Revival of MOND or the Gravity Law without Universalism

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Abstract

It is argued that modified gravity can describe Dark Matter if one understands the modification of gravity as the tensor field $X^{\mu\nu} = X^{\mu\nu}(t, x, y, z)$ in the Einstein's equations (as an additional mathematical parameter without correspondence to a new particles), which is filling the Universe in addition to the Higgs field and the inflaton field.

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I. CURRENT STATUS OF MOND

What is the nature of dark matter? Is it a particle, or do the phenomena attributed to dark matter actually require a modification of the laws of gravity?

Modified Newtonian dynamics (MOND) is a hypothesis that proposes a modification of Newton's laws to account for observed properties of galaxies. It is an alternative to the hypothesis of dark matter in terms of explaining why galaxies do not appear to obey the currently understood laws of physics. Created in 1982 and first published in 1983 by the Israel physicist Mordehai Milgrom [1], the hypothesis' original motivation was to explain why the velocities of stars in galaxies were observed to be larger than expected based on Newtonian mechanics.

MOND is an example of a class of theories known as modified gravity, and is an alternative to the hypothesis that the dynamics of galaxies are determined by massive, invisible dark matter halos. Since Milgrom's original proposal, MOND has successfully predicted a variety of galactic phenomena that are difficult to understand from a dark matter perspective [2]. However, MOND and its generalisations do not adequately account for observed properties of galaxy clusters, and no satisfactory cosmological model has been constructed from the hypothesis.

The accurate measurement of the speed of gravitational waves compared to the speed of light in 2017 ruled out many theories which used modified gravity to avoid dark matter [3]. However, both Milgrom's bi-metric formulation of MOND and nonlocal MOND are not ruled out according to the same study.

II. COMMON FEATURE OF MOND PROPOSALS

The common feature of all MOND proposals is the universalism. Given the energy-momentum tensor for "visible" (e.g., baryonic) matter one perfectly determines Dark Matter. However, that seems to be not true because galaxies without Dark Matter are discovered [4].

A. The source of universalism is the empirical observations

Newton's law of universal gravitation is usually stated that every particle attracts every other particle in the universe with a force which is directly proportional to the product of their masses and inversely proportional to the square of the distance between their centers. This is a general physical law derived from empirical observations by what Isaac Newton called inductive reasoning. [5]

However, I am introducing un-universal law of gravitation in Eq.(2). It means, that there are places and times in universe, where force of gravity can not be calculated just from the properties of visible (in the following – “actual”) matter.

To fix the problems of MOND the author suggests to include the tensor field of Dark Matter, in analogy with the Higgs field.

III. HOW I HAVE MODIFIED GRAVITY

One writes general expression for modified gravity

$$\mathrm{G}^{*\mu\nu} = 8\pi\, T^{\mu\nu}\,, \tag{1}$$

where on the left hand side is the modified Einstein tensor. The $T^{\mu\nu}$ is energy-momentum tensor of “actual” matter. Without loss of generality one can rewrite Eq. (1) using the definition $8\pi\, X^{\mu\nu} = \mathrm{G}^{\mu\nu} - \mathrm{G}^{*\mu\nu}$,

$$\mathrm{G}^{\mu\nu} = 8\pi\,(T^{\mu\nu} + X^{\mu\nu})\,, \tag{2}$$

where the unmodified Einstein tensor is on the left hand side. In the following I call $X^{\mu\nu}$ a virtual term, in particular Virtual Matter. It can not be detected in particle detectors, because it is not the actual matter, but rather a pure mathematical modification of Einstein’s equations. If the covariant divergence $X^{\mu\nu}_{;\nu}$ vanishes, we will call it Dark Matter. Then Dark Energy in my MOND proposal is a class of Dark Matter, because $(\Lambda\, g^{\mu\nu})_{;\nu} = 0$.

My main contribution is to allow the 10 independent functions $X^{\mu\nu} = X^{\mu\nu}(t,x,y,z)$ not to be universal, i.e. being not always the most popular expression of Dark Matter (which is dust-like tensor $X^{\mu}_{\nu} = \mathrm{diag}(-\rho,0,0,0)$), but different in any given task and problem. What determines the shape of $X^{\mu\nu}$? Is it theoretical physics or experimental/observational one? Both, because, e.g., in Section V the $X^{\mu\nu}$ came as solution to particular theoretical problem.

IV. DEMONSTRATION OF THE NECESSITY OF $X^{\mu\nu}$

Using known facts from General Relativity, it is indeed possible and easy to solve the mystery.

Any singularity is simply a mathematical blow up of the theory of Relativity. To fix this, to make the theory physical rather than mathematical then, I am using Virtual Term $x(r)$ in the Schwarzschild Black Hole following way

$$ds^2 = -\left(1 - \frac{2M}{r + x(r)}\right) dt^2 + \frac{dr^2}{1 - \frac{2M}{r+x(r)}} + r^2(d\theta^2 + \sin^2\theta\, d\phi^2)\,, \tag{3}$$

where function $x(r > 2M) = 0$, $x(r \leq 2M) = \epsilon\,(2M - r)$, $0 \leq r < \infty$, the small $\epsilon > 0$.

The tensor $X^{\mu\nu}$ one calculates from Eqs.(3),(2) with $T^{\mu\nu} = 0$.

The demand to fulfil the "energy conditions" (weak, strong, and others) is not applicable to the virtual matter $X^{\mu\nu}$, as it is not subject to measurements. So, one would not measure a negative energy.

A. The $X^{\mu\nu}$ is needed to fix the problem of vanishing of particles

If you release a particle in Kerr, Kerr-Newman, or Reissner-Nordström spacetime with zero of initial velocity $u^r = u^\theta = u^\phi = 0$ (in photon case $u^\theta = u^\phi = 0$, $u^r < 0$), then it will reach the abrupt end of trajectory at radius $r = r_m > 0$ because there is $(u^r)^2 < 0$ if $r < r_m$. The curvature singularity is at $r = 0$. The details are in [7].

P.S. In case of motion inside the equatorial plane $\theta = \pi/2$ the abrupt end geodesics are present for Kerr-Newman and Reissner-Nordström spacetimes.

V. INTERPRETATION OF $X^{\mu\nu}$

One should include such a concept as virtual terms, i.e. mathematical insertions into the equations and laws of nature which are made not from fundamental premises but "by hand" in order to fit the theory under observation. An example for such insertions are Dark Matter and Dark Energy. Therefore, these cannot be directly detected, but it is possible to measure their effect on nature. As a prime example, the Dark Matter anomaly has acted on the space-time grid in such an amount that it created an additional force of attraction of stars to the center of their galaxy. By the way, the proton radius measured by many experimenters was different in different years. This riddle did not find yet a solution [8]. I, personally, would solve this problem with a virtual insertion Ψ into the radius value, $r = R + \Psi$.

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[3] Sibel Boran, Shantanu Desai, Emre Kahya, Richard Woodard. “GW170817 Falsifies Dark Matter Emulators”. Phys. Rev. D 97, 041501 (2018), arXiv:1710.06168 [astro-ph.HE].

[4] see e.g. P. van Dokkum, S. Danieli, Y. Cohen, et al. “A galaxy lacking dark matter”. Nature 555, 629–632 (2018).

[5] Sir Isaac Newton: “In [experimental] philosophy particular propositions are inferred from the phenomena and afterwards rendered general by induction”: “Principia”, Book 3, General Scholium, at p.392 in Volume 2 of Andrew Motte’s English translation published 1729.

[6] A. P. Lightman, W. H. Press, R. H. Price, S. A. Teukolsky, “Problem Book in Relativity and Gravitation,” Princeton University Press, Princeton, 1975.

[7] Dmitri Martila, Broken Geodesics and Dark Matter, 2019, to be published.

[8] see e.g. Jean-Philippe Karr, Dominique Marchand, “Progress on the proton-radius puzzle”, Nature 2019.