Five new strange effects associated with galaxies

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Abstract

Dark matter in TGD sense corresponds to $h_{eff}/h = n$ phases of ordinary matter associated with magnetic flux tubes carrying monopole flux. These flux tubes are n-sheeted covering spaces, and n corresponds 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 a handful of the latest galactic anomalies supporting the proposed view.

1. Standard view about galactic dark matter strongly suggests that the stars moving around so called low surface brightness stars should not have flat velocity spectrum. The surprise has been that they have. It is demonstrated that this provides additional piece of support for the TGD view about dark matter and energy assigning them with cosmic strings having galaxies as knots along them.

2. The called 21-cm anomaly meaning that there is unexpected absorption of this line could be due to the transfer of energy from gas to dark matter leading to a cooling of the gas. This requires em interaction of the ordinary matter with dark matter but the allowed value of electric charge must be must much smaller than elementary particle charges. In TGD Universe the interaction would be mediated by an ordinary photon transforming to dark photon implying that em charge of dark matter particle is effectively reduced.

3. The unexpected migration of stars from Milky Way halo would in pearl-in-necklace model for galaxies be due to a cosmic traffic accident: a head-on collision of galaxy arriving along cosmic string having both Milky Way and arriving galaxy along it. The gravitational attraction of the arriving galaxy would strip part of stars from the galactic plane and distributions of stripped stars located symmetrically at the two sides of the galactic plane would be formed.

4. The rotation period of galaxy identified as the period of rotation at the edge of galaxy seems to be universal. In TGD Universe the period could be assigned to dark matter. The model allows to build a more detailed picture about the interaction of ordinary matter and dark matter identified as a knot in a long string containing galaxies as knots. This knot would have loop like protuberances extending up to the edge of the galaxy and even beyond it. In the region or radius r of few kpc the dark matter knot behaves like a rigid body and rotates with velocity v_{max} slightly higher velocity v_{rot} of distant stars. The rotation velocity of the flux loops extending to larger distances slows down with distance to roughly $v_{rot}/100$ at $\rho = R$ from its value v_{max} at $\rho = r$. In the region $\rho < r$ stars could be associated with sub-knots of the galactic knot and decayed partially (mostly) to ordinary matter. The stars in the region $\rho > r$ would be associated with flux loops de-reconnected from the galactic knot.

5. To my great surprise I learned that standard picture about star formation predicts that most of the stars are formed in the early cosmology and Sun like stars should not exist. The recent findings demonstrate that the star formation quenching slowing down the star formation involves the strong magnetic fields of galactic black hole in an essential manner. This leads to a TGD inspired proposal for how the formation of stars is slowed down and allows to understand the observations.

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1 Introduction

Dark matter in TGD sense corresponds to $h_{eff}/h = n$ phases of ordinary matter associated with magnetic flux tubes carrying monopole flux [K7, K7, K2]. These flux tubes are n-sheeted covering spaces, and n corresponds 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 4 latest galactic anomalies supporting the proposed view.

1. Sabine Hossenfelder had an inspiring post (see `http://tinyurl.com/ybmbzczr`) about some problems of the halo dark matter scenario (there are many of them [K6, K5] [L3]. 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.

2. Sabine Hossenfelder (see `http://tinyurl.com/y7h5ys2r`) told about the article [E3] 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 [E4]. The so called 21-cm anomaly meaning that there is an unexpected absorption of this line could be due to the transfer of energy from gas to dark matter leading to a cooling of the gas. This requires em interaction of the ordinary matter with dark matter but the required value of electric charge must be must smaller than elementary particle charges. In TGD Universe the interaction would be mediated by an ordinary photon transforming to dark photon implying that em charge of dark matter particle is effectively reduced.

3. 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 [E2] (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.

The unexpected migration of stars from Milky Way halo would in pearl-in-necklace model for galaxies [K1, K5, K4] be due to a cosmic traffic accident: a head-on collision of galaxy arriving along cosmic string having both Milky Way and arriving galaxy along it. The gravitational attraction of the arriving galaxy would strip part of stars from the galactic plane and distributions of stripped stars located symmetrically at the two sides of the galactic plane would be formed.

4. I learned in FB about very interesting finding about the angular rotation velocities of stars near the edges of the galactic disks [E6] (see `http://tinyurl.com/y7jlmkka`). The rotation period is about 1 Gy. 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 period T of galaxy is identified as the period of rotation at the edge of galaxy. The model allows to build a more detailed picture about the interaction of ordinary matter and dark matter identified as a knot in a long string containing galaxies as knots. Galactic knot would have loop-like protuberances extending up to the edge of the galaxy and even beyond it. In the region or radius $\rho \leq r \sim$ few kpc the dark matter knot would behave like a rigid body and rotate with velocity v_{max} slightly higher than the velocity v_{rot} of distant stars determined by the string tension of the flux tube. The angular rotation velocity of the flux loops extending to larger distances slows down with distance from its value ω_{max} at $\rho = r$ to $\omega_{rot} = v_{rot}/R$ at $\rho = R$ - roughly by a factor r/R. If stars are associated with sub-knots of the galactic knot and have decayed partially (mostly) to ordinary matter, the rotational velocities of stars and dark matter are same, and one can understand the peculiar features of the velocity spectrum. TGD Universe is fractal so that this description might apply also to the magnetic structure of Sun.

5. To my surprise I learned that standard picture about star formation predicts that most of the stars are formed in the early cosmology and Sun like stars should not exist. The empirical findings [E5] of a team of astronomers led by Fatemeh Tabatabaei published in Nature Astronomy (see `http://tinyurl.com/yc3mngtq`) provide considerable insights to the problem (see the popular discussion at (see`http://tinyurl.com/ybglb7t4`). The star formation quenching slowing down the star formation involves the strong magnetic fields of galactic black hole in an essential manner. This leads to a TGD inspired proposal for the formation of stars as generation of sub-knots in galactic knot involving reconnection explaining how the formation of stars is slowed down and allows to understand the observations.

2 The problem posed by low surface brightness galaxies

I am not specialist in the field of astrophysics and it was nice to read the post of Sabine Hossenfelder and refresh my views about the problem of galactic dark matter.

2.1 Some aspects of the problem of galactic dark matter

The halo model for galactic dark matter is plagued by several problems.

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.

2.2 TGD view about low surface brightness galaxies

One can look at the situation also in TGD framework.

1. In pearls-in-necklace model galaxies are knots of long cosmic strings [K1, K5] [L3]. 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) [K9]. 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 [K1, K8]. 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!

3 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.

3.1 21-cm anomaly

Sabine Hossenfelder (see http://tinyurl.com/y7h5ys2r) told about the article [E3] 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 [E4].

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.

3.2 TGD based explanation of 21-cm anomaly

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 [L2] (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.

4 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 [E2] (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.

4.1 The migration of the stars from the galactic disk

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 [E2] (see http://tinyurl.com/yb34t2kz) illustrates what the pattern of these vertical vibrations would look like according to simulations.

4.2 TGD based explanation for the migration

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) [L1].

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

$$\begin{array}{ll} g_{tot} = g_G - g_{MW} \ , & \text{between the galactic planes and above MW plane} \ , \\ g_{tot} = -g_G + g_{MW} \ , & \text{between the galactic planes and below MW plane} \ , \\ g_{tot} = -g_G - g_{MW} \ , & \text{above both galactic planes} \ , \\ g_{tot} = g_G + g_{MW} \ , & \text{below both galactic planes} \ . \end{array} \tag{4.1}$$

   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

$$\begin{array}{lll} h(t) = \frac{(g_G - g_{MW})}{2} t^2 \ , & v = (g_G - g_{MW})t \ , & t < T \ , \\ h(t) = -\frac{(g_G + g_{MW})}{2}(t-T)^2 + v(T)(t-T) + h(T) \ , & v(T) = (g_G - g_{MW})T \ , & \\ h(T) = \frac{(g_G - g_{MW})}{2} T^2 & t > T \ . & \end{array} \tag{4.2}$$

   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 $g_G = (1+x)g_{MW}$

$$T \sim \sqrt{\frac{1}{x}}\sqrt{\frac{2R}{g_{MW}}} \quad .$$

5. The direction of motion of O changes at $v(T_{max}) = 0$. One has

$$T_{max} = (\tfrac{2g_G}{g_G+g_{MW}}T \quad ,$$

$$h_{max} = -\tfrac{(g_G+g_{MW})}{2}(T_{max}-T)^2 + v(T)(T_{max}-T) + h(T) \quad .$$

6. For $t > T_{max}$ one has

$$h(t) = -\tfrac{(g_G+g_{MW})}{2}(t-T_{max})^2 + h_{max} \quad , \quad h_{max} = -\tfrac{(g_G+g_{MW})}{2}(T_{max}-T)^2 + h(T) \quad . \quad (4.3)$$

Expressing h_{max} in terms of T and parameter $x = (g_G - g_{MW})/g_{MW}$ one has

$$\begin{aligned} h_{max} &= y(x)g_{MW}\frac{T^2}{2} \quad , \\ y(x) &= x\frac{5x+4}{2(2+x)} \sim x \text{ for small values of } x \quad . \end{aligned} \quad (4.4)$$

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

$$T > \sqrt{\tfrac{2(2+x)}{x(5x+4)}}T_0 \quad , \quad T_0 = \tfrac{h_{now}}{g_{MW}} \quad . \quad (4.5)$$

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

$$g_{MW} = 2\pi G\frac{dM}{dS} = \frac{2GM}{R^2} \quad ,$$

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

$$g_{MW} \simeq 2g(\frac{R_E}{R})^2(\frac{M}{M_E}) \quad .$$

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

$$T_0 \sim 3\times 10^9 \text{ years} \quad . \quad (4.6)$$

The estimate $T \sim \sqrt{1/x}\sqrt{\tfrac{2R}{g_{MW}}}$ 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.

5 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 [E6] (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.

5.1 Universality of T and the interaction between visible and dark matter

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.

5.2 Quantal argument relating T to average surface gravity of galactic disk

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 [E1] is central in TGD, where dark matter corresponds to a hierarchy of Planck constants $h_{eff} = n \times h$. One would have

$$\hbar_{eff} = n \times \hbar = \hbar_{gr} = \frac{GMm}{v_0} \tag{5.1}$$

   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

$$\hbar_{gr} = \frac{GM^2}{v_0} . \tag{5.2}$$

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

$$\frac{MR^2\omega}{2} = L = m \times \hbar_{gr} = 2m \times \frac{GM^2}{v_0} \tag{5.3}$$

giving

$$\omega = 2m \times \frac{\hbar_{gr}}{MR^2} = 2m \times \frac{GM}{R^2 v_0} = m \times 2\pi \frac{g_{gal}}{v_0} \quad , \quad m = 1, 2, .., \tag{5.4}$$

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

$$T = \frac{v_0}{m \times g_{gal}} \quad , \quad m = 1, 2, ... \tag{5.5}$$

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 reasonably well the value of T.

6 Did you think that star formation is understood?

In Cosmos Magazine there is an interesting article about (see`http://tinyurl.com/ybglb7t4`) about the work [E5] 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 [K3]. 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 $L \sim 2^{10}R$.

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