Could the TGD view of galactic dark matter make same predictions as MOND?

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Abstract

I learned about a very interesting finding Kyu-Hyun Chae related to the dynamics of binaries of widely separated stars. The dynamics seems to violate Newtonian gravitation for low accelerations, which naturally emerge at large separations and the violations are roughly consistent with the MOND hypothesis. This raises the question whether the TGD based explanation of flat velocity spectra associated with galaxies could be consistent with the MOND hypothesis. The TGD based model for the binary system involving the monopole flux tubes associated with the stars of the binary leads to a prediction for the critical acceleration which is of the same magnitude as the galactic critical accelerations. This result generalizes if the scaling law $T^2(m)/m = constant$ for the system with mass m associated with a long monopole flux tube with string tension $T(m)$ holds true.

There is also a new contribution to the crisis of cosmology related to the additional support for the so called 8sigma anomaly. ΛCDM scenario predicts that the Universe should become clumpier but the opposite seems to be true. Both MOND and TGD predict this.

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1 Introduction

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The abstract of the research article [E2] (see this) summarizes the findings of Kyu-Hyun Chae.

A gravitational anomaly is found at weak gravitational acceleration $g_N \simeq 10^{-9}$ m/s^2 from analyses of the dynamics of wide binary stars selected from the Gaia DR3 database that have accurate distances, proper motions, and reliably inferred stellar masses. Implicit high-order multiplicities are required and the multiplicity fraction is calibrated so that binary internal motions agree statistically with Newtonian dynamics at a high enough acceleration of $\sim 10^{-8}$ ms^{-2}. The observed sky-projected motions and separation are deprojected to the 3D relative velocity v and separation r through a Monte Carlo method, and a statistical relation between the Newtonian acceleration $g_N \equiv GM/r^2$ (where M is the total mass of the binary system) and a kinematic acceleration $g \equiv v^2/r$ is compared with the corresponding relation predicted by Newtonian dynamics. The empirical acceleration relation at 10^{-9} ms^{-2} systematically deviates from the Newtonian expectation. A gravitational anomaly parameter $\delta_{obs-newt}$ between the observed acceleration at g_N and the Newtonian prediction is measured to be: $\delta_{obs-newt} = 0.034 \pm 0.007$ and 0.109 ± 0.013 at $g_N \sim 10^{-8.91}$ and $10^{-10.15}$ ms−2, from the main sample of 26,615 wide binaries within 200 pc. These two deviations in the same direction represent a 10 σ significance. The deviation represents a direct evidence for the breakdown of standard gravity at weak acceleration. At $g_N = 10^{-10.15}$ ms^{-2}, the observed to Newton-predicted acceleration ratio is $g_{obs}/g_{pred} = 10^{\sqrt{2}\delta_{obs-newt}} = 1.43 \pm 0.06$. This systematic deviation agrees with the boost factor that the AQUAL theory predicts for kinematic accelerations in circular orbits under the Galactic external field.

The findings lend strong support for a MOND type theory (see this) and for the notion of critical acceleration. The question is whether TGD and MOND could make the same prediction for the critical acceleration despite the fact the physical mechanism explaining the flat velocity spectrum of galaxies are completely different.

There is also a new contribution to the crisis of cosmology related to the additional support for the so called 8sigma anomaly. ΛCDM scenario predicts that the Universe should become clumpier but the opposite seems to be true. Both MOND and TGD predict this.

2 TGD view of the findings

How could one explain the findings in the TGD framework?

2.1 Basic ideas

The TGD inspired astrophysics and cosmology, actually the physics in all scales, relies crucially on the notions of cosmic string and monopole flux tube.

1. Cosmic strings as extremely thin 3-D surfaces would explain the flatness of the galactic rotation curve. They give rise to galaxies as local tangles involving thickening of the cosmic string to a monopole flux tube (MFT): the dark energy liberated in the reduction of the string tension T (energy per unit length) would transform to ordinary galactic matter. The process is analogous to the decay of the inflaton field to ordinary matter [L4].

   Also a second cosmic string at the galactic plane explaining the spiral structure could be involved and the galactic blackhole could have formed in the collision of cosmic strings as intersection.

   The cosmic string would create a $1/\rho$ force orthogonal to the string and this would predict a constant velocity spectrum at large distances at which the ordinary gravitational force between the galactic matter and distant star can be neglected.

2. The gravitational acceleration due to the cosmic string would become visible at distances at which the ordinary gravitational acceleration caused by $1/r^2$ force becomes smaller than that caused by the $1/\rho$ force. This prediction deviates from the MOND prediction and does not require giving up the Newtonian dynamics.

3. The cosmic string itself would consist of dark energy rather than dark matter. TGD predicts a hierarchy of phases of ordinary matter labelled by the value of effective Planck constant. These phases behave like dark matter and would explain the missing baryonic matter and the growth of its portion in the cosmic evolution. This form of dark matter would play a key role in living matter [L4].

4. Also stars would correspond to thickened tangles of a MFT, or more naturally, of its thickened version with a lower string tension T. They would be arranged along cosmic strings. This would also predict anomalous correlations between the dynamics of stars associated with the same cosmic string.

2.2 Can one generalize the TGD based model for the galactic velocity spectrum to binary stars?

Could cosmic strings assignable to the stars of the binary explain the findings of Chae?

1. The stars of the binary could be associated with the MFTs from which they have emerged as local thickening transforming dark energy to ordinary matter and energy. The natural assumption is that they are orthogonal to the orbital plane of the binary. The MFTs associated with the stars of the binary could also be parts of the same closed MFTs. TGD indeed predicts that the nonopole flux tubes must be closed.

2. The gravitational force between either star of the binary system and the MFT of the companion star gives rise to an additional $1/\rho$ force just as in the interactions of the star with the galaxy and the galactic cosmic string.

   One expects that cosmic strings must be replaced with MFTs, which have considerably lower string tension than galactic strings. The value of T is expected to scale like the inverse of the radius of the MFT and therefore decrease rapidly.

3. The gravitational force between the associated cosmic strings behaving like $1/\rho$ would be very weak at short distances as compared to the $1/r^2$ force would be weak at short distances. At large enough distances it would exceed the acceleration predicted by the ordinary matter galactic matter. The critical acceleration is indeed weak. For a fixed value of T, the distance at which this occurs would depend on T with the cosmic string of the first star and the mass of the second star of the binary binary.

Consider now an order of magnitude estimate.

1. The acceleration caused by the string or monopole flux tube is

$$a = \frac{GkT}{\rho} \tag{2.1}$$

   and it produces by Kepler's law constant velocity $\beta_0 = \beta_0/c$ of rotation

$$\beta_0^2 = kTG \ . \tag{2.2}$$

   Here k is a numerical constant, which disappears from the formulas).

2. The acceleration caused by the ordinary galactic matter (by the second star) is $a_{ord} = Gm/\rho^2$, where m is the ordinary galactic mass (mass of the star). By putting the accelerations caused by the cosmic string (monopole flux tube) associated with m and galactic matter equal, one obtains the estimate for the critical distance

$$\rho_{cr} = \frac{m}{T(m)k} = \frac{Gm}{\beta_0^2(m)} = \frac{r_s(m)}{2\beta_0^2(m)} \ , \tag{2.3}$$

   where r_s is Schwartschild radius.

3. From the data, one can ne estimate the value of $T(m)$ for the binary system. One expects it to be much smaller than the value of $T(M)$ associated with galactic cosmic strings since it should correspond to a MFT, which has suffered several phase transition-like thickenings during cosmic evolution liberating the dark energy of the MFT identifiable as magnetic and volume energy.

4. From the estimate for the value of T deduced from β_0, one can deduce the value critical acceleration $a_{cr} = \beta_0^2/r_{cr}$ and it should have at least the same order of magnitude as derived in [E2]. The critical acceleration determined in the article for the binary system is roughly of the same order of magnitude as the critical acceleration in the galactic situation determined by the rotational speed about $\beta_0 = 2.2 \times 10^2$ km/s for distant stars around the galaxy and supports the MOND mechanism. In TGD, the mechanism is completely different and this provides a killer test.

2.3 Quantitave estimates

Consider now the estimate in the case of galaxies (Milky Way is taken as a representative example) and binaries.

1. Consider first an estimate for β_0^2 for the galaxy. Kepler's law for string-star system gives

$$\beta_0^2 = kTG \ . \tag{2.4}$$

This gives

$$r_{cr} = \frac{M}{kT} = \frac{GM}{\beta_0^2} = \frac{r_s}{2\beta_0^2} \ , \tag{2.5}$$

where r_s is the Schwarshild radius of the galaxy without counting the contribution of the dark mass. The mass of the Milky way is given by $M_{gal}/M_{Sun} = r_{s,gal}/r_{s,Sun} \in [1.2, 1.9] \times 10^{12}$. The value of $\beta_0 = v_0/c = \simeq .7 \times 10^{-3}$ gives an estimate for r_{cr} .

It should be noticed that the value of $\beta_0 \simeq 10^{-3}$ is of the same order of magnitude as the velocity parameter appearing in the formula $\hbar_{gr} = GMm/\beta_0$, $\beta_0 = v_0/c \leq 1$ for the gravitational Planck constant introduced by Nottale [E1] in the case of Sun. Could these two velocity parameters be identified? This need not make sense: for the Earth $\beta_0 \simeq 1$ is suggestive, which looks unrealistic as a velocity of rotation of something rotating around a monopole flux tube assignable to the Earth.

2. For the binary system the critical radius r_{cr} is of order $r_{cr} \sim 100$ pc ~ 326 ly $\sim 2.9 \times 10^{12}$ km. A reasonable estimate for the Schwarschild radius r_s of the stars of the binary is as solar Schwartschild radius equal to $r_s = 3$ km.

The previous formula for r_{cr} gives an estimate for β_0^2

$$\beta_0^2 = \frac{Gm}{\beta_0^2} = \frac{r_s}{2r_{cr}} \ . \tag{2.6}$$

One obtains $\beta_0^2 \simeq 10^{-12}$ $(c = 1)$, which could correspond to $\beta_0 = 2^{-20}$ (powers of 2 are suggested by number theoretical considerations). This in turn gives $\frac{T_{gal}}{T_{bin}} \sim 10^6$.

3. Consider now the critical accelerations a_{cr}. One has

$$a_{cr} = \frac{\beta_0^2}{\rho_{cr}} = \frac{kTG}{\rho_{cr}} \ . \tag{2.7}$$

There are two cases to consider: galactic and binary.

The ratio of the critical accelerations is

$$\frac{a_{cr,gal}}{a_{cr,bin}} = (\frac{T_{gal}}{T_{bin}})^2 \frac{m_{bin}}{m_{gal}} = (\frac{\beta_{0,gal}}{\beta_{0,bin}})^4 \frac{m_{bin}}{m_{gal}} \ . \tag{2.8}$$

By feeding in the numbers the ratios of string tensions and masses and using reduces mass $m_{red} = m_{Sun}/2$, one obtains that the ratio is in the range $[1.3, 0.8]$ corresponding to the range for $M_{gal}/M_{Sun} \in [1.2, 1.9] \times 10^{12}$. The upper bound $a_{cr,bin} \sim 1.5 \times 10^{-10}$ m/s^2 for the estimate can be compared with the estimate $a_{cr,bin} \sim 10^{-9}$ m/s^2 of [E2] and the estimate $a_{cr,gal} \sim 1.9 \times 10^{-10}$ m/s^2 for the galactic critical acceleration. There is an order of magnitude discrepancy. The observations suggest $a_{cr,gal}/a_{cr,bin} \sim .7 \times 10^{-1}$ so that there would be discrepancy of an order of magnitude.

The mass of the star of the binary system should be roughly $m_{bin} = .1 \times M_{Sun}$ to get rid of the discrepancy. It is however known that the probability of the star to belong to a binary increases with the mass of the star (see this). This hower increases the estimate for the value of $a_{cr,gal}/a_{cr,bin}$.

Maybe, the assumption that the scaling law is exact over a mass scale range of 12 orders of magnitude is too much to hope for.

2.4 A scaling law implying that the predictions of TGD and MOND are identical

The predictions of TGD and MOND would be identical if the string tension $T(m)$ of the MFT assigned to an object with mass m (galaxy or star) satisfies the scaling law

$$\frac{T^2(m)}{m} = constant \ . \tag{2.9}$$

The scaling law would have rather dramatic implications. There are two forms of this proposal depending on whether T is constant or depends on the position along the MFT.

1. If one one assumes that $T = constant$ along the MFT, the masses of objects (galaxies or stars) associated with it have the same mass and could be in the same evolutionary state.

   The dynamics of the MFT and objects associated with it would be in synchrony. This is an enormously powerful prediction but would conform with the predicted long range gravitational quantum coherence of the TGD Universe, for which the long MFTs would serve as correlates. This view involves the hierarchy of effective Planck constants $h_{eff} = nh_0$ labelling phases of the ordinary matter located at the field bodies (magnetic or electric), in particular gravitational magnetic bodies. Nottale's proposal [E1] for the gravitational Planck constant $\hbar_{gr} = GMm/\beta_0$, $\beta_0 = \beta_0/c \leq 1$ is part of the hypothesis [L1, L2] and its generalization would hold true for systems involving electric fields in long scales [L3]. One could in principle assign galaxies/stars having the same visible mass and evolutionary stage to the same MFT and one could in principle construct a flux tube map as a road map of the Universe.

2. The weaker, and probably more realistic, option is that the dynamics of objects and associated flux tubes are in synchrony only locally. T for the MFT can indeed vary along the flux tube. One could also say that MFTs could control the dynamics of galaxies/stars. This would be a scaled up variant for the vision that the magnetic body constings of MFTs (more generally field bodies) carrying dark matter has $h_{eff} = nh_0$ phases control the dynamics of the biological bodies (organisms). Universe would be analogous to a biological organism.

2.5 A new contribution to the crisis of cosmology

Sabine Hossenfelder has a Youtube video (see this) about the latest anomaly in cosmology [E3] (see this). This anomaly is very problematic from the point of view of the ΛCDM scenario of dark energy and possibly also from the point of view of general relativity. The MOND scenario is however consistent with the findings.

The ΛCDM scenario involves 6 parameters. Among them is Hubble constant. Depending on the measurement method one obtains two values for it: this creates Hubble tension. The two kinds of measurements correspond to short and very long scales and this might relate to the problem.

There is also so called sigma8 tension with significance larger than 4 sigmas, which is something very serious. ΛCDM predicts that the Universe should become clumpier as it evolves. This implies that the gravitational potential wells should become narrower with time. In shoret scales the clumpying rate is not as high as predicted. Also the new results from a dark energy survey based on gravitational lensing suggest that the gravitational valleys are shallower than they should be at large values of cosmic time.

1. What is measured is so-called Weyl potential $\Psi_W = (\Psi + \Phi)/2$ defined in terms of the space-time metric in cosmic scales having the expression

$$ds^2 = a^2(\tau)(1 + 2\Psi)d\tau^2 - (1 + 2\Phi)dx_3^2) \ .$$

   Here τ and x_3 denote counterparts of linear Minkowski coordinates. For $Psi = \Phi = 0$ one has conformally flat metric. From the value of Psi_W one can deduce the clumpiness. The measurements are carried out for 3 widely differing values of the cosmic time τ. The value of the Weyl parameter Ψ_W characterizing the clumping differs from the prediction of the ΛCDM scenario and is consistent with the increasing shallowness of the gravitational potentials of the mass distributions.

2. The significance of the finding is estimated to be 2-2.8 sigma, which is potentially significant. Since the same method is used for different cosmic times, it is not possible to claim that the discrepancy is due to the different methods.

MOND has no problems with the findings. What about TGD?

1. The TGD view of galactic dark matter as dark energy assignable to cosmic strings, which are 3-D extremely thin 3-surfaces with a huge density of magnetic and volume energy [L4]. String tension parametrizes the density of this energy and creates a $1/\rho$ gravitational potential which predicts flat velocity spectrum for distant stars rotating around the galaxy. No dark matter halo nor dark matter particles are needed.

2. The $1/rho$ gravitational potential created by cosmic strings makes the gravitational wells shallower than the sole $1/r^2$ potential due to visible galactic matter. Also the halo creates $1/r^2$ potential in long enough scales but the prediction is that the dark matter halo becomes more clumpy so that the gravitational wells should become sharper.

   Cosmic strings are closed so that there is some scale above which this effect is not seen anymore since the entire closed cosmic strings become the natural objects. Therefore this effect should not be seen in long enough scales.

   It is important to notice that the shallowing would be due to the shortening of the observation scale rather than due to the time evolution. The same interpretation applies to the Hubble constant. In the TGD framework, the finite size of space-time sheets indeed brings in a hierarchy of scales, which is not present in General Relativity.

3. How does this relate to MOND? The basic objection against MOND is that it is in conflict with mathematical intuition: for small accelerations Newtonian gravitation should work excellently. In TGD, the critical acceleration of MOND is replaced with a critical distance from the galactic nucleus at which the $1/\rho$ potential due to the cosmic string wins the $1/r^2$ potential. Under a suitable assumption discussed in [L5], this translates to a critical acceleration of MOND so that the predictions are very similar. Note that the cosmic strings also cause a lensing effect used in the survey and this gives an upper bound for their string tension.

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