Revival of MOND or the Gravity Law without Universalism

Dmitri Martila

Institute of Theoretical Physics, Tartu University,

4 Tähe Street, 51010 Tartu, Estonia[*]

(Dated: February 5, 2020)

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.

[*]Electronic address: `eestidima@gmail.com`

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.

III. MY PROPOSAL

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

A. Motivation of this study

Everyone has an opinion. But can personal opinion be of use in Scientific Endeavour? In the best case scenario, which was perhaps during Albert Einstein's live time, the journals really read the articles of the authors trying to demonstrate them their fatal mistake. Then there could be a productive discussion between three authorities: the reviewers, the editor, and the author (is better for everyone to be informed, as each of the parties can read the article).

Besides logic, the scientific community always uses feelings (in my experience [6]), but feelings can be positive or negative, as there are two options in the realm of feelings: scepticism or trust. I follow my "guiding star" in a way that I must be convinced (by me or others) if I have made a mistake. This mistake must be found, and I must be convinced that it is a mistake. This principle is my guiding star. Some journals have rejected some of my papers without even trying to convince me of having done mistakes.

There is a historical case about Einstein. After his publication of the logical debunkment of Sir Newton's absolute space and absolute time, too many scientists were not accepting his debunkment. Therefore, the unexplainable feeling of scepticism has severely slowed down the "train" of science for as long as 17 years (and the greatest Theory of Relativity has not been renowned by a Nobel Prize)! [7] Described suffering of Prof. Einstein indicates, that "scientific scepticism" is nothing more than a negative emotion. But science could be conducted in positive way rather than negative. How exactly? If the mind of the reader would see that the logic of the paper seems not to be violated, the mind would trust this conclusion and accept the paper.

Humankind shows a terrible conflict between feelings and mind. Muting the mind in favour of emotions is simply called madness (in my opinion), but conflict between scientific mind and feeling of beauty is discussed in this book: [8].

IV. 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 Eq.(7) the $X^{\mu\nu} = -T^{\mu\nu}$ came as solution to particular theoretical problem, however, generally speaking $X^{\mu\nu} \neq -T^{\mu\nu}$.

Have you noticed the negative sign before the energy-momentum tensor in the two latter expressions? Do not worry about it. The demand to fulfil the "energy conditions" (weak, strong, and others) is not applicable to the virtual term $X^{\mu\nu}$, as it is not subject to measurements. So, one would not measure a negative energy.

V. PROOF OF THE NECESSITY OF $X^{\mu\nu}$

Using known facts from General Relativity, it is indeed possible and easy to solve the mystery. Let us study the influence of the volume on the inner metric tensor.

Is known that a body of finite density but perfectly zero size has zero energy and momentum, as such a body does not exist. Therefore, this body cannot modify the background spacetime even if its size is infinitesimally small. As a consequence of this, it is expected that in the limit of a vanishing volume $V_0 \to 0$ the metric tensor $g_{\mu\nu}$ inside the body converges to the background metric $g^{(0)}_{\mu\nu}$:

$$g_{\mu\nu}(V_0) \to g^{(0)}_{\mu\nu} + V_0\, g^{(1)}_{\mu\nu} \to g^{(0)}_{\mu\nu}\,. \tag{3}$$

As demonstration of this effect I refer the reader to the stationary metric of a star, which is model-ed by "perfect fluid" as given in Ref. [9]. In the limit $V_0 \sim R^3 \to 0$ the metric tensor in the star center turns to background flat spacetime $g^{(0)}_{\mu\nu} = \mathrm{diag}(-1,\, 1,\, r^2,\, r^2\sin^2\theta)$.

Let us consider now a falling body in the vacuum near a spherical Black Hole. Then

$$g^{(0)}_{\mu\nu} = \mathrm{diag}(1 - 2M/r,\; 1/(1 - 2M/r),\; r^2,\; r^2 \sin^2\theta)\,. \tag{4}$$

Inserting this form of the metric tensor $g_{\mu\nu}$ into Einstein's equations gives

$$G^{\mu\nu}(g^{(0)}_{\mu\nu} + V_0\, g^{(1)}_{\mu\nu}) = 8\pi\, T^{\mu\nu} \tag{5}$$

with $T^{\mu\nu}$ the matter tensor of the falling body. In the limit $V_0 \to 0$ one obtains

$$0 = 8\pi\, T^{\mu\nu}\,, \tag{6}$$

which is not possible unless one uses the virtual term (or Dark Matter contribution) $X^{\mu\nu}$ with

$$0 = 8\pi\,(T^{\mu\nu} + X^{\mu\nu})\,. \tag{7}$$

VI. MORE EXAMPLES

As an example, let us penetrate the Earth core with the long vertical pipe. Inside the pipe vacuum is generated. Newton gravity then tells us that the distribution of the gravity field inside the pipe is the same as if there would be matter inside the pipe instead of vacuum. Here is a conflict coming from General Relativity: the gravity field (described by the metric tensor) tells us what kind of stuff is inside the pipe. Therefore, there could not be any difference between matter and vacuum if the gravity field is the same for both cases. Another example is the collapse of a spherical dust cloud. The dust particles are divided by vacuum, and the metric tensor between the dust particles is known for the dust cloud collapse. Therefore, inserting the latter into Einstein's equations, one does not get vacuum between the dust particles. Thus, one has to use Dark Matter.

VII. 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 [10]. I, personally, would solve this problem with a virtual insertion Ψ into the radius value, $r = R + \Psi$.

---

[1] M. Milgrom. "A modification of the Newtonian dynamics as a possible alternative to the hidden mass hypothesis". Astrophys. J. 270, 365–370 (1983); M. Milgrom. "A modification of the Newtonian dynamics – Implications for galaxies". Astrophys. J. 270, 371–389 (1983); M. Milgrom. "A modification of the Newtonian dynamics – Implications for galaxy systems". Astrophys. J. 270, 384–389 (1983).

[2] S. McGaugh. "A Tale of Two Paradigms: the Mutual Incommensurability of LCDM and MOND". Can. J. Phys. 93 (2), 250–259 (2015), arXiv:1404.7525; P. Kroupa, M. Pawlowski, M. Milgrom. "The failures of the standard model of cosmology require a new paradigm". Int. J. Mod. Phys. D 21 (14), 1230003 (2012), arXiv:1301.3907.

[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] D. Martila, R. Mankin, R. Tammelo, A. Sauga, E. Reiter. "Constructive influence of noise-flatness in correlation ratchets". Eur. Phys. J. B 54 (3), 375–383 (2006).

[7] see e.g. "Genius Channel: Albert Einstein Part 1: The Biography", YouTube, 2017.

[8] Sabine Hossenfelder, "Lost in Math: How Beauty Leads Physics Astray", New York: Basic Books, 2018, 304 pages.

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

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