty years ago [E58] came the first indications that the planetary positions determined in this manner drift from their predicted values as if planets were in accelerated motion. The second method determines the relative positions of planets using radar ranging: this method does not reveal any such acceleration.

C. J. Masreliez [E28] has proposed that this acceleration could be due to a gradual scaling of the planetary system so that the sizes L of the planetary orbits are reduced by an over-all scale factor $L \rightarrow L/\lambda$, which implies the acceleration $\omega \rightarrow \lambda^{3/2}\omega$ in accordance with the Kepler's law $\omega \propto 1/L^{3/2}$. This scaling would exactly compensate the cosmological scaling $L \rightarrow (R(t)/R_0) \times L$ of the solar system size L, where $R(t)$ the curvature parameter of Robertson-Walker cosmology having the line element

$$ds^2 \quad = \quad dt^2 - R^2(t)\left(\frac{dr^2}{1+r^2} + r^2 d\Omega^2\right) \quad . \tag{6.1}$$

According to Masreliez, the model explains also some other anomalies in the solar system, such as angular momentum discrepancy between the lunar motion and the spin-down of the Earth [E28]. The model also changes the rate for the estimated drift of the Moon away from the Earth so that the Moon could have very well formed together with Earth some five billion years ago.

Bohr quantization of planetary orbits predicts that orbital radii are constant in Minkowski coordinates. Hence solar system would not participate cosmic expansion and the radii of planets shrink in Robertson-Walker coordinates. This model is definitely the simplest one.

6.1.2 The basic coordinate systems

Consider now the previous argument in more detail. The first task is to identify the coordinates appearing in the equations of motion of the planetary system. Denote the standard spherical Minkowski coordinates by (m^0, r_M, θ, ϕ). The line element reads as

$$ds^2 = d(m^0)^2 - dr_M^2 - r_M^2 d\Omega^2 \quad . \tag{6.2}$$

Light cone coordinates are related to these coordinates by the relationship

$$a = \sqrt{m_0^2 - r_M^2} \quad , \quad r = r_M/a \quad . \tag{6.3}$$

Here a is the light cone proper time along radii from the tip of the light cone $a = constant$ surfaces are hyperboloids. The line element is given

$$ds^2 = da^2 - a^2\left(\frac{dr^2}{1+r^2} + r^2 d\Omega^2\right) \tag{6.4}$$

and is nothing but the empty space Minkowski metric.

The Robertson-Walker metric for the space-time sheet reads as

$$ds^2 = g_{aa} da^2 - a^2 (\frac{dr^2}{1+r^2} + r^2 d\Omega^2) \quad . \tag{6.5}$$

The space-time sheet possessing this metric as induced metric is obtained as a map $M^4_+ \rightarrow CP_2$ having the form $s^k = s^k(a)$, where s^k denote CP_2 coordinates satisfying the constraint

$$g_{aa} = 1 - s_{kl}\partial_a s^k \partial_a s^l \quad , \tag{6.6}$$

where s_{kl} denotes the metric tensor of CP_2.

One can introduce cosmic time as proper time coordinate t, or Hubble time as it is called, by the equation

$$\frac{dt}{da} = \sqrt{g_{aa}} \quad . \tag{6.7}$$

For the matter-dominated cosmology one as

$$\frac{t}{t_0} = (\frac{a}{a_0})^{3/2} \quad . \tag{6.8}$$

$t \simeq 1.5 \times 10^{10}$ ly is the value which explains the planetary acceleration in the model of Masreliez.

The basic question concerns the connection between cosmic coordinates and the radial and time coordinates (r_{PN}, t_{PN}) used in Post-Newtonian approximation. The correspondence $(t = t_{PN}, r = r_{PN})$ is the natural first approximation.

The cosmic time dilation would slow down the time scale of the planetary dynamics and cosmic expansion would lead to adiabatic expansion of the size of the solar system. This would predict the scaling $L(a)/L(a_0) = a/a_0$ for the sizes of the planetary orbits as measured using the r_M coordinate of M^4_+ metric whereas angular velocities of planets would remain constant $\omega(a)/\omega(a_0) = constant$. The solar system would gradually decay.

6.1.3 The condition that solar system does not participate cosmic expansion

If the solar system does not participate in cosmic expansion, one has $L(a)/L(a_0) = constant$ and the scalings

$$\frac{\omega(a)}{\omega(a_0)} = (\frac{a}{a_0})^{3/2} = \frac{t}{t_0} \quad , \quad \frac{v(a)}{v(a_0)} = (\frac{a}{a_0})^{1/2} = (\frac{t}{t_0})^{1/2} \tag{6.9}$$

for the angular velocity ωandtangential velocity v along the orbit. The equation for the angular acceleration is $d\omega/dt = \omega/t$. This result differs by a factor of 3 from the equation $d\omega/dt = 3\omega/t$ of [E27, E28]. On basis of work of Masreliez one can conclude this kind of scaling indeed explains the observed drift quite satisfactorily for $t \simeq 5$ billion years (instead of $t = 15$ billion years of [E28]). Thus the effect would allow to see the effects of the cosmic expansion in human time scale and would make possible to determine the value of cosmic time t from the planetary dynamics.

6.1.4 Compensation of cosmic expansion from Bohr quantization of planetary orbits?

The Bohr quantization for planetary orbits predicts that the orbital radii measured in terms of M^4 radial coordinate r_M are constant. This means that planetary system does not participate cosmic expansion so that the orbital radii expressed in terms of the coordinate $r = r_M/a$ shrinking. Therefore the stars accelerate with respect to the Robertson-Walker coordinates $(t, r, \Omega))$ defined by the distant stars since in this case the radii correspond naturally to the coordinate $r = r_M/a$ and time variable corresponds to the $dt/da = \sqrt{g_{aa}}$ giving $dr/dt = -Hr_M$ so that cosmic expansion is exactly compensated. This model for the anomaly brings in no additional assumptions besides Bohr quantization and is favored by Occam's razor.

There is an objection against the model based on the effective shift of the space-time sheet of solar system towards geometric future in each quantum jump so that cosmic expansion is compensated and time effectively ceases to flow. The simplest model for the arrow of psychological time found hitherto [K8] assumes however that this kind of effective shifting indeed occurs but in the reverse direction so that the radii would seem to increase rather than decrease. If the M^4 size remains constant, apparent reduction of radii is predicted.

Quite recently (August 2008) there appeared a new experimental claim related to the problem discussed. There is evidence that the value of astronomical unit AU (distance between Sun and Earth) is increasing with a rate about $dAU/dt = 7$ cm/year [E53]. Expressed in terms of the Minkowski proper time $a = R(t)$ the rate is about

$$\frac{dlog(AU)}{da} \simeq 4.6 \times 10^{-13} \quad .$$

If the solar system indeed participates cosmic expansion, one has $\frac{dlog(AU)}{da} = 1/a$ and the prediction for the recent Minkowski age of the Universe is $a_{now} = 2.2 \times 10^{12}$ years. If one assumes $a_R \simeq 3.3 \times 10^7$ y for the time when matter began to dominate, one obtains

$$t - t_R = \int_{a_R}^{a} \sqrt{g_{aa}} da \ , \quad g_{aa} = (\frac{a}{a_R})^{1/2} \quad .$$

This would give $t_{now} \simeq 4 \times 10^{10}$ years which is about 8 times longer than the age $t_{now} = 0.5 \times 10^{10}$ ly explaining the claims of Mazreliez. The latter would give $a_{now} \simeq 4 \times 10^{11}$ y, which is ten times shorter than the value required by the interpretation of the increase of AU as being due to the cosmic expansion.

In any case, if the increase of AU is real, it challenges the hypothesis that the quantum size of the solar system remains exactly constant and increases only in the phase transitions increasing the value of the gravitational Planck constant. One could consider the possibility that some new effect which is by a factor 1/10 smaller than that caused by the cosmic expansion is present. A possible explanation consistent with the constant M^4 size of the solar system is based on the idea that the space-time sheet along which the radar radiation propagates, develops gradually riples. Also the emergence of new space-time sheets condensed to the space-time sheet along which radar photons propagate could be involved. This increasing metric noise would mean that the distance traveled by the radar photons along the space-time sheet in question gradually increases so that the time taken by the radar signal to travel from Earth to Sun and back increases.

6.2 In What Sense Speed Of Light Could Be Changing In Solar System?

There have been continual claims that the speed of light in solar system is decreasing. The latest paper about this is by Sanejouand [E47] and to my opinion must be taken seriously. The situation is summarized by an excerpt from the abstract of the article:

The empirical evidences in favor of the hypothesis that the speed of light decreases by a few centimeters per second each year are examined. Lunar laser ranging data are found to be consistent with this hypothesis, which also provides a straightforward explanation for the so-called Pioneer anomaly, that is, a time-dependent blue-shift observed when analyzing radio tracking data from distant spacecrafts, as well as an alternative explanation for both the apparent time-dilation of remote events and the apparent acceleration of the Universe.

Before one can speak about change of c seriously, one must specify precisely what the measurement of speed of light means. In GRT framework speed of light is by definition a constant in local Minkowski coordinates. It seems very difficult to make sense about varying speed of light since c is purely locally defined notion.

1. In TGD framework [K22] space-time as abstract manifold is replaced by 4-D surface in $H = M^4 \times CP_2$ (forgetting complications due to the hierarchy of Planck constants) and this brings in something new: the sub-manifold geometry allowing to look space-time surfaces "from outside", from H-perspective. The shape of the space-time surface appears as new degrees of freedom. This leads to the explanation of standard model symmetries, elementary particle quantum numbers and geometrization of classical fields, the dream of Einstein. Furthermore, CP_2 length scale provides a universal unit of length and p-adic length scale hypothesis brings in an entire hierarchy of fixed meter sticks defined by p-adic length scales. The presence of imbedding space $M^4 \times CP_2$ brings in light-like geodesics of M^4 for which c is maximal and by suitable choice of units could be taken $c = 1$. These geodesics serve as universal comparison standards when one measures speed of light: something which GRT does not provide.

2. In TGD framework the operational definition for the speed of light at given space-time sheet is in terms of the time taken for light to propagate from point A to Balong space-time surface. The time to propagate along space-time sheet is in general longer than along light-like geodesic of M^4. Even if the space-time surface is only warped (no curvature), this time is longer than along a light-like geodesic of $M^4(\times CP_2)$ and the speed of light measured in this manner is reduced from its maximal value. Secondly, in TGD framework the propagation can occur via several routes because of many-sheeted structure and each sheet gives its own value for c.

What TGD then predicts?

1. TGD inspired cosmology predicts that c measured in this manner increases in cosmological scales, just the opposite for what Louise Riofrio [E23] suggests. The reason is that strong gravitation makes space-surface strongly curved and it takes more time to travel from A to Bduring early cosmology. This means that TGD based explanation has different cosmological consequences as that of Riofrio. For instance, Hubble constant depends on space-time sheet in TGD framework.

2. The paradox however disappears that *local systems* like solar system do not not normally participate in cosmic expansion as predicted by TGD. This is known also experimentally. In TGD Universe local systems could however participate cosmic expansion in average sense via phase transitions increasing Planck constant of the appropriate space-time sheet and thus increasing its size. The transition would occur in relatively short time scales: this provides new support for expanding Earth hypothesis needed to explain the fact that continents fit nicely together to form single super continent covering entire Earth if the radius of Earth is by a factor 1/2 smaller than its recent radius [K14].

3. If one measures the speed of light in local system and uses its cosmic value taken constant by definition (fixing particular coordinate time) then one indeed finds that the speed of light is decreasing locally and the decrease should be expressible in terms of Hubble constant.

4. TGD based explanation of Pioneer anomaly is also based on completely analogous reasoning.

6.3 Pioneer Anomaly

The data gathered during one quarter of century [C1] seem to suggest that spacecrafts do not obey the laws of Newtonian gravitation. What has been observed is anomalous constant acceleration of order $(8 \pm 3) \times 10^{-11}g$ ($g = 9.81\ m/s^2$ is gravitational acceleration at the surface of Earth) for the Pioneer/10/11, Galileo and Ulysses ganomaly. The acceleration is directed towards Sun and could have an explanation in terms of $1/r^2$ long range force if the density of charge carriers of the force has $1/r$ dependence on distance from the Sun. From the data in [C1], the anomalous acceleration of the spacecraft is of order

$$\delta a \sim .8 \times 10^{-10} g \ ,$$

where $g \simeq 9.81\ m/s^2$ is gravitational acceleration at the surface of Earth. Using the values of Jupiter distance $R_J \simeq .8 \times 10^{12}$ meters, radius of Earth $R_E \simeq 6 \times 10^6$ meters and the value Sun to Earth mass ratio $M_S/M_E \simeq .3 * 10^6$, one can relate the gravitational acceleration

$$a(R) = \frac{GM_S}{R^2} = \frac{M_S}{M_E}\frac{R_E^2}{R^2}$$

of the spacecraft at distance $R = R_J$ from the Sun to g, getting roughly $a \simeq 1.6 \times 10^{-5} g$. One has also

$$\frac{\delta a}{a} \simeq 1.3 \times 10^{-4} \ .$$

The value of the anomalous acceleration has been found to be $a_F = (8.744 \pm 1.33) \times 10^{-8}$ cm/s^2 and given by Hubble constant: $a_F = cH$. $H = 82$ km/s/Mpc gives $a_F = 8 \times 10^{-8}$ cm/s^2. It is very difficult to believe that this could be an accident. There are also diurnal and annual variations in the acceleration anomaly [E35]. These variations should be due to the physics of Earth-Sun system. I do not know whether they can be understood in terms of a temporal variation of the Doppler shift due to the spinning and orbital motion of Earth with respect to Sun.

6.3.1 The model of Pioneer anomaly based on Doppler shift

It came as a surprise that also Pioneer anomaly has a simple explanation in terms of Doppler shift assuming that solar system is not participating in cosmic expansion. This predicts that the measured wavelength behaves as

$$\lambda_{meas} = \frac{c(t)}{f} \simeq (1 + \frac{a_c}{c_0}t)/f \ . \tag{6.10}$$

Here $c(t)$ is the local light velocity using as unit the light velocity in cosmological length scales. Since one has $a_c < 0$ in the lowest order, the measured wavelength behaves as if the source were accelerating towards observer with a constant acceleration. The value of a_c is consistent with that obtained from the argument explaining apparent reduction of light velocity in solar system.

6.3.2 Original model for the anomaly

The original explanation for the acceleration anomaly was based on the presence of dark matter increasing the effective solar mass at larger distances. Although this explanation did not survive Occam's razor, it deserves to be mentioned.

Since acceleration anomaly is constant, a dark matter density behaving like $\rho_d = (3/4\pi)(H/Gr)$, where H is Hubble constant giving $M(r) \propto r^2$, is required. For instance, at the radius R_J of Jupiter the dark mass would be about $(\delta a/a)M(Sun) \simeq 1.3 \times 10^{-4} M(Sun)$ and would become comparable to M_{Sun} at about $100R_J = 520$ AU. Note that the standard theory for the formation of planetary system assumes a solar nebula of radius of order 100AU having 2-3 solar masses. For Pluto at distance of 38 AU the dark mass would be about one per cent of solar mass. This model would suggest that planetary systems are formed around dark matter system with a universal mass density. For this option dark matter could perhaps be seen as taking care of the contraction compensating for the cosmic expansion by using a suitable dark matter distribution.

In [E35] the possibility that the acceleration anomaly for Pioneer 10 (11) emerged only after the encounter with Jupiter (Saturn) is raised. The model explaining Hubble constant as being due to a radial contraction compensating cosmic expansion would predict that the anomalous acceleration should be observed everywhere, not only outside Saturn. The model in which universal dark matter density produces the same effect would allow the required dark matter density $\rho_d = (3/4\pi)(H/Gr)$ be present only as a primordial density able to compensate the cosmic expansion. The formation of dark matter structures could have modified this primordial density and visible matter would have condensed around these structures so that only the region outside Jupiter would contain this density.

6.4 Flyby Anomaly

The so called flyby anomaly [E35] might relate to the Pioneer anomaly. Fly-by mechanism used to accelerate space-crafts is a genuine three body effect involving Sun, planet, and the space-craft. Planets are rotating around sun in an anticlockwise manner and when the space-craft arrives from the right hand side, it is attracted by a planet and is deflected in an anticlockwise manner and planet gains energy as measured with respect to solar center of mass system. The energy originates from the rotational motion of the planet. If the space-craft arrives from the left, it loses energy. What happens is analyzed in [E35] using an approximately conserved quantity known as Jacobi's integral $J = \mathcal{E} - \omega \overline{e}_z \cdot \overline{r} \times \overline{v}$. Here $\mathcal{E}$ is total energy per mass for the space-craft, ω is the angular velocity of the planet, $\overline{e}_z$ is a unit vector normal to the planet's rotational plane, and various quantities are with respect to solar cm system.

This as such is not anomalous and flyby effect is used to accelerate space-crafts. For instance, Pioneer 11 was accelerated in the gravitational field of Jupiter to a more energetic elliptic orbit directed to Saturn ad the encounter with Saturn led to a hyperbolic orbit leading out from solar system.

Consider now the anomaly. The energy of the space-craft in planet-space-craft cm system is predicted to be conserved in the encounter. Intuitively this seems obvious since the time and length scales of the collision are so short as compared to those associated with the interaction with Sun that the gravitational field of Sun does not vary appreciably in the collision region. Surprisingly, it turned out that this conservation law does not hold true in Earth flybys. Furthermore, irrespective of whether the total energy with respect to solar cm system increases or decreases, the energy in planet-spacecraft cm system increases during flyby in the cases considered.

Five Earth flybys have been studied: Galileo-I, NEAR, Rosetta, Cassina, and Messenger and the article of Anderson and collaborators [E35] gives a nice quantitative summary of the findings and of the basic theoretical notions. Among other things the tables of the article give the deviation $\delta\mathcal{E}_{g,S}$ of the energy gain per mass in the solar cm system from the predicted gain. The anomalous energy gain in rest Earth cm system is $\Delta\mathcal{E}_E \simeq \overline{v}\cdot\Delta\overline{v}$ and allows to deduce the change in velocity. The general order of magnitude is $\Delta v/v \simeq 10^{-6}$ for Galileo-I, NEAR and Rosetta but consistent with zero for Cassini and Messenger. For instance, for Galileo I one has $v_{\infty,S} = 8.949$ km/s and $\Delta v_{\infty,S} = 3.92 \pm .08$ mm/s in solar cm system.

Many explanations for the effect can be imagined but dark matter looks at first the most obvious candidate in TGD framework. The model for the Bohr quantization of planetary orbits assumes that planets are concentrations of the visible matter around dark matter structures. These structures could be tubular structures around the orbit or a nearly spherical shell containing the orbit. The contribution of the dark matter to the gravitational potential increases the effective solar mass $M_{eff,S}$. This of course cannot explain the acceleration anomaly which has constant value. One can also consider dark matter rings associated with planets and perhaps even Moon's orbit is an obvious candidate now. It turns out that the tube associated with Earth's orbit and deformed by Earth's presence to equatorial plane of Earth explains qualitatively the known facts.

Roughly half year after writing this, a rather convincing and very simple model explaining the effect as a relativistic transverse Doppler effect appeared [E51] (see the comment at the end of this section). Therefore the dark matter ring - if present - can give only an additional contribution to the transverse Doppler effect. Therefore it seems that all anomalous effects are related to Doppler shifts and thus basically kinematical: the only new element is the fact that solar system does not participate in cosmic expansion.

6.4.1 Dark matter at a spherical cell containing Earth's orbit?

For instance, if the space-craft traverses shell structure, its kinetic energy per mass in Earth cm system changes by a constant amount not depending on the mass of the space-craft:

$$\frac{\Delta E}{m} \simeq v_{\infty,E}\Delta v = \Delta V_{gr} = \frac{G\Delta M_{eff,S}}{R} \quad . \tag{6.11}$$

Here R is the outer radius of the shell and $v_{\infty,E}$ is the magnitude of asymptotic velocity in Earth cm system. This very simple prediction should be testable. If the space-craft arrives from the direction of Sun the energy increases. If the space-craft returns back to the sunny side, the net anomalous energy gain vanishes. This has been observed in the case of Pioneer 11 encounter with Jupiter [E35].

The mechanism would make it possible to deduce the total dark mass of, say, spherical shell of dark matter. One has

$$\begin{aligned} \frac{\Delta M}{M_S} &\simeq \frac{\Delta v}{v_{\infty,E}}\frac{2K}{V} \quad , \\ K &= \frac{v_{\infty,E}^2}{2} \quad , \quad V = \frac{GM_S}{R} \quad . \end{aligned} \tag{6.12}$$

For the case considered $\Delta M/M_S \geq 2\times 10^{-6}$ is obtained. Note that the amount of dark mass within sphere of 1 AU implied by the explanation of Pioneer anomaly would be about $6.2\times 10^{-6}M_S$ from Pioneer anomaly whereas the mass of Earth is $M_E \simeq 5\times 10^{-6}M_S$. Since the orders of magnitude are same one might consider the possibility that the primordial dark matter has concentrated in spherical shells in the case of inner planets as indeed suggested by the model for quantization of radii of planetary orbits. Of course, the total mass associated with $1/r$ density quite too small to explain entire mass of the solar system.

In the solar cm system the energy gain is not constant. Denote by $\overline{v}_{i,E}$ and $\overline{v}_{f,E}$ the initial and final velocities of the space-craft in Earth cm. Let $\Delta\overline{v}$ be the anomalous change of velocity in the encounter and denote by θ the angle between the asymptotic final velocity $\overline{v}_{f,S}$ of planet in solar cm. One obtains for the corrected $\mathcal{E}_{g,S}$ the expression

$$\mathcal{E}_{g,S} = \frac{1}{2}\left[(\overline{v}_{f,E}+\overline{v}_P+\Delta\overline{v})^2-(\overline{v}_{i,E}+\overline{v}_P)^2\right] \ . \tag{6.13}$$

This gives for the change $\delta\mathcal{E}_{g,S}$

$$\begin{aligned}\delta\mathcal{E}_{g,S} &\simeq (\overline{v}_{f,E}+\overline{v}_P)\cdot\Delta\overline{v} \simeq v_{f,S}\Delta v\times cos(\theta_S) \\ &= v_{\infty,S}\Delta v\times cos(\theta_S) \ .\end{aligned} \tag{6.14}$$

Here $v_{\infty,S}$ is the asymptotic velocity in solar cm system and in excellent approximation predicted by the theory.

Using spherical shell as a model for dark matter one can write this as

$$\delta\mathcal{E}_{g,S} = \frac{v_{\infty,S}}{v_{\infty,E}}\frac{G\Delta M}{R}cos(\theta_S) \ . \tag{6.15}$$

The proportionality of $\delta\mathcal{E}_{g,S}$ to $cos(\theta_S)$ should explain the variation of the anomalous energy gain.

For a spherical shell $\Delta\overline{v}$ is in the first approximation orthogonal to v_P since it is produced by a radial acceleration so that one has in good approximation

$$\begin{aligned}\delta\mathcal{E}_{g,S} &\simeq \overline{v}_{f,S}\cdot\Delta\overline{v} \simeq \overline{v}_{f,E}\cdot\Delta\overline{v} \simeq v_{f,S}\Delta v\times cos(\theta_S) \\ &= v_{\infty,E}\Delta v\times cos(\theta_E) \ .\end{aligned} \tag{6.16}$$

For Cassini and Messenger $cos(\theta_S)$ should be rather near to zero so that $v_{\infty,E}$ and $v_{\infty,S}$ should be nearly orthogonal to the radial vector from Sun in these cases. This provides a clear cut qualitative test for the spherical shell model.

6.4.2 Dark matter at the orbit of Earth?

An alternative model is based on dark matter on the orbit of Earth. One can estimate the change of the kinetic energy in the following manner.

1. Assume that the orbit is not modified at all in the lowest order approximation and estimate the kinetic energy gained as the work done by the force caused by the dark matter on the space-craft.

$$\begin{aligned}\frac{\Delta E}{m} &= -G\frac{d\rho_{dark}}{dl}\int_{\gamma_E} dl_E\int_{\gamma_S} d\overline{r_S}\cdot\frac{\overline{r}_{SE}}{r_{SE}^3}) \ , \\ \overline{r}_{SE} &\equiv \overline{r}_S-\overline{r}_E \ .\end{aligned} \tag{6.17}$$

   Here γ_S denotes the portion of the orbit of space-craft during which the effect is noticeable and γ_E denotes the orbit of Earth.

   This expression can be simplified by performing the integration with respect to r_S so that one obtains the difference of gravitational potential created by the dark matter tube at the initial and final points of the portion of γ_S:

$$\begin{aligned}\frac{\Delta E}{m} &= V(\overline{r}_{S,f})-V(\overline{r}_{S,i}) \ , \\ V(\overline{r}_S) &= -G\frac{d\rho_{dark}}{dl}\times\int_{\gamma_E} dl_E\frac{1}{r_{SE}} \ .\end{aligned} \tag{6.18}$$

2. Use the standard approximation (briefly described in [E35]) in which the orbit of the spacecraft consists of three parts joined continuously together: the initial Kepler orbit around Sun, the piece of orbit which can be approximate with a hyperbolic orbit around Earth, and the final Kepler orbit around Sun. The piece of the hyperbolic orbit can be chosen to belong inside the so called sphere of influence, whose radius r is given in terms of the distance R of planet from Sun by the Roche limit $r/R = (3m/M_{Sun})^{2/5}$. γ_S could be in the first approximation taken to correspond to this portion of the orbit of spacecraft.

3. The explicit expression for the hyperbolic orbit can be obtained by using the conservation of energy and angular momentum and reads as

$$\begin{aligned} u = \frac{r_s}{r} = \frac{2GM}{r} &= \frac{u_0^2}{2v_0^2}[1 + \sqrt{1 + 4u_0^2\frac{v_\infty^2 v_0^2}{sin^2(\phi)}}] \ , \\ u_0 &\equiv \frac{r_s}{a} \ , \ \ |v \times r| \equiv vr \times sin(\phi) \ . \end{aligned} \tag{6.19}$$

The unit $c = 1$ is used to simplify the formulas. r_s denotes Schwartschild radius and v_∞ the asymptotic velocity. v_0 and a are the velocity and distance at closest approach and the conserved angular momentum is given by $L/m = v_0 a$. In the situation considered value of r_S is around 1 cm, the value of a around 10^7 m and the value of v_∞ of order 10 km/s so that the approximation

$$u \simeq u_0\frac{v_\infty}{v_0}sin(\phi) \tag{6.20}$$

is good even at the distance of closest approach. Recall that the parameters characterizing the orbit are the distance a of the closest approach, impact parameter b, and the angle 2θ characterizing the angle between the two straight lines forming the asymptotes of the hyperbolic orbit in the orbital plane P_E.

Consider first some conclusions that one can make from this model.

1. Simple geometric considerations demonstrate that the acceleration in the region between Earth's orbit and the part of orbit of spacecraft for which the distance from Sun is larger than that of Earth is towards Sun. Hence the distance of the spacecraft from Earth tends to decrease and the kinetic energy increases. In fact, one could also choose the portion of γ_S to be this portion of the spacecraft's orbit.

2. ΔE depends on the relative orientation of the normal n_S of the the orbital plane P_E of spacecraft with respect to normal n_O the orbital plane P_O of Earth. The orientation can be characterized by two angles. The first angle could be the direction angle Θ of the position vector of the nearest point of spacecraft's orbit with respect to cm system. Second angle, call it Φ, could characterize the rotation of the orbital plane of space-craft from the standard orientation in which orbital plane and space-craft's plane are orthogonal. Besides this ΔE depends on the dynamical parameters of the hyperbolic orbit of space-craft given by the conserved energy $E_{tot} = E_\infty$ and angular momentum or equivalently by the asymptotic velocity v_∞ and impact parameter b.

3. Since the potential associated with the closed loop defined by Earth's orbit is expected to resemble locally that of straight string one expects that the potential varies slowly as a function of $\overline{r}_S$ and that ΔE depends weakly on the parameters of the orbit.

The most recent report [E34] provides additional information about the situation.

1. ΔE is reported to be proportional to the total orbital energy E_∞/m of the space-craft. Naively one would expect $\sqrt{E_\infty/m}$ behavior coming from the proportionality ΔE to $1/r$. Actually a slower logarithmic behavior is expected since a potential of a linear structure is in question.

2. ΔE depends on the initial and final angles θ_i and θ_f between the velocity $\overline{v}$ of the space-craft with respect to the normal $\overline{n}_E$ of the equatorial plane P_E or Earth and the authors are able to give an empirical formula for the energy increment. The angle between P_E and P_O is 23.4 degrees. One might hope that the formula could be written also in terms of the angle between v and the normal n_O of the orbital plane. For $\theta_i \simeq \theta_f$ the effect is known to be very small. A particular example corresponds to a situation in which one has $\theta_i = 32$ degrees and $\theta_f = 31$ degrees. Obviously the $P_O \simeq P_E$ approximation cannot hold true. Needless to say, also the model based on spherical shell of dark matter fails.

6.4.3 Is the tube containing the dark matter deformed locally into the equatorial plane?

The previous model works qualitatively if the interaction of Earth and flux tube around Earth's orbit containing the dark matter modifies the shape of the tube locally so that the portion of the tube contributing to the anomaly lies in a good approximation in P_E rather than P_O. In this case the minimum value of the distance r_{ES} between γ_E and γ_S is maximal for the symmetric situation with $\theta_i = \theta_f$ and the effect is minimal. In an asymmetric situation the minimum value of r_{ES} decreases and the size of the effect increases. Hence the model works at least qualitatively of the motion of Earth induces a moving deformation of the dark matter tube to P_E. One can actually write ΔE in a physically rather transparent form showing that it is consistent with the basic empirical findings.

1. By using linear superposition one can write the potential as sum of a potential associated with a tube associated with Earths orbit plus the potential associated with the deformed part minus the potential associated with corresponding non-deformed portion of Earth's orbit:

$$\begin{aligned} \frac{\Delta E}{m} &= V(\overline{r}_{S,f}) - V(\overline{r}_{S,i}) \ , \\ V(\overline{r}_S) &= -G\frac{d\rho_{dark}}{dl}Z(\overline{r}_S) \ , \\ Z(\overline{r}_S) &= X(\gamma_{orb};\overline{r}_S) + X(\gamma_d;\overline{r}_S) - X(\gamma_{nd};\overline{r}_S) \ , \\ X(\gamma_i;\overline{r}_S) &= \int_{\gamma_i} dl\frac{1}{r_{Si}} \ . \end{aligned} \tag{6.21}$$

Here the subscripts "orb", "d" and "nd" refer to the entire orbit of Earth, to its deformed part, and corresponding non-deformed part. The entire orbit is analogous to a potential of straight string and is expected to give a slowly varying term which is however non-vanishing in the asymmetric situation. The difference of deformed and non-deformed parts gives at large distances dipole type potential behaving like $1/r^2$ and thus being proportional to v_∞^2 by the above expression for the $u = r_s/r$. The fact that ΔE is proportional to v_∞^2 suggests that dipole approximation is good.

2. One can therefore parameterize ΔE as

$$\begin{aligned} \frac{\Delta E}{m} &= V(\overline{r}_{S,f}) - V(\overline{r}_{S,i}) \ , \\ V(\overline{r}_S) &= -G\frac{d\rho_{dark}}{dl}Z \ , \\ Z(\overline{r}_S) &= X(\gamma_{orb};\overline{r}_S) + \frac{dcos(\Theta)}{r_S^2} \ . \end{aligned} \tag{6.22}$$

where Θ is the angle between $\overline{r}$ and the dipole $\overline{d}$, which now has dimension of length. The direction of the dipole is in the first approximation in the equatorial plane and and directed orthogonal to the Earth's orbit.

Consider now the properties of ΔE.

1. In a situation symmetric with respect to the equator E_d vanishes but E_{nd} is non-vanishing which gives as a result potential difference associated with entire Earth's orbit minus the part of orbit contributing to the effect so that the result is by the definition of the approximation very small.

2. As already noticed, dipole field like behavior that the large contribution to the potential is proportional to the conserved total energy $v_\infty^2/2$ at the limit of large kinetic energy.

3. From the fact that potential difference is in question it follows that the expression for the energy gain is the difference of parameters characterizing the initial and final situations. This conforms qualitatively with the observation that this kind of difference indeed appears in the empirical fit. $1/r^2$-factor is also proportional to $sin^2(\phi)$ which by the symmetry of the situation is expected to be same for initial and final situation. Furthermore, ΔE is proportional to the difference of the parameter $cos(\Theta_f) - cos(\Theta_i)$ and this should correspond to the reported behavior: it indeed does as I learned after having received the article in email (the prices of PRL on line articles are too dirty for me!). Note that the result vanishes for the symmetric situation in accordance with the empirical findings.

To sum up, it seems that the qualitative properties of ΔE are indeed consistent with the empirical findings. The detailed fit of the formula of [E34] should allow to fix the shape of the deformed part of the orbit.

6.4.4 What induces the deformation?

Authors suggest that the Earth's rotation is somehow involved with the effect. The first thing to notice is that the gravimagnetic field of Earth, call it B_E, predicted by General Relativity is quite too weak to explain the effect as a gravimagnetic force on spacecraft and fails also to explain the fact that energy increases always. Gravito-Lorentz force does not do any work so that the total energy is conserved and $\Delta E = -\Delta V = -\nabla V \cdot \Delta\overline{r}$ holds true, where $\Delta\overline{r}$ is the deflection caused by the gravimagnetic field on the orbit during flyby. Since $\Delta\overline{r}$ is linear in v, ΔE changes sign as the velocity of space-craft changes sign so that this option fails in several manners.

Gravimagnetic force of Earth could be however involved but in a different manner. The gravimagnetic force between Earth and flux tube containing the dark matter could explain this deformation as a kind of frame drag effect: dark matter would tend to follow the spinning of Earth.

1. If the dark matter inside the tube is at rest in the rest frame of Sun (this is not a necessary assumption), it moves with respect to Earth with a velocity $v = -v_E$, where v_E is the orbital velocity of Earth. If the tube is thin, the gravito-Lorentz force experienced by dark matter equals in the first approximation to $F = -v_E \times B_E$ with B_E evaluated at the axis of the tube. TGD based model for B_E [K22] does not allow B_E to be a dipole field. B_E has only the component B^θ and the magnitude of this component relates by a factor $1/sin(\theta)$ to the corresponding component of the dipole field and becomes therefore very strong as one approaches poles. The consistency with the existing experimental data requires that B_E at equator is very nearly equal to the strength of the dipole field. The magnitude of B_E and thus of F is minimal when the deformation of the tube is in P_E, and the deformation occurs very naturally into P_E since the non-gravitational forces associated with the dark matter tube must compensate a minimal gravitational force in dynamical equilibrium.

2. B_E^θ at equator is in the direction of the spin velocity ω of the Earth. The direction of v_E varies. It is convenient to consider the situation in the rest system of Sun using Cartesian coordinates for which the orbital plane of Earth corresponds to (x, y) plane with x- and y-axis in the direction of semi-minor and semi-major axes of the Earth's orbit. The corresponding spherical coordinates are defined in an obvious manner. v_E is parallel to the tangent vector $e_\phi(t) = -sin(\Omega t)e_x + cos(\Omega t)e_y$ of the Earth's orbit. The direction of B_E at equator is parallel to ω and can be parameterized as $e_\omega = cos(\theta)e^z + sin(\theta)(cos(\alpha)e_x + sin(\alpha)e_y)$. F is parallel to the vector $-cos(\theta)e_\rho(t) + sin(\theta)cos(\Omega t - \alpha)e_z$, where $e_\rho(t)$ is the unit vector directed from Sun to Earth. The dominant component is directed to Sun.

6.4.5 Flyby anomaly as transverse relativistic Doppler effect?

A new twist in the story of fly-by anomaly emerged at September twelfth 2007. The proposal of Jean-Paul Mbelek [E51] explains fly-by effect as a relativistic transverse Doppler effect and thus purely kinematic effect. Also the functional dependence of the parameter K characterizing the size of the effect on the kinematic parameters is predicted and the prediction is consistent with the empirical findings in the example considered. Therefore the story of fly-by anomaly might be finished and dark matter at the orbit of Earth could bring in only an additional effect. It is probably too much to hope for this kind of effect to be large enough if present.

6.5 Pioneer And Flyby Anomalies For Almost Decade Later

The article [E32] (see `http://tinyurl.com/avmndwa`) is about two old anomalies discovered in the solar system: Pioneer anomaly [E13] and Flyby anomaly [E35, E34, E30, E51] with which I worked for years ago.

I remember only the general idea that dark matter concentrations at orbits of planets or at spheres with radii equal that of orbit could cause the anomalies. So I try to reconstruct all from scratch and during reconstruction become aware of something new and elegant that I could not discover for years ago.

The popular article [E32] claims that Pioneer anomaly is understood. I am not at all convinced about the solution of Pioneer anomaly. Several "no new physics" solutions have been tailored during years but later it has been found that they do not work.

Suppose that dark matter is at the surface of sphere so that by a well-known text book theorem it does not create gravitational force inside it. This is an overall important fact, which I did not use earlier. The model explains both anomalies and also allow to calculate the total amount of dark matter at the sphere.

1. Consider first the Pioneer anomaly.

   (a) Inside the dark matter sphere with radius of Jupiter's orbit the gravitational force caused by dark matter vanishes. Outside the sphere also dark matter contributes to the gravitational attraction and Pioneer's acceleration becomes a little bit smaller since the dark matter at the sphere containing the orbit radius of Jupiter or Saturn also attracts the space-craft after the passby. A simple test for spherical model is the prediction that the mass of Jupiter effectively increases by the amount of dark matter at the sphere after passby.

   (b) The magnitude of the Pioneer anomaly is about $\Delta a/a = 1.3\times10^{-4}$ [K18] and translates to $M_{dark}/M \simeq 1.3\times10^{-4}$. What is highly non-trivial is that the anomalous acceleration is given by Hubble constant suggesting that there is a connection with cosmology fixing the value of dark mass once the area of the sphere containing it is fixed. This follows as a prediction if the surface mass density is universal and proportional to the Hubble constant.

   Could one interpret the equality of the two accelerations as an equilibrium condition? The Hubble acceleration H associated with the cosmic expansion (expansion velocity increases with distance) would be compensated by the acceleration due to the gravitational force of dark matter. The formula for surface density of dark matter is from Newton's law $GM_{dark} = H$ given by $\sigma_{dark} = H/4\pi G$. The approximate value of dark matter surface density is from $Hc = 6.7 \times 10^{-10}$ m/s^2 equal to $\sigma = .8$ kg/m^2 and surprisingly large.

   (c) The value of acceleration is $a = .8 \times 10^{-10} \times g$, $g = 9.81$ m/s^2 whereas the MOND model (see `http://tinyurl.com/32t9wt`) finds the optimal value for the postulated minimal gravitational acceleration to be $a_0 = 1.2 \times 10^{-10}$ m/s^2. In TGD framework it would be assignable to the traversal through the dark matter shell. The ratio of the two accelerations is $a/a_0 = 6.54$.

   (d) TGD inspired quantum biology requiring that the universal cyclotron energy spectrum of dark photons $h_{eff} = h_{gr}$ transforming to to bio-photons is in visible and UV range for charged particles gives the estimate $M_{dark}/M_E \simeq 2 \times 10^{-4}$ [K28] and is of the same order of magnitude smaller than for Jupiter. The minimum value of the magnetic field at flux tubes has been assumed to be $B_E = .2$ Gauss, which is the value of endogenous magnetic field explaining the effects of ELF em radiation on vertebrate brain. The two estimates are clearly consistent.

2. In Flyby anomaly spacecraft goes past Earth to gain momentum (Earth acts as a sling) for its travel towards Jupiter. During flyby a sudden acceleration occurs but this force is on only during the flyby but not before or after that. The basic point is that the spacecraft visits near Earth, and this is enough to explain the anomaly.

   The space-craft enters from a region outside the orbit of Earth containing dark matter and thus experiences also the dark force created by the sphere. After that the space craft enters inside the dark matter region, and sees a weaker gravitational force since the dark matter sphere is outside it and does not contribute. This causes a change in its velocity. After flyby the spacecraft experiences the forces caused by both Earth and dark matter sphere and the situation is the same as before flyby. The net effect is a change in the velocity as observed. From this the total amount of dark matter can be estimated. Also biology based argument gives an estimate for the fraction of dark matter in Earth.

This model supports the option in which the dark matter is concentrated on sphere. The other option is that it is concentrated at flux tube around orbit: quantitative calculations would be required to see whether this option can work. One can consider of course also more complex distributions: say $1/r$ distribution outside the sphere giving rise to constant change in acceleration outside the sphere.

A possible very simple TGD model for the sphere containing dark matter could be in terms of a boundary defined by a gigantic wormhole contact with large $h_{eff} = h_{gr}$ (at its space-time sheet representing "line of generalized Feynman diagram" one has deformation of CP_2 type vacuum extremal with Euclidian signature of induced metric) with radius given by the radius of Bohr orbit with gravitational Planck constant equal to $\hbar_{gr} = GMm/v_0$, where v_0 is a parameter with dimensions of velocity. This radius does not depend on the mass of the particle involved and is given by $r_n = GM/v_0^3$ where $r_S = 2GM$ is Schwartschild radius equal to 3 km for Sun [K18]. One has $v_0/c \simeq 2^{-11}$ for three inner planets. For outer planets v_0 is scaled down by a factor $1/5$.

The sphere should also correspond to a magnetic flux sheet with field line topology of dipole field. By flux conservation the flux must arrive along flux tube parallel to a preferred axis presumably orthogonal to the plane of planets and flux conservation should must true. This kind of structure is predicted also by the TGD model in terms of cylindrically symmetric candidate for an extremal of Kähler action representing astrophysical object [K1].

An interesting possibility is that also Earth-Moon system contains a spherical shell of dark matter at distance given by the radius of Moon's orbit (about 60 Earth's radii). If so the analogs of the two effects could be observed also in Earth Moon system and the testing of the effects would become much easier. This would also mean understanding of the formation of Moon. Also interior of Earth (and also Sun) could contain spherical shells containing dark matter as the TGD inspired model for the spherically symmetric orbit constructed for more than two decades ago [K1] suggests. One can raise interesting questions. Could also the matter in small scale systems be accompanied by dark matter shells at radii equal to Bohr radii in the first approximation and could these effects be tested? Note that a universal surface density for dark matter predicts that the change of acceleration universally be given by Hubble constant H.

6.6 Further Progress In The Understanding Of Dark Matter And Energy In TGD Framework

The remarks below were inspired by an extremely interesting link to a popular article (see `http://tinyurl.com/ybjox4zb`) about a possible explanation of dark matter in terms of vacuum polarization associated with gravitation. The model can make sense only if the sign of the gravitational energy of antimatter is opposite to that of matter and whether this is the case is not known. Since the inertial energies of matter and antimatter are positive, one might expect that this is the case also for gravitational energies by Equivalence Principle but one might also consider alternative and also I have done this in TGD framework.

The popular article lists four observations related to dark matter that neither cold dark matter (CMD) model nor modified gravitation model (MOND) can explain, and the claim is that the vacuum energy model is able to cope with them.

Consider first the TGD based model.

1. The model assumes that galaxies are like pearls along strings defined by cosmic strings expended to flux tubes during cosmic expansion survives also these tests. This is true also in longer scales due to the fractality if TGD inspired cosmology: for instance, galaxy clusters would be organized in a similar manner.

2. The dark magnetic energy of the string like object (flux tube) is identifiable as dark energy and the pearls would correspond to dark matter shells with a universal mass density of.8 kg/m^2 estimated from Pioneer and Flyby anomalies assuming to be caused by spherical dark matter shells assignable to the orbits of planets. This value follows from the condition that the anomalous acceleration is identical with Hubble acceleration. Even Moon could be accompanied by this kind of shell: if so, the analog of Pioneer anomaly is predicted.

3. The dark matter shell around galactic core could have decayed to smaller shells by h_{eff} reducing phase transition. This phase transition would have created smaller surfaces with smaller values of $h_{eff} = h_{gr}$. One can consider also the possibility that it contains all the galactic matter as dark matter. There would be nothing inside the surface of the gigantic wormhole throat: this would conform with holography oriented thinking.

I checked the four observations listed in the popular article (see `http://tinyurl.com/ybjox4zb`) some of which CMD (cold dark matter) scenario and MOND fail to to explain. TGD explains all of them.

1. It has been found that the effective surface mass density $\sigma = \rho_0 R_0/3$ (volume density times volume of ball equals to effective surface density times surface area of the ball for constant volume density) of galactic core region containing possible halo is universal and its value is .9 kg/m^2 (see the article (see `http://tinyurl.com/y864lfyx`). Pioneer and Flyby anomalies fix the surface density to.8 kg/m^2. The difference is about 10 per cent! One must of course be cautious here: even the correct order of magnitude would be fine since Hubble acceleration parameter might be different for the cluster than for the solar system now.

   Note that in the article the effective surface density is defined as $\sigma = \rho_0 r_0$, where r_0 is the radius of the region and ρ_0 is density in its center. The correct definition for a constant 3-D density inside ball is $\sigma = \rho_0 r_0/3$.

2. The dark matter has been found to be inside core region within few hundred parsecs. This is just what TGD predicts since the velocity spectrum of distant stars is due to the gravitational field created by dark energy identifiable as magnetic energy of cosmic string like object - the thread containing galaxies as pearls.

3. It has been observed that there is no dark matter halo in the galactic disk. Also this is an obvious prediction of TGD model.

4. The separation of matter - now plasma clouds between galaxies - and dark matter in the collisions of galaxy clusters (observed for instance for bullet cluster consisting of two colliding clusters) is also explained qualitatively by TGD. The explanation is qualitatively similar to that in the CMD model of the phenomenon. Stars of galaxies are not affected except from gravitational slow-down much but the plasma phase interacts electromagnetically and is slowed down much more in the collision. The dominating dark matter component making itself visible by gravitational lensing separates from the plasma phase and this is indeed observed: the explanation in TGD framework would be that it is macroscopically quantum coherent ($h_{eff} = h_{gr}$) and does not dissipate so that the thermodynamical description does not apply.

   In the case of galaxy clusters also the dark energy of cosmic strings is involved besides the galactic matter and this complicates the situation but the basic point is that dark matter component does not slow down as plasma phase does.

CMD model has the problem that the velocity of dark matter bullet (smaller cluster of bullet cluster) is higher than predicted by CMD scenario. Attractive fifth force acting between dark matter particles becoming effective at short distances has been proposed as an explanation: intuitively this adds to the potential energy negative component so that kinetic energy is increased. I have proposed that gravitational constant might vary and be roughly twice the standard value: I do not believe this explanation now.

The most feasible explanation is that the anomaly relates to the presence of thickened cosmic strings carrying dark energy as magnetic energy and dark matter shells instead of 3-D cold dark matter halos. This additional component would contribute to gravitational potential experienced by the smaller cluster and explain the higher velocity.

6.7 Variation Of Newston's Constant And Of Length Of Day

J. D. Anderson et al [E36] have published an article discussing the observations suggesting a periodic variation of the measured value of Newton constant and variation of length of day.

According to the article, about a dozen measurements of Newton's gravitational constant, G, since 1962 have yielded values that differ by far more than their reported random plus systematic errors. Authors find that these values for G are oscillatory in nature, with a period of $P = 5.899 \pm 0.062$ yr , an amplitude of , $S = 1.619 \pm 0.103 \times 10^{-14}$ m^{3}kg^{-1} s^{-2} and mean-value crossings in 1994 and 1997. The relative variation $\Delta G/G \sim 2.4 \times 10^{-4}$. Authors suggest that the actual values of G does not vary but some unidentified factor in the measurement process is responsible for an apparent variations.

According to the article, of other recently reported results, the only measurement with the same period and phase is the Length of Day (LOD defined as a frequency measurement such that a positive increase in LOD values means slower Earth rotation rates and therefore longer days). The period is also about half of a solar activity cycle, but the correlation is far less convincing. The 5.9 year periodic signal in LOD has previously been interpreted as due to fluid core motions and inner-core coupling. We report the G/LOD correlation, whose statistical significance is 0.99764 assuming no difference in phase, without claiming to have any satisfactory explanation for it. Least unlikely, perhaps, are currents in the Earth's fluid core that change both its moment of inertia (affecting LOD) and the circumstances in which the Earth-based experiments measure G. In this case, there might be correlations with terrestrial-magnetic-field measurements.

In the popular article "Why do measurements of the gravitational constant vary so much?" (see `http://tinyurl.com/k5onwoe`) Anderson states that there is also a possible connection with Flyby anomaly [E35], which also shows periodic variation.

In the following TGD inspired model for the findings is developed. The gravitational coupling would be in radial scaling degree of freedom and rigid body rotational degrees of freedom. In rotational degrees of freedom the model is in the lowest order approximation mathematically equivalent with Kepler model. The model for the formation of planets around Sun suggests that the dark matter shell has radius equal to that of Moon's orbit. This leads to a prediction for the oscillation period of Earth radius: the prediction is consistent with the observed 5.9 years period. The dark matter shell would correspond to $n = 1$ Bohr orbit in the earlier model for quantum gravitational bound states based on large value of Planck constant if the velocity parameter $v_0$appearing in $\hbar_{gr} = GM_EM_D/v_0$ equals to the rotation velocity of Moon. Also $n > 1$ orbits are suggestive and their existence would provide additional support for TGD view about quantum gravitation. There are further amazing co-incidences. The gravitational Compton length GM/v_0 of particle is very near to to the Earth's radius in case Earth if central mass is Earth mass. For the mass of dark matter shell it is the variation ΔR_E. This strongly suggest that quantum coherence in astrophysical scales has been and perhaps still is present.

6.7.1 Coupled oscillations of radii of Earth and dark matter shell as an explanation for the variations

A possible TGD explanation for the variation emerges from the following arguments.

1. By angular momentum conservation requiring $I\omega = L = constant$ the oscillation of the length of day (LOD) can be explained by the variation of the radius R_E of Earth since the

moment of inertia is proportional to R_E^2. This gives $\Delta LOD/LOD = 2\Delta R/R$. This explains also the apparent variation of G since the gravitational acceleration at the surface of Earth is $g = GM/R_E^2$ so that one has $\Delta g/g = 2\Delta R/R$. Note that the variations have opposite phase.

2. Flyby and Pioneer anomalies [K4] relies on the existience of dark matter shell with a universal surface mass density, whose value is such that in the case of Earth the total mass in the shell would be $M_D \sim 10^{-4} M_E$. The value $M_D/M_E \simeq 1.3\times 10^{-4}$ suggested by TGD is of the same order of magnitude as $\Delta R/R$. Even galactic dark matter around galactic core could correspond to a shell with this surfaces density of mass [K4]. This plus the claim that also Flyby anomaly has oscillatory character suggest a connection. Earth and dark mass shell are in a collective pulsation with a frequency of Earth pulsation about 6 years and the interaction is gravitational attraction. Note that the frequencies need not be the same. Momentum conservation in radial direction indeed requires that both of them participate in oscillation.

6.7.2 A detailed model

One can construct a model for the situation.

1. Earth and dark matter shell are modelled as rigid bodies with spatially constant density except that their radii can change. Earth and dark matter shell are characterized by moments of inertia $I_E = (3/5)\times M_E r_E^3$ and $I_D = (2/3)\times M_D r_D^2$. If one restricts the consideration to a rigid body rotation around fixed axis (call it z-axis), one has effective point masses $M_1 = 3M_E/5$ and $M_2 = 2M_D/3$ and the problem is mathematically very similar to a motion point like particles with these effective masses in plane subject to the mutual gravitational force obtained by averaging the gravitational $1/r$ potential over the volumes of the two mass distributions. In the lowest order the problem is very similar to a central force problem with $1/r$-potential plus corrections coming as series in r_E/r_D. This problem can be solved by using angular momentum conservation and energy conservation.

2. In the lowest order approximation $r_E/r_D = 0$ one has just Kepler problem in $1/r_D$ force between masses M_1 and M_2 for M_D and one obtains the analogs of elliptic orbit in the analog of plane defined by r_D and ϕ. Kepler's law $T_D^2 \propto r_D^3$ fixes the average value of r_D, call this value R_D.

3. In the next approximation one feeds this solution to the equations for r_E by replacing r_D with its average value R_D to obtain the interaction potential depending on the radius r_E. It must be harmonic oscillator potential and the elastic constant determines the oscillation period of r_E. The value of this period should be about 6 yr.

The Lagrangian is sum of kinetic terms plus potential term

$$L = T_E + T_D + V_{gr} \ ,$$

$$T_E = \frac{1}{2}M_E(\frac{dR_E}{dt})^2 + \frac{1}{2}I_E(\frac{d\Phi_E}{dt})^2 \ , \quad T_D = \frac{1}{2}M_D(\frac{dR_D}{dt})^2 + \frac{1}{2}I_D(\frac{d\Phi_D}{dt})^2 \ . \tag{6.23}$$

One could criticize the choice of the coefficients of the kinetic terms for radial coordinates R_E and R_D as masses and one could indeed consider a more general choices. One can also argue, that the rigid bodies cannot be completely spherically since in this case it would not be possible to talk about rotation - at least in quantum mechanical sense.

Gravitational interaction potential is given by

$$
\begin{aligned}
&V_{gr} = -G \int dV_E \int dA_D \rho_E \sigma_D \frac{1}{r_{D,E}} \quad , \quad r_{D,E} = |\overline{r}_D - \overline{r_E}| \quad , \\
&dA_D = r_D^2 d\Omega_D \qquad\qquad dV_E = r_E^2 dr_E d\Omega_E \quad , \\
&\rho_E = \frac{3M_E}{4\pi R_E^3} \quad , \qquad\qquad \sigma_D = \frac{M_D}{4\pi R_D^2} \quad .
\end{aligned}
\tag{6.24}
$$

The integration measures are the standard integration measures in spherical coordinates.

One can extract the r_D factor from $r_{D,E}$ (completely standard step) to get

$$
\begin{aligned}
&\frac{1}{r_{D,E}} = \frac{1}{r_D} X \quad , \\
&X = \frac{1}{|\overline{n}_D - x\overline{n}_E|} = \frac{1}{[1+x^2-2xcos(\theta)]^{1/2}} = \frac{1}{(1+x^2)^{1/2}} \frac{1}{(1-2xcos(\theta)/(1+x^2))^{1/2}} \quad , \\
&x = \frac{r_E}{r_D} \quad , \quad cos(\theta) = \overline{n}_D \cdot \overline{n}_E \quad .
\end{aligned}
\tag{6.25}
$$

Angular integration over θ is trivial and only the integration over r_E remains.

$$
\begin{aligned}
&V_{gr} = -GM_D M_E \frac{3r_D^2}{r_E^3} \int_0^{r_E/r_D} F(\epsilon(x)) \frac{x^2}{(1-x^2)^{1/2}} dx \quad , \\
&F(\epsilon) = \frac{(1+\epsilon)^{1/2} - (1-\epsilon)^{1/2})}{\epsilon} \simeq 1 - \frac{\epsilon}{8} \quad , \\
&\epsilon = \frac{2x}{1+x^2} \quad , \quad x = \frac{r_E}{r_D} \quad .
\end{aligned}
\tag{6.26}
$$

In the approximation $F(\epsilon) = 1$ introducing error of few per cent the outcome is

$$
\begin{aligned}
&V_{gr} = -\frac{3GM_D M_E}{r_D} \times \left[arcsin(x) - x\sqrt{1-x^2} \right] = \frac{3GM_D M_E}{r_D} \left[\frac{2}{3} + \frac{x^2}{5} + O(x^3) + ... \right] \quad , \\
&x = \frac{r_E}{r_D} \quad .
\end{aligned}
\tag{6.27}
$$

The physical interpretation of the outcome is clear.

1. The first term in the series gives the gravitational potential between point like particles depending on r_D only giving rise to the Kepler problem. The orbit is closed - an ellipse whose eccentricity determines the amplitude of $\Delta R_D/R_D$. In higher orders one expects that the strict periodicity is lost in the general case. From the central force condition $M_2\omega_d^2 r_D = GM_D M_E/r_D^2$ one has

$$
T_D = \sqrt{\frac{2}{3}} \times \sqrt{\frac{R_D}{r_{S,E}}} \frac{2\pi R_D}{c} \quad , \quad r_{S,E} = 2GM_E \quad .
\tag{6.28}
$$

$r_{S,E} \simeq 8.87$ mm is the Earth's Schwartschild radius. The first guess is that the dark matter shell has the radius of Moon orbit $R_{Moon} \simeq 60.33 \times R_E$, $R_E = 6.731 \times 10^6$ m. This would give $T_D = T_{Moon} \simeq 30$ days.

2. Second term gives harmonic oscillator potential $k_E R_E^2/2$, $k_E = 6GM_D M_E/5R_D^3$ in the approximation that r_D is constant. Oscillator frequency is

$$T\omega_E^2 = \frac{k_E}{M_E} \times \frac{6GM_D}{5R_D^3} \quad . \tag{6.29}$$

The oscillator period is given by

$$T_E = 2\pi \times \sqrt{\frac{5R_D^3}{6GM_D}} = 2\pi \times \sqrt{53} \times \sqrt{\frac{R_D}{R_{S,D}}} \times \frac{R_D}{c} \quad . \tag{6.30}$$

In this approximation the amplitude of oscillation cannot be fixed but the non-linearity relates the amplitude to the amplitude of r_D.

3. One can estimate the period of oscillation by feeding in the basic numbers. One has $R_D \sim R_{Moon} = 60.34 R_E$, $R_E = 6.371 \times 10^6$ m. A rough earlier estimate for M_D is given by $M_D/M_E \simeq 1.3 \times 10^{-4}$. The relative amplitude of the oscillation is $\Delta G/G = 2\Delta R/R \simeq 2.4 \times 10^{-4}$, which suggests $\Delta R/R \simeq M_D/M_E$.

   The outcome is $T_E \simeq 6.1$ yr whereas the observed period is $T_E \simeq 5.9$ yr. The discrepancy could be due to non-linear effects making the frequency continuous classically.

An interesting question is whether macroscopic quantal effects might be involved.

1. The applicability of Bohr rules to the planetary motion [K18] first proposed by Nottale [E31] encourages to ask whether one could apply also to the effective Kepler problem Bohr rules with gravitational Planck constant $\hbar_{gr} = GM_E M_D/v_0$, where v_0 is a parameter with dimensions of velocity. The rotation velocity of Moon $v_0/c = 10^{-5}/3$ is the first order of magnitude guess. Also one can ask whether also $n > 1$ other dark matter layers are possible at Bohr orbits so that one would have the analog of atomic spectroscopy.

2. From angular momentum quantization requires $L = m\omega^2 R = n\hbar_{gr}$ and from central force condition one obtains the standard formula for the radius of Bohr orbit $r_n = n^2 GM_E/v_0^2$. For $n = 1$ the radius of the orbit would be radius of the orbit of Moon with accuracy of 3 per cent. Note that the mass of Moon is about 1 per cent of the Earth's mass and thus roughly by a factor 100 higher than the mass of the spherical dark matter shell.

Clearly, the model might have caught something essential about the situation. What remains to be understood is the amplitude $\Delta R/R$. It seems that $\Delta R/R \simeq M_D/M_E$ holds true. This is not too surprising but one should understand how this follows from the basic equations.

6.8 The new findings about the structure of Milky from TGD viewpoint

I learned about two very interesting findings forcing to update the ideas about to the structure of Milky Way and allowing to test the TGD inspired Bohr model of galaxy based on the notion of gravitational Planck constant [K18, K14, K26, K28].

The first popular article (see `http://tinyurl.com/gwj5ybv`) tells about a colossal void extending from radius $r_0 = 150$ ly to a radius of $r_1 = 8,000$ ly (ly=light year) around galactic nucleus discovered by a team led by professor Noriyuki Matsunaga. What has been found that there are no young stars known as Cepheids in this region. For Cepheids luminosity and the period of pulsation in brightness correlate and from the period for pulsation one can deduce luminosity and from the luminosity the distance. There are however Cepheids in the central region with radius about 150 ly.

Second popular article (see `http://tinyurl.com/ztdzs9x`) tells about the research conducted by an international team led by Rensselaer Polytechnic Institute Professor Heidi Jo Newberg. Researchers conclude that Milky Way is at least 50 per cent larger than estimated extending therefore to $R_{gal} = 150,000$ ly and has ring like structures in galactic plane. The rings are actually ripples in the disk having a higher density of matter. Milky way is said to be corrugated: there are at least 4 ripples in the disk of Milky Way. The first apparent ring of stars about at distance of $R_0 = 60,000$ ly from the center. Note that R_0 is considerably larger than $r_1 = 8,000$ ly: the ratio is $R_0/r_1 = 15/2$ so that this findings need not have anything to do with the first one.

Consider now the TGD based quantum model of galaxy. Nottale [E31] proposed that the orbits of planets in solar system are actually Bohr orbits with gravitational Planck constant (different for inner and outer planets and proportional to the product of masses of Sun and planet). In TGD this idea is developed further [K18]: ordinary matter would condense around dark matter at spherical cells or tubes with Bohr radius. Bohr model is certainly over-simplification but can be taken as a starting point in TGD approach.

Could Bohr orbitology apply also to the galactic rings and could it predict ring radii as radii with which dark matter concentrations - perhaps at flux tubes assignable to Bohr orbits - are associated? One can indeed apply Bohr orbitology by assuming TGD based model for galaxy formation.

1. Galaxies are associated with long cosmic string like objects carrying dark matter and energy (as magnetic energy) [K3, K18]. Galaxies are like pearls along necklace and experience gravitational potential which is logarithmic potential. Gravitational force is of form $F = mv_1^2/\rho$, where ρ is the orthogonal distance from cosmic string. Here v_1^2 has dimensions of velocity squared being proportional to $v_1^2 \propto GT$, $T = dM/dl$ the string tension of cosmic string.

2. Newtons law $v^2/r = v_1^2/r$ gives the observed constant velocity spectrum

$$v = v_1 \quad . \tag{6.31}$$

   The approximate constancy originally led to the hypothesis that there is dark matter halo. As a matter of fact, the velocity tends to increase (see `http://tinyurl.com/hqzzpfs`). Now there is no halo but cosmic string orthogonal to galactic plane: the well-known galactic jets would travel along the string. The prediction is that galaxies are free to move along cosmic string. There is evidence for large scale motions.

This was still just classical Newtonian physics. What comes in mind that one could apply also Bohr quantization for angular momentum to deduce the radii of the orbits.

1. This requires estimate for the gravitational Planck constant

$$h_{gr} = \frac{GMm}{v_0} \tag{6.32}$$

   assignable to flux tubes connecting mass m to central mass M.

2. The first guess for v_0 would be as

$$v_0 = v_1 \quad . \tag{6.33}$$

   The value of v_1 is approximately $v_1 = 10^{-3}/3$ (unit $c = 1$ are used) (see `http://tinyurl.com/hqzzpfs`).

3. What about mass M? The problem is that one does not have now a central mass M describable as a point mass but an effective mass characterizing the contributions of cosmic string distributed along string and also the mass of galaxy itself inside the orbit of star. It is not clear what value of central mass M should be assigned to the galactic end of the flux tubes.

   One can make guesses for M.

(a) The first guess for M would be as the mass of galaxy $x \times 10^{12} \times M(Sun)$, $x \in [.8 - 1.5]$. The corresponding Schwartschild radius can be estimated from that of Sun (3 km) and equals to .48 ly for $x = 1.5$. This would give for the mass independent gravitational Compton length the value

$$\Lambda_{gr} = \frac{h_{gr}}{m} = \frac{GM}{v_0} = \frac{r_S}{2v_0} \quad (c = 1) \ . \tag{6.34}$$

For $v_0 = v_1$ this would give $\Lambda_{gr} = 4.5 \times 10^3$ ly for $x = 1.5$. Note that the colossal void extends from 150 ly to 8×10^3 ly. This guess is very probably too large since M should correspond to a mass within R_0 or perhaps even within r_0.

(b) A more reasonable guess is that the mass corresponds to mass within $R_0 = 60,000$ ly or perhaps even radius $r_0 = 150$ ly. r_0 turns out to make sense and gives a connection between the two observations.

4. The quantization condition for angular momentum reads as

$$mv_1\rho = n \times \tfrac{h_{gr}}{2\pi} \ . \tag{6.35}$$

This would give

$$\rho_n = n \times \rho_0 \ , \quad \rho_0 = \tfrac{GM}{2\pi v_1 \times v_0} = \tfrac{\Lambda_{gr}}{2\pi v_1} \ . \tag{6.36}$$

The radii ρ_n are integer multiples of a radius ρ_0.

(a) Taking $M = M_{gal}$, the value of ρ_0 would be for the simplest guess $v_0 = v_1$ about $\rho_0 = 2.15 \times 10^6$ ly. This is roughly 36 times larger than the value of the radius $R_0 = 6 \times 10^4$ ly for the lowest ring. The use of the mass of the entire galaxy as estimate for M of course explains the too large value.

(b) By scaling M down by factor 1/36 one would obtain $R_0 = 6 \times 10^4$ ly and $M = M_{gal}/36 = .033. \times M_{gal}$: this mass should reside within R_0 ly, actually within radius Λ_{gr}. Remarkably, the estimate for $\Lambda_{gr} = 2\pi v_1 M$ gives $\Lambda_{gr} = 127$ ly, which is somewhat smaller than $r_0 = 150$ ly associated with void. The model therefore relates the widely different scales r_0 and R_0 assignable with the two findings to each other in terms of small parameter v_0 appearing in the role of dimensionless gravitational "fine structure constant" $\alpha_{gr} = GMm/2h_{gr} = v_0/2$.

The TGD inspired prediction would be that the radii of the observed rings are integer multiples of basic radius. 4 rings are reported implying that the outermost ring should be at distance of 240,000 ly, which is considerably larger than the claimed updated size of 150,000 ly. The simple quantization as integer multiples would not be quite correct. Orders of magnitude are however correct.

This would suggest that visible matter has condensed around dark matter at Bohr quantized orbits or circular flux tubes. This dark matter would contribute to the gravitational potential and imply that the velocity spectrum for distance stars is not quite constant but increases slowly as observed (see `http://tinyurl.com/hqzzpfs`).

6.9 Is Dragonfly a "failed" galaxy?

In Phys.Org (see `http://tinyurl.com/zycob9x`) there was an article telling about the discovery of a dark galaxy - Dragonfly 44 - with mass, which is of the same order of magnitude as that of Milky Way from the estimate based on standard model of galactic dark matter, for which the region within half-light radius is deduced to be 98 per cent dark. The dark galaxies found earlier have been much lighter. Dragonfly 44 posesses 94 globular clusters and in this respects remembles ordinary galaxies in this mass range.

The abstract of the article [E63] (see `http://tinyurl.com/y8z3n8o3`) gives a more quantitative summary about the finding.

Recently a population of large, very low surface brightness, spheroidal galaxies was identified in the Coma cluster. The apparent survival of these Ultra Diffuse Galaxies (UDGs) in a rich cluster suggests that they have very high masses. Here we present the stellar kinematics of Dragonfly 44, one of the largest Coma UDGs, using a 33.5 hr integration with DEIMOS on the Keck II telescope. We find a velocity dispersion of 47 km/s, which implies a dynamical mass of $M_{dyn} = 0.7 \times 10^{10} M_{sun}$ *within its deprojected half-light radius of* $r_{1/2} = 4.6$ *kpc. The mass-to-light ratio is* $M/L = 48 M_{sun}/L_{sun}$*, and the dark matter fraction is 98 percent within the half-light radius. The high mass of Dragonfly 44 is accompanied by a large globular cluster population. From deep Gemini imaging taken in 0.4" seeing we infer that Dragonfly 44 has 94 globular clusters, similar to the counts for other galaxies in this mass range. Our results add to other recent evidence that many UDGs are "failed" galaxies, with the sizes, dark matter content, and globular cluster systems of much more luminous objects. We estimate the total dark halo mass of Dragonfly 44 by comparing the amount of dark matter within* $r = 4.6$ *kpc to enclosed mass profiles of NFW halos. The enclosed mass suggests a total mass of* $\sim 10^{12} M_{sun}$*, similar to the mass of the Milky Way. The existence of nearly-dark objects with this mass is unexpected, as galaxy formation is thought to be maximally-efficient in this regime.*

To get some order of manitude perspective it is good to start by noticing that $r_{1/2} = 4.6$ kpc is about 15,000 ly - the distance of Sun from galactic center is about 3 kpc. The diameter of Milky Way is 31-55 kpc and the radius of the blackhole in the center of Milky Way, which is smaller than 17 light hours.

The proposed interpretation is as a *failed* galaxy. What could this failure mean? Did Dragonfly 44 try become an ordinary galaxy but dark matter remained almost dark inside the region defined by half radius? It is very difficult to imagine what the failure of dark matter to become ordinary matter could mean. In TGD framework this could correspond to phase transition transforming dark identified as $h_{eff} = n \times h$ phases to ordinary matter but this option is not considered in the following. Could the unexpected finding challenge the standard assumption that dark matter forms a halo around galactic center?

The mass of Dragonfly 44 is deduce from the velocities of stars. The faster they move, the larger the mass. The model for dark matter assumes dark matter halo and this in turn gives estimate for the total mass of the galaxy. Here a profound difference from TGD picture emerges.

1. In TGD most of dark matter and energy are concentrated at long cosmic strings transformed to magnetic flux tubes like pearls along string. Galaxies are indeed known to be organized to form filaments. Galactic dark energy could correspond to the magnetic energy. The twistor lift of TGD predicts also cosmological constant [K31]. Both forms of dark energy could be involved. The linear distribution of dark matter along cosmic strings implies a effectively 2-D gravitational logarithmic potential giving in Newtonian approximation and neglecting the effect of the ordinary matter constant velocity spectrum serving as a good approximation to the observed velocity spectrum. A prediction distinguishing TGD from halo model is that the motion along the cosmic string is free. The self-gravitation of pearls however prevents them from decaying.

2. Dark matter and energy at galactic cosmic string (or flux tube) could explain most of the mass of Dragonfly 44 and the velocity spectrum for the stars of Dragonfly 44. No halo of dark stars would be needed and there would be no dark stars within $r_{1/2}$. Things would be exactly what they look like apart from the flux tube!

   The "failure" of Dragonfly 44 to become ordinary galaxy would be that stars have not been gathered to the region within $r_{1/2}$. Could the density of the interstellar gas been low in this region? This would not have prevented the formation of stars in the outer regions and feeling the gravitational pull of cosmic string.

This extremely simple explanation of the finding for which standard halo model provides no explanation would distinguish TGD inspired model from the standard intuitive picture about the formation of galaxies as a process beginning from galactic nucleus and proceeding outwards. Dragonfly 44 would be analogous to a hydrogen atom with electrons at very large orbits only. This analogy goes much further in TGD framework since galaxies are predicted to be quantal objects (see http://tinyurl.com/zgstd9q).

6.10 TGD interpretation for the new discovery about galactic dark matter

A very interesting new result related to the problem of dark matter has emerged: see the ScienceDaily article "In rotating galaxies, distribution of normal matter precisely determines gravitational acceleration" (see http://tinyurl.com/htcgpqe). The original article [E56] can be found at arXiv.org (see http://tinyurl.com/julxz4b).

What is found that there is rather precise correlation between the gravitational acceleration produced by visible baryonic dark matter and the observed acceleration usually though to be determined to a high degree by the presence of dark matter halo. According to the article, this correlation challenges the halo model model and might even kill it.

It turns out that the TGD based model in which galactic dark matter is at long cosmic strings having galaxies along it like pearls in necklace [K19, K3, K14] allows to interpret the finding and to deduce a formula for the density from the observed correlation.

1. The model contains only single parameter, the rotation velocity of stars around cosmic string in absence of baryonic matter defining asymptotic velocity of distant stars, which can be determined from the experiments. Besides this there is the baryonic contribution to matter density which can be derived from the empirical formula. In halo model this parameter is described by the parameters characterizing the density of dark halo.

2. The gravitational potential of baryonic matter deduced from the empirical formula behaves logarithmically, which conforms with the hypothesis that baryonic matter is due to the decay of short cosmic string. Short cosmic strings be along long cosmic strings assignable to linear structures of galaxies like pearls in necklace.

3. The critical acceleration appearing in the empirical fit as parameter corresponds to critical radius. The interpretation as the radius of the central bulge with size about 10^4 ly in the case of Milky Way is suggestive.

6.10.1 The formula for the correlation between the observed acceleration and the contribution of baryonic mass to it

The article represents a nice formula expressing the correlation. The empirical result states that gravitational acceleration created by dark matter correlates very precisely with that produced by baryonic matter.

1. Denote by a_{obs} the observed acceleration of stars. At large distances, where the density of baryonic matter satisfies $\rho_B \sim 0$, the contribution of total baryonic mass M_B to the acceleration is small one has $v^2 = v_{obs}^2$ reflecting the fact that the gravitational potential behaves like v_{obs}^2/R as function of distance.

   Denote by a_B the acceleration created by the baryonic matter. In the region $\rho_B \simeq 0$ a_B is due the total baryonic mass M_B and given by

$$a_B = \frac{v_B^2}{R} = -\partial_R \Phi_B = \frac{GM_B}{R^2} \quad . \tag{6.37}$$

2. Newton's law with a spherically symmetric mass distribution requires $v^2/R = -\partial_R \Phi_R$, which requires that gravitational potential behaves as $log(R/R_0)$ for large distances. To understand this in terms of halo model, one must assume that the dark mass inside sphere of radius R behaves like $M(R) \propto R$ so that gravitational potential $\Phi(R)$ behaves like $log(R/R_0)$.

3. The empirical formula expressing the finding goes as follows:

$$a_{obs}(R) = \frac{a_B(R)}{1-exp(-x)} \quad , \quad v_{obs}^2(R) = \frac{v_B^2(R)}{1-exp(-x)} \quad , \quad x = \sqrt{\frac{a_B}{a_{cr}}} \quad . \tag{6.38}$$

.

What this says that the observed acceleration is related to the acceleration that would be created by mere baryonic matter by an algebraic formula in the quite long range of distances: this is something unexpected. For large distances a_B approaches zero like $1/R^2$ and the first two terms in the Taylor expansion of the exponent are important. This gives the approximation

$$a_{obs}(R) \simeq \sqrt{a_B a_{cr}} \quad . \tag{6.39}$$

This formula is consistent with $a_{obs} = v_{obs}^2/R$. If the baryonic mass density vanishes above R_{cr} corresponding to $a_{cr} = GM_B/R_{cr}^2$, one obtains for $R > R_{cr}$ in approximation $1 - exp(-x_{cr}) = x_{cr}$

$$v_{as}^2 = \frac{GM_B}{R_{cr}(1-exp(-x_{cr}))} = \frac{R_{S,B}}{2R_{cr}(1-exp(-x_{cr}))} \quad . \tag{6.40}$$

Here $R_{S,B} = 2GM_B$ is the Schwartchild radius assignable to the baryonic matter. If one has $\rho_B \sim 0$ at R_{cr} , one has $a_{cr} \equiv -\partial_R \Phi_B = GM_B/R_{cr}^2$. Otherwise one expects a different value of a_{cr}.

4. There are two cases to consider. Baryonic mass density is non-vanishing above R_{cr} (General case) or vanishes in good approximation above R_{cr} (Special case). Accordingly, one has

$$\begin{aligned} v_{obs}^2 &= R\sqrt{a_B a_{cr}} \quad \text{for} \quad R \geq R_{cr} \quad \text{(General case)} \quad , \\ v_{obs}^2 &= v_{as}^2 = \frac{R_{S,B}}{2R_{cr}(1-exp(-x_{cr}))} \quad \text{for} \quad R \geq R_{cr} \quad \text{(Special case)} \quad . \end{aligned} \tag{6.41}$$

6.10.2 TGD based model

Can one interpret the finding in TGD Universe and what implications it has for a model of galaxy?

1. In TGD Universe dark matter does not form a halo but is concentrated at dark cosmic string (thickened magnetic flux tube) along which galaxies are organized like pearls in necklace. The cosmic string corresponds to a geodesic sphere of CP_2, which can be either homologically trivial or non-trivial. In the first case both Kähler action and volume term contribute to string tension T, in the latter case only volume term. Criticality hypothesis states that the string tensions are same: this condition relates their transverse cross-sectional areas [L2].

2. The basic implication is that the gravitational potential depends on the orthogonal distance ρ from the cosmic string only and has a logarithmic dependence so that constant velocity spectrum follows automatically at large distances. The motion along cosmic string is free apart from self-gravitation of baryonic matter. Constant velocity spectrum is modified by the presence of the baryonic matter but the modification is small at large distances. The general prediction for the velocity in the region with $\rho_B = 0$ is

$$v_{as}^2 = nTG \quad . \tag{6.42}$$

where n is numerical constant. If one takes seriously the quantum criticality hypothesis [L2], T is expressible in terms of the basic parameters of TGD (cosmological constant Λ

in recent cosmology, CP_2 radius, Kähler coupling strength $\alpha_K \simeq \alpha_{U(1)}$ [K9], and the area S of transversal section of cosmic string, which approaches the area S of CP_2 geodesic sphere in primordial cosmology for homologically non-trivial (magnetically charged) cosmic strings [K31] [L2].

3. This gives for the two options

$$\begin{aligned} v_{as}^2 &= nTG = \sqrt{\frac{R_{S,B}a_{cr}}{2}} \quad \text{(General case)} \ , \\ v_{as}^2 &= \frac{R_{S,B}}{2R_{cr}(1-exp(-x_{cr}))} \quad \text{(Special case)} \ . \end{aligned} \tag{6.43}$$

From either formula one could estimate the value of T and R_{cr} if M_B and v_{obs}^2 are known. The assumption that the value of $T$is universal need not hold true but would predict that R_{cr} is proportional to $R_{S,B}$ and thus to the baryonic mass M_B. This prediction could be tested by studying velocity spectra for galaxies along big cosmic string.

4. The general condition gives in the region with $\rho_B \sim 0$ the equation

$$\begin{aligned} & v_{obs}^2(R) = v_B^2 \times f(x) \ , && f(x) = \frac{1}{1-exp(-x)} = \frac{1+\frac{x}{2}+\frac{x^2}{12}+...}{x} \ , \\ & x = x_a = \sqrt{\frac{a_B}{a_{cr}}} \ \text{(General case)} \ , && x = x_b = \frac{R_{cr}}{R} \ \text{(Special case)} \ . \end{aligned} \tag{6.44}$$

5. In the region $\rho_B \sim 0$ Newton's equations allow to solve $v_{obs}^2(R)$

$$v_{obs}^2(R) = v_{as}^2 + v_B^2 = v_{as}^2 + \frac{R_{S,B}}{2R} \ , \tag{6.45}$$

Note that in halo model v_{as}^2 is replaced with the velocity squared associated with the dark model halo and is function of R.

Comparing with the previous formula one obtains in this region the consistency condition

$$f(x) \ = \ 1 + \frac{v_{as}^2}{v_B^2} = 1 + \frac{2v_{as}^2 R}{R_{S,B}} \ . \tag{6.46}$$

The expression for $v_{obs}^2(R)$ can be written in the region $\rho_B \sim 0$ in terms of x

$$\begin{aligned} & v_{obs}^2 = v_{as}^2 + Kx \ , \\ & K = \sqrt{\frac{R_{S,B}a_{cr}}{2}} \ , \quad x = x_a = \sqrt{\frac{a_B}{a_{cr}}} \ \text{(General case)} \ , \\ & K = \frac{R_{S,B}}{2R_{cr}} \ , \quad x = x_b = \frac{R_{cr}}{R} \ \text{(Special case)} \ . \end{aligned} \tag{6.47}$$

6. At smaller distances one can express v^2/R as sum of stringy and baryonic accelerations require consistency with the empirical formula:

$$v_{as}^2 + Ra_{cr}x^2 = v_B^2 f(x) = Ra_{cr}x^2 f(x) \ , \quad x = \sqrt{\frac{a_B}{a_{cr}}} \tag{6.48}$$

giving a highly non-linear transcendental equation for x. This allows a numerical determination of x.

7. One can deduce also ρ_B as the source of the baryonic gravitational potential in terms of the Laplace equation

$$\partial_R a_B + \frac{2}{R} a_B = kG\rho_B \quad . \tag{6.49}$$

Here k is a numerical constant. Note that spherical symmetry is assumed for ρ_B. Expressing this equation in terms of $x_a = \sqrt{a_B a_{cr}}$ using $a_B = x_a^2/a_{cr}$ one obtains

$$\rho_B = 2\frac{a_{cr}}{kG}\left[x_a \frac{dx_a}{dR} + \frac{x_a^2}{R}\right] \quad . \tag{6.50}$$

Therefore it is possible to solve ρ_B numerically essentially uniquely. One must also use the approximate condition of Eq. **??** determining a_{cr}.

6.10.3 Consistency condition for large distances

The first thing coming in mind is that one could solve ρ_B iteratively from Eqs. 6.48 and 6.50. Consider first the lowest order approximation at large distances.

Recall that the general consistency condition reads as

$$\begin{array}{ll} v_{as}^2 + Kx = v_B^2 f(x) = Rx^2 a_{cr} f(x) \ , & f(x) = \frac{1}{1-e^{-x}} \ . \\ K = \sqrt{\frac{R_{S,B} a_{cr}}{2}} \ , & x = x_a = \sqrt{\frac{a_B}{a_{cr}}} \ \text{(General case)} \ , \\ K = \frac{R_{S,B}}{2R_{cr}} \ , & x = x_b = \frac{R_{cr}}{R} \ \text{(Special case)} \ . \end{array} \tag{6.51}$$

Consider first this condition for large values of R for which the approximation $f(x) \simeq 1/x$ holds true.

1. Using the approximation $f(x) \simeq 1/x$ one obtains

$$\begin{array}{ll} x = \frac{v_{as}^2}{a_{cr}} \frac{1}{R-R_{min}} \ , & R_{min} = \frac{K}{a_{cr}} \ , \\ K = \sqrt{\frac{R_{SB} a_{cr}}{2}} \ \text{(General case)} & K = \frac{R_{SB}}{R_{cr}} \ \text{(Special case)} \ , \\ a_B = a_{cr} x^2 = \frac{v_{as}^4}{a_{cr}} \frac{1}{(R-R_{min})^2} \ . & \end{array} \tag{6.52}$$

In the region, where one has $\rho_B \sim 0$ the expression for a_B must reduce to $R_{S,B}/2R^2$ in good approximation and this gives the consistency condition

$$a_{cr} = \frac{2v_{as}^4}{R_{S,B}} \ , \quad a_B = \frac{R_{SB}}{2(R-R_{min})^2} \ \text{(General case)} \ . \tag{6.53}$$

The expression differs from the acceleration field of point mass M_B only by the shift $R \rightarrow R - R_{min}$. One expects that the emergence of of singularity at R_{min} is due to the failure of the fact that the first term in the Taylor expansion of $1 - exp(-x)$ is not a good approximation. R_{min} could however have physical counterpart too.

For the (Special case) one obtains and additional consistency condition allowing to determine the value of R_{cr}

$$R_{cr} = \frac{R_{SB}}{2v_{as}} \text{ (Special case) } . \tag{6.54}$$

For Milky Way (see `http://tinyurl.com/hqr6m27`) one has $M_B \sim 10^{10}$ solar masses. From $R_{S,Sun} \sim 3$ km one has $R_{S,B} \sim 1$ ly. For Milky with $R_{SB} \sim 1$ ly one has $R_{cr} \sim 10^3$ ly to be compared with the radius of high density bulk about 10^4 ly. This looks rather reasonable. For the general solution $R_{cr} = R_{min}$ is a free parameter and the natural guess is $R_{cr} = R_{min} \sim 10^4$ ly. Note that R_{cr} is of same order of magnitude as the smallest radius in the determination of the correlation between v_{obs} and v_B [E56].

The solution becomes singular at $R = R_{min} = R_{cr}$. This gives

$$R_{min} = R_{cr} \text{ (General case) } , \quad R_{min} = R_{cr} = \frac{R_{SB}}{2v_{as}} \text{ (Special case) } . \tag{6.55}$$

Taking the limit $R \to \infty$ the equation for a_B should should give $a_B \simeq R_{S,B}/2R^2$. This is true for (Special case) in this region. It seems however that in this case is predicts too small R_{min}. This suggests that R_{min} as a free parameter should have identification as the radius of galactic bulk. The formulas for R_{cr} and a_{cr} depend only on string tension and galactic Schwartschild radius. Interestingly, the proposal for the Bohr quantization of planetary orbits using gravitational Planck constant $h_{gr} = GMm/v_{obs}$ leads to analogous formulas for their radii [K18].

2. One obtains an estimate for ρ_B from Eq. 6.50 as

$$\rho_B = \frac{2v_{as}^2 R_{SB}}{|k|G} \frac{R_{min}}{R(R-R_{min})^3} \quad , \quad R_{min} = R_{cr} = \frac{R_{SB}}{2v_{as}} \text{ (Special case) } . \tag{6.56}$$

Near R_{min} the density would become singular as $1/(R-R_{min})^3$, a symptom about the failure of the approximation. At distances $R >> R_{min}$ one has

$$\rho_B = \frac{2v_{as}^2 R_{SB} R_{cr}}{|k|G} \frac{1}{R^4} = \frac{v_{as} R_{SB}^2}{|k|G} \frac{1}{R^4} . \tag{6.57}$$

The total baryonic mass $M_B(R_1, R_2)$ for any region $R_{min} < R_1 < R < R_2$ is finite and for $R_1 >> R_{min}$ one can express it has

$$\frac{M_B(R_1,R_2)}{M_B} = C\frac{R_{SB}(R_2-R_1)}{R_1R_2} \quad , \quad C = 8\pi\frac{v_{as}^2 R_{cr}}{R_{SB}M_B} \text{ for (General case)}$$
$$C = \frac{4\pi}{3}\frac{v_{as}M_B}{|k|} \text{ (Special case) } . \tag{6.58}$$

The fraction is very small since the size scale of say Milky way is 10^5 ly and the formula states that the contribution to the total baryonic mass from the regions, where the approximation makes sense, is essentially zero. It is certainly not sensible to assume that most of the baryonic mass comes from region near R_{min}. The higher order contributions must be crucial since the expression for $f(x)$ is proportional to the factor $1/(1-exp(-x))$ diverging for large values of x (small values of R).

6.10.4 Consistency condition for small distances

One can study the consistency condition in the lowest order approximation also for small radii (large value of x).

1. At the limit of small radii one has $f(x) = 1$. Substituting this to the consistency condition of Eq. 6.48, one obtains

$$\begin{array}{l} v_{obs}^2 + Kx = Rx^2 a_{cr} \ , \qquad K = \sqrt{\frac{R_{SB} a_{cr}}{2}} \ \text{for (General case)} \ , \\ K = \frac{R_{SB}}{2R_{cr}} \ \text{(Special case)} \ . \end{array} \tag{6.59}$$

allowing to solve x and a_B as

$$x = \frac{R_{SB}}{4v_{as}R}\left[1 + \epsilon\sqrt{1+z}\right] \quad z = \frac{8v_{as}^2}{R_{SB}} R \ , \quad \epsilon = \pm 1 \ . \tag{6.60}$$

Here also the option $\epsilon = -1$ is excluded because it leads to negative density.

2. Acceleration $a_B$andthe baryonic contribution to the velocity squared $v_B^2 = Ra_B$ are given as

$$a_B = \frac{R_{SB}}{8R^2}\left[1 + \sqrt{1+z}\right]^2 \ , \quad v_B^2(R) = \frac{R_{SB}}{8R}\left[1 + \sqrt{1+z}\right]^2 \ . \tag{6.61}$$

Note that their is no dependence on R_{cr}. a_B approaches zero roughly like $1/R^2$ for small values of z: the interpretation is in terms of the gravitational field of point like mass. a_B behaves like $1/R$ large values of R: the interpretation is in terms of cosmic string dominance. The result conforms with the observed slow gradual increase of $v_{obs}^2(R)$. Φ_B can be integrated from a_B as $\Phi = -\int a_B dR$.

3. Only the terms involving square root term in a_B contribute to ρ_B, and one obtains the expression

$$\rho_B = \frac{v_{as}^2 m_P}{|k| l_P R^2} \times \left[1 + \frac{1}{\sqrt{1+z}}\right] \ , \quad z = \frac{8v_{as}^2}{R_{SB}} R \ , \ . \tag{6.62}$$

ρ_B is proportional to $1/R^2$ but for the physically acceptable option $\epsilon = 1$ it becomes infinite at R_{cr} suggesting in TGD framework the presence of dark matter shell around which baryonic dark matter is condensed.

In the case of Milky Way the order of magnitude for ρ_B near $R = R_{S,B}$, where the contribution from z-dependent term is small, is

$$\rho_B \sim \frac{v_{as}^2 m_P}{2 l_P R_{S,B}^2 |k|} \ .$$

For $v_{obs} = 2^{-11}$ one would have $\rho_B \sim 8 \times 10^{16} m_p$ per cubic meter. At smaller radii the density increases as $1/R^2$.

The numerical iteration of the consistency condition Eq. 6.48 combined with the mass formula 6.50 is possible by solving x at the left hand side of the consistency condition by substituting the previous value for x_a to the right hand side of Eq. 6.48.

6.10.5 Velocity curves of galaxies decline in the early Universe

A new twist in the galactic dark matter puzzles emerged as Sabine Hossenfelder gave a link to a popular article "Declining Rotation Curves at High Redshift" (see `http://tinyurl.com/l6lpgk2`) telling about a new strange finding about galactic dark matter. The rotation curves are declining in the early Universe meaning distances about 10 billion light years [E43] (see `http://tinyurl.com/jvp6fey`). In other words, the rotation velocity of distant stars decreases with radius rather than approaching constant - as if dark matter would be absent and galaxies were baryon dominated.

This challenges the halo model of dark matter. For the illustrations of the rotation curves see the article. Of course, the conclusions of the article are uncertain.

Some time ago also a finding about correlation of baryonic mass density with density of dark matter emerged: the ScienceDaily article "In rotating galaxies, distribution of normal matter precisely determines gravitational acceleration" can be found at `http://tinyurl.com/htcgpqe`. The original article [E56] can be found in arXiv.org (see `http://tinyurl.com/julxz4b`). TGD explanation involves only the string tension of cosmic strings and predicts the behavior of baryonic matter on distance from the center of the galaxy.

In standard cosmology based on single-sheeted GRT space-time large redshifts mean very early cosmology at the counterpart of single space-time sheet, and the findings are very difficult to understand. What about the interpretation of the results in TGD framework? Let us first summarize the basic assumptions behind TGD inspired cosmology and view about galactic dark matter.

1. The basic difference between TGD based and standard cosmology is that many-sheeted space-time brings in fractality and length scale dependence. In zero energy ontology (ZEO) one must specify in what length scale the measurements are carried out. This means specifying causal diamond (CD) parameterized by moduli including the its size. The larger the size of CD, the longer the scale of the physics involved. This is of course not new for quantum field theorists. It is however a news for cosmologists. The twistorial lift of TGD allows to formulate the vision quantitatively.

2. TGD view resolves the paradox due to the huge value of cosmological constant in very small scales. Kähler action and volume energy cancel each other so that the effective cosmological constant decreases like inverse of the p-adic length scale squared because these terms compensate each other. The effective cosmological constant suffers huge reduction in cosmic scales and solves the greatest (the "most gigantic" would be a better attribute) quantitative discrepancy that physics has ever encountered. The smaller value of Hubble constant in long length scales finds also an explanation [K27]. The acceleration of cosmic expansion due to the effective cosmological constant decreases in long scales.

3. In TGD Universe galaxies are located along cosmic strings like pearls in necklace, which have thickened to magnetic flux tubes. The string tension of cosmic strings is proportional to the effective cosmological constant. There is no dark matter hallo: dark matter and energy are at the magnetic flux tubes and automatically give rise to constant velocity spectrum for distant stars of galaxies determined solely by the string tension. The model allows also to understand the above mentioned finding about correlation of baryonic and dark matter densities [L4].

What could be the explanation for the new findings about galactic dark matter?

1. The idea of the first day is that the string tension of cosmic strings depends on the scale of observation and this means that the asymptotic velocity of stars decreases in long length scales. The asymptotic velocity would be constant but smaller than for galaxies in smaller scales. The graphs of `http://tinyurl.com/l6lpgk2` show that in the velocity range considered the velocity decreases. One cannot of course exclude the possibility that velocity is asymptotically constant.

   The grave objection is that the scale is galactic scale and same for all galaxies irrespective of distance. The scale characterizes the object rather than its distance for observer. Fractality suggests a hierarchy of string like structures such that string tension in long scales decreases and asymptotic velocity associated with them decreases with the scale.

2. The idea of the next day is that the galaxies at very early times have not yet formed bound states with cosmic strings so that the velocities of start are determined solely by the baryonic matter and approach to zero at large distances. Only later the galaxies condense around cosmic strings - somewhat like water droplets around blade of grass. The formation of these gravitationally bound states would be analogous to the formation of bound states of ions and electrons below ionization temperature or formation of hadrons from quarks but taking place in much longer scale. This model explains the finding about the decline of the rotation velocities [E43]: the early galaxies are indeed baryon dominated.

6.10.6 Further support for TGD view about galactic dark matter

The newest finding is described in popular article "This Gigantic Ring of Galaxies Could Bring Einstein's Gravity Into Question" (see http://tinyurl.com/jwnfanl). What has been found that in a local group of 54 galaxies having Milky Way and Andromeda near its center the other dwarf galaxies recede outwarts as a ring. The local group is in good approximation in plane and the situation is said to look like having a spinning umbrella from which the water droplets fly radially outwards.

The authors of the article "Anisotropic Distribution of High Velocity Galaxies in the Local Group" [E49] (see http://tinyurl.com/mtm5vcm) argue that the finding can be understood aif Milky Way and Andromeda had nearly head-on collision about 10 billion light-years ago. The Milky Way and Andromeda would have lost the radially moving dwarf galaxies in this collision during the rapid acceleration turning the direction of motion of both. Coulomb collision is good analog.

There are however problems. The velocities of the dwards are quite too high and the colliding Milky Way and Andromeda would have fused together by the friction caused by dark matter halo.

What says TGD? In TGD galactic dark matter (actually also energy) is at cosmic strings thickened to magnetic flux tubes like pearls along necklace. The finding could be perhaps explained if the galaxies in same plane make a near hit and generate in the collision the dwarf galaxies by the spinning umbrella mechanism.

In TGD Universe dark matter is at cosmic strings and this automatically predicts constant velocity distribution. The friction created by dark matter is absent and the scattering in the proposed manner could be possible. The scattering event could be basically a scattering of approximately parallel cosmic strings with Milky Way and Andromeda forming one pearl in their respective cosmic necklaces.

But were Milky Way and Andromeda already associated with cosmic strings at that time? The time would be about 10 billion years. One annot exclude this possibility. Note however that the binding to strings might have helped to avoid the fusion. The recent finding [E43] (see http://tinyurl.com/l6lpgk2) about effective absence of dark matter about 10 billion light years ago - velocity distributions decline at large distances - suggests that galaxies formed bound states with cosmic strings only later. This would be like formation of neutral atoms from ions as energies are not too high!

6.11 Bullet cluster, cold dark matter, and MOND

Sabine Hossenfelder (see http://tinyurl.com/jm4kevp) wrote about Bullet Cluster (see http://tinyurl.com/jm4kevp). Usually Bullet Cluster is seen to favor dark matter and disfavor MOND theory (see http://tinyurl.com/pu36kqgs) introducing a modification of Newtonian gravity. Sabin Hossenfelder saw it differently.

Cold dark matter model (ΛCDM) and MOND are two competing mainstream models explaining the constant velocity spectrum of stars in galaxies.

1. ΛCDM (see http://tinyurl.com/zv6wg4s) assumes that dark matter forms a spherical halo around galaxy and that its density profile is such that it gives the observed velocity spectrum of distant stars approaching to constant and even increasing at large distances (see http://tinyurl.com/ohbdqj6). The problem of the model is that dark matter distribution can have many shapes and it is not easy to understand why approximately constant velocity spectrum is obtained. Also the attempts to find dark matter particles identified as some exoticons have failed one after another. The recent finding that the velocity spectrum of distant stars around galaxies correlates strongly with the density of baryonic matter (see http://tinyurl.com/julxz4b) also challenges this model: it is difficult to believe that the halo would have so universal baryonic mass density (for TGD view see [L4].

2. MOND does not assume dark matter but makes an ad hoc modification of gravitational force for small accelerations. The problem of MOND is that it is indeed an ad hoc modification and it is not easy to see how to make it consistent with general relativity: it is difficult to do cosmology using MOND. For small accelerations (small space-time curvatures) one would expect Newtonian theory to be an excellent approximation.

Consider now how Bullet Cluster relates to these two options. Bullet cluster is a pair of galaxy clusters which has emerged from collision (see the figure at `http://tinyurl.com/jamzykd`). There exists data at optical wave lengths about stars. Stars experience only a small gravitational slowing down and are expected to go through the collision region rather fast. Data from X-ray measurements give information about the intergalactic gas associated with clusters. This gas interacts electromagnetically and is slowed down much more and remains in the collision region for a longer time. The *red* region regions in the figure correspond to the gas. Gravitational lensing in turn gives information about space-time curvature and these two regions are farthest away from the collision center. These regions are *blue* and would naturally correspond to dark matter in ΛCDM model.

Both models have severe problems.

1. In cold dark matter model the event would require too high relative velocity for colliding clusters - about c/100. The probability for this kind of collision in cold dark matter model is predicted to be very low - about 6.4×10^{-6}. Something seems to be wrong with ΛCDM model.

2. In MOND the relative collision velocities are argued to be much more frequent. Bee however forgot to mention that in MOND the lensing is expected to be associated with X-ray region (hot gas in the center of figure) rather than with the blue regions disjoint from it. This observation is a very severe blow against MOND model.

The logical conclusion is that there indeed seems to be dark matter there but it is something different from the cold dark matter. What it could be?

What could be the interpretation in TGD?

1. In TGD galaxies are associated with cosmic string or more general string like objects like pearls with necklace [K22, K3, K18, L2]: that this is the case is known for decades but for some mysterious reason to me has not been used as guideline in dark matter models. Maybe it is very difficult to see things from bigger perspective than galaxies.

   The flux tubes carry Kähler magnetic energy, dark energy, and dark matter in TGD sense having $h_{eff}/h = n$. The galactic matter experiences transversal $1/\rho$ gravitational force predicting constant velocity spectrum for distant stars when baryonic matter is neglected. Note that one avoids a model for the profile of the halo altogether. The motion of the galaxy along the flux tube is free apart from the forces caused by galaxy. The presence of baryonic matter implies that the velocity increases slowly with distance up to some critical radius. By recent findings correlating observed velocity spectrum with density of baryonic matter one can deduce the density of baryonic matter [L4](see `http://tinyurl.com/gvdclqg`). A possible interpretation is as remnants of cosmic string like object produced in its decay to ordinary matter completely analogous to the decay of the vacuum energy of inflaton field to matter in inflation theory.

   The order of magnitude for velocity v_{gal} for distant stars in galaxies is about $v_{gal} \sim c/1000$. In absence of baryonic matter it is predicted to be constant and proportional satisfy $v \propto (TG)^{1/2}$, T string tension and G Newton's constant ($c = 1$). T in turn is proportional to $1/R^2$, where R is CP_2 radius. Maximal velocity is obtained for cosmic strings. For magnetic flux tubes resulting when cosmic strings develop 4-D M^4 projection string tension T and thus v_{gal} is reduced. One obtains larger velocities if there are several parallel flux tubes forming a gravitational bound state so that tensions add.

2. By fractality also galaxy clusters are expected to form similar linear structures. Concerning the interpretation of the Bullet Cluster one can imagine two options.

   (a) The two colliding clusters could belong to the same string like object and move in opposite directions along it. In this case gravitational lensing would be most naturally associated with the flux tube and there would be single linear blue region instead of the two blue spots of the figure.

(b) The clusters could also belong to different flux tubes, which pass by each other and induce the collision of clusters and the gas associated with them. If the flux tubes are more or less parallel and orthogonal to the plane of the figure, the gravitational lensing would be from the two string like objects and two disjoint blue spots would appear in the figure. This option conforms with the figure.

3. The collision velocity would correspond to the relative velocity of flux tubes. Can one say anything about the needed collision velocities? The naive first guess of dimensional analyst is that the rotation velocity $v_{gal} \propto (TG)^{1/2}$ determining galactic rotation spectrum determines also the typical relative velocity between galaxies. Here T would be the string tension of flux tubes containing galaxy clusters along it. T would gradually decrease during the cosmic evolution as flux tubes gets thicker and magnetic energy density is reduced. The velocity $v \sim c/100$ suggested by ΛCDM model is 10 times larger than $v \sim c/1000$ for distant stars in galaxies.

   By fractality similar view would apply to galaxy clusters assigned to flux tubes. Cluster flux tubes containing clusters along them could correspond to bound states of parallel galactic flux tubes containing galaxies along them.

4. The simplest model for collision of flux tubes treats them as parallel rigid strings so that dimensional reduction to $D = 2$ occurs. The gravitational potential is logarithmic potential: $V = Klog(\rho)$. One can use conservation laws of angular momentum and energy to solve the equations of motion just as in 3-D central force problem. The initial and final angular momentum per mass equals to $J = v_0 a$, where a is the impact parameter and v_0 the initial velocity. The initial energy per unit mass equals to $e = v_0^2/2$ and is same in the final state. Conservation law for e gives $e = v^2/2 + Klog(\rho) = v_0^2/2$.

   Conservation law for angular momentum reads $j = v\rho sin(\phi) = v_0 a$ and gives $v = j/(\rho sin(\phi))$. Velocity is given from $v^2 = (d\rho/dt)^2 + \rho^2(d\phi/dt)^2$ and leads together with conservation laws a first order differential equation for $d\rho/dt$.

   Since the potential is logarithmic, there is rather small variation of energy in the collision so that the clusters interact rather weakly. This could produce the same effect as larger relative collision velocity in ΛCDM model with kinetic energy dominating over gravitational potential.

6.12 TGD view about universal galactic rotation curves for spiral galaxies

7 TGD view about universal galactic rotation curves for spiral galaxies

The TGD inspired model for galaxy formation [L4, L7, L5] [K3, K18, L5] describes spiral galaxies as pearls in necklace defined by long cosmic string, whose gravitational field explains asymptotically constant rotation curve. In its recent form does not however say much about the situation near the galactic center.

1. Is all dark matter associated with the long cosmic strings defining the necklace around which galaxies are bound? Do also galaxies contain dark matter? If so, do galaxies correspond to separate closed dark cosmic strings or do they correspond to knots of long cosmic strings?

2. Is galactic center a reconnection point of two cosmic strings, which led to the formation of galaxies as some findings suggest? Or does it correspond to self-intersection of long knotted cosmic string?

3. What happened to the cosmic strings if the reconnection happened? Who ordinary galactic matter emerged Did the cosmic string thicken? If so, the conservation of monopole magnetic flux would have reduced dark magnetic energy density of the string density by a factor, which is roughly the ratio of original and final transversal area. Did the liberated dark energy give rise to the ordinary matter?

4. Could TGD based model say something interesting about constant density core region for which there is now more empirical evidence [L8] but which is not consistent with the halo model of dark matter nor with the idea about un-knotted cosmic string.

5. Could TGD provide some ideas about the origin of Fermi bubbles [E67, E25] and supermassive blackhole at galactic center?

The observed universality rotation curves for mini spiral galaxies [L8] led to a considerable progress in TGD inspired model of galaxy formation. In TGD universality reduces to scaling invariance of the rotation curves natural since TGD Universe is quantum critical. The study of mini spiral galaxies supports the conclusion that they have a dark matter core of radius of few parsecs - 2-3 times the optical radius. This is a problem in the halo models. The simplest TGD based explanation is that galaxies correspond to knots or even spaghetti like tangles of long dark strings defining a kind of necklace containing galaxies as pearls. The model also suggests that dark matter core gives rise to Fermi bubble. Dark cosmic ray protons from supermassive galactic black hole containing dark matter would scatter from dark matter and some fraction of the produced dark photons would transform to ordinary ones. This would take place only inside the dark matter sphere and double sphere structure would be due to the fact that cosmic rays would not proceed far in galactic plane.

7.1 Universal rotation curves for mini spirals

There was an interesting popular article "Beyond the standard model through 'mini spirals'" in ScienceDaily (see `http://tinyurl.com/j7mbeyt`), which gave the stimulus for posing the above questions. Mini spirals with size scale about 1 tenth of Milky Way were studied statistically by Professor Paolo Salucci of the International School for Advanced Studies (SISSA) in Trieste, and Ekaterina Karukes, who recently earned her PhD at SISSA.

The abstract of their article [L8] (see `http://tinyurl.com/yac5gpo3`) gives idea about what is involved.

> *We use the concept of the spiral rotation curves universality to investigate the luminous and dark matter properties of the dwarf disc galaxies in the local volume (size ~ 11 Mpc). Our sample includes 36 objects with rotation curves carefully selected from the literature. We find that, despite the large variations of our sample in luminosities ($\sim$ 2 of dex), the rotation curves in specifically normalized units, look all alike and lead to the lower-mass version of the universal rotation curve of spiral galaxies found in Persic et al.*
>
> *We mass model the double normalized universal rotation curve $V(R/R_{opt})/V_{opt}$ of dwarf disc galaxies: the results show that these systems are totally dominated by dark matter whose density shows a core size between 2 and 3 stellar disc scale lengths. Similar to galaxies of different Hubble types and luminosities, the core radius R_0 and the central density ρ_0 of the dark matter halo of these objects are related by $\rho_0 R_0 \sim 100M(Sun)pc^2$.*
>
> *The structural properties of the dark and luminous matter emerge very well correlated. In addition, to describe these relations, we need to introduce a new parameter, measuring the compactness of light distribution of a (dwarf) disc galaxy. These structural properties also indicate that there is no evidence of abrupt decline at the faint end of the baryonic to halo mass relation. Finally, we find that the distributions of the stellar disc and its dark matter halo are closely related.*

Authors assume dark halo model in their analysis. Core radius R_0 defined as radius below which mass density is constant and central density ρ_0 of dark matter appears as parameters of the model. Authors conclude that the properties of dark and visible parts of mini spirals are closely correlated, dark matter dominates and has core size about 2-3 times the stellar disk size, and that standard models of dark matter cannot explain this: mini spirals could serve as "portals" to new physics.

The work gives additional support for the proposal that the rotation curves of all spiral galaxies are universal obeying scaling invariance typical for critical systems. The parameters in the rotation curve are optical radius R_{opt} characterizing the visible size of the galaxy and the velocity $v(R_{opt})$ of star at distance R_{opt} defining the size of the region containing start. Authors report the function

$$\frac{v(\frac{R}{R_{opt}})}{v_{opt}} = f(x) \ , \ x = \frac{R}{R_{opt}} \ . \tag{7.1}$$

us universal, that is the shape of the $f(x)$ does not depend on mini spiral and differs only by the unit v_{opt} of velocity and unit R_{opt} of distance of different galaxies.

The authors try to explain the universal shape using dark matter halo model and conclude that the core radius is 2-3 times the stellar disk size so that dark matter density would be constant below this radius and give to gravitational potential a harmonic oscillator contribution proportional to R^2 predicting rigid body rotation. The presence of constant density sphere is in conflict with halo models predicting typically density dependence of form $1/R$ at small radii. This is known as halo-cusp problem [E66].

7.2 TGD view about mini spirals

One can approach the situation also from TGD point of view. Consider first how to obtain scaling invariant velocity spectrum if the gravitational force in galactic plane as sum of dark matter/energy contribution from string with string tension T and a contribution from visible matter? If dark matter dominates, how it is possible to obtain constant density of matter. One option is that there is pearl defined by closed magnetic flux tube containing dark matter but in this case the long string would give a large and dominating contribution to the velocity. Second option is that the long string is "knotted": the pearl would be actually a knot.

7.2.1 Scaling law

Consider first the situation for $R > R_0$.

1. Flux tube has some radius about which is expected to be of the order of CP_2 radius as it is for ideal cosmic strings. Thickening however increases the radius but not much.

2. Newton's law gives

$$v^2 = kTG + \frac{GM(R)}{R} \tag{7.2}$$

   giving

$$\frac{v^2}{v_{opt}^2} = \frac{kTG + GM(R)/R}{kTG + GM(R_{opt})/R_{opt}} \ . \tag{7.3}$$

3. To get scaling invariance one must assume

$$M(R) = M_{opt}x^{n+1} \ , \ x = \frac{R}{R_{opt}} \ . \tag{7.4}$$

   The density of visible matter should therefore satisfy $\rho_{vis} \propto x^{n-2}$. This gives universal velocity spectrum

$$\frac{v^2}{v_{opt}^2} = \frac{kTG + GM(R_{opt})x^n}{kTG + GM(R_{opt})} \ , \tag{7.5}$$

which is very natural since string tension is the only parameter characterizing the density of dark matter and TGD Universe is quantum critical. The value of the exponent n can be determined from the shape of the rotation curve. Since the density must decrease with distance, one must have $n < 2$. Note that the value of n cannot be same below R_0 and for $R \geq\geq R_0$. Below R_0 one has $n = 3$ for constant density and for large values of R_0 one as $n < 0$.

7.2.2 How to understand the dark matter core in TGD framework?

The second finding is that the core radius R_0 and the central density ρ_0 of the dark matter halo of these objects are related by the condition

$$\rho_0 \sim \frac{9.4M_S}{ly^2 R_0} \ , \tag{7.6}$$

where M_S is the mass of the Sun. If the density of dark matter is constant for $R < R_0$, this gives rise to rigid body rotation $v = \omega R$ inside the sphere of radius R_0. Halo models however predicts that the density of dark matter behaves like $1/R$ for small distances. This is known as core-cusp problem [E66] (see `http://tinyurl.com/yabhmxdm`).

This finding about mini spirals relates to TGD based model of galaxy in very interesting manner.

1. Since the dark matter dominates over the visible matter in mini spiral galaxies, the matter associated with this region must be modtly dark also in TGD based model. If there is mere cosmic string and if it dominates, the rotational curve would be constant rather than depending linearly on R as for solid body rotation. This cannot be the case.

2. Constant density of dark matter could be due to a formation of a knot- or spaghetti-like structure to the necklace containing galaxies as pearls. Also a thickening of the flux tube could take place. The thickening of the flux tube would reduce by the conservation of magnetic flux its energy density by ratio $T_i/T_f = (R_f/R_{CP_2})^2$. If the length of cosmic string inside R_0 is $R_1 = xR_0$, the total dark mass of this string enclosed inside volume R_0 would

$$M = T_f R_1 = T_f x R_0 = \frac{4\pi}{3} \times \rho_0 R_0^3 = \frac{4\pi}{3} \times \frac{9.4M(Sun)R_0^2}{ly^2} \ , \tag{7.7}$$

   and one would have effective blackhole like entity but with T_f replacing $1/G$. This gives

$$T_f G = \frac{4\pi}{3} \times \frac{9.4 r_S(Sun) x R_0}{ly^2} \tag{7.8}$$

   giving $T_f G = 1.22 \times 10^{-6}/x$. If the string tension is same as that of long string (the necklace), the value of x is about $x = 3.6$. If the thickening occurs the length of the knotted structure is longer and looks like spaghetti and the modelling as constant density of dark matter is better approximation. Note that the total length of knotted string portion behaves as R_0^2 and increases like the area of the dark sphere.

3. The model also explains why the dark matter inside R_0 does not have the same constant velocity spectrum as at large distances. Without the knotting one ends up with contradiction with empirical facts since constant velocity in this region would be much larger than the observed velocities.

4. Also the proposal that stars could be associated with long cosmic strings with possibly reduced string tension due to thickening finds support. Most stars of minimi galaxies reside within region defined by optical radius $R_D/R = \in [.3 - .5]$. If this is the case also for Milky Way, they could correspond to to sub-knots in the galactic knot in long cosmic string. This string might become visible in pulsars: the light beam would naturally propagate along the

cosmic string. This is consistent with the fact that Sun has distance about 8 kpc from the center of Milky Way and the size of Milky Way is about 10 times larger than the size of the minispirals studied.

Also the interiors of TGD counterparts of blackholes would be knots and have magnetic structure, which could predict unexpected features such as magnetic moments not possible for GRT blackholes. Already the model for the first LIGO event [?]xplained the unexpected gamma ray bursts in terms of twisting of the rotating flux tubes as an effect analogous to what causes sunspots: twisting and finally reconnection. What about collisions of blacholes? Could they correspond to two knots moving along same string and colliding or two cosmic strings with possible self-intersect or are very near to each other: galactic traffic accident?

Could one consider instead of constant density of dark matter a genuine spherical surface with surface mass density $\sigma = \rho_0 R_0/3$? It could be present but cannot explain velocity spectrum for $R < R_0$: knotted long string is necessary. I have earlier considered the possibility of this kind of spherical shell consisting of dark matter around galactic nucleus. The key motivation for the idea about surface density is that σ would be universal - at least for mini spirals. This kind of surface associated with Earth and with radius about distance of Moon could explain Flyby anomaly. This kind of dark matter shells could also induce the formation of moons and planets in solar system.

7.2.3 Knotted strings, Fermi bubble, and supermassive blackholes

Galactic centers involve poorly understood phenomena, which TGD based vision should be able to cast some light.

1. Fermi bubbles [E67] (see http://tinyurl.com/y9z3doj9 and http://tinyurl.com/y9qkjdau) detected by Fermi telescope above and below the plane of Milky Way have radius about 2-3 kpc, whereas the optical radii for mini spirals are slightly below 1 kpc and R_0 is reported to be 2-3 times larger - about 2-3 kpc too. Milky Way is not a mini spiral but there could be a connection.

   Could Fermi spheres be a universal phenomenon and relate to the dark matter sphere? Could the radius of the dark matter sphere define the size scale of Fermi bubbles? Fermi bubble is probably related to cosmic ray radiation emerging from the center of the galaxy and inducing in collisions with visible and possibly also dark matter gamma rays, X-ray and microwaves. Since cosmic rays cannot not propagate far in the galactic plane, one has two spheres rather than one. The radius of dark matter sphere defines the upper bound for the propagation distance.

   If cosmic rays interact also with dark matter and induce dark radiation such that part of it transforms to ordinary radiation, the radius of the dark matter sphere would naturally define the upper limit for the distance at which radiation is generated. The simplest option is that the cosmic rays propagate as dark particles from the blackhole and transform only later to ordinary particles. The mechanism transforming dark photons to ordinary ones would be analogous to that producing biophotons [K24].

2. Could there be a connection with the supermassive galactic blackhole in Milky Way (see http://tinyurl.com/y9fhabdk)? One particular model for Fermi bubbles [E25] (see http://tinyurl.com/y6vjw6ej and http://tinyurl.com/yafcz2lh and) assumes that they are remnants of stars eaten by galactic blackhole with mass about 4×10^6 solar masses with Schwartschildt radius about 40 ls (for Sun one gas $r_S = 3$ km): one has roughly $r_S \sim 10^{-6} R_0$. Blackhole would devour part of the stars and burp the rest back out as cosmic ray radiation.

3. One can also wonder about the origin of galactic super-massive blackhole. Could galactic blackhole be a reconnection point of two cosmic strings, which led to the formation of galaxies as some empirical findings such as satellite galaxies in plane nearly orthogonal to the galactic plane suggest? If this is the case the matter of the galactic blackhole could be dark and would emit dark cosmic rays. Or could the blackhole correspond to self-intersection and knotting of a long cosmic string so that second cosmic string would not be necessary?

7.2.4 New view about blackhole like objects and galaxy formation?

I had very interesting discussions with Gareth Lee Meredith who has founded the discussion group Beyond Standard Model. One of the topics of discussion were results related to supermassive blackholes at the centers of galaxies. Gareth gave a link to a popular article (see `http://tinyurl.com/jbn56ul`) telling about correlations between supermassive blackhole in galactic center and the evolution of galaxy itself.

1. The size of the blackhole like object - that is its mass if blackhole in GRT sense is in question - correlates with the constant rotation velocity of distant stars for spiral galaxies.

2. The relationship between the masses of black hole and galactic bulge are in constant relation: the mass ratio is about 700.

3. A further finding is that galactic blackholes of very old stars are much more massive than the idea about galactic blackhole getting gradually bigger by "eating" surrounding stars would suggests.

This looks strange if one believes in the standard dogma that the galactic blackhole started to form relatively lately. What comes in mind is rather unorthodox idea. What if the large blackhole like entity was there from the beginning and gradually lost its mass? In TGD framework this could make sense!

1. In TGD Universe galaxies are like pearls in a necklace defined by a long cosmic string. This explains the flat rotational spectrum and predicts essentially free motion along the string related perhaps to coherent motions in very long length scales. This explains also the old observation that galaxies form filament like structures and the correlations between spin directions of galaxies along the same filament since one expects that the spin is parallel to the filament locally. Filament can of course change its direction locally so that charge of direction of rotation gives information about the filament shape.

2. The channelling of gravitational flux in the radial direction orthogonal to the string makes gravitational force very long ranged ($1/\rho$, ρ the transversal distance, instead of $1/r^2$, r the radial distance) and also stronger and predicts rotational spectrum. This model of dark matter differs dramatically from the fashionable halo model and involves only the string tension as a parameter unlike the halo model.

   The observed rigid body rotation within radius 2-3 times the optical radius (region inside which most stars are) can be understood if the long cosmic string is either strongly knotted or has closed galactic string around long cosmic string. The knotted portion would formed a highly knotted spaghetti like structure giving approximately constant mass density. Stars would be associated with the knotted structure as sub-knots. Light beams from supernovas could be along the string going through the star. Maybe even planets might be associated with thickened strings! One can also imagine intersections of long cosmic strings and Milky Way could contain such.

3. Galactic black hole like object could correspond to a self intersection of the long cosmic string or of closed galactic cosmic string bound to it. There could be several intersections. They would contain both dark matter and energy in TGD sense and located inside the string. Matter antimatter asymmetry would mean that there is slightly more antimatter inside string and slightly more matter outside it. Twistor lift of TGD predicts the needed new kind of CP breaking. What is new that the galactic blackhole like objects would be present from the beginning and lose their dark mass gradually. Time evolution would be opposite to what it has been usually thought to be!

   Most of the energy of the cosmic string would be magnetic energy identifiable as dark energy. During the cosmic evolution various perturbations would force the cosmic string to gradually thicken so that in M^4 projection ceases to be pointlike. Magnetic monopole flux is conserved ($BS=$ constant, S the transversal area), which forces magnetic energy density per unit length - string tension - to be reduced like $1/S$. The lost energy becomes ordinary matter: the energy of inflaton field would be replaced with dark magnetic energy and the TGD counterpart for inflationary period would be transition from cosmic string dominated period to radiation dominated cosmology and also the emergence of space-time in GRT sense.

The primordial cosmic string dominated phase would consist of cosmic strings in $M^4 \times CP_2$. The explanation for the constancy of CMB temperature would suggest quantum coherence in even cosmic scales made possible by the hierarchy of dark matters labelled by the valued of Planck constant $h_{eff}/h = n$. Maybe characterization as a super-fluid rather than gas discussed with Gareth is more precise manner to say it. What would be fantastic that these primordial structures would be directly visible nowadays.

4. The dark matter particles emanating from the dark supermassive blackhole would transform gradually to ordinary matter so that galaxy would be formed. This would explain the correlation of the bulge size with the mass (and size) of the blackhole correlating with the string tension. The rotational velocity of distant stars with string tension so that the strange correlation between velocity of distant stars and size of galactic blackhole is implied by a common cause.

   This also explains the appearance of Fermi bubbles. Fermi bubbles are formed when dark particles from the blackhole scatter with dark matter and partially transform to ordinary cosmic rays and produce dark photons transformed to visible photons partially. This occurs only within the region where the spaghetti like structure containing dark matter inside the cosmic string exists. Fermi bubbles indeed have the same size as this region.

5. While writing this I realized that also the galactic bar (2/3 of spiral galaxies have it) should be understood (see `http://tinyurl.com/p5xez38`). This is difficult if there is nothing breaking the rotational symmetry around the long cosmic string. The situation changes if one has a portion of cosmic string along the plane of galaxy.

   There is indeed evidence for the second straight string portion: in Milky Way there are mini-galaxies rotating in the plane forming roughly 60 degrees angle with respect to galactic plane and the presence of two cosmic strings portions roughly orthogonal to each other could explain this [L5]. Galactic blackhole could be associated with the intersection of string portions. The horizontal string portion could be part of long cosmic string, a separate closed cosmic string, or even another long cosmic string. One can imagine two basic options for the formation of the bar.

   (a) The first option is that galactic bar is formed around the straight portion of string. The gravitational force orthogonal to the string portion would create the bar. The ordinary matter in rigid body rotation would be accelerated while approaching the bar and then slow down and dissipate part of its energy in the process. The slowed down stars would after a further rotation of π tend to stuck around the string portion forming bound states with it and start to rotate around it: a kind of galactic traffic jam. Bars would be asymptotic outcomes of the galactic dynamics. Recent studies have confirmed the idea that bars are now are signs of full maturity as the "formative years" end (see `http://tinyurl.com/p5xez38`).

   (b) Second option is that bar is formed as dark matter inside bar is transformed to ordinary matter as the portion thickens and loses dark energy identified as Kähler magnetic energy by a process analogous to the decay of inflaton vacuum energy. Bars would be transients in the evolution of galaxies rather than final outcomes. This option is not consistent with the idea that that only the galactic blackhole serves as the source of dark matter transforming to ordinary matter.

6. The pearls in string model explains also why elliptic galaxies have declining rotational velocity. They correspond to "free" closed strings which have not formed bound states with long cosmic strings transforming them to spiral galaxies. The recently found 10 billion old galaxies with declining rotational velocity could correspond to elliptical galaxies of this kind.

   One can also imagine the analog of ionization. The bound state of closed cosmic string and long cosmic string decays and spiral galaxy starts to decay under centrifugal force not anymore balanced by the gravitational force of the long cosmic strings and would transform to elliptic galaxy. Also the central bulge would start to increase in size.

It would also lose its central blackhole if is associated with the long cosmic string. I am grateful for Gareth for giving a link to a popular article (see http://tinyurl.com/komloy8) telling about this kind of elliptic galaxy with very large size of one million light years and without central blackhole and unusually large bulge region.

This view about galactic blackholes also suggests a profound revision of GRT based view for the formation of blackholes. Note that in TGD one must of course speak about blackhole like objects differing from their GRT counterparts inside Schwartschildt radius and also outside it in microscopic scales (gravitational flux is mediated by magnetic flux tubes carrying dark particles). Perhaps also ordinary blachholes were once intersections of dark cosmic strings containing dark matter which gradually produce the stellar matter! If so, old blackholes would be more massive than the young ones.

1. This new thinking conform with the findings of LIGO [K18] [L3]. All the three stellar blackholes have been by more than order of magnitude massive than expected. There are also indications that the members of the second blackhole pair merging together did not have parallel spin directions. This does not fit with the idea that a twin pairs of stars was in question. It is very difficult to understand how two blackholes, which do not form bound system could find each other. Similar problem is encountered in bio-catalysis: who to biomolecules manage to find each other in the molecular crowd. The solution to the both problem is very similar.

2. TGD suggests that the collision could have occurred when to blackholes travelling along strings or portions of the same knotted string arrived from different directions. The gravitational attraction between strings would have helped to generate the intersection and strings would have guided the blackholes together. In biological context even a phase transition reducing Planck constant to the flux tube connecting the molecules could occur and bring the molecules together.

7.2.5 Are stars borne in pairs?

Stars seem to be born in pairs! For a popular article see http://tinyurl.com/ybto4tux. The research article “Embedded Binaries and Their Dense Cores” [E62] is at http://tinyurl.com/ycnye48y.

For instance, our nearest neighbor, Alpha Centauri, is a triplet system. Explanation for this have been sought for for a long time. Does star capture occur leading to binaries or triplets. Or does its reverse process in which binary splits up to become single stars occur? There has been even a search for a companion of Sun christened Nemesis.

The new assertion is based on radio survey of a giant molecular cloud filled with recently formed sunlike stars (with age less than 4 million years) in constellation Perseus, a star nursery located 600 ly from us in Milky Way. All singles and twins with separations above 15 AUs were counted.

The proposed mathematical model was able to explain the observations only if all sunlike stars are born as wide binaries. “Wide” means that the mutual distance is more than 500 AU, where AU is the distance of Earth from Sun. After the birth the systems would shrink or split t within time about million years. It was found that wide binaries were not only very young but also tended to be aligned along the long axes of an egg-shaped dense core. Older systems did not have this tendency. For instance, triplets could form as binary captures a single star.

The theory says nothing about why the stars should born as binaries and what could be the birth mechanism. Could TGD say anything interesting about the how the binaries are formed?

1. TGD based model for galaxies leads to the proposal that the region in which dark matter has constant density corresponds to a very knotted and possibly thickened cosmic string portion or closed very knotted string associated with long cosmic string. There would be an intersection of separate cosmic strings or self-intersection of single cosmic string giving rise to a galactic blackhole from which dark matter emerges and transforms to ordinary matter. Star formation would take place in this region 2-3 times larger than the optical region.

2. Could an analogous mechanism be at work in star formation? Suppose that there is cosmic string in galactic plane and it has two nearby non-intersecting portions roughly parallel to

each other. Deform the other one slightly locally so that it forms intersections with another one. The minimal number of stable intersections is 2 and even number in the general case. Single intersection corresponding to mere touching is a topologically unstable situation. If the intersections give rise to dark blackholes generating later the stars would have explanation for why stars are formed as twin pairs.

This would also explain why the blackholes possibly detected by LIGO are so massive (there is still debate about this going on): they would have not yet produced ordinary stars, a process in which part of dark matter and dark energy of cosmic strings transforms to ordinary matter.

1. Suppose that these blackhole like objects are indeed intersections of two portions of cosmic string(s). The intersections have gravitational interaction and could move along the second cosmic string towards each other and eventually collide.

2. More concretely, one can imagine a straight horizontal starionary string A (at x-axis with $y = 0$ in (x,y)-coordinates) and a folded string B with a shape of an inverted vertical parabola ($y = -ax^2 + y_0(t)$, $a > 0$, and moving downwards. In other words, $y_0(t)$ decreases with time. The strings A and B have two nearby intersections $x_\pm = \pm\sqrt{y_0(t)/a}$. Their distance decreases with time and eventually the intersection points fuse together at $y_0(t) = 0$ and give rise to the fusion of two black-hole like entities to single one.

7.2.6 Death blow to dark matter disks

The standard view about dark matter is as a halos associated with galaxies and also other astrophysical objects. Nature however seems to be reluctant to behave according to the dictates of halo theorists. The reproduction of the simple flat velocity spectrum for distant stars in galactic plane requires tuning of the parameters characterizing the dark mass distribution in the halo. There is also a small constant density core around the center of galaxy behaving like rigid body rather than a density peak with maximum at the center. Also the attempts to detect various exotic particles proposed to serve as building bricks of dark matter have chronically failed. Quite recently very old galaxies which do not have dark matter have been found.

The latest trouble of the model, one might say a death blow, is that dark matter disks do not seem to exist at all (see `http://tinyurl.com/y7o6fmfe`)! I am afraid that this means serious funding problems for the model builders.

The death of one idea is the victory of second one. I have been preaching for almost two decades that galactic dark matter along cosmic string containing galaxies like pearls in necklace: there would be no dark matter halo [L7, L5]. The model predicts correct velocity profile for distant stars without furher assumptions: the value of string tension determines the value of the velocity. The model solvs a multitude of anomalies of halo model, and leads to a rather detailed model for evolution of galaxies and also provides insights to problems like matter-antimatter asymmetry.

7.3 Further problems of the halo model of dark matter

7.4 Further problems of the halo model of dark matter

The anomalies of the halo model of dark matter have begun to accumulate rapidly. MOND is the most well-known competitor of the halo model for dark matter but has its own problems. TGD is less known alternative for the halo model.

In the following brief comments about some of anomalies about which I did not know before are discussed. They are discussed in detail in the blog "Dark matter crisis" of Prof. Pavel Kroupa and Marcel S. Pawlowski (see `http://tinyurl.com/l73ztp8`).

7.4.1 Zwicky paradox

Zwicky paradox (see `http://tinyurl.com/mltvwmz`) implies that neither cold nor warm dark matter particles in the usual sense of the word (different from that in TGD based model) can play a significant role in cosmology.

The standard/concordance model of dark matter relies on two hypothesis formulated originally by Zwicky assuming that a) GRT is correct in all scales and b) all matter is created during Big

Bang. Zwicky formulated two hypothesis (for references see the article) leading to the halo model of dark matter and also to Zwicky paradox.

1. Zwicky noticed (1937) that galaxies must about 500 heavier in the Coma galaxy cluster than judged from their light emission: cold or hot dark matter must exist. Note that this does not require that the dark matter consists of some exotic particles or that the dark matter forms halos. To get historical perspective note also that Vera Rubin published 1976 an article about the flatness of velocity curves for distant stars for Andromeda, which is spiral galaxy.

2. Zwicky noticed (1956) that when galaxies collide, the expelled matter can condense in new regions and form new smaller dwarf galaxies. These so called tidal galaxies are thus formed from the collisional debris of other galaxies.

From these observations one ends up with a computer model allowing to simulate the formation of galaxies (for details see `http://tinyurl.com/mltvwmz`this). The basic elements of the model are collisions of galaxies possibly leading to a fusion and formation of tidal galaxies. The model assumes a statistical distribution of dark matter lumps defining the halos of the dwarf galaxies formed in the process.

The model predicts a lot of dark matter dominated dwarf galaxies formed around the dark matter lumps: velocity spectrum should approach constant. There are also tidal dwarf galaxies formed from collision debris of other galaxies. Unless also now condensation around a dark matter lump is involved, these should not contain dark matter and velocity spectrum for tidal dwarfs should be declining.

It turns out that tidal dwarfs alone are able to explain the observed dwarf galaxies, which are typically elliptic. Furthermore, there is no empirical manner to distinguish between tidal dwarfs and other dwarfs.

Do the elliptic galaxies contain dark matter? What does one know about the rotation curves of elliptic galaxies? There is an article "The rotation curves of elliptic galaxies" of J. Binney published around 1979 about the determination of the rotation curves of elliptic galaxies giving also some applications (see`http://tinyurl.com/l7qrlho`). The velocity curves are declining as if no dark matter were present in tidal dwarfs. Therefore dark matter would not be present in dwarf galaxies so that the prediction of the halo model would be wrong.

Could this finding be also a problem for MOND? Assuming that the laws governing gravitation are modified for small accelerations, shouldn't elliptic and spiral galaxies have similar velocity curves?

What about TGD?

1. In TGD Universe dark energy and matter reside at flux tubes along which disk galaxies condense like pearls in string.

2. The observation about velocity curves suggests a TGD based explanation for the difference between elliptic and spiral galaxies. Elliptic galaxies - in particular tidal dwarfs - are not associated with a flux tube containing dark matter. Spiral galaxy can form as elliptic galaxy if it becomes bound with flux tube as the recent finding about declining velocity curves for galaxies with age about 10 Gy suggest. This also conforms with the fact that the stars in elliptic galaxies are much older than in spiral galaxies (see `http://tinyurl.com/ayyvg9n`).

3. Dwarf galaxies produced from the collision debris contain only ordinary matter. Elliptic galaxies can later condense around magnetic flux tubes so that velocity spectrum approaches constant at large distances. The breaking of spherical symmetry to cylindrical symmetry might allow to understand why the oblate spheroidal shape is flattened to that of disk.

7.4.2 Vast polar structure

The vast polar structure (VPS) is a planar structure nearly orthogonal to galactic plane (see `http://tinyurl.com/k553545` and `http://tinyurl.com/lk53s3v`) [E26] is also a blow against halo theory. I have already commented this structure [K3] and I add my earlier comments below essentially as such.

The observation is that Milky Way has a distribution of satellite galaxies and star clusters, which rotate around the Milky Way in plane orthogonal to Milky Way's plane. One can visualize the situation in terms of two orthogonal planes such that the second plane contains Milky Way and second one the satellite galaxies and globular clusters. The Milky Way itself has size scale of .1 million light years whereas the newly discovered structure extends from about 33, 000 light years to 1 million light years. The study is carried out by astronomers in Bonn University and will be published in journal Monthly Notices of the Royal Astronomical Society. The lead author is Ph. D. student Marcel Pawlowski.

According to the authors, it is not possible to understand the structure in terms of the standard model for dark matter. This model assumes that galactic dark matter forms a spherical halo around galaxy. The problem is the planarity of the newly discovered matter distribution. Not only satellite galaxies and star clusters but also the long streams of material left - stars and also gas - behind them as they orbit around Milky Way move in this plane. Planarity seems to be a basic aspect of the internal dynamics of the system. As a matter fact, quantum view about the formation of also galaxies predicts planarity and this allows also to understand approximate planarity of solar system [K14]: common quantization axis of angular momentum defined by the direction of string like object in the recent case with a gigantic value of gravitational Planck constant defining the unit of angular momentum would provide a natural explanation for planarity.

TGD explanation for different anomaly led few years ago to the proposal that Milky Way is in the crossing of two magnetic flux tubes (cosmic strings), whose mass density explains the constant velocity spectrum. Quite generally, ordinary matter would be formed in reconnections of flux tubes inducing transformation of the energy of flux tubes to ordinary matter. This does not conform with LambdaCDM model. The so called vast polar structures are in plane nearly orthogonal to the plane of Milky Way which conforms with the hypothesis.

The third blow (see `http://tinyurl.com/lk53s3v`) [E26] against the theory comes from the observation that Milky Way has a distribution of satellite galaxies and star clusters, which rotate around the Milky Way in plane orthogonal to Milky Way's plane. One can visualize the situation in terms of two orthogonal planes such that the second plane contains Milky Way and second one the satellite galaxies and globular clusters. The Milky Way itself has size scale of .1 million light years whereas the newly discovered structure extends from about 33, 000 light years to 1 million light years. The study is carried out by astronomers in Bonn University and will be published in journal Monthly Notices of the Royal Astronomical Society. The lead author is Ph. D. student Marcel Pawlowski.

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The proposal of the researchers is that the situation is an outcome of a collision of two galaxies.

1. An amusing co-incidence is that the original TGD inspired model for the formation of spiral galaxies [K3] assumed that they result when two primordial cosmic strings intersect each other. This would be nothing but the counterpart of closed string vertex giving also rise to reconnection of magnetic flux tubes. Later I gave up this assumption and introduced the model in which galaxies are like pearls in necklace defined by primordial cosmic strings which since then have thickened to magnetic flux tubes. These pearls could themselves correspond to closed string like objects or their decay products. Magnetic energy would transform to matter and would be the analog for the decay of inflaton field energy to particles in inflationary scenarios.

2. As already noticed, in TGD Universe galactic dark matter would correspond to the matter assignable to the magnetic flux tube defining the necklace creating $1/\rho$ gravitational accelerating explaining constant velocity spectrum of distant stars in galactic plane.

Could one interpret the findings by assuming two big cosmic strings which have collided and decayed after that to matter? Or should one assume that the galaxies existed before the collision.

1. The collision would have induced the decay of portions of these cosmic strings to ordinary and dark matter with large value of Planck constant. The magnetic energy of the cosmic strings identifiable as dark energy would have produced the matter. It is however not clear why the decay products would have remained in the planes orthogonal to the colliding orthogonal flux tubes. According to the researchers the planar structures must have existed before the collision. This would support the idea about cosmic traffic accident. This supports the view about cosmic collision.

2. This suggests that the two flux tubes pass near each other and the galaxies have moved along the flux tubes and collided and remained stuck to each other by gravitational attraction. The probability of this kind of galactic collisions depends on what one assumes about the distribution of string like objects. Due to their mutual gravitational attraction the flux tubes could be attracted towards each other to form web like structures forming a network of cosmic highways. Milky Way would represent on particular node at which two highways form a cross-road. In this kind of situation the collisions resulting s cross-road crashes could be more frequent than those resulting from encounters of randomly moving strings. The galaxies arriving to this kind of nodes would tend to form a bound state and remain in the node. It could also happen that the second galaxy continues its journey but leaves matter behind in the form of satellite galaxies and globular clusters.

7.4.3 A further blow against dark matter halo paradigm

The following is essentially a comment about the the most recent finding (see `http://tinyurl.com/ybxnycmz`) challenging the dark matter halo paradigm. The article titled "*A whirling plane of satellite galaxies around Centaurus A challenges cold dark matter cosmology*" by Mueller O et al published in Science [E45] can be found also in Archive (see `http://tinyurl.com/yblckuqv`).

The halo model for dark matter encounters continually lethal problems as I have repeatedly tried to tell in my blog postings and articles. But still this model continues to add items to the curriculum vitae of the specialists - presumably as long as the funding continues. Bad ideas never die.

Halo model predicts that the dwarf galaxies around massive galaxies like Milky should move randomly. The newest fatal blow comes from the observation that dwarf galaxies move along neat circular orbits in the galactic plane of Centaurus A.

Just like the TGD based pearls-in-necklace model of galaxies as knots (the pearls) of long cosmic strings [L8] (see `http://tinyurl.com/yagh95q4`) predicts! The long cosmic string creates gravitational field in transversal direction and the dwarf galaxies move along nearly circular orbits. The motion along long cosmic string would be free motion and would give rise to streams. The prediction is that at large distances the rotational velocities approach constant just as in the case of distant stars.

7.4.4 Missing matter and dark matter

One problem of ΛCDM scenario is missing of matter and dark matter in some places (see `http://tinyurl.com/k5bu445`). There missing dark matter in the scale of $R = .2$ Gy and also in the vicinity of solar system in the scale 1.5-4 kpc.

In the work titled "Missing Dark Matter in the Local Universe", Igor D. Karachentsev studied a sample of 11,000 galaxies in the local Universe around the MW (see `http://tinyurl.com/mnzxhyu`). Karachentsev summed up the masses of individual galaxies and galaxy-groups and used this to test a very fundamental prediction of ΛCDM.

1. Standard cosmology predicts the average fraction of matter to be $\Omega_{m,glob} = 28 \pm 3$ per cent of critical mass density (83 percent matter would be dark and 17 per cent visible matter). 72 per cent of total density would be dark energy, 28 per cent dark matter, and 4.8 per cent visible matter.

To test this one can simply sum up all the galactic masses in some volume Karachentsev chose the volume to be a sphere of radius $R = .2$ Gy surrounding Milky Way and containing 11,000 galaxies. In this scale the density is expected to fluctuate only 10 per cent. Note that horizon radius is estimated to be about $R_H = 14$ Gly giving $R_H = 70R$.

2. The visible galactic mass in certain large enough volume of space was estimated as also the sum of galactic dark masses estimated as so called virial mass (see http://tinyurl.com/lfm8msr). The sum of these masses gave the estimate for the total mass.

3. The estimate for the total galactic was $\Omega_{m,glob} = 8 \pm 3$ per cent from critical mass, which is only 28 per cent of the fraction predicted by concurrent cosmology. The predicted fraction of visible matter is 4.8 per cent and marginally consistent with 8 ± 3 per cent but it seems plausible that also dark matter is present although its amount is small. The total contribution to the dark matter could be at most of the same size as that of visible matter.

4. One explanation is that all matter has not been included. Second not very plausible explanation is that the measurement region corresponds to a region with abnormally low density.

Can on understand the finding in TGD framework?

1. In TGD based model part of dark energy/matter would reside at the long flux tubes with which galaxies form bound states. Constraints come from accelerated expansion and galactic velocity curves allowing to determine string tension for given galaxy. Let us assume that the GRT limit of TGD and its predictions hold true.

   The estimate for the virial mass assumes that galaxy's dark mass forms a halo. The basic observation is that in TGD flux tubes give the dark energy and mass and virial mass would underestimate the dark mass of the galaxy.

2. How long length of the flux tube effectively corresponds to the dark and visible mass of disk galaxy? This length should be roughly the length containing the dark mass and energy estimated from cosmology: $L = M_{dark}/T$. If GRT limit of TGD makes sense, one has $M_{dark} = xM_{vis}/T$, where M_{dark} is the amount of dark energy + matter associated with the flux tube, M_{vis} is visible mass, $x \simeq \rho_{dark}/\rho_{vis} \simeq 83/17$, and $T$is string tension deduced from the asymptotic rotation velocity.

   If these segments do not cover the entire flux tubes containing the galaxies along it, the amount of dark matter and energy will be underestimated. By the above argument elliptic galaxies would not have considerable amount of dark matter and energy so that only disk galaxies should contribute unless there are flux tubes in shorter scales inside elliptic galaxies.

   Also larger and smaller scale flux tube structures contribute to the dark energy + dark matter. Fractality suggests the presence of both larger and smaller flux tube structures than those associated with spiral galaxies (even stars couldbe associated with flux tubes).

   One should have estimates for the lengths of various flux tubes involved. Unfortunately this kind of estimate is not available.

3. If GRT limit makes sense then the total dark mass then the dark energy and matter obtained in this manner should give 95 per cent of critical mass density. The fraction of dark matter included would be at most a fraction $5/28 \simeq 18$ per cent of the total dark matter. 82 per cent of dark matter and energy would be missed in the estimate. This could allow to get some idea about the lengths of flux tubes and density of galaxies along flux tubes.

The amount of dark matter in the solar neighborhood was investigated in the work "Kinematical and chemical vertical structure of the Galactic thick disk II. A lack of dark matter in the solar neighborhood" by Christian Moni Bidin and collaborators (see http://tinyurl.com/yapbqnwo). Moni Bidin et al have studied as sample of 400 red giants in the vicinity of solar system at vertical distances 1.5 to 4 kpc and deduce 3-D kinematics for these start. From this data they estimate the surface mass density of the Milky Way within this range of heights from the disk. This surface density should be sum of both visual and dark mass.

According to their analysis, the visible mass is enough to explain the data. No additional mass is needed. Only highly flattened dark matter halo would be consistent with the findings. This conforms with the TGD prediction that dark mass/energy are associated with magnetic flux tubes.

7.4.5 Low surface brightness galaxies as additional support for pearls-in-necklace model for galaxies

Sabine Hossenfelder had an inspiring post (see `http://tinyurl.com/ybmbzczr`) about the problems of the halo dark matter scenario. My attention was caught by the title "Shut up and simulate". It was really to the point. People stopped first to think, then to calculate, and now they just simulate. Perhaps AI will replace them at the next step.

While reading I realized that Sabine mentioned a further strong piece of support for the TGD view about galaxies as knots along cosmic strings, which create cylindrically symmetric gravitational field orthogonal to the string rather than spherically symmetric field as in halo models. The string tension determines the rotation velocity of distant stars predicted to be constant constant up to arbitrarily long distances (the finite size of space-time sheet of course brings in cutoff length).

To express it concisely: Sabine told about galaxies, which have low surface brightness. In the halo model the density of both matter and dark matter halo should be low for these galaxies so that the velocity of distant stars should decrease and lead to a breakdown of so called Tully-Fisher relation. It doesn't.

I am not specialist in the field of astrophysics and it was nice to read the post and refresh my views about the problem of galactic dark matter.

1. Tully-Fisher-relation (TFR) (see `http://tinyurl.com/ybhaat64`) is an empirically well-established relation between the brightness of a galaxy and the velocity of its outermost stars. Luminosity L equals to apparent brightness (luminosity per unit area) of the galaxy multiplied by the area $4\pi d^2$ of sphere with radius equal to the distance d of the observed galaxy. The luminosity of galaxy is also proportional to the mass M of the galaxy. TFR says that luminosity of spiral galaxy - or equivalently its mass - is proportional to the emission line width, which is determined by the spectrum of angular velocities of stars in the spiral galaxy. Apparent brightness and line width can be measured, and from these one can deduce the distance d of the star: this is really elegant.

2. It is easy to believe that the line width is determined by the rotation velocity of galaxy, which is primarily determined by the mass of the dark matter halo. The observation that the rotational velocity is roughly constant for distant stars of spiral galaxies - rather than decreasing like $1/\rho$ - this led to the hypothesis that there is dark matter halo around galaxy. By fitting the density of the dark matter properly, one obtains constant velocity. Flat velocity spectrum implies that the line width is same also for distant stars as for stars near galactic center.

   To explain this in halo model, one ends up with complex model for the interactions of dark matter and ordinary matter and here simulations are the only manner to deduce the predictions. As Sabine tells, the simulations typically take months and involve huge amount of bits.

3. Since dark matter halo is finite, the rotation velocity should decrease at large enough distances like $1/R$, R distance from the center of the galaxy. If one has very dilute galaxy - so called low surface brightness galaxy, which is very dim - the rotational velocities of distant stars should be smaller and therefore also their contribution to the average line width assignable to the galaxy. TFR is not expected to hold true anymore. The surprising finding is that it does!

The conclusion seems to be that there is something very badly wrong with the halo model. This is the message that the observational astrophysicist Stacy McGaugh is trying to convey in his blog (see `http://tinyurl.com/y9rwjjve`): about this the post of Sabine told.

Halo model of dark matter has also other problems.

1. Too many dwarf galaxies tend to be predicted.

2. There is also so called cusp problem: the density peak at the center of the galaxy tends to be too high. Observationally the density seems to be roughly constant in the center region, which behaves like rotating rigid body.

The excuses for the failures claim that the physics of normal matter is not well enough understood: the feedback from the physics of ordinary matter is believed to solve the problems. Sabine lists some possibilities.

1. There is the pressure generated when stars go supernovae, which can prevent the formation of the density peak. The simulations however show that practically 100 per cent of energy liberated in the formation of supernovas should go to the creation of pressure preventing the development of the density peak.

2. One can also claim that the dynamics of interstellar gas is not properly understood.

3. Also the accretion and ejection of matter by supermassive black holes, which are at the center of most galaxies could reduce the density peak.

One can of course tinker with the parameters of the model and introduce new ones to get what one wants. This is why simulations are always successful!

1. For instance, one can increase the relative portion of dark matter to overcome the problems but one ends up with fine tuning. The finding that TFR is true also for low surface brightness galaxies makes the challenge really difficult. Mere parameter fit is not enough: one should also identify the underlying dynamical processes allowing to get rid of the normal manner, and this has turned out to be difficult.

2. What strongly speaks against the feedback from the ordinary matter is that the outcome should be the same irrespective of how galaxies were formed: directly or through mergers of other galaxies. The weak dependence on the dynamics of ordinary matter strongly suggests that stellar feedback is not a correct manner to overcome the problem.

One can look at the situation also in TGD framework.

1. In pearls-in-necklace model galaxies are knots of long cosmic strings [K3, K18] [L8]. Knots have constant density and this conforms with the observation: the cusp problem disappears.

2. The long string creates gravitational field orthogonal to it and proportional to $1/\rho$, ρ the orthogonal distance from the string. This cylindrically symmetric field creates correlations in much longer scales than the gravitational field of spherical halo, which for long distances is proportional to $1/r^2$, r the distance from the center of the galaxy.

   Pearls-in-necklace model predicts automatically constant velocity spectrum at *arbitrary long*(!) distances. The velocity spectrum is independent of the details of the distribution of the visible matter and is proportional to the square root of string tension. There is almost total independence of the velocity spectrum of the ordinary matter as also the example of low surface brightness galaxies demonstrates. Also the history for the formation of the galaxy matters very little.

3. From TFR one can conclude that the mass of the spiral galaxy is (proportional to the luminosity proportional to the line width) and also proportional to the string tension. Since galactic mass varies also string tension must vary. This is indeed predicted. String tension is essentially the energy per unit length for the thickened cosmic string and would characterize the contributions of dark matter in TGD sense (phases of ordinary matter with large $h_{eff}h = n$ as well as dark energy, which contains both Kähler magnetic energy and constant term proportional to the 3-volume of the flux tube.

   Cosmology suggests that string thickness increases with time: this would reduce the Kähler magnetic contribution to the string tension but increase the contribution proportional to the 3-volume. There is also the dependence of the coefficient of the volume term (essentially the formal counterpart of cosmological constant), which depends on p-adic length scale like the inverse of the p-adic length scale squared $L(k) \propto 2^{k/2}$, where k must be positive integer, characterizing the size scale involved (this is something totally new and solves the cosmological constant problem) [L2]. It is difficult to say which contribution dominates.

4. Dwarf galaxies would require small string tension, hence the strings with small string tension should be rather rare.

If this picture is correct, the standard views about dark matter are completely wrong, to put it bluntly. Dark matter corresponds to $h_{eff}/h = n$ phases of ordinary matter rather than some exotic particle(s) having effectively only gravitational interaction, and there is no dark matter halo. TGD excludes also MOND. Dark energy and dark matter reside at the thickened cosmic strings, which belong to the simplest extremals of the action principle of TGD [K3, K29]. It should be emphasized that flux tubes are not ad hoc objects introduced to understand galactic velocity spectrum: they are a basic prediction of TGD and by fractality of TGD Universe present in all scales and are fundamental also for the TGD view about biology and neuroscience.

Maybe it might be a good idea to start to think again. Using brains instead of computers is also must a more cost-effective option: I have been thinking intensely for four decades, and this hasn't cost a single coin for the society! Recommended!

7.4.6 Dark matter and 21-cm line of hydrogen

Dark matter in TGD sense corresponds to $h_{eff}/h = n$ phases of ordinary matter associated with magnetic flux tubes. These flux tubes would be n-sheeted covering spaces, and n would correspond to the dimension of the extension of rationals in which Galois group acts. The evidence for this interpretation of dark matter is accumulating. Here I discuss one of the latest anomalies - so called 21-cm anomaly.

Sabine Hossenfelder (see `http://tinyurl.com/y7h5ys2r`) told about the article [E38] discussing the possible interpretation (see `http://tinyurl.com/yasgfgq8`) of so called 21-cm anomaly associated with the hyperfine transition of hydrogen atom and observed by EDGES collaboration [E39].

The EDGES Collaboration has recently reported the detection of a stronger-than-expected absorption feature in the global 21-cm spectrum, centered at a frequency corresponding to a redshift of $z \sim 17$. This observation has been interpreted as evidence that the gas was cooled during this era as a result of scattering with dark matter. In this study, we explore this possibility, applying constraints from the cosmic microwave background, light element abundances, Supernova 1987A, and a variety of laboratory experiments. After taking these constraints into account, we find that the vast majority of the parameter space capable of generating the observed 21-cm signal is ruled out. The only range of models that remains viable is that in which a small fraction, $\sim 0.3-2$ per cent, of the dark matter consists of particles with a mass of $\sim$ 10-80 MeV and which couple to the photon through a small electric charge, $\epsilon \sim 10^{-6}-10^{-4}$. Furthermore, in order to avoid being overproduced in the early universe, such models must be supplemented with an additional depletion mechanism, such as annihilations through a $L_\mu - L_\tau$ gauge boson or annihilations to a pair of rapidly decaying hidden sector scalars.

What has been found is an unexpectedly strong absorption feature in 21-cm spectrum: the redshift is about $z = \Delta f/f \simeq v/c \simeq 17$, which from Hubble law $v = HD$ corresponds to a distance $D \sim 2.3 \times 10^{11}$ ly. Dark matter interpretation would be in terms of scattering of the baryons of gas from dark matter at lower temperature. The anomalous absorption of 21 cm line could be explained with the cooling of gas caused by the flow of energy to a colder medium consisting of dark matter. If I understood correctly, this would generate a temperature difference between background radiation and gas and consequent energy flow to gas inducing the anomaly.

The article excludes large amount of parameter space able to generate the observed signal. The idea is that the interaction of baryons of the gas with dark matter. The interaction would be mediated by photons. The small em charge of the new particle is needed to make it "dark enough". My conviction is that tinkering with the quantization of electromagnetic charge is only a symptom about how desperate the situation is concerning interpretation of dark matter in terms of some exotic particles is. Something genuinely new physics is involved and the old recipes of particle physicists do not work.

In TGD framework the dark matter at lower temperature would be $h_{eff}/h = n$ phases of ordinary matter residing at magnetic flux tubes. This kind of energy transfer between ordinary and dark matter is a general signature of dark matter in TGD sense, and there are indications from some experiments relating to primordial life forms for this kind of energy flow in lab scale [L6] (see http://tinyurl.com/yassnhzb) .

The ordinary photon line appearing in the Feynman diagram describing the exchange of photon would be replaced with a photon line containing a vertex in which the photon transforms to dark photon. The coupling in the vertex - call it m^2 - would have dimensions of mass squared. This would transform the coupling e^2 associated with the photon exchange effectively to e^2m^2/p^2, where p^2 is photon's virtual mass squared. The slow rate for the transformation of ordinary photon to dark photon could be see as an effective reduction of electromagnetic charge for dark matter particle from its quantized value.

Remark: In biological systems dark cyclotron photons would transform to ordinary photons and would be interpreted as bio-photons with energies in visible and UV.

To sum up, the importance of this finding is that it supports the view about dark matter as ordinary particles in a new phase. There are electromagnetic interactions but the transformation of ordinary photons to dark photons slows down the process and makes these exotic phases effectively dark.

7.4.7 Strange finding about galactic halo as a possible further support for TGD based model of galaxies

A team led by Maria Bergemann from the Max Planck Institute for Astronomy in Heidelberg, has studied a small population of stars in the halo of the Milky Way (MW) and found its chemical composition to closely match that of the Galactic disk [E37] (see http://tinyurl.com/yb34t2kz). This similarity provides compelling evidence that these stars have originated from within the disc, rather than from merged dwarf galaxies. The reason for this stellar migration is thought to be theoretically proposed oscillations of the MW disk as a whole, induced by the tidal interaction of the MW with a passing massive satellite galaxy.

One can divide the stars in MW to the stars in the galactic disk and those in the galactic halo. The halo has gigantic structures consisting of clouds and streams of stars rotating around the center of the MW. These structures have been identified as a kind of debris thought to reflect the violent past of the MW involving collisions with smaller galaxies.

The scientists investigated 14 stars located in two different structures in the Galactic halo, the Triangulum-Andromeda (Tri-And) and the A13 stellar over-densities, which lie at opposite sides of the Galactic disc plane. Earlier studies of motion of these two diffuse structures revealed that they are kinematically associated and could relate to the Monoceros Ring, a ring-like structure that twists around the Galaxy. The position of the two stellar over-densities could be determined as each lying about 5 kiloparsec (14000 ly) above and below the Galactic plane. Chemical analysis of the stars made possible by their spectral lines demonstrated that they must must originate from MW itself, which was a complete surprise.

The proposed model for the findings is in terms of vertical vibrations of galactic disk analogous to those of drum membrane. In particular the fact that the structures are above and below of the Monoceros Ring supports this idea. The vibrations would be induced by the gravitational interactions of ordinary and dark matter of galactic halo with a passing satellite galaxy. The picture of the the article [E37] (see http://tinyurl.com/yb34t2kz) illustrates what the pattern of these vertical vibrations would look like according to simulations.

In TGD framework this model is modified since dark matter halo is replaced with cosmic string. Due to the absence of the dark matter halo, the motion along cosmic string is free apart from gravitational attraction caused by the galactic disk. Cosmic string forces the migrated stars to rotate around to the cosmic string in plane parallel to the galactic plane and the stars studied indeed belong to ring like structures: the prediction is that these rings rotate around the axis of galaxy.

One can argue that if one has stars are very far from galactic plane - say dwarf galaxy - the halo model of dark matter suggests that the orbital plane arbitrary but goes through galactic center since spherically symmetric dark matter halo dominates in mass density. TGD would predict that the orbital plane is parallel to to the galactic plane.

Are the oscillations of the galactic plane necessary in TGD framework?

1. The large size of and the ring shape of the migrated structures suggests that oscillations of the disk could have caused them. The model for the oscillations of MW disk would be essentially that for a local interaction of a membrane (characterized by tension) with its own gravitational field and with the gravitational field of G passing by. Some stars would be stripped off from the membrane during oscillations.

2. If the stars are local knots in a big knot (galaxy) formed by a long flux tube as TGD based model for galaxy formation suggests, one can ask whether reconnections of the flux tube could take place and split from the flux tube ring like structures to which migrating stars are associated. This would reduce the situation to single particle level and it is interesting to see whether this kind of model might work. One can also ask whether the stripping could be induced by the interaction with G without considerable oscillations of MW.

The simplest toy model for the interaction of MW with G would be following: I have proposed this model of cosmic traffic accidents already earlier. Also the fusion of blackholes leading could be made probable if the blackholes are associated with the same cosmic string (stars would be subknots of galactic knots) [L3].

1. G moves past the MW and strips off stars and possibly also larger structures from MW: denote this kind of structures by O. Since the stripped objects at the both sides of the MW are at the same distance, it seems that the only plausible direction of motion of G is along the cosmic string along which galaxies are like pearls in necklace. G would go through MW! If the model works it gives support for TGD view about galaxies.

   One can of course worry about the dramatic implications of the head on collisions of galaxies but it is interesting to look whether it might work at all. On the other hand, one can ask whether the galactic blackhole for MW could have been created in the collision possibly via fusion of the blackhole associated with G with that of MW in analogy with the fusion of blackholes detected by LIGO.

2. A reasonable approximation is that the motions of G and MW are not considerably affected in the collision. MW is stationary and G arrives with a constant velocity v along the axis of cosmic string above MW plane. In the region between galactic planes of G and MW the constant accelerations caused by G and MW have opposite directions so that one has

$$\begin{array}{lll} g_{tot} = g_G - g_{MW} \ , & \text{between the galactic planes and above MW plane} \ , \\ g_{tot} = -g_G + g_{MW} \ , & \text{between the galactic planes and below MW plane} \ , \\ g_{tot} = -g_G - g_{MW} \ , & \text{above both galactic planes} \ , \\ g_{tot} = g_G + g_{MW} \ , & \text{below both galactic planes} \ . \end{array} \tag{7.9}$$

   The situation is completely symmetric with respect to the reflection with respect to galactic plane if one assumes that the situation in galactic plane is not affected considerably. Therefore it is enough to look what happens above the MW plane.

3. If G is more massive, one can say that it attracts the material in MW and can induce oscillatory wave motion, whose amplitude could be however small. This would induce the reconnections of the cosmic string stripping objects O from MW, and O would experience upwards acceleration $g_{tot} = g_G - g_{MW}$ towards G (note that O also rotates around the cosmic string). After O has passed by G, it continues its motion in vertical direction and experiences deceleration $g_{tot} = -g_G - g_{MW}$ and eventually begins to fall back towards MW.

   One can parameterize the acceleration caused by G as $g_G = (1+x) \times g_{MW}$, $x > 1$ so that the acceleration felt by O in the middle regions between the planes is $g_{tot} = g_G - g = x \times g_{MW}$. Above planes of both G and MW the acceleration is $g_{tot} = -(2+x)g_{MW}$.

4. Denote by T the moment when O and G pass each other. One can express the vertical height h and velocity v of O in the 2 regions above MW as

$$\begin{array}{lll} h(t) = \frac{(g_G - g_{MW})}{2} t^2 \ , & v = (g_G - g_{MW})t \ , & t < T \ , \\ h(t) = -\frac{(g_G + g_{MW})}{2}(t-T)^2 + v(T)(t-T) + h(T) \ , & v(T) = (g_G - g_{MW})T \ , & \\ h(T) = \frac{(g_G - g_{MW})}{2} T^2 & t > T \ . & \end{array} \qquad (7.10)$$

Note that time parameter T tells how long time it takes for O to reach G if its has been stripped off from MW. A naive estimate for the value of T is as the time scale in which the gravitational field of galactic disk begins to look like that of point mass.

This would suggest that $h(T)$ is of the order of the radius R of MW so that one would have using $g_G = (1+x)g_{MW}$

$$T \sim \sqrt{\frac{1}{x}}\sqrt{\frac{2R}{g_{MW}}} \ .$$

5. The direction of motion of O changes at $v(T_{max}) = 0$. One has

$$\begin{aligned} T_{max} &= (\frac{2g_G}{g_G + g_{MW}} T \ , \\ h_{max} &= -\frac{(g_G + g_{MW})}{2}(T_{max} - T)^2 + v(T)(T_{max} - T) + h(T) \ . \end{aligned}$$

6. For $t > T_{max}$ one has

$$h(t) = -\frac{(g_G + g_{MW})}{2}(t - T_{max})^2 + h_{max} \ , \quad h_{max} = -\frac{(g_G + g_{MW})}{2}(T_{max} - T)^2 + h(T) \ . \qquad (7.11)$$

Expressing h_{max} in terms of T and parameter $x = (g_G - g_{MW})/g_{MW}$ one has

$$\begin{aligned} h_{max} &= y(x) g_{MW} \frac{T^2}{2} \ , \\ y(x) &= x\frac{5x+4}{2(2+x)} \sim x \ \text{for small values of } x \ . \end{aligned} \qquad (7.12)$$

7. If one assumes that $h_{max} > h_{now}$, where $h_{now} \sim 1.4 \times 10^5$ ly the recent height of the objects considered, one obtains an estimate for the time T from $h_{max} > h_{now}$ giving

$$T > \sqrt{\frac{2(2+x)}{x(5x+4)}} T_0 \ , \quad T_0 = \frac{h_{now}}{g_{MW}} \ . \qquad (7.13)$$

Note that $T_{max} < 2T$ holds true.

It is interesting to see whether the model really works.

1. It is easy to find (one can check the numerical factors at `http://tinyurl.com/t0om`) that g_{MW} can be expressed at the limit of infinitely large galactic disk as

$$g_{MW} = 2\pi G \frac{dM}{dS} = \frac{2GM}{R^2} \ ,$$

where R is the radius of galactic disk and $dM/dS = M/\pi R^2$ is the density of the matter of galactic disk per unit area. This expression is analogous to $g = GM/R_E^2$ at the surface of Earth.

2. One can express the estimate in terms of the acceleration $g = 10$ m/s^2 as

$$g_{MW} \simeq 2g(\frac{R_E}{R})^2(\frac{M}{M_E}) \ .$$

The estimate for MW radius has lower bound $R = 10^5$ ly, MW mass $M \sim 10^{12} M_{Sun}$, using $M_{Sun}/M_E = 3 \times 10^6$ and $R_{Earth} \sim 6 \times 10^6$ m, one obtains $g_{MW} \sim 2 \times 10^{-10} g$.

3. Using the estimate for g_{MW} one obtains $T > \sqrt{2(2+x)/[x(5x+4)]} T_0$ with

$$T_0 \sim 3 \times 10^9 \ \text{years} \ . \tag{7.14}$$

The estimate $T \sim \sqrt{1/x}\sqrt{\frac{2R}{g_{MW}}}$ proposed above gives $T > \sqrt{1/x} \times 10^8$ years. The fraction of ordinary mass from total mass is roughly 10 per cent of the contribution of the dark energy and dark particles associated with the cosmic string. Therefore $x < .1$ is a reasonable upper bound for x parametrizing the mass difference of G and MW. For $x \simeq .1$ one obtains T in the range $1 - 10$ Gy.

7.4.8 TGD based explanation for why the rotation periods of galaxies are same

I learned in FB about very interesting finding about the angular rotation velocities of stars near the edges of the galactic disks [E44] (see `http://tinyurl.com/y7jlmkka`). The rotation period is about one giga-year. The discovery was made by a team led by professor Gerhardt Meurer from the UWA node of the International Centre for Radio Astronomy Research (ICRAR). Also a population of older stars was found at the edges besides young stars and interstellar gas. The expectation was that older stars would not be present.

The rotation periods are claimed to in a reasonable accuracy same for all spiral galaxies irrespective of the size. The constant velocity spectrum for distant stars implies $\omega \propto 1/r$ for $r > R$. It is important do identify the value of the radius R of the edge of the visible part of galaxy precisely. I understood that outside the edge stars are not formed. According to Wikipedia, the size R of Milky Way is in the range $(1 - 1.8) \times 10^5$ ly and the velocity of distant stars is $v = 240$ km/s. This gives $T \sim R/v \sim .23$ Gy, which is by a factor $1/4$ smaller than the proposed universal period of $T = 1$ Gy at the edge. It is clear that the value of T is sensitive to the identification of the edge and that one can challenge the identification $R_{edge} = 4 \times R$.

In the following I will consider two TGD inspired arguments. The first argument is classical and developed by studying the velocity spectrum of stars for Milky Way, and leads to a rough view about the dynamics of dark matter and rigid matter. Second argument is quantal and introduces the notion of gravitational Planck constant $\hbar_{gr}$ and quantization of angular momentum as multiples of $\hbar_{gr}$. It allows to predict the value of T and deduce a relationship between the rotation period T and the average surface gravity of the galactic disk.

In the attempts to understand how T could be universal in TGD framework, it is best to look at the velocity spectrum of Milky Way depicted in a Wikipedia article about Milky Way (see `http://tinyurl.com/hqr6m27`).

1. The illustration shows that the $v(\rho)$ has maximum at $r \sim 1$ kpc. The maximum corresponds in a reasonable approximation to $v_{max} = 250$ km/s, which is only 4 per cent above the asymptotic velocity $v_{rot} = 240$ km/s for distant stars as deduced from the figure.

   Can this be an accident? This would suggest that the stars move under the gravitational force of galactic string alone apart from a small contribution from self-gravitation! The dominating force could be due to the straight portions of galactic string determining also the velocity v_{rot} of distant stars.

   It is known that there is also a rigid body part of dark matter having radius $r \sim 1$ kpc (3.3×10^3 ly) for Milky Way, constant density, and rotating with a constant angular velocity ω_{dark} to be identified as the ω_{vis} at r. The rigid body part could be associated with a separate closed string or correspond to a knot of a long cosmic string giving rise to most of the galactic dark matter.

Remark: The existence of rigid body part is serious problem for dark matter as halo approach and known as core-cusp problem.

For $\rho < r$ stars could correspond to sub-knots of a knotted galactic string and v_{rot} would correspond to the rotation velocity of dark matter at r when self-gravitation of the knotty structure is neglected. Taking it into account would increase v_{rot} by 4 per cent to v_{max}. One would have $\omega_{dark} = v_{max}/r$.

2. The universal rotation period of galaxy, call it $T \sim 1$ Gy, is assigned with the edge of the galaxy and calculated as $T = v(R)/R$. The first guess is that the the radius of the edge is $R_{edge} = R$, where $R \in (1 - 1.8) \times 10^5$ ly (30-54 kpc) is the radius of the Milky Way. For $v(R) = v_{rot} \sim 240$ km/s one has $T \sim .225$ Gy, which is by a factor 1/4 smaller that $T = 1$ Gy. Taking the estimate $T = 1$ Gy at face value one should have $R_{edge} = 4R$.

3. The velocity spectrum of stars for Milky Way is such that the rotation period $T_{vis} = \rho/v_{vis}(\rho)$ is quite generally considerably shorter than $T = 1$ Gy. The discrepancy is from 1 to 2 orders of magnitude. The $v_{vis}(\rho)$ varies by only 17 per cent at most and has two minima (200 km/s and 210 km/s) and eventually approaches $v_{rot} = 240$ km/s.

   The simplest option is that the rotation $v(\rho)$ velocity of dark matter in the range $[r, R]$ is in the first approximation same as that of visible matter and in the first approximation constant. The angular rotation ω would decrease roughly like r/ρ from ω_{max} to $\omega_{rot} = 2\pi/T$: for Milky Way this would mean reduction by a factor of order 10^{-2}. One could understand the slowing down of the rotation if the dark matter above $\rho > r$ corresponds to long - say U-shaped as TGD inspired quantum biology suggests - non-rigid loops emanating from the rigid body part. Non-rigidity would be due to the thickening of the flux tube reducing the contribution of Kähler magnetic energy to the string tension - the volume contribution would be extremely small by the smallness of cosmological constant like parameter multiplying it.

   If the stars form sub-knots of the galactic knot, the rotational velocities of dark matter flux loops and visible matter are same. This would explain why the spectrum of velocities is so different from that predicted by Kepler law for visible matter as the illustration of the Wikipedia article shows (see `http://tinyurl.com/y8k6l6su`). Second - less plausible - option is that visible matter corresponds to closed flux loops moving in the gravitational field of cosmic string and its knotty part, and possibly de-reconnected (or "evaporated") from the flux loops.

   What about the situation for $\rho > R$? Are stars sub-knots of galactic knot having loops extending beyond $\rho = R$. If one assumes that the differentially rotating dark matter loops extend only up to $\rho = R$, one ends up with a difficulty since $v_{vis}(\rho)$ must be determined by Kepler's law above $\rho = R$ and would approach v_{rot} from above rather from below. This problem is circumvented if the loops can extend also to distances longer than R.

4. Asymptotic constant rotation velocity v_{rot} for visible matter at $r > R$ is in good approximation proportional to the square root of string tension T_s defining the density per unit length for the dark matter and dark energy of string. $v_{rot} = (2GT_s)^{1/2}$ is determined from Kepler's law in the gravitational field of string. In the article R is identified as the size of galactic disk containing stars and gas.

5. The universality of T (no dependence on the size R of the galaxy) is guaranteed if the ratio R/r is universal for given string tension T_s. This would correspond to scaling invariance. To my opinion one can however challenge the idea about universality of T since its identification is far from obvious. Rather, the period at r would be universal if the angular velocity ω and perhaps also r are universal in the sense that they depend on the string tension T_s of the galactic string only.

The above argument is purely classical. One can consider the situation also quantally.

1. The notion of gravitational Planck constant h_{gr} introduced first by Nottale [E31] is central in TGD, where dark matter corresponds to a hierarchy of Planck constants $h_{eff} = n \times h$. One would have

$$\hbar_{eff} = n \times \hbar = \hbar_{gr} = \frac{GMm}{v_0} \quad (7.15)$$

for the magnetic flux tubes connecting masses M and m and carrying dark matter. For flux loops from M back to M one would have

$$\hbar_{gr} = \frac{GM^2}{v_0} . \quad (7.16)$$

v_0 is a parameter with dimensions of velocity.

The first guess is $v_0 = v_{rot}$, where v_{rot} corresponds to the rotation velocity of distant stars - roughly $v_{rot} = 4 \times 10^{-3} c/5$. Distant stars would be associated with the knots of the flux tubes emanating from the rigid body part of dark matter, and $T = .25$ Gy is obtained for $v_0 = R/v_{rot}$ in the case of Milky Way. The universality of r/R guaranteeing the universality of T would reduce to the universality of v_0.

2. Assume quantization of dark angular momentum with unit h_{gr} for the galaxy. Using $L = I\omega_{dark}(R)$, where $I = MR^2/2$ is moment of inertia and ω is short hand for $\omega_{dark}(R)$, this gives

$$\frac{MR^2\omega}{2} = L = m \times \hbar_{gr} = 2m \times \frac{GM^2}{v_0} \quad (7.17)$$

giving

$$\omega = 2m \times \frac{\hbar_{gr}}{MR^2} = 2m \times \frac{GM}{R^2 v_0} = m \times 2\pi \frac{g_{gal}}{v_0} \ , \ m = 1, 2, .., \quad (7.18)$$

where $g_{gal} = GM/\pi R^2$ is the average surface gravity of galactic disk.

If the average surface mass density of the galactic disk and the value of m do not depend on galaxy, one would obtain constant $\omega_{dark}(R)$ as observed ($m = 1$ is the first guess but also other values can be considered).

3. For the rotation period one obtains

$$T = \frac{v_0}{m \times g_{gal}} \ , \ m = 1, 2, ... \quad (7.19)$$

Does the prediction make sense for Milky Way? For $M = 10^{12} M_{Sun}$ represents a lower bound for the mass of Milky Way (see `http://tinyurl.com/hqr6m27`). The upper bound is roughly by a factor 2 larger. For $M = 10^{12} M_{Sun}$ the average surface gravity g_{gal} of Milky Way would be approximately $g_{gal} \simeq 10^{-10} g$ for $R = 10^5$ ly and by a factor 1/4 smaller for $R = 2 \times 10^5$ ly. Here $g = 10$ m/s^2 is the acceleration of gravity at the surface of Earth. $m = 1$ corresponds to the maximal period.

For the upper bound $M = 1.5 \times 10^{12} M_{Sun}$ of the Milky Way mass (see `http://tinyurl.com/hqr6m27`) and larger radius $R = 2 \times 10^5$ ly one obtains $T \simeq .23/m$ Gy using $v_0 = v_{rot}(R/r)$, $R = 180r$ and $v_{rot} = 240$ km/s.

4. One can criticize this argument since the rigid body approximation fails. Taking into account the dependence $v = v_{rot}R/\rho$ in the integral defining total angular momentum as $2\pi(M/\pi R^2) \int v(\rho)\rho\rho d\rho = M\omega R^2$ rather than $M\omega R^2/2$ so that the value of ω is reduced by factor 1/2 and the value of T increases by factor 2 to $T = .46/m$ Gy which is rather near to the claimed value of 1 Gy.

To sum up, the quantization argument combined with the classical argument discussed first allows to relate the value of T to the average surface gravity of the galactic disk and predict correctly the value of T.

7.4.9 Did you think that star formation is understood?

In Cosmos Magazine there is an interesting article about (seehttp://tinyurl.com/ybglb7t4) about the work [E41] of a team of astronomers led by Fatemeh Tabatabaei published in Nature Astronomy (see http://tinyurl.com/yc3mngtq).

The problem is following. In the usual scenario for the star formation the stars would have formed almost instantaneously and star formation would not continue anymore. The mystery is that stars with the age of our sun even exist at all. Star formation is indeed still taking place: more than one half of galaxies is forming stars. So called starburst galaxies do this very actively. The standard story is that since stars explode as supernovae, the debris from supernovae condenses to stars of later generations. This does not seem to be the whole story.

Remark: It seems incredible that astrophysics would still have unsolved problems at this level. During years I have learned that standard reductionistic paradigm is full of holes.

The notion of star-formation quenching has been introduced: it would slow down the formation of stars. It is known that quenched galaxies mostly have a super-massive blackhole in their center and that quenching starts at their centers. Quenching would preserve star forming material for future generations of stars.

To study this process a team of astronomers led by Tabatabaei turned their attention to NCG 1079 located at distance of 45 million light years. It is still forming stars in central regions but shows signs of quenching and has a super-massive blackhole in its center. What was found that large magnetic fields, probably enhanced by the central black hole, affect the gas clouds that would normally collapse into stars, thereby inhibiting their collapse. These forces can even break big clouds into smaller ones, ultimately leading to the formation of smaller stars.

This is highly interesting from TGD point of view. In the simplest TGD based model galaxies are formed as knots of long cosmic strings. Stars in turn would be formed as sub-knots of these galactic knots. There is also alternative vision in which knots are just closed flux tubes bound to long strings containing galaxies as closed flux tubes like pearls in necklace. These closed flux tubes could emerge from long string by reconnection and form elliptic galaxies. The signature would be non-flatness for the velocity spectrum of distant stars. Also in the case of stars similar reconnection process splitting star as sub-knot of galactic string can be imagined.

If stars are sub-knots in knots of galactic string representing the galaxies, the formation of star would correspond to a formation of knot. This would involve reconnection process in which some portions of knot go "through each other". This is the manner how knots are reduced to trivial knot in knot cobordism used to construct knot invariants in knot theory [K12]. Now it would work in opposite direction: to build a knots.

This process is rather violent and would initiate star formation with dark matter from the cosmic string forming the star. This process would continue forever and would allow avoid the instantaneous transformation of matter into stars as in the standard model. At deeper level star formation would be induced by a process taking place at the level of dark matter for magnetic flux tubes: similar vision applies in TGD inspired biology. One could perhaps see these knots as seeds of a phase transition like process leading to a formation of star. This reconnection process could take place also in the formation of spiral galaxies. In Milky Way there are indeed indications for the reconnection process, which could be related to the formation of Milky as knot which has suffered or suffering reconnection.

The role of strong magnetic fields supposed to be amplified by the galactic blackhole is believed to be essential in quenching. These magnetic fields would be associated with dark flux tubes, possibly as return fluxes (flux lines must be closed). These magnetic fields would prevent the collapse of gas clouds to stars. These magnetic fields could also induce a splitting of the gas clouds to smaller cloud. The ratio of mass to magnetic flux ratio for clouds is studied and the clouds are found to be magnetically critical or stable against collapse to a core regions needed for the formation of star. The star formation efficiency of clouds drops with increasing magnetic field strength.

Star formation would begin, when the magnetic field has strength below a critical value. If the reconnection plays a role in the process, this would suggest that reconnection is probable for magnetic field strengths below critical value. Since the thickness of the magnetic flux tube associated with its M^4 projection increases as magnetic field strength decreases, one can argue that the reconnection probability and thus also star formation rate increases. The development of galactic blackhole would amplify the magnetic fields. During cosmic evolution the flux tubes would thicken so that also the field strength would be reduced and eventually the star formation would begin if the needed gas clouds are present. This is just what observations tell.

A natural model for the galactic blackhole is as a highly wounded portion of cosmic string. The blackhole Schwartschild radius would be $R = 2GM$ and the mass due to dark energy of string (there would be also dark matter contribution) to mass would be $M \sim TL$, where T is roughly $T \sim 2^{-11}$. This would give the estimate $L \sim 2^{10}R$.

8 Do We Really Understand The Solar System?

The recent experimental findings have shown that our understanding of the solar system is surprisingly fragmentary. As a matter fact, so fragmentary that even new physics might find place in the description of phenomena like the precession of equinoxes and the recent discoveries about the bullet like shape of heliosphere and strong magnetic fields near its boundary bringing in mind incompressible fluid flow around obstacle. TGD inspired model is based on the heuristic idea that stars are like pearls in a necklace defined by long magnetic flux tubes carrying dark matter and strong magnetic field responsible for dark energy and possibly accompanied by the analog of solar wind. Heliosphere would be like bubble in the flow defined by the magnetic field inside the flux tube inducing its local thickening. A possible interpretation is as a bubble of ordinary and dark matter in the flux tube containing dark energy. This would provide a beautiful overall view about the emergence of stars and their helio-spheres as a phase transition transforming dark energy to dark and visible matter. Among other things the magnetic walls surrounding the solar system would shield the solar system from cosmic rays. The model leads to a vision about formations of stars and galaxies as "boiling" of dark energy to matter. Also a model for the cosmic rays emerges allowing to identify the acceleration mechanism using recent findings about cosmic rays.

8.1 Motivations

The inspiration to this little contribution came from a discussion with my friend Pertti Kärkkainen who told me about the work of Walter Cruttenden (see `http://tinyurl.com/o7453p5`) [E65]. Cruttenden is a free researcher working with an old problem related to the astronomy of the solar system, namely the precession of equinoxes (see `http://tinyurl.com/y7mmojcd`) [E15]. Equinoxes (see `http://tinyurl.com/zebl7`) [E4] correspond to the two points at the orbit of Earth at which the Sun is in the plane of the equator (if Earth's spin axes were not tilted this would be the case always). What has been observed is an apparent movement of fixed stars relative to the Earth bound observer. The period of the equinox precession is about 26, 000 years. The angular radius of the precession cone is about 23.5 degrees. The rate of precession is approximately 50 arc seconds per year but is not strictly constant.

The precession of equinoxes reduces to precession which is a well-known phenomenon associated with the motion of a rigid body with one point fixed. Precession (see `http://tinyurl.com/cm2jz`) [E14] means that the spin axis of the spinning system rotates around fixed axis along the surface of a cone. One can distinguish between a torque free precession and precession induced by torque. Precession can be accompanied by a nutation (see `http://tinyurl.com/5fv5xu`) [E11]: the tilt angle of the spin axes with respect to fixed axes varies with time. The nutation for Earth is well-understood process determined by the local gravitational physics. In the case of precession the situation is not so clear.

8.1.1 Two basic theories explaining the precession of equinoxes

There are two basic theories of precession.

1. The precession of equinoxes could be governed by a local dynamics being due to the precession of the Earth with respect to solar system. Earth is indeed a prolate ellipsoid and the precession would be caused mainly by the gravitational fields of Sun and Moon (lunisolar model). According to the summary of Cruttenden (see `http://tinyurl.com/o7453p5`) [E65], Newton's equations did not work and d'Alembert and others have added and changed input values to fit the observed precession. The latest 2000A version includes almost 1400 terms but it

still fails to accurately predict variations in the precession rate. The theory is also plagued by a "measurement paradox". Studies show that the changes in Earth's orientation relative to Sun and other planets are small (few arc seconds per year instead of 50 arc seconds) as compared to the equinox precession.

2. The precession of equinoxes could be also due to the precession of the entire solar system regarded as a rigid body with one point fixed and would be caused by some hypothetical binary companion of Sun. Usually the binary companion is thought to be star of planet like system but this is not necessary. This model is known as binary model and was first proposed by Indian astronomer Sri Yukteswar (see `http://tinyurl.com/ycfx87zr`). The predicted period was 24, 000 years. According to the summary of Cruttenden (see `http://tinyurl.com/o7453p5`), the binary model of Yukteswar has turned out to be more accurate over 100 year period [E65].

In principle the observation of the precession from some other planet could select between the two approaches. If the precession were similar at two planets then the precession of the entire solar system would be strongly favored as an explanation of the equinox precession.

8.1.2 Some hints

The basic challenge for the binary theory is of course the identification of the binary. There are some hints (see `http://tinyurl.com/ych6y4c3`) in this respect listed by W. Cruttenden in the articles at his homepage. Consider first what has been learned from the structure of heliosphere during last years.

1. The data from Voyager 1 and Voyager 2 have revealed that heliosphere is asymmetric (see `http://tinyurl.com/ycuhbsf6`) [E64]. The edge of the heliosphere (the place where the solar wind slows down to sub-sonic speeds and is heated) appears to be 1.2 billion kilometers shorter on the south side of the solar system than it is on the edge of the planetary plane. This indicates the heliosphere is not a sphere but has a shape of a bullet. In a sharp contrast with the naive expectations, the magnetosphere of Sun would not be like that of Earth which is compressed on the day side by solar wind and has a long tail on the night side.

2. There is also evidence from Voyager 2 for a strong magnetic field (see `http://tinyurl.com/ycowpzqe`) [E29]. Also the temperature just outside the boundary zone defining the boundary of the solar inner magnetosphere was ten times cooler than expected. The presence of the strong magnetic field is not easy to understand since the interstellar space consists of extremely tenuous gas. The proposal is that the interstellar magnetic field could be forced to flow around the helio-magnetosphere much like fluid flows around obstacle. This increases the density of flux lines and interstellar magnetic field would become stronger locally. Heliosphere would be like a bubble inside magnetic flux tube expanding it locally.

   The direction of the local magnetic field at the edge of the heliosphere differs considerably from that for the interstellar magnetic field thought to be parallel to the galactic plane. The tilt angle is about 60 degrees. Therefore one can challenge the identification of the strong local magnetic field as galactic magnetic field.

3. Between June and October 2007, the STEREO spacecraft (see `http://tinyurl.com/69asv9j`) [E19] "detected atoms originating from the same spot in the sky: the shock front and the helio-sheath beyond, where the sun plunges through the interstellar medium", and found "energetic neutral particles from beyond the heliosphere" that are moving towards the sun [E22]. This would suggest magnetic flux tube like structure and the flow of neutral particles along the flux tube towards the Sun so that an analog of solar wind would be in question.

Also the behavior of comets suggests that the understanding of the solar system is far from complete. The behavior of the comet Sedna thought to belong to the inner Oort cloud (see `http://tinyurl.com/cx2yd`) [E12] cannot be explained in terms of theory assuming only solar and planetary gravitational fields. Typically comets move along periodic orbits returning repeatedly near some planet of solar system (typically Neptune) which has kicked the comet to its highly eccentric orbit. Sedna (see `http://tinyurl.com/pvz6j`) [E1] (thought to be a "dwarf planet") seems to be an exception in this respect. Sedna has an exceptionally long and elongated orbit (aphelion about 937 AU and perihelion about 89.6 AU), period is estimated to be 11, 400 years, and Sedna does not return near any planet periodically as the assumption that it belongs to the scattered disk would require.

What could be the origin of Sedna?

1. It has been suggested that that Sun has an dim binary companion - christened as Nemesis (see `http://tinyurl.com/676c7s7`) [E10] - at a distance of thousands of AUs. This companion could explain the behavior of Sedna, and has been also proposed to be responsible for the conjectured periodicity of mass extinctions, the lunar impact record, and the common orbital elements of a number of long period comets.

2. Second proposal is that Sedna has been kicked to its orbit by some object. This object could be an unseen planet much beyond the Kuiper belt (see `http://en.wikipedia.org/wiki/Kuiper_belt`) [E7] (Kuiper belt is outside planet Neptune and extends from 30 AU to 55 AU). It would have mass about 5 times the mass of Jupiter and be at distance of roughly 7850 AU from the Sun in the inner Oort cloud. It could be a single passign star or one of the young stars embedded with the Sun in the stellar cluster in which it formed. This might have happened already in the Sun's birth cluster (cluster of stars).

3. Also the behavior of the comets in outer Oort cloud (very eccentric orbits and long orbital periods) might reflect the influence of a binary companion whose mass distribution is such that this kind of orbits are generic. For spherical objects one would expect nearly circular orbits. String like object would satisfy this condition as will be found.

8.1.3 The identification of the companion of the Sun in the framework of standard physics

Consider first the identification of the companion of the Sun responsible for the precession of the solar system as a whole but staying in the framework of the standard physics. In this context only objects with a spherical symmetry can be considered.

1. The strange behavior of Sedna suggests that binary could be an unseen planet at distance of about 7850 AU in the inner Oort cloud. Note that Oort could extend up to 50, 000 AUs which corresponds to.75 ly whereas the closest star - Proxima Centauri- is at distance of about 4.2 light years.

2. The identification of the binary as the hypothetical Nemesis might explain the analog of the solar wind. If the dim Nemesis is at the same distances as the hypothetical planet, its mass would be only.5 per cent of solar mass.

3. An analog of solar wind flowing along magnetic flux tubes could also come from some other star, say Proxima Centauri (see `http://tinyurl.com/csarf`) [E16]. Proxima Centauri is however too light as red dwarf and too distant to induce the precession of the solar system as whole.

8.1.4 The identification of the companion of the Sun in TGD framework

In TGD framework one can consider more speculative ideas concerning the identification of the binary of the Sun.

1. In TGD Universe dark matter and dark energy can be understood as phases of matter with large Planck constant [K10]. For the dark energy assignable to the flux tubes mediating gravitational interaction between Sun and given planet the value of the Planck constant is of order $\hbar_{gr} = GMm/v_0$, where $v_0/c \simeq 2^{-11}$ holds true for the inner planets. For dark matter the value of Planck constant is much smaller integer multiple of its minimal value identified as the ordinary Planck constant. Whether only magnetic energy should be counted as dark energy or whether also dark particles with a gigantic value of Planck constant should be identified as dark energy is not quite clear.

2. Magnetic flux tubes are identified as carriers of dark matter. This hypothesis plays a key role in TGD inspired quantum biology and cosmology. The flux tubes can have arbitrary large length scales. During the cosmology space-time would have consisted of cosmic strings of form $X^2 \times Y^2 \subset M^4 \times CP_2$ with X^2 minimal surface and Y^2 complex sub-manifold of CP_2. In the course of the cosmic evolution their M^4 projection would have become 4-dimensional and they would have become magnetic flux tubes. The proposal is that galaxies are like pearls in a necklace formed by flux tubes [K3].

   The density ρ_{dark} of the magnetic energy is enormous for cosmic strings: the length L of cosmic string corresponds to a mass which is a fraction $G/\hbar_0 R^2 \sim 10^{-4}$ of the mass of a black hole with radius L. The thickening of the cosmic string to a flux tube respects the conservation of the magnetic flux so that the strength of the magnetic field scales down like $B \propto 1/S$, where S is the area for the transversal cross section of the flux tube. By a simple scaling argument the density of the magnetic energy per unit length of the flux tube scales down like $dE_m/dl \propto 1/S$.

   If energy is conserved if the length of the cosmic string scales up like S in the cosmic expansion: $d \propto \sqrt{L}$ proportionality analogous to that encountered in the case of diffusion would relate to each other flux tube radius and length. Also the primary p-adic length scales L_p assignable to particles and the secondary p-adic length scales $L_{p,2}$ characterizing the corresponding causal diamond CD relate in a similar manner. This would suggest that the p-adic length scale assignable to a given particle (of order Compton length) corresponds to the thickness of the magnetic flux tube(s) assignable to the particle and the size of CD to the length of the(se) magnetic flux tube(s). Similar scaling holds true for the density of dark matter per unit length of the flux tube.

   The dark matter associated with the flux tubes would generate transversal $1/\rho$ gravitational field explaining the constant velocity spectrum of distance stars in the galactic halo. The basic prediction is free motion along the direction of the cosmic string perturbed only by the mass of the galaxy itself.

3. The fractality of the TGD Universe suggests the pearls in the necklace model applies also to stars. The magnetic flux tube idealizable straight string would be roughly orthogonal to the plane of the planetary system possibly associated with the star and the spin axis of the star would be nearly parallel to the flux tube. If one combines this picture with the previous discussion, the simplest proposal is obvious. The binary companion of the Sun is the magnetic flux tube containing dark matter. An analog of the solar wind could blow from the nearest star associated with the flux tube.

Newtonian theory for the gravitation in planetary system works excellently and this poses strong constraints on the pearls in a necklace model will be discussed in more detail.

1. If the magnetic flux tube idealizable as a straight string carries dark matter, this dark matter gives an additional transversal $1/\rho$ contribution to the gravitational field in the exterior of the flux tube experienced by comets and also by planets. Near the Sun this contribution should be small as compared to the contribution of the Sun but this is not obvious. Inside the flux tube the gravitational potential would be apart from a constant proportional to ρ^2. It could affect much the gravitational potential of Sun in a detectable manner.

2. The contribution of the gravitational potential of dark matter to the dynamics of the solar system is certainly negligible if the heliosphere is a bubble inside the magnetic flux tube having fluid flow as an analog. Stars could be bubbles of ordinary and dark matter inside flux tubes containing dark energy with a gigantic value of Planck constant. Fractality suggests that this picture might apply also to galactic magnetospheres and even in biological systems where TGD inspired quantum biology predicts that the flux tubes containing dark matter use visible matter as sensory receptor and motor instrument [K5, K6]. Cell would be a fractal analog of the solar heliosphere in this framework!

3. At long distances the transversal gravitational field created by the dark matter at the magnetic flux tube begins to dominate and the situation is very much like in the case of galaxies.

In particular, for circular orbits the rotation velocity is constant. The logarithmic behavior of the gravitational potential implies that the orbits tend to be highly eccentric and the it might be that the behavior of comets in the outer Oort cloud at least could be dictated by the gravitational field of the flux tube.

How thick the flux tube in question is and is its thickness affected by the presence of Sun and heliosphere?

1. The magnetic flux tube should have transversal dimensions not must larger than those of planetary system or heliosphere. The heliosphere has radius of about 80-100 AU to be compared to the distance 40 AU of Neptune. The distance of Neptune about 30 AU gives the first guess for the thickness of the flux tube. Kuiper belt extends from 30 AU to 55 AU and would surround the flux tube in this case.

2. Second guess is that the flux tube is so thick that it contains also Kuiper belt.

3. Third guess motivated by the above experimental findings is that the magnetic flux flows past the heliosphere like fluid flow: this would apply also to the dark matter matter inside flux tube. Heliosphere corresponds to a hollow bullet like bubble of ordinary and dark matter formed inside the flux tube carrying dark energy and carrying only the magnetic fields of Sun and planets.

   The dark energy and possible dark matter inside the flux tube (particular kind of space-time sheet) would have no effect on the gravitational field inside heliosphere so that no modifications of the existing model of solar system would be needed. Outside the heliosphere the effect would be in a good approximation described by a logarithmic gravitational potential created by an infinitely thin string like structure. The strong magnetic field of the flux wall surrounding the heliosphere would form a shield against the effects of cosmic rays coming from interstellar space.

The third guess seems to be consistent with the recent findings about the heliosphere boundary.

1. The strong magnetic field detected by Voyager 2 (see `http://tinyurl.com/osddsvw`) [E20] has been identified as galactic magnetic field which has changed its direction locally and for which the density of flux tubes has increased. Near the helio-sheath heliosphere would have deformed it locally inducing a tilt angle of 60 degrees with respect to the galactic plane.

   The article contains a video (see `http://tinyurl.com/y7zjs3yb`) giving an artist's view about the magnetic field suggesting strongly that flux tube develops a hole representing heliosphere. Could the magnetic field actually correspond to the dark magnetic field associated with the proposed magnetic flux tube? Helio-sheath has radius of order 80-100 AU so that this interpretation could make sense. This would challenge the interpretation as a galactic magnetic field unless the galactic magnetic field itself decomposes into flux tubes some of which contain stars as bubbles of ordinary and dark matter.

2. The findings of STEREO suggest that neutral atoms - presumably hydrogen atoms- arrive from a spot in the sky. It is not clear to me whether the spot refers to something in interstellar space (say another star) or just to the tip of the bullet like structure defined by the heliosphere. The simplest guess is that Proxima Centauri belongs to the same flux tube as Sun: this hypothesis is easy to kill if one assumes that the flux tube connecting Sun and Proxima Centauri is straight. The red dwarf character of Proxima Centauri does not however favor this hypothesis. Unfortunately I could not find any data about the direction of of the analog of the solar wind.

3. Interstellar Explorer (see `http://tinyurl.com/ybb6lhot`) discovered a narrow ribbon (see `http://tinyurl.com/obuex7j`) in heliosphere [E9]. This ribbon could correspond to the locus in which the deflection for the magnetic magnetic flux tubes caused by the heliosphere is such that the neutral particle of the solar wind can return back. The proposal is that magnetic walls act as mirrors. The reflection would involve ionization of neutral particle following by a confinement around flux tube plus possible motion in the direction of the flux tube and subsequent neutralization followed by a free linear motion possible back to Sun.

Only when the neutral particle arrives to the magnetic flux wall in approximately orthogonal direction, the reflection would occur via this process. Otherwise the particle would leak out along the magnetic flux wall.

An interesting question concerns the criteria for what it is to be pearls in the same necklace.

1. One possible criterion would be correlated motion in the absence of gravitational binding. The moving groups of stars (see `http://tinyurl.com/7rtndu9`) [E18] not bound by gravitational interaction would satisfy this criterion.

2. Another criterion that one can imagine is that the stars are in the same developmental stage. Maybe stellar nurseries contain tangled magnetic flux tubes inside which bubbles of ordinary and dark matter are formed in a phase transition transforming dark energy to ordinary and dark matter: the flux tubes mediating gravitational interaction would still carry dark energy as magnetic energy and have a gigantic value of Planck constant.

One can imagine also other dark options besides the proposed one: such as dark planets or dark Nemesis but these options are more speculative and might fail to explain the analog of the solar wind. Also the proposed dark matter matter at the orbits of the planets might have some role and fractality suggests that dark matter is present in in all scales so that one has bubbles inside bubbles inside....

In the following the idea that magnetic flux tube containing dark matter is tested by building simple models for the orbits of comets in the gravitational field of the flux tube and for the precession of the solar system in this field. The models are oversimplified and can be taken only as first steps to test whether the proposed vision might work.

8.2 A Model For The Motion Of Comet In The Gravitational Field Of Flux Tube

One should derive tests for the idea that also stars are mass concentrations around magnetic flux tube like structures evolved from extremely thin cosmic strings forming linear structures analogous to pearls in a necklace.

1. One possible signature might be the motion of comets. If the general structure of the orbits of comets in outer (at least) Oort cloud (see `http://tinyurl.com/cx2yd`) [E12] are determined by the gravitational field of the magnetic flux tube structure their general characteristics should reflect the very slowly variation of the logarithmic gravitational potential of the flux tube. What one would expect is typically very eccentric orbits in the plane of the solar system orthogonal to the flux tube and having very long orbital periods. Comet orbits in the outer Oort cloud indeed have these characteristics.

2. Second characteristic signature is free motion in direction parallel to the flux tube apart from effects caused by the solar gravitational field. This could imply the leakage of the comets from the system if the velocity is higher than the escape velocity from the solar system in presence of only solar gravitational field. Also the concentration of comets strongly in the plane of the solar system would imply that the total number of comets is much lower than predicted by the spherically symmetric model for the Oort cloud: this conforms with experimental facts [E12]. A more complex situation corresponds to a motion to which the gravitational fields of Sun and flux tube are both important. This could be relevant for motions which are not in the plane of planetary system.

8.2.1 Gravitational potential of a straight flux tube with constant mass density

The gravitational potential for a straight flux tube with constant density of dark energy (or matter) ρ_{dark} will be needed in the sequel.

1. Gravitational potential satisfies the Poisson equation

$$\nabla^2\phi_{gr} = 4\pi G\rho_{dark} \quad . \tag{8.1}$$

2. For a straight flux tube of radius d the mass density is constant and the situation is cylindrically symmetric and the solution inside the flux tube reads as

$$\begin{aligned} \phi_{gr} &= G\pi\rho_{dark}\rho^2 = GT\frac{\rho}{d}^2 \ , \\ T &= \frac{dM}{dl} \ . \end{aligned} \tag{8.2}$$

   T is the linear mass density.

   Outside the straight flux tube the potential is given by Gauss theorem as

$$\phi_{gr} = 2TG \times log(\frac{\rho}{\rho_0}) \ . \tag{8.3}$$

   The choice of the value ρ_0 is dictated by boundary conditions at the boundary of the flux tube if one assumes that the potential energy vanishes at origin. Its change induces only an additive constant to the total energy and does not effect equations of motion.

8.2.2 Motion of a test particle in the region exterior to the flux tube

One can construct a model for the motion of comet in gravitational field of flux tube by idealizing it with an infinitely thin straight string with string tension kept as a free parameter. For simplicity the motion will be assumed to take place in the plane orthogonal to the flux tube.

1. The gravitational potential energy of mass in the field of straight string like object is given by

$$V(\rho) = klog(x) \ , \ x = \frac{\rho}{\rho_0} \ , \ k = 2TG \tag{8.4}$$

   Here ρ_0 is a parameter which can be chosen rather freely since only the value of the conserved energy changes as ρ_0 is changed. One possible choice is $\rho_0 = \rho_{min}$, the minimum value of the radial distance from the flux tube idealized to be infinitely thin.

2. Conserved quantities are angular momentum

$$L = m\rho^2\frac{d\phi}{dt} \ , \tag{8.5}$$

   and energy

$$E = \frac{m}{2}(\frac{d\rho}{dt})^2 + \frac{L^2}{2m\rho^2} + V(\rho) \ . \tag{8.6}$$

3. One can integrate these equations to get for the period of the motion the expression

$$\begin{aligned} \frac{T}{\rho_0}\sqrt{2Em} &= 2\int_{x_-}^{x_+} \frac{dx}{\sqrt{1-\frac{L^2}{E^2\rho_0^2x^2} - klog(x)}} \ , \\ x_- &= \frac{\rho_-}{\rho_0} \ , \ x_+ = \frac{\rho_+}{\rho_0} \ . \end{aligned} \tag{8.7}$$

4. The turning points of the motion corresponds to the vanishing of the argument of the square root. At x_+ the logarithmic term dominates under rather general conditions whereas logarithmic term can be neglected at x_-, and one has in good approximation

$$x_+ \simeq e^{\frac{L}{k}} \ , \ x_- = \frac{L}{E\rho_0} \ . \tag{8.8}$$

   Without a loss of generality one can choose $\rho_0 = L/E$ giving $x_- = 1$ which gives

$$\rho_- \simeq \frac{L}{E} \ , \ \rho_+ \simeq \rho_- \times e^{\frac{L}{k}} \ , \ . \tag{8.9}$$

   For large values of L/k the orbits is very eccentric since one has $\rho_+/\rho_- \simeq exp(L/k)$.

A highly eccentric orbit with a very long orbital period is expected to represent the generic situation so that the model could indeed explain the characteristics of the comets in the outer Oort cloud. In the inner Oort cloud the eccentricities are smaller and the natural explanation would be that the gravitational field of Sun determines the characteristics of these orbits in good approximation.

8.3 A Model For The Precession Of The Solar System In The Gravitational Field Of Flux Tube

The model for the precession of the solar system in the gravitational field of the flux tube is obtained by idealizing the solar system with a cylindrically symmetry top with one point fixed in the gravitational field of the flux tube. The calculation is a little modification of that appearing in any text book of classical mechanics: I have used Herbert Goldstein's "Classical Mechanics" familiar from my student days [B1].

1. The model above requires that the solar system is a bullet like bubble inside the flux tube and dark energy induces no gravitational interaction inside the bubble. The bubble is approximated as a rigid body with one point fixed, which can thus perform precession. The torque must be due to the dependence of the total gravitational potential energy on the tilt angle θ of the bubble with respect to the axis of the flux tube.

2. One can apply the same trick as in the case of estimating the force on levitating super-conductor in external magnetic field. Since the magnetic field does not penetrate the super-conductor, the interaction energy is the negative of the magnetic energy of the external field in the volume occupied by the super-conductor. Now one obtains the *negative* of the interaction energy of the dark matter with its own gravitational potential. This can be written as

$$E_{gr} = -\frac{1}{8\pi G}\int(\nabla\phi_{gr})^2 dV \ . \tag{8.10}$$

   The value of the interaction energy depends on the orientation of the heliosphere which gives rise to a torque.

8.3.1 Calculation of the gravitational potential energy

The value of the potential energy must be calculated for various orientations of the bubble. Cylindrical coordinates (ρ, z, ϕ) are obviously the proper choice of coordinates. Cylindrical rotational symmetry implies that the potential energy depends on the inclination angle θ only characterizing the cone of precession. Potential energy is defined as an integral over the bubble. Potential energy is proportional to the transverse distance from the axis of the magnetic flux tube and this simplifies the analytical calculations considerably.

1. The change of the orientation of the bubble by a rotation which can be taken to be a rotation in (y,z) plane by angle (θ means that the expression for the transverse distance squared - call it $(\rho')^2$ - from the axis of the flux tube is given by

$$\begin{aligned} (\rho')^2 &= x^2 + (sin(\theta)z + cos(\theta)y)^2 \\ &= \rho^2 cos^2(\phi) + \rho^2 cos^2(\theta) sin^2(\phi) + z^2 sin^2(\theta) + 2z\rho cos(\theta) sin(\theta) sin(\phi) \ . \end{aligned} \quad (8.11)$$

By the rotational symmetry the contribution of the term linear in $sin(\phi)$ vanishes in the integral and the integral of $\rho')^2$ over ϕ can be done trivially so that one obtains the integral of quantity

$$I = \pi \left[\rho^2 + \rho^2 cos^2(\theta) + 2z^2 sin^2(\theta)\right] \ . \quad (8.12)$$

over z and ρ. The integral of the ρ^2 gives a term which does not depend on θ and therefore does not contribute to torque and can be dropped and one obtains

$$I = \int dV \left[\rho^2 cos^2(\theta) + 2z^2 sin^2(\theta)\right] \ . \quad (8.13)$$

To simplify the situation one can assume that bullet is hemisphere so that one has $z^2 = d^2 - \rho^2$ at the upper boundary. It is convenient to introduce scaled coordinates $x = \rho/d$ and $y = z/d$. The integration over ϕ can be carried out trivially so that apart from additive constant term one has

$$\begin{aligned} I &= \pi d^5 (I_1 cos^2(\theta) + I_2 sin^2(\theta)) \ , \\ I_1 &= \int_0^1 dy \int_0^{\sqrt{1-y^2}} x^3 dx = \frac{1}{4}\int_0^1 dy (1-y^2)^2 = \frac{44}{45} \ , \\ I_2 &= 2\int_0^1 dx x \int_0^{\sqrt{1-x^2}} dy y^2 = \frac{2}{3}\int_0^1 dx x (1-x^2)^{3/2} = \frac{2}{15} \end{aligned} \quad (8.14)$$

2. By replacing the upper limit of x integral with $z = f(\rho)$ one obtains the more general situation.

3. The value of the integral I is given by

$$\begin{aligned} I &= \pi d^5 \left[\frac{44}{45} cos^2(\theta) + \frac{2}{15} sin^2(\theta)\right] \equiv \frac{38}{45}\pi u^2 \ , \\ u &= cos(\theta) \ . \end{aligned} \quad (8.15)$$

Here a constant term not contributing to the torque has been dropped away.

4. By substituting the explicit expression for the gravitational potential one obtains the following expression for the gravitational potential

$$V = V_1 u^2 \ , \ V_1 = -\frac{19}{15} \times \frac{3}{8\pi} \frac{GM_{dark}^2}{d} \ . \quad (8.16)$$

The proportionality to GM_{dark}^2/d could have been guessed using dimensional analysis.

8.3.2 Solving the equations of motion from conservation laws

The equations of motion can be solved using standard procedure applicable to cylindrically symmetry top with one point fixed. The potential has the following general form for the bubble model;

$$V(u) = V_1 u^2 \ \text{(bubble)} \ . \tag{8.17}$$

Note that one has $V_1 < 0$ is by previous arguments more realistic than the potential when the magnetic flux penetrates the solar system (note that solar system would repel the magnetic flux like super-conductor). In the latter case analytical calculation would be also impossible although also now the potential depends on u only.

The calculation proceeds in the following manner [B1].

1. The Lagrangian is given in terms of Euler angles (θ, ϕ, ψ) by

$$L = \frac{I_1}{2}\left[(\frac{d\theta}{dt})^2 + (1-u^2)(\frac{d\phi}{dt})^2\right] + \frac{I_3}{2}(\frac{d\psi}{dt} + u\frac{d\phi}{dt})^2 - V_1 u^2 \ . \tag{8.18}$$

Here $I_1 = I_2$ *resp.* I_3 are the eigen values of the inertia tensor in the directions orthogonal *resp.* parallel to symmetry axis. In the recent case I_1 and I_2 correspond to the two directions orthogonal to the symmetry axis of the bullet like heliosphere and I_3 to the direction of the symmetry axis of the heliosphere.

2. ϕ and ψ are cyclic coordinates and give rise to two conserved quantities corresponding to conserved angular momentum components

$$\begin{aligned} p_\psi &= I_3(\frac{d\psi}{dt} + u\frac{d\phi}{dt}) \equiv I_1 a \ , \\ p_\phi &= \left[I_1(1-u^2) + I_3 u^2\right]\frac{d\phi}{dt} + I_3 u \frac{d\psi}{dt} \equiv I_1 b \ . \end{aligned} \tag{8.19}$$

From these equations one can solve $d\psi/dt$ and $d\phi/dt$ (recession velocity) in terms of u and various parameters and integrate this equations with respect to time if $u(t)$ is known.

3. Energy conservation gives an additional condition. By noticing that also the quantity $p_\psi^2/2I_3$ is conserved and one obtains

$$E' = E - \frac{p_\psi^2}{2I_3} = \frac{I_1}{2}(\frac{d\theta}{dt})^2 + (1-u^2)(\frac{d\phi}{dt})^2 + V_1 u^2 \tag{8.20}$$

is conserved. By little manipulations one can integrate θ or equivalently t from this equation and one obtains for the period T of motion the expression of form

$$\begin{aligned} T &= 2\int_{u_-}^{u_+} \frac{du}{\sqrt{(1-u^2)(\alpha - \beta u^2) - (b - au)^2}} \ , \\ \alpha &= \frac{2E'}{I_1} \ , \ \beta = \frac{2V_1}{I_1} \ , \ V_1 = -\frac{19}{15}\times\frac{3}{8\pi}\frac{GM_{dark}^2}{d} \ . \end{aligned} \tag{8.21}$$

The coefficients α and β can be deduced from the conservation laws for p_ψ and p_ϕ. Note that for the cylindrically symmetric rotating rigid body in Earth's magnetic field the negative

$V_1 u^2$ term is replaced with $2GMl \times u$ term having positive sign. By replacing u_+ with u as the upper integration limit one obtains the relationship $t = t(u)$ and can in principle invert this relationship to get $u = u(t)$.

The integral in question is elliptic integral (see `http://tinyurl.com/ycmwzs6y`) [A2, A1], whose general form is

$$P(a,b) = \int_a^b R(u,\sqrt{P(u)})du \ , \tag{8.22}$$

where R is rational function of its arguments and $P(t)$ is a polynomial with degree not higher than 4. Now the degree of P is maximal and the rational function reduces to a rational function $R(u,\sqrt{P(u)}) = 1/\sqrt{P(u)}$ of single variable. The limits are given by $(a,b) = (u_-, u)$ in the general case. By an appropriate change of variables elliptic integrals can be always reduced to three canonical elliptic integrals known as Legendre forms (see `http://tinyurl.com/ycbpwcfc`) [A3].

1. In the recent case the elliptic integral is of the standard form

$$\begin{aligned} t &= \int_{u_-}^{u} dv \frac{1}{\sqrt{P_4(v)}} \ , \ P_4(v) = a_4 v^4 + a_3 v^3 + a_2 v^2 + a_1 v + a_0 \ , \\ a_4 &= -\beta \ , \ a_3 = 0 \ , \ a_2 = -\alpha - a^2 \ , \ a_1 = 2ab \ , \ a_0 = \alpha - b^2 \ . \end{aligned} \tag{8.23}$$

   It can be computed analytically (see `http://tinyurl.com/2u7zflo`) [A1] in terms of Weierstrass elliptic function (see `http://tinyurl.com/czov55b`) $\mathcal{P}(t; g_2, g_3)$ [A4, A5] with invariants

$$\begin{aligned} g_2 &= a_0 a_4 - 4a_1 a_3 + 3a_2^2 \ , \\ g_3 &= a_0 a_2 a_4 - 2a_1 a_2 a_3 - a_4 a_1^2 - a_3^2 a_0 \ . \end{aligned} \tag{8.24}$$

2. Weierstrass elliptic function is the inverse of the function defined by the elliptic integral

$$t = \int_t^{\infty} \frac{ds}{4s^3 - g_2 s - g_3} \ . \tag{8.25}$$

   g_2 and g_3 are expressible in terms of zeros e_1, e_2, e_3 of $4s^3 - g_2 s + g_3$ satisfying $e_1 + e_2 + e_3 = 0$ (the quadratic term in the polynomial vanishes)

$$\begin{aligned} g_2 &= -4(e_1 e_2 + e_1 e_3 + e_2 e_3 = 2(e_1^2 + e_2^2 + e_3^2) \ , \\ g_3 &= 4e_1 e_2 e_3 \ . \end{aligned} \tag{8.26}$$

   The zeros of this polynomial must correspond to the zeros of the third order polynomial obtained when the zero u_- of P_4 is factorized out but for variable which is not u anymore.

   Either all the zeros are real or one os real and two complex conjugates of each other. This depends on the sign of the discriminant $\Delta = g_2^3 - 27g_3^2$. The possibly complex half periods ω_i (in the generic case) are related to the roots by $\mathcal{P}(\omega_1) = e_1$, $\mathcal{P}(\omega_2) = e_2$,, $\mathcal{P}(\omega_3) = e_3 = -e1 - e_2$ and satisfy $\omega_3 = -\omega_1 - \omega_2$. For real roots e_i ω_1 is real and ω_3 purely imaginary so that $\omega_2 = -\omega_1 - \omega_3$ is complex.

   The ratio $\tau = \omega_1/\omega_2$ defines so called modular parameter τ characterizing the periodicity properties of the Weierstrass function in complex plane (or effectively on torus whose conformal structures is characterized by τ).

3. If u_- is root of the P_4 as in the recent case, the expression for integral is given by

$$u = u_- + \frac{1}{4}P_4'(u_-)\left[\mathcal{P}(t;g_2,g_3) - \frac{1}{24}P_4''(u_-)\right]^{-1} . \quad (8.27)$$

   Here $\mathcal{P}(t;g_2,g_3)$ is the Weierstrass elliptic function. This expression gives $u = cos(\theta)$ as function of time t. The period T corrresponds to the situation $u = u_+$ and must correspond to the $t = \omega_1$ (real period in the argument of $\mathcal{P}$. The values of this function can be calculated numerically using Mathematica.

4. The relationship $u = u(t)$ giving by the above expression allows to integrate the equations for ψ and ϕ from the corresponding conservation laws by substituting the expression for $u(t)$ to these equations. Note that if nutation is absent so that $d\theta/dt = 0$ holds true and the above description fails since P_4 has a pair of degenerate real roots $u_+ = u_-$ meaning that nutation amplitudes becomes vanishing. This situation must be treated separately.

8.3.3 Exact solution when nutation is neglected

In the recent case the nutation can be neglected in the first approximation so that one has $d\theta/dt = 0$. In this case the two roots of the fourth order polynomial whose roots define the turning points are degenerate. This situation must be treated separately since the previous treatment fails.

1. The Lagrange equations of motion for θ give $\partial L/\partial\theta = 0$ stating that the torque vanishes in the equilibrium position for θ. The condition allows three solutions

$$\begin{aligned} u &= \pm 1 \text{ (no precession)} , \\ u &= \frac{1}{r_{13}-1} \times \frac{(\frac{d\psi}{dt})^2}{(\frac{d\phi}{dt})^2} \text{ (precession)} , \\ r_{13} &\equiv \frac{I_1}{I_3} . \end{aligned} \quad (8.28)$$

   If the bubble were a hemisphere with constant mass density one would have $r_{13} = 1/2$. Since the mass is concentrated in the orbital plane of planets, the value of I_3 is however smaller than I_1 and r_{13} is large suggesting that $r_{31} \equiv 1/r_{13}$ is a more convenient parameter for numerical calculations. If dark matter and energy do not contribute significantly inside heliosphere, Jupiter would give the dominating contribution to I_1 and Sun to I_3 inside planetary system. Kuiper belts are expected to give a large contribution to I_1. A rough estimate for r_{31} using various masses, solar radius, and planetary distances as basic data and neglecting Kuiper belt would give $r_{31} \sim 10^{-3}$. The actual value would be smaller than this unless dark matter changes the situation.

2. The conservation laws for p_ψ and p_ϕ read as

$$\begin{aligned} p_\psi &= I_3(\tfrac{d\psi}{dt} + u\tfrac{d\phi}{dt}) \equiv I_1 a , \\ p_\phi &= \left[I_1(1-u^2) + I_3u^2\right]\tfrac{d\phi}{dt} + I_3u\tfrac{d\psi}{dt} \equiv I_1 b , \end{aligned} \quad (8.29)$$

   and give

$$\begin{aligned} \begin{pmatrix} \frac{d\psi}{dt} \\ \frac{d\phi}{dt} \end{pmatrix} &= \frac{1}{1-u^2}\begin{pmatrix} a\left[r_{13}(1-u^2)+u^2\right] - bu \\ b - au \end{pmatrix} , \\ \frac{\frac{d\psi}{dt}}{\frac{d\phi}{dt}} &= \pm\frac{a\left[r_{13}(1-u^2)+u^2\right] - bu}{b-au} . \end{aligned} \quad (8.30)$$

   Note that $d\psi/dt$ and $d\phi/dt$ are constants.

3. By substituting the expression for the ratio of these angular velocities to the equation for the equilibrium value of u, one obtains

$$u(b-au)^2 = \frac{1}{r_{13}-1}\{a\left[r_{13}(1-u^2)+u^2\right]-bu\}^2 \ . \tag{8.31}$$

   This is fourth order polynomial and the number of real roots is at most four. $u \to -u, b \to -b$ is a symmetry of this equation. The interpretation is as change of the direction of spin axis and precession axis.

4. By feeding $d\theta/dt = 0$ into the conservation law of energy, one obtains an expression for the conserved energy

$$E = \frac{I_1}{2}\left[(1-u^2)(b-au)^2 + r_{13}b^2\right] + V_1u^2 \ . \tag{8.32}$$

   An interesting possibility is that the rotational motion of the bubble is stabilized against dissipation by the negativity of even the total energy E. The problem is that r_{13} is large and b is non-vanishing for precession so that the negativity of the total energy does not seem plausible.

   A weaker condition is that $E' = E - p_\psi^2/2I_3$ is negative. This gives

$$E' = \frac{I_1}{2}\left[(1-u^2)(b-au)^2 + r_{13}(b^2-a^2)\right] + V_1u^2 < 0 \ . \tag{8.33}$$

   For $b^2 < a^2$ the sign of the large term in the kinetic energy changes. What this would mean that the rate of rotation of solar system around the instantaneous precessing instantaneous rotation axis is large as compared to the precession rate.

5. The estimate for the period of precession given by $T = 2.6 \times 10^4$ years. In the approximation that nutation is absent $d\phi/dt = \omega$ is constant, and one has $d\phi/dt = 2\pi/T = 2.4 \times 10^{-4}$/year. The actual precession rate is not constant but its order of magnitude is same as the estimate obtained neglecting the nutation. Nutation would induce a time dependence of the precession rate. A reasonable expectation is that nutation represents a small oscillation around the solution representing mere precession.

8.3.4 Approximate solution when nutation is allowed

The model for non-nutating precession and the fact that precession rate is not quite constant suggest that a small nutation is present and induces the variation of the precession rate. A natural guess is that nutation represents a small perturbation around of non-nutating solutions. If this the case one can consider a standard treatment using standard perturbation theory assuming $u = u-0+\Delta u(t)$ and assuming that angular velocities are not affected at all so that only the u is perturbed.

1. The Lagragian for small perturbations of this kind is

$$\Delta L = \frac{I_1}{2}(\frac{d\Delta u}{dt})^2 + \left[\frac{(I_3-I_1)}{2}\omega_\phi^2 - \frac{V_1}{2}\right]\Delta u^2 \ . \tag{8.34}$$

   Here the shorthand notation $d\phi/dt \equiv \omega_\phi$ is introduced.

2. The equation for small oscillations is

$$\begin{aligned} \frac{d^2\Delta u}{dt^2} + \omega_0^2\Delta u &= 0 \ , \\ \omega_0^2 &= \left[(1-r_{31})\omega_\phi^2 + \frac{V_1}{I_1}\right]\Delta \ . \end{aligned} \tag{8.35}$$

3. Stability requires $\omega_0^2 > 0$. Since r_{13} is small the first term in ω_0^2 is positive. The second term is negative and this poses an upper bound for the magnitude of V_1 or alternatively lower bound for the magnitude of ω_ϕ:

$$\frac{I_1\omega_\phi^2}{|V_1|} > \frac{1}{1-r_{31}} = \frac{r_{13}}{r_{13}-1} \quad . \tag{8.36}$$

   A possible interpretation of this condition that sufficiently high precession rate prevents the instability causing the value of u to increase. Note that V_1u^2 is analogous to harmonic oscillator potential with a wrong sign. Note that for $\omega_\phi = 0$ which corresponds to $u_0 = 0$ the situation is unstable so that precession is necessary to stabilize the system against gravitational torque.

4. The period of nutation defines the period of oscillation for the rate of precession and this condition gives additional constraint on the parameters of the model.

9 Appendix: Orbital Radii Of Exoplanets As A Test For The Theory

In this appendix the orbital radii of exo-planets as test of the theory are considered.

Orbital radii of exoplanets serve as a test for the theory. Hundreds of them are already known and in [E8] tables listing basic data for for 136 exoplanets can be found. Tables provide also references and links to sources giving data about stars, in particular star mass M using solar mass M_S as a unit. Hence one can test the formula for the orbital radii given by the expression

$$\begin{aligned}
\frac{r}{r_E} &= \frac{n^2}{5^2}\frac{M}{M_S}X \quad , \\
X &= (\frac{n_1}{n_2})^2 \quad , \\
n_i &= 2^{k_i} \times \prod_{s_i} F_{s_i} \quad , \quad F_{s_i} \in \{3, 5, 17, 257, 2^{16}+1\} \quad .
\end{aligned} \tag{9.1}$$

Here a given Fermat prime F_{s_i} can appear only once.

It turns out that the simplest option assuming $X = 1$ fails badly for some planets: the resulting deviations of order 20 per cent typically but in the worst cases the predicted radius is by factor of $\sim .5$ too small. The values of X used in the fit correspond to $X \in \{(2/3)^2, (3/4)^2, (4/5)^2, (5/6)^2, (15/17)^2, (15/16)^2, (16/17)^2\} \simeq \{.44, .56, .64, .69, .78, .88, .89\}$ and their inverses. The tables summarizing the resulting fit using both $X = 1$ and value giving optimal fit are given below. The deviations are typically few per cent and one must also take into account the fact that the masses of stars are deduced theoretically using the spectral data from star models. I am not able to form an opinion about the real error bars related to the masses.

Tables 3, **4**, and **5** represent the fit of the Bohr model to the radii of the associated exoplanets. R denotes the value of minor semiaxis of the planetary orbit using AU as a unit and M the mass of star using solar mass M_S as a unit. n is the value of the principal quantum number and R_1 the radius assuming $X = (r/s)^2 = 1$ and R_2 the value for the best choice of X as ratio of "ruler and compass integers". The data about radii of planets are from tables at `http://tinyurl.com/y7j6tns7` and star masses from the references contained by the tables.

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Table 3: Fit of the Bohr model to the radii of the associated exoplanets. R denotes the value of minor semiaxis of the planetary orbit using AU as a unit and M the mass of star using solar mass M_S as a unit. n is the value of the principal quantum number and R_1 the radius assuming $X = (r/s)^2 = 1$ and R_2 the value for the best choice of X as ratio of "ruler and compass integers".

Star Name	R	M	n	R1	R1/R	r	s	R2/R
HD73256	0.037	1.05	1	0.042	1.14	16	15	1.00
HD83443	0.040	0.79	1	0.032	0.79	15	17	1.01
HD46375	0.040	1.00	1	0.040	1.00	1	1	1.00
HD179949	0.040	1.24	1	0.050	1.24	17	15	0.97
HD187123b	0.040	1.06	1	0.042	1.06	1	1	1.06
HD120136	0.050	1.30	1	0.052	1.04	1	1	1.04
HD330075	0.046	0.70	1	0.028	0.61	4	5	0.95
BD103166	0.050	1.10	1	0.044	0.88	15	16	1
HD209458	0.050	1.05	1	0.042	0.84	16	17	0.95
HD76700	0.050	1.00	1	0.040	0.8	15	17	1.03
HD217014	0.050	1.06	1	0.042	0.85	15	16	0.96
HD9826b	0.059	1.30	1	0.052	0.88	15	16	1.00
HD49674	0.060	1.00	1	0.040	0.67	5	6	0.96
HD68988	0.070	1.20	1	0.048	0.69	5	6	0.99
HD168746	0.065	0.88	1	0.035	0.54	3	4	0.96
HD217107	0.070	0.98	1	0.039	0.56	3	4	1
HD162020	0.074	0.75	1	0.030	0.41	2	3	0.91
HD130322	0.088	0.79	1	0.032	0.36	3	5	1
HD108147	0.102	1.27	1	0.051	0.50	3	4	0.89
HD38529b	0.129	1.39	1	0.056	0.43	2	3	0.97
HD75732b	0.115	0.95	1	0.038	0.33	3	5	0.92
HD195019	0.140	1.02	2	0.163	1.17	16	15	1.02
HD6434	0.150	0.79	2	0.126	0.84	15	16	0.96
HD192263	0.150	0.79	2	0.126	0.84	15	16	0.96
GJ876c	0.130	0.32	3	0.115	0.89	15	16	1.01
HD37124b	0.181	0.91	2	0.146	0.80	15	17	1.03
HD143761	0.220	0.95	2	0.152	0.69	5	6	0.99
HD75732c	0.240	0.95	2	0.152	0.63	4	5	0.99
HD74156b	0.280	1.27	2	0.203	0.73	5	6	1.05
HD168443b	0.295	1.01	2	0.162	0.55	3	4	0.97
GJ876b	0.210	0.32	4	0.205	0.98	1	1	0.98
HD3651	0.284	0.79	3	0.284	1.00	1	1	1
HD121504	0.320	1.18	2	0.189	0.59	3	4	1.05
HD178911	0.326	0.87	3	0.313	0.96	1	1	0.96
HD16141	0.350	1.00	3	0.360	1.03	1	1	1.03
HD114762	0.350	0.82	3	0.295	0.84	15	16	0.96
HD80606	0.469	1.10	3	0.396	0.84	15	16	0.96
HD117176	0.480	1.10	3	0.396	0.83	15	16	0.94
HD216770	0.460	0.90	3	0.324	0.70	5	6	1.01

Table 4: Fit of the Bohr model to the radii of the associated exoplanets. R denotes the value of minor semiaxis of the planetary orbit using AU as a unit and M the mass of star using solar mass M_S as a unit. n is the value of the principal quantum number and R_1 the radius assuming $X = (r/s)^2 = 1$ and R_2 the value for the best choice of X as ratio of "ruler and compass integers".

Star Name	R	M	n	R1	R1/R	r	s	R2/R
HD52265	0.49	1.13	3	0.41	0.83	15	16	0.94
HD73526	0.65	1.02	4	0.65	1	1	1	1.00
HD82943c	0.73	1.05	4	0.67	0.92	16	17	1.04
HD8574	0.77	1.17	4	0.75	0.97	1	1	0.97
HD169830	0.82	1.40	4	0.90	1.09	17	16	0.97
HD9826c	0.83	1.30	4	0.83	1.00	1	1	1.00
HD202206	0.83	1.15	4	0.74	0.89	15	16	1.01
HD89744	0.89	1.40	4	0.9	1.01	1	1	1.01
HD134987	0.81	1.05	4	0.67	0.83	15	16	0.94
HD12661b	0.82	1.07	4	0.68	0.84	15	16	0.95
HD150706	0.82	0.98	5	0.98	1.20	16	15	1.05
HD40979	0.81	1.08	4	0.69	0.85	15	16	0.97
HD92788	0.95	1.06	5	1.06	1.12	16	15	0.98
HD142	0.97	1.10	5	1.1	1.13	16	15	1.00
HD28185	1.03	0.99	5	0.99	0.96	1	1	0.96
HD142415	1.07	1.03	5	1.03	0.96	1	1	0.96
HD108874b	1.06	1.00	5	1.00	0.94	1	1	0.94
HD4203	1.09	1.06	5	1.06	0.97	1	1	0.97
HD177830	1.14	1.17	5	1.17	1.03	1	1	1.03
HD128311b	1.02	0.80	6	1.15	1.13	1	1	1.13
HD27442	1.18	1.20	5	1.20	1.02	1	1	1.02
HD210277	1.12	0.99	5	0.99	0.88	15	16	1.01
HD82943b	1.16	1.05	5	1.05	0.91	15	16	1.03
HD20367	1.25	1.17	5	1.17	0.94	1	1	0.94
HD114783	1.19	0.92	6	1.32	1.11	1	1	1.11
HD137759	1.28	1.05	5	1.05	0.82	15	17	1.05
HD19994	1.42	1.34	5	1.34	0.94	1	1	0.94
HD147513	1.26	1.11	5	1.11	0.88	15	16	1.00
HD222582	1.35	1.00	6	1.44	1.07	1	1	1.07
HD65216	1.31	0.92	6	1.32	1.01	1	1	1.01
HD141937	1.52	1.10	6	1.58	1.04	1	1	1.04
HD41004A	1.31	0.70	7	1.37	1.05	1	1	1.05
HD160691b	1.87	1.08	7	2.12	1.13	16	15	0.99

Table 5: Fit of the Bohr model to the radii of the associated exoplanets. R denotes the value of minor semiaxis of the planetary orbit using AU as a unit and M the mass of star using solar mass M_S as a unit. n is the value of the principal quantum number and R_1 the radius assuming $X = (r/s)^2 = 1$ and R_2 the value for the best choice of X as ratio of "ruler and compass integers".

Star Name	R	M	n	R1	R1/R	r	s	R2/R
HD23079	1.65	1.10	6	1.58	0.96	1	1	0.96
HD186427	1.67	1.01	6	1.45	0.87	15	16	0.99
HD4208	1.67	0.93	7	1.82	1.09	16	15	0.96
HD114386	1.62	0.68	8	1.74	1.07	17	16	0.95
HD213240	2.03	1.22	6	1.76	0.87	15	16	0.98
HD10647	2.10	1.07	7	2.10	1.00	1	1	1
HD10697	2.13	1.10	7	2.16	1.01	1	1	1.01
HD95128b	2.09	1.03	7	2.02	0.97	1	1	0.97
HD190228	2.00	0.83	8	2.12	1.06	1	1	1.06
HD114729	2.08	0.93	7	1.82	0.88	15	16	1
HD111232	1.97	0.78	8	2.00	1.01	1	1	1.01
HD2039	2.19	0.98	7	1.92	0.88	15	16	1
HD136118	2.40	1.24	7	2.43	1.01	1	1	1.01
HD50554	2.32	1.07	7	2.09	0.9	15	16	1.02
HD9826d	2.53	1.30	7	2.55	1.01	1	1	1.01
HD196050	2.43	1.10	7	2.16	0.89	15	16	1.01
HD216437	2.43	1.07	8	2.74	1.13	17	15	0.88
HD216435	2.70	1.25	7	2.45	0.91	1	1	0.91
HD169830c	2.75	1.40	7	2.74	1	1	1	1
HD106252	2.54	0.96	8	2.46	0.97	1	1	0.97
HD12661c	2.60	1.07	8	2.74	1.05	1	1	1.05
HD23596	2.86	1.30	7	2.55	0.89	15	16	1.01
HD168443c	2.87	1.01	8	2.59	0.9	15	16	1.03
HD145675	2.85	1.00	8	2.56	0.9	15	16	1.02
HD11964b	3.10	1.10	8	2.82	0.91	16	17	1.03
HD39091	3.29	1.10	9	3.56	1.08	17	16	0.96
HD38529c	3.71	1.39	8	3.56	0.96	1	1	0.96
HD70642	3.30	1.00	9	3.24	0.98	1	1	0.98
HD33636	3.56	0.99	9	3.21	0.9	15	16	1.03
HD95128c	3.73	1.03	10	4.12	1.1	16	15	0.97
HD190360	3.65	0.96	10	3.84	1.05	1	1	1.05
HD74156c	3.82	1.27	9	4.11	1.08	1	1	1.08
HD22049	3.54	0.80	11	3.87	1.09	16	15	0.96
HD30177	3.86	0.95	10	3.80	0.98	1	1	0.98
HD89307	4.15	0.95	10	3.80	0.92	1	1	0.92
HD72659	4.50	0.95	11	4.60	1.02	1	1	1.02
HD75732d	5.90	0.95	13	6.42	1.09	16	15	0.96

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