Exploration

TGD View on the Findings Challenging the Halo Model of Galactic Dark

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Abstract

Bullet Cluster gives support for the existence of dark matter and can be used as an objection against MOND. Bullet cluster is however a problem also for the cold dark matter scenario. Recently several new findings challenging the halo models of galactic dark matter and suggesting that baryonic matter dominated in galaxies for about 10 Gy ago, have emerged. In this article both Bullet cluster problem and the newest findings will be discussed in TGD inspired pearls-in-necklace model assuming that galactic dark matter is in string-like objects containing galaxies along them. The gravitational field of string would automatically give rise to the constant velocity spectrum. The new findings suggest that this has not been the case for 10 Gy ago, and that bound states of galaxies and cosmic strings were formed later.

1 Introduction

Rather interesting developments challenging the halo model have occurred recently in the understanding of galactic dark matter and it is useful to summarized some background.

A very interesting new result related to the problem of dark matter has emerged: see the ScienceDaily article "In rotating galaxies, distribution of normal matter precisely determines gravitational acceleration" (see http://tinyurl.com/htcgpqe). The original article [3] can be found at arXiv.org (see http://tinyurl.com/julxz4b).

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

It turns out that the TGD based model [9] in which galactic dark matter is at long cosmic strings having galaxies along it like pearls in necklace allows to interpret the finding and to deduce a formula for the density from the observed correlation.

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

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

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

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There is a lot of pieces of evidence for the pearls-in-string model. Bullet cluster is one such piece of evidence (see `http://tinyurl.com/jm4kevp`) also challenging the halo model. The newest findings are about galaxies 10 billion years ago.

The first finding is that velocities curves decline as if baryonic matter would dominate or that dark matter is not at all present. In the first case the TGD explanation would be that at that time galaxies had not yet formed bound states with the cosmic strings and formed them only later. If galaxies are formed from ordinary matter around dark cosmic rings, the necklace would have been formed later.

There is also evidence coming from a study of a local group of galaxies. The findings suggest that an almost head-one collision of Milky Way and Andromeda took place about 10 billion years ago and led to an emission of a ring of dwarf galaxies moving rapidly in the common plane of galaxies. GRT based model however predicts that the collision would have led to a fusion of the galaxies if dark matter halos were present. The first finding would suggest that Milky Way and Andromeda (, which are in same plane) were not bound to their cosmic strings yet but also this possibility can be considered.

These three pieces of evidence are discussed below.

2 TGD view about the new findings challenging the halo model

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

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

1. ΛCDM (see `http://tinyurl.com/zv6wg4s`) assumes that dark matter forms a spherical halo around galaxy and that its density profile is such that it gives the observed velocity spectrum of distant stars approaching to constant and even increasing at large distances (see `http://tinyurl.com/ohbdqj6`). The problem of the model is that dark matter distribution can have many shapes and it is not easy to understand why approximately constant velocity spectrum is obtained. Also the attempts to find dark matter particles identified as some exoticons have failed one after another. The recent finding that the velocity spectrum of distant stars around galaxies correlates strongly with the density of baryonic matter (see `http://tinyurl.com/julxz4b`) also challenges this model: it is difficult to believe that the halo would have so universal baryonic mass density (for TGD view see [9].

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

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

Both models have severe problems.

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

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

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

What could be the interpretation in TGD?

1. In TGD galaxies are associated with cosmic string or more general string like objects like pearls with necklace [6, 4, 5, 8]: that this is the case is known for decades but for some mysterious reason to me has not been used as guideline in dark matter models. Maybe it is very difficult to see things from bigger perspective than galaxies.

   The flux tubes carry Kähler magnetic energy, dark energy, and dark matter in TGD sense having $h_{eff}/h = n$. The galactic matter experiences transversal $1/\rho$ gravitational force predicting constant velocity spectrum for distant stars when baryonic matter is neglected. Note that one avoids a model for the profile of the halo altogether. The motion of the galaxy along the flux tube is free apart from the forces caused by galaxy. The presence of baryonic matter implies that the velocity increases slowly with distance up to some critical radius. By recent findings correlating observed velocity spectrum with density of baryonic matter one can deduce the density of baryonic matter [9] (see `http://tinyurl.com/gvdclqg`). A possible interpretation is as remnants of cosmic string like object produced in its decay to ordinary matter completely analogous to the decay of the vacuum energy of inflaton field to matter in inflation theory.

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

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

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

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

3. The collision velocity would correspond to the relative velocity of flux tubes. Can one say anything about the needed collision velocities? The naive first guess of dimensional analyst is that the rotation velocity $v_{gal} \propto (TG)^{1/2}$ determining galactic rotation spectrum determines also the typical

relative velocity between galaxies. Here T would be the string tension of flux tubes containing galaxy clusters along it. T would gradually decrease during the cosmic evolution as flux tubes gets thicker and magnetic energy density is reduced. The velocity $v \sim c/100$ suggested by ΛCDM model is 10 times larger than $v \sim c/1000$ for distant stars in galaxies.

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

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

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

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

2.1 Velocity curves of galaxies decline in the early Universe

A new twist in the galactic dark matter puzzles emerged as Sabine Hossenfelder gave a link to a popular article "Declining Rotation Curves at High Redshift" (see `http://tinyurl.com/l6lpgk2`) telling about a new strange finding about galactic dark matter. The rotation curves are declining in the early Universe meaning distances about 10 billion light years [1] (see `http://tinyurl.com/jvp6fey`). In other words, the rotation velocity of distant stars decreases with radius rather than approaching constant - as if dark matter would be absent and galaxies were baryon dominated. This challenges the halo model of dark matter. For the illustrations of the rotation curves see the article. Of course, the conclusions of the article are uncertain.

Some time ago also a finding about correlation of baryonic mass density with density of dark matter emerged: the ScienceDaily article "In rotating galaxies, distribution of normal matter precisely determines gravitational acceleration" can be found at `http://tinyurl.com/htcgpqe`. The original article [3] can be found in arXiv.org (see `http://tinyurl.com/julxz4b`). TGD explanation involves only the string tension of cosmic strings and predicts the behavior of baryonic matter on distance from the center of the galaxy.

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

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

2. TGD view resolves the paradox due to the huge value of cosmological constant in very small scales. Kähler action and volume energy cancel each other so that the effective cosmological constant

decreases like inverse of the p-adic length scale squared because these terms compensate each other. The effective cosmological constant suffers huge reduction in cosmic scales and solves the greatest (the "most gigantic" would be a better attribute) quantitative discrepancy that physics has ever encountered. The smaller value of Hubble constant in long length scales finds also an explanation [7]. The acceleration of cosmic expansion due to the effective cosmological constant decreases in long scales.

3. In TGD Universe galaxies are located along cosmic strings like pearls in necklace, which have thickened to magnetic flux tubes. The string tension of cosmic strings is proportional to the effective cosmological constant. There is no dark matter hallo: dark matter and energy are at the magnetic flux tubes and automatically give rise to constant velocity spectrum for distant stars of galaxies determined solely by the string tension. The model allows also to understand the above mentioned finding about correlation of baryonic and dark matter densities [9].

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

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

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

2. The idea of the next day is that the galaxies at very early times have not yet formed bound states with cosmic strings so that the velocities of start are determined solely by the baryonic matter and approach to zero at large distances. Only later the galaxies condense around cosmic strings - somewhat like water droplets around blade of grass. The formation of these gravitationally bound states would be analogous to the formation of bound states of ions and electrons below ionization temperature or formation of hadrons from quarks but taking place in much longer scale. This model explains the finding about the decline of the rotation velocities [1]: the early galaxies are indeed baryon dominated.

2.2 Did Milky way and Andromeda have almost head on collision for billion years ago?

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

The authors of the article "Anisotropic Distribution of High Velocity Galaxies in the Local Group" [2] (see `http://tinyurl.com/mtm5vcm`) argue that the finding can be understood aif Milky Way and Andromeda had nearly head-on collision about 10 billion light-years ago. The Milky Way and Andromeda would have lost the radially moving dwarf galaxies in this collision during the rapid acceleration turning the direction of motion of both. Coulomb collision is good analog.

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

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

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

But were Milky Way and Andromeda already associated with cosmic strings at that time? The time would be about 10 billion years. One annot exclude this possibility. Note however that the binding to strings might have helped to avoid the fusion. The recent finding [1] (see `http://tinyurl.com/l6lpgk2`) about effective absence of dark matter about 10 billion light years ago - velocity distributions decline at large distances - suggests that galaxies formed bound states with cosmic strings only later. This would be like formation of neutral atoms from ions as energies are not too high!

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