# Some astrophysical and cosmological findings from TGD point of view

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**Abstract**

There are five rather recent findings not easy to understand in the framework of standard astrophysics and cosmology. The first finding is that the model for the absorption of dark matter by blackholes predicts must faster rate than would be consistent with observations. Second finding is that Milky Way has large void extending from 150 ly up to 8,000 light years. Third finding is the existence of galaxy estimated to have mass of order Milky Way mass but for which 98 per cent of mass within half-light radius is estimated to be dark in halo model. The fourth finding confirms the old finding that the value of Hubble constant is 9 per cent larger in short scales (of order of the size large voids) than in cosmological scales. The fifth finding is that astrophysical object do not co-expand but only co-move in cosmic expansion. TGD suggests an explanation for the two first observation in terms of dark matter with gravitational Planck constant $h_{gr}$, which is very large so that dark matter is at some level quantum coherent even in galactic scales. Second and third findings can be explained using TGD based model of dark matter and energy assigning them to long cosmic strings having galaxies along them like pearls in necklace. Fourth finding can be understood in terms of many-sheeted space-time. The space-time sheets assignable to large void and entire cosmology have different Hubble constants and expansion rate. Fifth finding follows as a prediction of TGD: space-time sheets do not expand smoothly but in jerks in phase transition like manner.

## 1 Introduction

There are five rather recent findings not easy to understand in the framework of standard astrophysics and cosmology. The first finding (see the popular article at http://tinyurl.com/h6pjxpn and article at http://arxiv.org/abs/1002.0553) is that the model for the absorption of dark matter by blackholes predicts must faster rate than would be consistent with observations. Second finding (see http://tinyurl.com/gwj5ybv) is that Milky Way has large void extending from 150 ly up to 8,000 light years. Third finding [E3] (see http://tinyurl.com/zycob9x) is the existence of a galaxy estimated to have mass of order Milky Way mass but for which 98 per cent of mass within half-light radius is estimated to be dark in halo model. The fourth finding [E2] (see http://tinyurl.com/hlr7gah) gives support for an old puzzling finding: the value of Hubble constant is 9 per cent larger in short scales (of order of the size large voids) than in cosmological scales. The fifth finding (see http://tinyurl.com/o6vyb9g) is that astrophysical objects whose visible sizes are expected to expand if they co-expand, does not take place.

1. The first finding can be explained in terms of TGD based model of dark matter as phases with large value of gravitational Planck constant [K4]: the gigantic value of gravitational Planck constant $h_{gr}$ implies that the gravitational Compton length of dark matter is considerably larger than black hole radius. If the rate for the transformation of dark matter to visible matter is slow, dark matter remains outside the blackhole.

2. Second observation can be explained in terms of dark matter and energy assignable to cosmic strings having galaxies along them like pearls in necklace. Logarithmic gravitational potential gives rise to constant velocity spectrum explained usually in terms of dark matter halo.

Since $h_{gr}$ is very large, dark matter is quantum coherent even in galactic scales [K5]. Bohr orbitology in the gravitational potential of cosmic string gives the first approximation for the radii of flux tubes at which dark matter condenses and induces the formation of rings of ordinary matter around them. Also explanation for the large void around galactic nucleus is provided by Bohr orbitology.

3. Also third observation can be also understood in terms of TGD based model of galaxy formation in simple manner. The density of interstellar gas has been very low within half light-radius and only very few stars have formed in the gravitational field of cosmic string.

4. The fourth finding can be understood in terms of many-sheeted space-time. The space-time sheets assignable to large void and entire cosmology have different Hubble constants and expansion rates [K8].

5. The fifth finding follows as a prediction of TGD: space-time sheets do not expand smoothly but in jerks in phase transition like manner.

# 2 Blackholes do not absorb dark matter so fast as they should

Astronomers claim that blackholes do not absorb dark matter as fast as they should [E4] (see the popular article at `http://tinyurl.com/h6pjxpn` and article at `http://arxiv.org/abs/1002.0553`). The claim is based on a model for dark matter: if the absorption rate were what one would expect by identifying dark matter as some exotic particle, the rate would be quite too fast and the Universe would look very different.

How could this relate to the vision that dark matter is ordinary matter in large Planck constant phase with $h_{eff} = n \times h = h_{gr} = GMm/v_0$ proposed to be generated at quantum criticality [K7]? Gravitational Planck constant $h_{gr}$ was originally introduced by Nottale [E1]. In this formula $M$ is some mass, say that of black hole or astrophysical object, $m$ is much smaller mass, say that of elementary particle, and $v_0$ is velocity parameter, which is assumed to be in constant ratio to the spinning velocity of $M$ in the model for quantum biology explaining biophotons as decay products of dark cyclotron photons.

Could the large value of Planck constant force dark matter be delocalized in much longer scale than blackhole size and in this manner imply that the absorption of dark matter by blackhole is not a sensible notion unless dark matter is transformed to ordinary matter? Could it be that the transformation does not occur at all or occurs very slowly and is therefore the slow bottle neck step in the process leading to the absorption to the interior of the blackhole? This could be the case! The dark Compton length would be $\Lambda_{gr} = h_{gr}/m = GM/v_0 = r_S/2v_0$, and for $v_0/c << 1$ this would give dark Compton wavelength considerable larger than the radius $r_S = 2GM$ of blackhole. Note that dark Compton length would not depend on m in accordance with Equivalence Principle and natural if one accepts gravitational quantum coherence is astrophysical scales. The observation would thus suggest that dark matter around blackhole is stable against phase transition to ordinary matter or the transition takes place very slowly. This in turn would reflect Negentropy Maximization Principle favoring the generation of entanglement negentropy assignable to dark matter.

# 3 New findings about the structure of Milky Way 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 [K5, K4, K7, K9].

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 [E1] 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 [K5]: 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) [K1, K5]. 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 $\rho$ 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

$$v = v_1 \quad . \tag{3.1}$$

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

$$h_{gr} = \frac{GMm}{v_0} \tag{3.2}$$

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

2. The first guess for $v_0$ would be as

$$v_0 = v_1 \quad . \tag{3.3}$$

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

   $$\Lambda_{gr} = \frac{h_{gr}}{m} = \frac{GM}{v_0} = \frac{r_S}{2v_0} \quad (c = 1) \quad . \tag{3.4}$$

   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 $8 \times 10^3$ 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

   $$mv_1\rho = n \times \frac{h_{gr}}{2\pi} \quad . \tag{3.5}$$

   This would give

   $$\rho_n = n \times \rho_0 \quad , \quad \rho_0 = \frac{GM}{2\pi v_1 \times v_0} = \frac{\Lambda_{gr}}{2\pi v_1} \quad . \tag{3.6}$$

   The radii $\rho_n$ are integer multiples of a radius $\rho_0$.

   (a) Taking $M = M_{gal}$, the value of $\rho_0$ 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 $\Lambda_{gr}$. 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" $\alpha_{gr} = GMm/2h_{gr} = v_0/2$.

# 4 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 [E3] (see `http://arxiv.org/abs/1606.06291`) 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 twistorial lift of TGD predicts also cosmological constant [K10]. 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).

# 5 The problem of two Hubble constants persists

The rate of cosmic expansion manifesting itself as cosmic redshift is proportional to the distance $r$ of the object: the expansion velocity satisfies in good approximation $v = Hr$. The proportionality coefficients $H$ is known as Hubble constant. Hubble constant has dimensions of 1/s. A more convenient parameter is Hubble length defined as $L_H = c/H$, whose nominal value is 14.4 light years and corresponds to the limit at which the distant object recedes with light velocity from observer.

1. The measurement of Hubble constant requires determination of distance of astrophysical object (see http://tinyurl.com/qe8rqh6). For instance, the distance using so called standard candles - type I a supernovae having always same brightness decreasing like inverse square of distance (cosmic redshift also reduces the total intensity by shifting the frequencies). This method works for not too large distances (few hunder million light years, the size scale of the large voids (see http://tinyurl.com/gug9264)): therefore this method gives the value of the local Hubble constant.

2. The rate can be also deduced from cosmic redhift for CMB radiation. This method gives the Hubble constant in cosmic scales considerably longer than the size of large voids: one speaks of global determination of Hubble constant.

The problem has been that local and global method give different values for H. One might hope that the discrepancy should disappear as measurements become more precise. The recent determinination of the local value of the Hubble constant however demonstrates that the problem persists [E2] (see http://tinyurl.com/hlr7gah). The global value is roughly 9 per cent smaller than the local value. For a popular article about the finding see ).

The explanation of the discrepancy [K6] in terms of many-sheeted space-time was one of the first applications of TGD inspired cosmology. The local value of Hubble constant would correspond to space-time sheets of size at most that of large void. Global value would correspond to space-time sheets with size scales up to ten billion years assignable to the entire observed cosmos. The smaller value of the Hubble constant for space-time sheets of cosmic size would reflect the fact that the metric for them corresponds to a smaller average density for them. Mass density would be fractal in accordance with the fractality of TGD Universe implied by many-sheetedness.

Reader has perhaps noticed that I have been talking about space-time sheets in plural. The space-time of TGD is indeed many-sheeted 4-D surface in 8-D $M^4 \times CP_2$. It corresponds approximately to GRT space-time in the sense that the gauge potentials and gravitational fields (deviation of induced metric from Minkowksi metric) for sheets sum up to the gauge potential and gravitational field for the space-time of GRT characterized by metric and gauge potentials in standard model. Many-sheetedness leads to predictions allowing to distinguish between GRT and TGD. For instance, the propagation velocities of particles along different space-time sheets can differ since the light-velocity along space-time sheets is typically smaller than the maximal signal velocity in empty Minkowski space $M^4$. Evidence for this effect has been observed [K2]. For the first time for supernova 1987A: neutrinos arrived in two bursts and also gamma ray burst arrived at different time than neutrinos: as if the propagation would have taken place along different space-time sheets. Second time for the neutrinos arriving from galactic blackhole Sagittarius A. Two pulses were detected and the difference for arrival time was few hours.

# 6 Cosmic redshift but no expansion of receding objects: one further piece of evidence for TGD cosmology

"Universe is Not Expanding After All, Controversial Study Suggests" was the title of very interesting Science News article (see http://tinyurl.com/o6vyb9g) telling about study, which forces to challenge Big Bang cosmology. The title of course involved the typical exaggeration.

The idea behind the study was simple. If Universe expands and also astrophysical objects - such as stars and galaxies - participate the expansion, they should increase in size. The observation was that this does not happen! One however observes the cosmic redshift so that it is too early to start to bury Big Bang cosmology. This finding is however a strong objection against the strongest version of expanding Universe. That objects like stars do not participate the expansion was actually known already when I developed TGD inspired cosmology for quarter century ago, and the question is whether GRT based cosmology can model this fact naturally or not.

The finding supports TGD cosmology based on many-sheeted space-time. Individual space-time sheets do not expand continuously. They can however expand in jerk-wise manner via quantum phase transitions increasing the p-adic prime characterizing space-time sheet of object by say factor two of increasing the value of $h_{eff} = n \times h$ for it. This phase transition could change the properties of the object dramatically. If the object and suddenly expanded variant of it are not regarded as states of the same object, one would conclude that that astrophysical objects do not expand but only comove. The sudden expansions should be observable and happen also for Eart. I have proposed a TGD variant of Expanding Earth hypothesis along these lines [K3].

When one approximates the many-sheeted space-time of TGD with GRT space-time, one compresses the sheets to single region of slightly curved piece of $M^4$ and gauge potentials and the deviation of induced metric from $M^4$ metric are replaced with their sums over the sheets to get standard model. This operation leads to a loss of information about many-sheetedness. Many-sheetedness demonstrates its presence only through anomalies such as different value of Hubble constant in scales of order large void and cosmological scales, arrival of neutrinos and gamma rays from supernova SN1987A as separate bursts (arrival through different space-time sheets). The above observation represents one such anomaly.

One can of course argue that cosmic redshift is a strong counter argument against TGD. Conservation of energy and momentum implied by Poincare invariance at the level of imbedding space $M^4 \times CP_2$ does not seem to allow cosmic redshift. This is not the case. Photons arrive from the source without losing their energy. The point is that the source and observer are different gravitationally. The local gravitational field defined by the induced metric induces Lorentz boost of the $M^4$ projection of the tangent space of the space-time surface so that the tangent spaces at source and receiver are boosted with respect to other: this causes the gravitational redshift as analog of Doppler effect in special relativity.

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`).

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