Essay

More Anomalies Related to the Standard Model of Galaxy Formation

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Abstract

Various anomalies associated with the ΛCDM model assuming that dark matter forms halos and with the general view of galaxy formation have been accumulating rapidly during years. The MOND model assumes no dark mass but modifies Newton's law of gravitation and is inconsistent with the Equivalence Principle. In TGD, the halo is replaced with a cosmic string and the Equivalence Principle and Newtonian gravitation survive. Both MOND and TGD can handle these anomalies because there is no dark mass halo. In this article, three new anomalies disfavoring ΛCDM but consistent with MOND and TGD are discussed. There are too many thin disk galaxies, dwarf galaxies do not have dark matter halos, and tidal tails associated with star clusters are asymmetric.

1 Introduction

Various anomalies associated with the ΛCDM model [1] assuming that dark matter forms halos and with the general view of galaxy formation have been accumulating rapidly during years. The MOND model [5] assumes no dark mass but modifies Newton's law of gravitation and is inconsistent with the Equivalence Principle. In TGD [7, 11, 8, 10, 9] [12, 13, 14], the halo is replaced with a cosmic string and the Equivalence Principle and Newtonian gravitation survive. Both MOND and TGD can handle these anomalies because there is no dark mass halo.

The basis difference between TGD and MOND is that critical acceleration is replaced with a critical radius at which the $1/rho$ contribution of the long cosmic string to gravitational force becomes larger than the $1/r^2$ contribution of ordinary matter. This radius and corresponding acceleration depends on the visible mass of the galaxy and on string tension.

For instance, the satellite galaxies of larger galaxies tend to move in a plane around the host as described in the review article [6] whereas the ΛCDM predicts that the orbits are more or less random. The article gives illustrations showing the concentration around the planes for the Milky Way, Andromeda, and Centaurian. The plane of satellites is approximately orthogonal to the plane of the host galaxy in all cases.

This anomaly was discussed from the TGD point of view in the article [15]. TGD automatically predicts preferred galactic planes as planes orthogonal to the cosmic string along which galaxies are located as tangles at which the string has thickened to a flux tube.

In this article three new anomalies disfavoring ΛCDM but consistent with MOND and TGD are discussed. There are too many thin disk galaxies [3], dwarf galaxies do not have dark matter halos [2], and tidal tails associated with star clusters are asymmetric [4].

2 Three anomalies of the standard model of galaxy formation

In the sequel "standard model of galaxy formation" refers to ΛCDM matter in which dark matter appears as a halo assumed to consist of not-yet-discovered dark particles. Both MOND and TGD approach are consistent with the empirical findings, the reason being that in both of them dark matter halos are absent.

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2.1 Too many thin disk galaxies

The title of the article "Breaking Cosmology: Too Many Disk Galaxies A Significant Discrepancy Between Prediction and Reality (`https://cutt.ly/LNPTtYp`) describes qite well the situation in the cosmology. The views of the dynamics of galaxies seem to be wrong.

In the current study [3], Pavel Kroupas doctoral student, Moritz Haslbauer, led an international research group to investigate the evolution of the universe using the latest supercomputer simulations. The calculations are based on the Standard Model of Cosmology; they show which galaxies should have formed by today if this theory were correct. The researchers then compared their results with what is currently probably the most accurate observational data of the real Universe visible from Earth.

The fraction of disk galaxies was found to be much larger than predicted. This suggests that the morphology of disk galaxies is very slowly changing and mergers of galaxies, favoured by dark matter halos, are not so important as though in the dynamics of galaxies. The cold dark matter scenario predicts spherical halos, which does not fit well with the large fraction of disk galaxies. The MOND approach is favored because there are no dark matter halos favoring spherical galaxies and mergers.

In the TGD framework [12, 13, 14], galactic dark matter or rather, dark energy would be associated with what I call cosmic strings so that halos are absent. Cosmic strings are extremely massive and create a $1/\rho$ transversal gravitational field, which explains the flat velocity spectrum of distant stars automatically.

The orbits of stars are helical since there is free motion in the direction of a long string. This strongly favors the formation of disk galaxies with the plane of the disk orthogonal to the string and correlation between the normals of the disks along the long cosmic string. In accordance with the findings, the concentration of matter at the galactic plane is very natural in the TGD framework.

The intersections of the string-like objects moving at 3-surface are topologically unavoidable and one can ask whether the disk galaxies are formed as two cosmic string intersect and the resulting perturbation induces their thickening leading to the transformation of the dark energy of the cosmic string to ordinary matter. This would be an analogy for the decay of an inflaton field to ordinary matter.

2.2 Dwarf galaxies do not have dark matter halos

Evidence for the failure of the dark halo model has been steadily accumulating during years. The popular article "New Discovery Indicates an Alternative Gravity Theory" published in SciTechDaily (`https://cutt.ly/dBVUBUn`) tells of the most recent discovery challenging the halo model. The dwarf galaxies of one of Earth's closest galaxy clusters do not behave as the halo model predicts.

Elena Asencio, a Ph.D. student at the University of Bonn was the lead author of the article *"The distribution and morphologies of Fornax Cluster dwarf galaxies suggest they lack dark matter* published in Monthly Notices of the Royal Astronomical Society [2] (`https://cutt.ly/wNPRLI5`).

The following summarizes the abstract of the article in somewhat shortened form.

1. Due to their low surface brightness, dwarf galaxies are particularly susceptible to tidal forces. The expected degree of disturbance depends on the assumed gravity law and whether they have a dominant dark halo. This makes dwarf galaxies useful for testing different gravity models.

2. Tidal susceptibility η (half-mass radius divided by theoretical tidal radius at which the density profile becomes zero (`https://cutt.ly/KNF44Po`) is the basic notion. Below a certain critical value η_{destr}, tidal forces destroy the dwarf galaxy.

3. The properties of dwarf galaxies in the Fornax Cluster were compared with those predicted by the ΛCDM as a standard model of cosmology and Milgromian dynamics (MOND). To achieve this, a test particle simulation of the Fornax system was constructed. The Markov Chain Monte Carlo (MCMC) method was used to fit this to the FDS distribution of η, the fraction of dwarfs that visually appear disturbed as a function of η, and the distribution of projected separation from the cluster centre.

4. It was possible to constrain the η value at which dwarfs should get destroyed by tides. Accounting for the so-called r'-band surface brightness limit of 27.8 magnitudes per square arcsec, the required stability threshold is $\eta_{destr} = 0.25 + 0.07 - 0.03$ in ΛCDM. This value is in tension with previous N-body dwarf galaxy simulations, which indicate that $\eta_{destr} \sim 1$.

5. The MOND N-body simulations indicated $\eta_{destr} = 1.70 \pm 0.30$, which agreed well with the MCMC analysis of the FDS. The conclusion was that the observed deformations of dwarf galaxies in the Fornax Cluster and the lack of low surface brightness dwarfs towards its centre are incompatible with ΛCDM expectations but well consistent with MOND. In accordance with findings, the observed half mass radii tend to be larger in MOND than in ΛCDM dynamics.

Intuitively, the dwarfs are more sensitive to the effects of the tidal forces in the MOND dynamics than in ΛCDM dynamics because the dark matter halo surrounding the dwarf galaxy and acting like a mattress, would shield it from the tidal forces. The observed tidal forces are too strong to be consistent with the presence of the dark matter halo.

In the TGD framework [12, 13, 14], the dark matter halo is replaced with a long cosmic string whose energy density giving rise to dark energy explains also the flat velocity spectrum of galaxies. There is no shielding.

2.3 The asymmetry of tidal tails as a support for the TGD view of dark matter

The most recent puzzling discovery related to the galactic dynamics is that for certain star clusters associated with tidal tails there is an asymmetry with respect to the direction of the motion along the tail [4] (`https://arxiv.org/abs/2210.13472`). The trailing tail directed to the galactic nucleus is thin and the leading tail is thick and there are many more stars in it. Stars also tend to leak out along the direction of motion along the tail. One would not expect this kind of asymmetry in the Newtonian theory since the contribution of the ordinary galactic matter to the gravitational potential possibly causing the asymmetry is rather small.

MOND theory [5]is reported to explain the finding satisfactorily.

1. The tidal tails of the star cluster are directed towards (leading tail) and outwards from it (trailing tail). The standard explanation is that gravitational forces produce them as a purely gravitational effect. These tails can be however often thin and long, which has raised suspicions concerning this explanation.

2. MOND hypothesis assumes that gravitational acceleration starts to transform above some critical radius from $1/r^2$ form to $1/r$ form. This applies to galaxies and star clusters modelled as a point-like object. This idea is realized in terms of a non-linear variant of the Poisson equation by introducing a coefficient $\mu(a/a_0)$ depending on the ratio a/a_0 of the strength of gravitational acceleration a expressible as gradient of the gravitational potential. a_0 is the critical acceleration appearing as a fundamental constant in the MOND model. μ approaches unity at large accelerations and a linear function of a/a_0 at small accelerations. Note that MOND violates the Equivalence Principle.

3. For MOND, the effective gravitational potential of the galactic nucleus becomes logarithmic. Therefore the outwards escape velocity in the trailing tail is higher than the inwards escape velocity in the leading tail so that the stars tend to be reflected back from the trailing tail. This would cause tidal asymmetry implying that the tail directed to the galactic nucleus contains more stars than the outwards tail. The MOND model uses the effective gravitational mass of the galaxy to model the situation in a quasi-Newtonian way.

TGD allows us to consider both the variant of the MOND model. The model provides also a possible explanation for the formation of the star cluster itself.

1. In the TGD framework, cosmic strings are expected to form a network [12, 13, 14]. In particular, one can assign to the tidal tails a cosmic string oriented towards the galactic nucleus, call it L_t to distinguish it from the long cosmic string along L along which galaxies are located. The thickening of a long string and the associated formation of a tangle generates ordinary matter as the dark energy of the string transforms to ordinary matter. This is the TGD counterpart for the transformation of the energy of an inflaton field to ordinary matter.

   This process can occur for both the galactic string L andL_t. In the first case it would give rise to galaxies along L and in the case of L_t to the formation of star clusters. Unlike in MOND, the gravitation remains Newtonian and the Equivalence Principle is satisfied in TGD.

2. The long cosmic string L along which the galaxies are located gives an additive logarithmic contribution to the total gravitational potential of the galaxy. This contribution explains the flat velocity spectrum of distant stars.

   At some critical distance, the contribution of L begins to dominate over the contribution of ordinary matter. The critical acceleration of the MOND model is replaced with the value of acceleration at which this occurs. In contrast to MOND, this acceleration is not a universal constant and depends on the mass of the visible part of the galaxy. TGD predicts a preferred plane for the galaxy and free motion in the direction of the cosmic string orthogonal to it. Also the absence of dark matter halo is predicted.

3. Concerning the formation of the tidal tails, the simplest TGD based model is very much the same as the MOND model except that one has 2-D logarithmic gravitational potential of string rather than modification of the ordinary 3-D gravitational potential of the galaxy. Therefore TGD allows a very similar model at qualitative level.

One can however challenge the assumption that the mechanism is purely gravitational.

1. The tidal tails tend to have a linear structure. Could they correspond to linear structures, long strings or tentacles extending towards the galactic nucleus? Could the formation of star clusters itself be a process, which is analogous to the formation of galaxies as a thickening of cosmic string leading to formation of a flux tube tangle?

2. Why more stars at the rear end rather than the frontal end of the moving star cluster? Could one have a phase transition transforming dark energy to matter proceeding along the cosmic L_t string rather than a star cluster moving. Dark energy would burn to ordinary matter and give rise to the star cluster.

3. The burning could proceed in both directions or in a single direction only. If the burning proceeds outwards from the galactic nucleus, the star formation is just beginning at the trailing end. In the leading end, the tangle formed by cosmic string has expanded and stretched due to the reduction of string tension. This could explain the asymmetry between trailing and leading ends at least partially.

   If the burning proceeds both outwards and inwards, only the MOND type explanation remains.

4. Second asymmetry is that the stars tend to leak out along the direction of motion. The gravitational field of the galaxy containing the logarithmic contribution explains this at least partially. Long cosmic string L_t creates a transversal gravitational field and this could strengthen this tendency. The motion along L_t is free so that the stars tend to leak out from the system along the direction of L_t.

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