TGD view about universal galactic rotation curves for spiral galaxies

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Abstract

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

Contents

1 Introduction

The TGD inspired model for galaxy formation [L2, L4, L3] [K1, K3, L3] describes spiral galaxies as pearls in necklace defined by long cosmic string, whose gravitational field explains asymptotically constant rotation curve. In its recent form does not however say much about the situation near the galactic center.

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

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

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

4. Could TGD based model say something interesting about constant density core region for which there is now more empirical evidence [L5] but which is not consistent with the halo model of dark matter nor with the idea about un-knotted cosmic string.

5. Could TGD provide some ideas about the origin of Fermi bubbles [E5, E1] and super-massive blackhole at galactic center?

The observed universality rotation curves for mini spiral galaxies [L5] led to a considerable progress in TGD inspired model of galaxy formation. In TGD universality reduces to scaling invariance of the rotation curves natural since TGD Universe is quantum critical. The study of mini spiral galaxies supports the conclusion that they have a dark matter core of radius of few parsecs - 2-3 times the optical radius. This is a problem in the halo models. The simplest TGD based explanation is that galaxies correspond to knots or even spaghetti like tangles of long dark strings defining a kind of necklace containing galaxies as pearls. The model also suggests that dark matter core gives rise to Fermi bubble. Dark cosmic ray protons from supermassive galactic black hole containing dark matter would scatter from dark matter and some fraction of the produced dark photons would transform to ordinary ones. This would take place only inside the dark matter sphere and double sphere structure would be due to the fact that cosmic rays would not proceed far in galactic plane.

2 Universal rotation curves for mini spirals

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

The abstract of their article [L5] (see `http://tinyurl.com/yac5gpo3`) gives idea about what is involved.

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

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

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

$$\frac{v(\frac{R}{R_{opt}})}{v_{opt}} = f(x) \quad , \quad x = \frac{R}{R_{opt}} \quad . \tag{2.1}$$

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

The authors try to explain the universal shape using dark matter halo model and conclude that the core radius is 2-3 times the stellar disk size so that dark matter density would be constant below this radius and give to gravitational potential a harmonic oscillator contribution proportional to R^2 predicting rigid body rotation. The presence of constant density sphere is in conflict with halo models predicting typically density dependence of form $1/R$ at small radii. This is known as halo-cusp problem [E4].

3 TGD view about mini spirals

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

3.1 Scaling law

Consider first the situation for $R > R_0$.

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

2. Newton's law gives

$$v^2 = kTG + \frac{GM(R)}{R} \tag{3.1}$$

giving

$$\frac{v^2}{v_{opt}^2} = \frac{kTG + GM(R)/R}{kTG + GM(R_{opt})/R_{opt}} \quad . \tag{3.2}$$

3. To get scaling invariance one must assume

$$M(R) = M_{opt}x^{n+1} \quad , \quad x = \frac{R}{R_{opt}} \quad . \tag{3.3}$$

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

$$\frac{v^2}{v_{opt}^2} = \frac{kTG + GM(R_{opt})x^n}{kTG + GM(R_{opt})} \ , \tag{3.4}$$

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

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

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

$$\rho_0 \sim \frac{9.4 M_S}{ly^2 R_0} \ , \tag{3.5}$$

where M_S is the mass of the Sun. If the density of dark matter is constant for $R < R_0$, this gives rise to rigid body rotation $v = \omega R$ inside the sphere of radius R_0. Halo models however predicts that the density of dark matter behaves like $1/R$ for small distances. This is known as core-cusp problem [E4] (see `http://tinyurl.com/yabhmxdm`).

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

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

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

$$M = T_f R_1 = T_f x R_0 = \frac{4\pi}{3} \times \rho_0 R_0^3 = \frac{4\pi}{3} \times \frac{9.4 M(Sun) R_0^2}{ly^2} \ , \tag{3.6}$$

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

$$T_f G = \frac{4\pi}{3} \times \frac{9.4 r_S(Sun) x R_0}{ly^2} \tag{3.7}$$

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

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

4. Also the proposal that stars could be associated with long cosmic strings with possibly reduced string tension due to thickening finds support. Most stars of minimi galaxies reside within region defined by optical radius $R_D/R = \in [.3 - .5]$. If this is the case also for Milky Way, they could correspond to to sub-knots in the galactic knot in long cosmic string. This string might become visible in pulsars: the light beam would naturally propagate along the cosmic string being bound to helical orbits along cosmic string. This is consistent with the fact that Sun has distance about 8 kpc from the center of Milky Way and the size of Milky Way is about 10 times larger than the size of the minispirals studied.

   Also the interiors of TGD counterparts of blackholes would be knots and have magnetic structure, which could predict unexpected features such as magnetic moments not possible for GRT blackholes. Already the model for the first LIGO event [K2] explained the unexpected gamma ray bursts in terms of twisting of the rotating flux tubes as an effect analogous to what causes sunspots: twisting and finally reconnection. What about collisions of blacholes? Could they correspond to two knots moving along same string and colliding or two cosmic strings with possible self-intersect or are very near to each other: galactic traffic accident?

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

3.3 Knotted strings, Fermi bubble, and supermassive blackholes

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

1. Fermi bubbles [E5] (see `http://tinyurl.com/y9z3doj9` and `http://tinyurl.com/y9qkjdau`) detected by Fermi telescope above and below the plane of Milky Way have radius about 2-3 kpc, whereas the optical radii for mini spirals are slightly below 1 kpc and R_0 is reported to be 2-3 times larger - about 2-3 kpc too. Milky Way is not a mini spiral but there could be a connection.

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

   If cosmic rays interact also with dark matter and induce dark radiation such that part of it transforms to ordinary radiation, the radius of the dark matter sphere would naturally define the upper limit for the distance at which radiation is generated. The simplest option is that the cosmic rays propagate as dark particles from the blackhole and transform only later to ordinary particles. The mechanism transforming dark photons to ordinary ones would be analogous to that producing biophotons [K4].

2. Could there be a connection with the supermassive galactic blackhole in Milky Way (see `http://tinyurl.com/y9fhabdk`)? One particular model for Fermi bubbles [E1] (see `http://tinyurl.com/y6vjw6ej` and `http://tinyurl.com/yafcz2lh` and) assumes that they are remnants of stars eaten by galactic blackhole with mass about 4×10^6 solar masses with Schwartschildt radius about 40 ls (for Sun one gas $r_S = 3$ km): one has roughly $r_S \sim 10^{-6} R_0$. Blackhole would devour part of the stars and burp the rest back out as cosmic ray radiation.

3. One can also wonder about the origin of galactic super-massive blackhole. Could galactic blackhole be a reconnection point of two cosmic strings, which led to the formation of galaxies

as some empirical findings such as satellite galaxies in plane nearly orthogonal to the galactic plane suggest? If this is the case the matter of the galactic blackhole could be dark and would emit dark cosmic rays. Or could the blackhole correspond to self-intersection and knotting of a long cosmic string so that second cosmic string would not be necessary?

3.4 New view about blackhole like objects and galaxy formation?

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

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

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

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

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

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

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

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

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

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

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

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

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

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

   There is indeed evidence for the second straight string portion: in Milky Way there are mini-galaxies rotating in the plane forming roughly 60 degrees angle with respect to galactic plane and the presence of two cosmic strings portions roughly orthogonal to each other could explain this [L3]. Galactic blackhole could be associated with the intersection of string portions. The horizontal string portion could be part of long cosmic string, a separate closed cosmic string, or even another long cosmic string. One can imagine two basic options for the formation of the bar.

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

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

6. The pearls in string model explains also why elliptic galaxies have declining rotational velocity. They correspond to "free" closed strings which have not formed bound states with

long cosmic strings transforming them to spiral galaxies. The recently found 10 billion old galaxies with declining rotational velocity could correspond to elliptical galaxies of this kind.

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

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

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

1. This new thinking conform with the findings of LIGO [K3] [L1]. All the three stellar blackholes have been by more than order of magnitude massive than expected. There are also indications that the members of the second blackhole pair merging together did not have parallel spin directions. This does not fit with the idea that a twin pairs of stars was in question. It is very difficult to understand how two blackholes, which do not form bound system could find each other. Similar problem is encountered in bio-catalysis: who to biomolecules manage to find each other in the molecular crowd. The solution to the both problem is very similar.

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

3.5 Are stars borne in pairs?

Stars seem to be born in pairs! For a popular article see `http://tinyurl.com/ybto4tux`. The research article "Embedded Binaries and Their Dense Cores" [E3] is at `http://tinyurl.com/ycnye48y`.

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

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

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

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

1. TGD based model for galaxies leads to the proposal that the region in which dark matter has constant density corresponds to a very knotted and possibly thickened cosmic string

portion or closed very knotted string associated with long cosmic string. There would be an intersection of separate cosmic strings or self-intersection of single cosmic string giving rise to a galactic blackhole from which dark matter emerges and transforms to ordinary matter. Star formation would take place in this region 2-3 times larger than the optical region.

2. Could an analogous mechanism be at work in star formation? Suppose that there is cosmic string in galactic plane and it has two nearby non-intersecting portions roughly parallel to each other. Deform the other one slightly locally so that it forms intersections with another one. The minimal number of stable intersections is 2 and even number in the general case. Single intersection corresponding to mere touching is a topologically unstable situation. If the intersections give rise to dark blackholes generating later the stars would have explanation for why stars are formed as twin pairs.

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

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

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

3.6 Death blow to dark matter disks

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

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

The death of one idea is the victory of second one. I have been preaching for almost two decades that galactic dark matter along cosmic string containing galaxies like pearls in necklace: there would be no dark matter halo [L4, L3]. The model predicts correct velocity profile for distant stars without furher assumptions: the value of string tension determines the value of the velocity. The model solvs a multitude of anomalies of halo model, and leads to a rather detailed model for evolution of galaxies and also provides insights to problems like matter-antimatter asymmetry.

3.7 Low surface brightness galaxies as additional support for pearls-in-necklace model for galaxies

3.8 Low surface brightness galaxies as additional support for pearls-in-necklace model for galaxies

Sabine Hossenfelder had an inspiring post (see `http://tinyurl.com/ybmbzczr`) about the problems of the halo dark matter scenario. My attention was caught by the title "Shut up and simulate". It was really to the point. People stopped first to think, then to calculate, and now they just simulate. Perhaps AI will replace them at the next step.

While reading I realized that Sabine mentioned a further strong piece of support for the TGD view about galaxies as knots along cosmic strings, which create cylindrically symmetric gravitational field orthogonal to the string rather than spherically symmetric field as in halo models. The string tension determines the rotation velocity of distant stars predicted to be constant constant up to arbitrarily long distances (the finite size of space-time sheet of course brings in cutoff length).

To express it concisely: Sabine told about galaxies, which have low surface brightness. In the halo model the density of both matter and dark matter halo should be low for these galaxies so that the velocity of distant stars should decrease and lead to a breakdown of so called Tully-Fisher relation. It doesn't.

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

1. Tully-Fisher-relation (TFR) (see `http://tinyurl.com/ybhaat64`) is an empirically well-established relation between the brightness of a galaxy and the velocity of its outermost stars. Luminosity L equals to apparent brightness (luminosity per unit area) of the galaxy multiplied by the area $4\pi d^2$ of sphere with radius equal to the distance d of the observed galaxy. The luminosity of galaxy is also proportional to the mass M of the galaxy. TFR says that luminosity of spiral galaxy - or equivalently its mass - is proportional to the emission line width, which is determined by the spectrum of angular velocities of stars in the spiral galaxy. Apparent brightness and line width can be measured, and from these one can deduce the distance d of the star: this is really elegant.

2. It is easy to believe that the line width is determined by the rotation velocity of galaxy, which is primarily determined by the mass of the dark matter halo. The observation that the rotational velocity is roughly constant for distant stars of spiral galaxies - rather than decreasing like $1/\rho$ - this led to the hypothesis that there is dark matter halo around galaxy. By fitting the density of the dark matter properly, one obtains constant velocity. Flat velocity spectrum implies that the line width is same also for distant stars as for stars near galactic center.

   To explain this in halo model, one ends up with complex model for the interactions of dark matter and ordinary matter and here simulations are the only manner to deduce the predictions. As Sabine tells, the simulations typically take months and involve huge amount of bits.

3. Since dark matter halo is finite, the rotation velocity should decrease at large enough distances like $1/R$, R distance from the center of the galaxy. If one has very dilute galaxy - so called low surface brightness galaxy, which is very dim - the rotational velocities of distant stars should be smaller and therefore also their contribution to the average line width assignable to the galaxy. TFR is not expected to hold true anymore. The surprising finding is that it does!

The conclusion seems to be that there is something very badly wrong with the halo model. This is the message that the observational astrophysicist Stacy McGaugh is trying to convey in his blog (see `http://tinyurl.com/y9rwjjve`): about this the post of Sabine told.

Halo model of dark matter has also other problems.

1. Too many dwarf galaxies tend to be predicted.

2. There is also so called cusp problem: the density peak at the center of the galaxy tends to be too high. Observationally the density seems to be roughly constant in the center region, which behaves like rotating rigid body.

The excuses for the failures claim that the physics of normal matter is not well enough understood: the feedback from the physics of ordinary matter is believed to solve the problems. Sabine lists some possibilities.

1. There is the pressure generated when stars go supernovae, which can prevent the formation of the density peak. The simulations however show that practically 100 per cent of energy liberated in the formation of supernovas should go to the creation of pressure preventing the development of the density peak.

2. One can also claim that the dynamics of interstellar gas is not properly understood.

3. Also the accretion and ejection of matter by supermassive black holes, which are at the center of most galaxies could reduce the density peak.

One can of course tinker with the parameters of the model and introduce new ones to get what one wants. This is why simulations are always successful!

1. For instance, one can increase the relative portion of dark matter to overcome the problems but one ends up with fine tuning. The finding that TFR is true also for low surface brightness galaxies makes the challenge really difficult. Mere parameter fit is not enough: one should also identify the underlying dynamical processes allowing to get rid of the normal manner, and this has turned out to be difficult.

2. What strongly speaks against the feedback from the ordinary matter is that the outcome should be the same irrespective of how galaxies were formed: directly or through mergers of other galaxies. The weak dependence on the dynamics of ordinary matter strongly suggests that stellar feedback is not a correct manner to overcome the problem.

One can look at the situation also in TGD framework.

1. In pearls-in-necklace model galaxies are knots of long cosmic strings [K1, K3] [L5]. 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) [K6]. 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, K5]. 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!

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