TGD based view about star formation

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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. In this article I discuss two latest galactic anomalies supporting the proposed view and leading to a more detailed view about star formation.

1. 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.
2. 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.

Contents

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 [K3, K3, K1]. 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 two latest galactic anomalies supporting the proposed view.

1. I learned in FB about very interesting finding about the angular rotation velocities of stars near the edges of the galactic disks [E3] (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.

2. 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 [E2] 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 (seehttp://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.

I have already earlier commented the first finding from the point of view of galactic dynamics [L1] but have included these comments in this article because they are highly relevant for the proposed view about star formation.

2 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 [E3] (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.

2.1 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.

2.2 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

$$\hbar_{eff} = n \times \hbar = \hbar_{gr} = \frac{GMm}{v_0} \tag{2.1}$$

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

$$\hbar_{gr} = \frac{GM^2}{v_0}. \tag{2.2}$$

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

$$\frac{MR^2\omega}{2} = L = m \times \hbar_{gr} = 2m \times \frac{GM^2}{v_0} \tag{2.3}$$

giving

$$\omega = 2m \times \frac{\hbar_{gr}}{MR^2} = 2m \times \frac{GM}{R^2 v_0} = m \times 2\pi \frac{g_{gal}}{v_0} \quad , \quad m = 1, 2, .., \tag{2.4}$$

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

$$T = \frac{v_0}{m \times g_{gal}} \quad , \quad m = 1, 2, ... \tag{2.5}$$

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.

3 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 [E2] 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 [K2]. 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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