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Espen Gaarder Haug
Norwegian University of Life Sciences
e-mail espenhaug@mac.com
. ORCID https://orcid.org/0000-0001-5712-6091

April 15, 2022

Abstract

Standard Newton theory, as well as general relativity theory, is not able to predict galaxy rotation without the hypothesis of dark matter. Even after considerable effort, no direct observations of dark matter have been made. This could simply mean dark matter cannot be detected directly or that it is extremely hard to detect due to very weak interactions, but it could also mean there exist other explanations for the observed galaxy rotation curves currently not accounted for in the Λ-CDM model. Other alternative theories should therefore also be investigated until we have the "final" answer. Here we demonstrate that the matter definition given by collision space-time leads to a minimum acceleration somewhat similar to that of modified Newton dynamics (MOND), but different in both size and mathematical function. Further, MOND does not have a deeper theory for why there should be a minimum acceleration. We introduce rest-mass acceleration and explain why this is naturally to be expected in matter, and how it is also likely linked to Planck acceleration. We are testing the modified acceleration predicted by this model against 2,793 data points from 153 galaxies from the Spitzer Photometry and Accurate Rotation Curves (SPARC) database and it seems to give very accurate predictions without the need for dark matter.

Key Words: galaxy rotation, minimum acceleration, rest-mass acceleration, Planck mass acceleration.

1 Introduction

In 1983, Milgrom [1] published a theory he called modified Newton dynamics (MOND) that basically states:

$$G\frac{Mm}{R^2} = \frac{m\left(\frac{v^2}{r}\right)^2}{a_0} \tag{1}$$

where a_0 basically is an "arbitrary" constant that gives an extra degree of freedom to calibrate the model to observational data. The a_o parameter is seen as a minimum acceleration, and has been calibrated to be $a_0 = 1.2 \times 10^{-10}\ m/s^2$. What is of particular interest here is that this simple adjustment of the Newton gravity formula makes it fit galaxy rotations very well without any need for dark matter.

The Milgrom theory has been criticized for not being a very deep theory and to be more of a curve-fitting model. It does not have any solid foundation or explanation for why there should be such a minimum acceleration. Still the Milgrom model could be important, as it was the first model giving us a hint to where the answer to the missing dark matter can be found, it could be linked to minimum acceleration. If that is the case, the dark matter needed in the standard Λ-CDM model could simply be a fudge factor because, for some unknown reason, it is missing a minimum acceleration.

Several different minimum acceleration models have been suggested in recent years that, unlike the Milgrom model, also give possible explanations for why there should minimum acceleration. In 2021, Tonin [2], as well as Haug [3], proposed a slightly different model that suggests the mass of the observable universe should also be taken into account. Also a model suggested in 2006 by Brownstein and Moffat [4] gives a minimum acceleration linked to the cosmological scale. Yet another minimum acceleration model is the so-called quantized inertia that McCulloch [5] tested against galaxy rotation curves in 2017, and this model also predicts rotation curves very accurately without the need for dark matter. Quantized inertia modifies the standard inertial mass in a way that links the adjustment to the scale of the diameter of the universe. So, these four models all link the minimum acceleration to the cosmic scale. These are all interesting minimum acceleration models that should be investigated further. However, in this paper, the focus is on a new minimum acceleration model that indicates that matter also could have rest-mass acceleration. That is, this model claims such a minimum acceleration

comes from the quantum scale internally in matter, rather than from interactions with cosmological scales; something we will look at in the next sections.

2 Collision-Space Time Minimum Acceleration from Rest Mass Acceleration

In collision space-time [6, 7] everything consists of only indivisible particles and empty space; this is very similar to Newton's [8, 9] corpuscular theory. These indivisible particles move at the speed of light when not colliding and are massless, and are then the building blocks of photons. The wavelength of the photon is then simply the distance between such indivisible particles traveling after each other so also in this theory, they have a wave-particle duality. This a very different interpretation than the one found in standard physics.

When a photon collides with another indivisible particle, this collision itself is defined as mass: the most essential off all masses, as it makes up all observable masses. Calibration to observable gravitational phenomena, as is described in the two references above, shows that such a collision remarkably lasts for the Planck time and also that the mass of this collision corresponds to the Planck mass and, further, the diameter of the indivisible particle is the Planck length. So collision space-time is a quantum theory directly linked to the Planck scale, and we have recently published a quantum gravity field equation, rooted in the Planck scale, and that gives a series of predictions of observable gravity phenomena identical to standard gravitational theory, but there are also a few differences, such as the radius where the escape velocity is c is half that of the Schwarzschild radius [10, 11]. This is not, however, easily testable. The main focus in this paper is on whether our theory can also predict galaxy rotation, something that is testable.

The Planck mass is much larger than any known particle or even any known atom, but still, it makes up all known particles, even the electron, in this theory. This is possible since the Planck mass, which is the collision between two indivisible particles, only lasts the Planck time before again dissolving into non-mass (internal energy). Inside all matter, our theory suggests, collisions between indivisible particles happen at the reduced Compton frequency $f = \frac{c}{\bar{\lambda}}$, where $\bar{\lambda}$ is the reduced Compton [12] wavelength, $\bar{\lambda} = \frac{\hbar}{mc}$. This is more than pure speculation, as recent research indicates that matter can be seen as Compton clocks, see [6, 13, 14]. The question is then what exactly happens at the Compton periodicity. We claim a collision between indivisible particles making up the mass is happening at this interval, but that the collision itself only lasts the Planck time. To give a practical example, in an electron there is an internal collision between two indivisible particles the following number of times per second:

$$f_e = \frac{c}{\bar{\lambda}_e} \approx 7.76 \times 10^{20} \tag{2}$$

That is, the electron is a Planck mass 7.76×10^{20} times per second, but since each of these Planck masses only last the Planck time, this gives the correct electron mass (and also correct output dimensions):

$$m_e = f_e m_p t_p = \frac{c}{\bar{\lambda}_e} m_p t_p \approx 9.11 \times 10^{-31} \text{ kg} \tag{3}$$

What is interesting here in relation to galaxy rotations is that, in each of these events, the indivisible particles making up the electron stand still for the Planck time in a collision but then, after the Planck time, move away from each other at the speed of light. This means that an acceleration from zero to the speed of light is happening every time such a collision takes place. This is, interestingly, identical to the Planck acceleration over the Planck time, that indeed leads to an object at rest going to speed c. We will soon get back to the Planck acceleration, but what is important at this stage is to understand this acceleration as something that happens internally in matter due to the building blocks making up the mass. One can think of two indivisible particles each traveling over the reduced Compton wavelength at the speed of light but, at each reduced Compton time periodicity, they are colliding and standing still for the Planck time. After this Planck time, they again move away from each other at the speed of light. Since this all happens internally inside matter in this model, we can coin it rest-mass acceleration.

In standard theory, there is no such thing as rest-mass acceleration, but we are all familiar with rest-mass energy, so that there can also be a rest-mass acceleration should not be excluded before being investigated properly. It is easy to be overly negative towards totally new concepts, but we ask the reader to carefully consider this before rejecting it.

As planets, stars, and galaxies in this model consist of baryonic matter, and since protons (and neutrons) make up almost all of baryonic matter, then it is the rest- mass acceleration of the proton that seems relevant, and it is given by:

$$a_r = \frac{c}{1s} \frac{\frac{l_p}{c}}{\frac{\bar{\lambda}_P}{c}} = \frac{c}{1s} \frac{l_p}{\bar{\lambda}_P} \approx 2.3 \times 10^{-11} \ m/s^2 \tag{4}$$

where $\frac{l_p}{\lambda_P}$ is simply the percentage of total time we have rest-mass acceleration of c internally in the proton. The division by one second can be mistaken for arbitrary, but it is simply because acceleration is normally expressed as meters per second squared. So to divided by 1 second is only relevant when working with SI units, that is the speed of light c is also expressed in meters per second. In the natural unit system where one set $G = \hbar = c = 1$, then the minimum acceleration would simply be $\frac{l_p}{\lambda}$, that is dimensionless. However, it is most normal and perhaps practical to work in SI units here, so we will stay to that in the rest of the paper. That is, even if the acceleration is enormous and happens an enormous number of times per second, the fraction of the total time inside, for example, a second that such enormous acceleration happens in, is very small. The calculated minimum rest-mass acceleration can be seen almost as an average between most of the time, when there is no acceleration, and the many Planck time periods when there is enormous acceleration internally in matter.

Photon-photon collisions happen at the Compton frequency inside the proton. That photon-photon collisions can create mass has been predicted even by standard theory for many years; see, for example, [15]. What is different in this model is that this is how matter is created and maintained: by photon-photon collisions internally in matter at the Compton periodicity.

This acceleration of approximately $2.3 \times 10^{-11}\ m/s^2$ can be seen as the minimum acceleration in a proton, and since almost all matter is built from protons or neutrons (and we assume approximately the same mass and Compton wavelength as the proton), then this is also the minimum acceleration for large masses, such as planets and stars and even galaxies. This means we must likely have the following relation:

$$\begin{aligned} m(a - a_r) &= G\frac{Mm}{R^2} \\ a &= G\frac{M}{R^2} + a_r \\ a &= G\frac{M}{R^2} + \frac{c}{1\text{s}}\frac{l_p}{\bar{\lambda}} \end{aligned} \tag{5}$$

That is, the total observed acceleration is adjusted to allow for the fact that there likely is a rest-mass acceleration. A good starting point is to try to find out if this makes any sense by testing the predictions from this simple model and comparing them with actual observations. This is the topic of section 4, but before that we will shortly look at Planck mass acceleration and how it seems linked to the minimum acceleration in our theory.

3 Is Planck mass acceleration linked to the missing rest-mass acceleration?

Max Planck [16, 17] assumed there were three important universal constants: the Newton gravitational constant, the Planck constant, and the speed of light. Based on dimensional analysis, he came up with a unique length: $l_p = \sqrt{\frac{G\hbar}{c^3}}$, time; $t_p = \sqrt{\frac{G\hbar}{c^5}}$, mass; $m_p = \sqrt{\frac{\hbar c}{G}}$, temperature; $T_p = \sqrt{\frac{\hbar c^5}{k_b G}}$, today known as the Planck units.

Scarpetta [18] introduced what today is known as the Planck acceleration (see also [19]):

$$a_p = \sqrt{\frac{c^7}{G\hbar}} \tag{6}$$

which corresponds to $a = \frac{c^2}{l_p}$. Also, Fala and Landsberg [20] in 1994 thought the Planck acceleration was the maximum acceleration. As nothing can move faster than the speed of light, then the Planck acceleration cannot last longer than the Planck time, as we have:

$$a_p t_p = \sqrt{\frac{c^7}{G\hbar}} t_p = \frac{c^2}{l_p}\frac{l_p}{c} = c \tag{7}$$

However, nothing with mass can move at the speed of light as it would take infinite energy to bring a mass to speed c as can be easily seen from Einstein's relativistic mass formula, $E = mc^2\gamma = mc^2/\sqrt{1 - v^2/c^2}$, that when setting $v = c$, needs infinite energy. Electromagnetic radiation (photons) is the only thing that always moves at the speed of light so, in standard theory, it would be meaningless to talk about Planck acceleration for light. However, in our theory, when the Planck mass is indeed created or defined as the collision between two light particles, (indivisible particles) that collide for one Planck time and then dissolve into light again, the Planck mass acceleration fits very well. The Planck mass acceleration is therefore related to the internal acceleration that happens inside matter; it is a rest-mass acceleration, but it only lasts a very small fraction of time, as it only happens for the Planck time, and this again happens at the reduced Compton frequency.

4 Testing our theory for galaxy rotation

To test our theory, we use 2,793 data points from 153 galaxies from the Spitzer Photometry and Accurate Rotation Curves (SPARC) database. SPARC is likely the largest galaxy database to date with rotation curves for galaxies. In Figure 1, we can see that our model, only using baryonic matter, fits these observations very well. Our model is the red line, and the observations are the black dots. We see the standard model, the green line, is far off, which is why the standard model needs to introduce the hypotheses of dark matter to fit the data. The standard model needs both dark matter and a distribution of this dark matter to make it fit the observation.

The figure also shows the MOND model as the yellow line. McGaugh et al [21] have shown that the following function fits the observational data very well:

$$g_{MOND} = \frac{g_{bar}}{1 - e^{-\sqrt{g_{bar}/g_{min}}}} \tag{8}$$

where g_{bar} is the Newton (and GR) acceleration predicted from baryonic matter only and g_{min} is an ad-hoc minimum acceleration. This minimum acceleration corresponds to the MOND minimum acceleration of approximately $1.2 \times 10^{-10}\ m/s^2$.

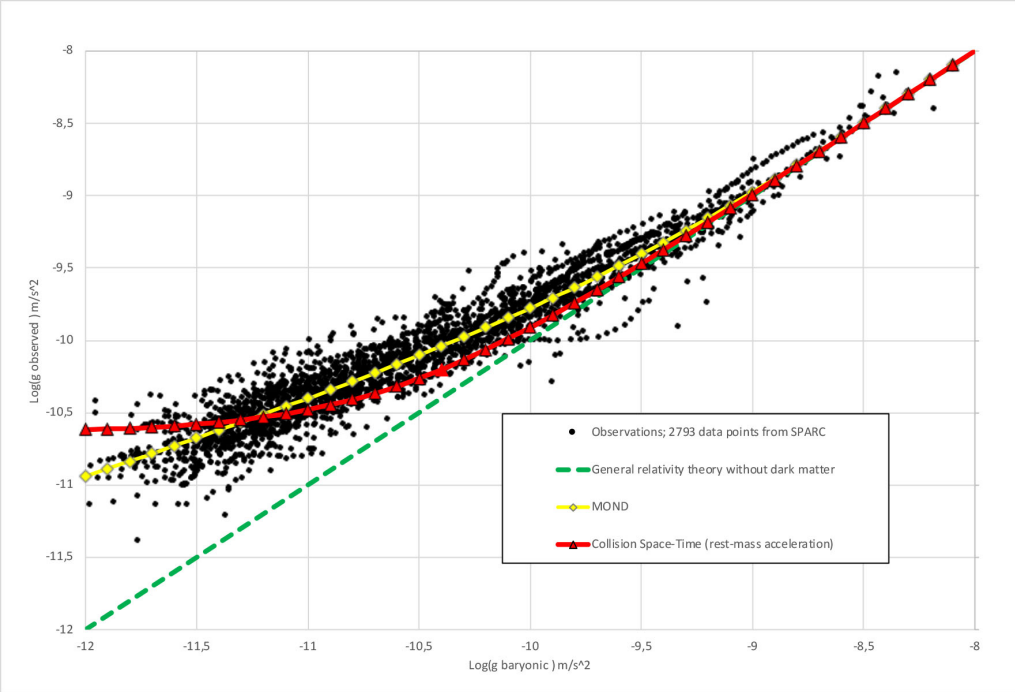

Figure 1: Galactic accelerations in Collision-Space-Time compared to data and other models. Exactly 2,793 individual data points for 153 SPARC galaxies are shown in black. Predictions by general relativity theory, when not taking into account dark matter, are shown in green. The yellow line is MOND and the red line is collision-space-time. The red line takes into account rest-mass acceleration as discussed in this paper.

The MOND model gives a better fit to observation than our suggested model, but we must bear in mind that MOND has a free parameter that is optimized to observed data. Our model has no free parameters here, but it is blind and simply rooted in an assumption about matter and energy at the depth of reality. We have not taken into account any relativistic effects, which could be an additional adjustment to look into. One would then have to take into account the relativistic Compton wavelength in the minimum acceleration calculation; see [22]. Still, even this very simple model seems to give a very good fit. So we think this approach should be interesting enough to encourage further research to discern whether there could be something to the idea of rest-mass acceleration, which is basically an internal acceleration in matter.

5 Conclusion

We have shown that the Planck acceleration could be linked to what we will call rest-mass acceleration. The mass definition in collision-space-time theory leads to such a rest-mass acceleration, as all matter here consists of

indivisible particles (building blocks of photons) moving back and forth over the reduced Compton wavelength of the particle in question, to then collide for the duration of the Planck time. This rest-mass acceleration leads to a minimum acceleration in all matter and seems to lead to predictions that fit quite accurately with observations from galaxy rotation curves without the need to introduce dark matter. This is, therefore, yet another minimum acceleration theory. However, compared to MOND that also predicts galaxy rotation curves very well without dark matter, this theory provides a deeper explanation for why this is the case. Naturally, the model should not be taken for granted, but the idea of rest-mass acceleration should be worth further investigation by more researchers.

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6 DECLARATIONS:

- Data availability statement; data from the Spitzer Photometry and Accurate Rotation Curves database have been used as observation points in the figure given in this paper. This is a publicly available database that anyone can access from http://astroweb.cwru.edu/SPARC/ and thereby also easily back test our findings.
- Conflict of interest: there is no conflict of interest to report and this study have been undertaken under the highest ethical standards.