Revision of the Theory of Gravity

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Abstract –We add a mass term into Newton's equation for gravity. This mass term is negligible at small distances but dominates at asymptotic distances. It represents the missing mass. The theory predicts rising radial velocities in galaxies, derives Hubble's Law, together with an expression for the Hubble's parameter. The theory reveals inner unity of the three overarching phenomena: rising rotation velocities, Hubble's law, and value of the Hubble parameter.

Motivational Background

Theory of Universal Gravity by Newton and the Theory of General Relativity by Einstein are currently accepted theories of gravitation. However, both require to employ assumptions to explain the experimental observations. One such assumption is the hypothesis of Dark Energy [1] in General Relativity. Another one is the assumption of Dark Matter [2], in both theories. They are needed to explain two of the most significant experimental observations in modern cosmology. One is the observation that the radial velocities of the galactic bodies do not fall with increasing distance from the galactic center, as is predicted to happen under both these theories. This is why the existence of Dark Matter (DM) is assumed. The second experimental observation is Hubble's Law [3] based upon the experiments by Edvin Powell Hubble [4] [5]. That is why the existence of Dark Energy (DE) is assumed. Both these assumptions are unproven, and do not inspire theoretical confidence, nor do they have predictive power. Both assumptions are necessary in the sense that they cannot be reduced to one or zero. There has been no successful research, so far, to do cosmology without them.

In addition, DE postulate poses a problem of its own, at least for two reasons. First, the researchers generally attribute DE to the vacuum energy in Quantum Field Theory. The calculation of DE in particle physics turns out to be 120 orders of magnitude greater than what is observed [6]. The result is referred to as the worst prediction in theoretical physics. To circumvent this situation, some researchers have attributed DE to the dynamics of General Relativity. They modify the theory using f(R) models [7]. However, such modifications have not proved promising [8].

The above hypotheses in themselves are not enough without a framework called Lambda Cold Dark Matter Model, also known as the standard model of cosmology [9]. It is based on the standard model in particle physics [10] which in turn is based on Salam-Weinberg theory [11]. Here Lambda refers to a parameter in General Relativity that was originally introduced to achieve a static universe, but is now used for the opposite purpose, to explain the Hubble's Law. The "cold dark matter" part of this model incorporates the Dark Matter hypothesis. It is worth noting that the standard model of particle physics works well and is well established, while the standard model of cosmology has serious difficulties, especially with James Webb observations of galaxies near the big bang where the model predicts that there should be none.

In the present research we have two main objectives. First, we want to replace both the above-mentioned assumptions with a separate and new assumption, thus reducing the number of assumptions to one. Second, we will use this new assumption to generalize the scope and applicability of Newton's universal gravity formula. It should, however, not be perceived that our theory is within the Newtonian theory. For example, our one assumption, that we will discuss momentarily, is not part of the Newtonian theory, nor are the results and predictions that we derive. We merely adopt the mathematical framework of Newton's formula because of its simplicity and the fact that it admits generalization of the theory by adding a term for the missing mass. This approach is valid because, at normal gravity and sub relativistic speeds, Newton's framework is valid.

Hamost Postulate

The theory we present in this paper, takes a fresh start. It does not use the DM and DE postulates. This makes it unnecessary for us to postulate ad hoc density profiles and galactic halos of DM; and also makes it unnecessary to attribute strange properties to the DM such as that it clumps, is bound to the ordinary Baryonic matter, and Baryonic matter is anchored in dark matter so that the dark matter is dragged along the Baryonic matter even when galaxies collide [12]. Similarly, because we do not use DE, we do not encounter the worst prediction in theoretical physics [6]. These are some advantages of our approach, as well as the predictions that we will discuss.

We aim to replace the two assumptions of DE and DM with a separate and new assumption, namely Hamost Postulate. We will demonstrate that our new postulate reveals a commonality between Hubble law and rotation velocities, and therefore offers an opportunity to explain both problems using just one postulate, versus having to use both DM and DE postulates.

We start with the ansatz that the space is filled with something that permeates all space. We will name this entity as "hamost" to emphasize that it is different than DM and DE. It fills the space with tiny mass density $\rho_0(t)$, that is distributed uniformly and isotropically throughout the space. Hamost is a carrier of mass but it is different than DM because it has properties of being part of the space or vacuum, and has uniform and isotropic distribution. It is also different than the ordinary Baryonic matter for the same reasons. These properties are rather unlike the properties we attribute to DM, as mentioned earlier. The properties of hamost are rather like the properties of DE - for example, DE does not coalesce or clump together, and it maintains a uniform and isotropic distribution. In this respect, hamost resembles how DE is perceived. However, hamost is different than DE because it is a carrier of mass. As a carrier of mass, it is different than Baryonic matter, because it does not condense and remains uniformly and isotropically distributed. The origin of hamost is probably in space or vacuum, something we intend to explore in future reasearch.

Our Theory

Now, let us insert our picture of hamost into Newton's formula of Universal Gravitation. For this purpose, we will introduce a term into Newton's gravitation equation in order to represent mass due to hamost, and make the theory universal.

Newton's law of gravity can be stated as in equation (1) below.

$$F(r) = -\frac{GMm}{r^2} \qquad (1)$$

Where F(r) represents the gravitational force exerted on a probe body of mass m by another body of mass M. Here G is the universal constant of gravity, and r is the distance between the two bodies. The negative sign signifies that the force is directed oppositely to the radius vector.

This equation is valid under the assumption that M and m are the only masses involved. Now, that assumption does not hold because, in addition to the masses M and m, we now also have additional mass due to hamost. Let us denote this mass by $m_h(r)$ and we can re-write Newton's law of gravitation in its universal form as in equation (2) below.

$$F(r) = -\frac{Gm}{r^2}[M + m_h(r)] \qquad (2)$$

where $m_h(r)$ is the additional mass due to hamost enclosed in a sphere of radius r around the mass M at the galactic center. How much is this mass $m_h(r)$ due to hamost? If the two bodies are separated by a distance r, then the mass due to hamost is that which is enclosed in a sphere of radius r around the body of mass M as in equation 3 below.

$$m_h(r)=\int_0^r 4\pi r^2\rho_0(t)\,dr \qquad (3)$$

where $\rho_0(t)$ is the mass density due to hamost at the present time epoch. It is understood that it can be time dependent, though we sometime do not explicitly annotate this time dependence, because at the present epoch it is regarded as constant, being a very slowly varying function at the present epoch, though not necessarily so during all epochs.

Recall Newton's Shell Theorem, according to which the gravitational force of mass in a spherical shell of radius r behaves as if the total mass is concentrated at the center of the spherical shell. And the gravitational force at a point within the spherical shell is identically zero. To calculate equation (3), we recall Newton's shell theorem, which states that the part of hamost mass in equation (3) that lies beyond the distance r contributes nothing to the force in equation (2). Combining equations (2) and (3) we get.

$$F(r) = -Gm[\frac{M}{r^2} + \frac{4}{3}\pi\rho_0(t)r] \qquad (4)$$

Equation 4 is the new universal law of gravity. It replaces Newton's gravitation as stated in equation (1).

The second term in equation (4) adds an additional force coming from the mass due to hamost. The generalization of Newton's law of gravitation effectively increases the mass M that was present at the galactic center by an amount $\frac{4}{3}\pi\rho_0(t)r$. The increased mass yields increased force by an amount $\frac{4}{3}\pi Gm\rho_0(t)r$. This force due to hamost, or hamost force, increases linearly with r.

The force due to hamost is a new force that was not previously accounted for in the theories of gravity. This new force due to hamost F_h can be written as follows.

$$F_h(r,t) = -\frac{4}{3}\pi Gm\rho_0(t)r \qquad (5)$$

This is the equation for a harmonic oscillator with force constant $\frac{4}{3}\pi Gm\rho_0(t)$. There are two important consequences of this force.

First, the gravitational force is increased compared to the original Newtonian gravitation force. This additional attractive force can be significant for original coalescence of Baryonic matter in relation to galaxy formation, possibly hastening the process. In this capacity, our theory can potentially be a complement for Lambda Cold Dark Matter standard model. We will explore this aspect in future research.

Second, the linear increase of the hamost force with distance means that it will become asymptotically dominant. This makes the force important over cosmological distances. We will see some examples in the next section.

The conventional gravitational force represented by the first term in equation (4) dominates at small distances where mass due to hamost is negligible, in comparison with the Baryonic mass. This leaves the currently known gravitation results unaffected. However, the first term vanishes like $\frac{1}{r^2}$ and the new force due to hamost keeps increasing with radial distance, r. The new force due to hamost, thus, plays a critical role in cosmology, as we will see in the next section.

Predictions of our theory

Many new experimentally testable predictions arise from the new force in equation (5) which is the second term in equation (4). For example, hamost force in equation (5) requires that the galactic rotation curves will not fall with increasing radial distances. It also requires that the velocity will obey Hubble's law, and it makes a statement about the acceleration. These and other results are discussed below.

1. Galactic Rotation Curves

The asymptotic rotation curves and Hubble's Law are related in our theory.

The centripetal force in equation (4) is balanced by the centrifugal force on mass m, moving in an orbit with velocity V at a position represented by the radius r. The centrifugal force is given by the following equation.

$$- F(r) = mV^2/r.$$

where the negative sign indicates that the centrifugal force is equal and opposite of the centripetal force in equation 4. Equating the two gives the following expression for the radial velocity.

$$V^2 = G[\frac{M}{r} + \frac{4}{3}\pi r^2 \rho_0(t)] \qquad (6)$$

For small radial distances the Newtonian term on the right-hand side dominates, while for large radial distances the hamost term dominates. For asymptotic values of r, equation 6 can be written as follows.

$$V(r) \approx \sqrt{\frac{4}{3}\pi G\, \rho_0(t)}\ r \qquad (7)$$

where the symbol ≈ represents equation for asymptotic values of r.

According to equation 7 the galactic radial velocity curves will not fall with increasing radial distances. Instead, equation 7 shows that they will asymptotically rise linearly with the increasing radial distance r.

For non asymptotic values of r there are two main complications that make the radial velocities deviate from the linearly rising behavior. First, the presence of Baryonic matter term in equation 6 tends to make it drop down. The second factor is the variable nature of the Baryonic matter M in equation 6 with increasing radius r. As the radius vector increases, more and more galactic bodies are included in the sphere, and their mass gets added to the term M in equation 6. Therefore, the interaction of Baryonic masses included in the sphere of radius r produces the experimentally observed radial velocities.

What does asymptotic mean in this context? It means that the Newtonian term is negligibly small compared to the hamost term in equation 6. It is not just the values of r being large, we also need to recall the quantities in the numerator of the two terms. The mass M in the Newtonian term is too large compared to the hamost density $\rho_0(t)$ in the hamost term. Asymptotic in this context means when the contribution due to the Baryonic mass is small compared to the contribution due to the hamost mass.

Phenomenologically, the data are fitted over non asymptotic distances, typically below 40 kpc, and data in this distance range display a myriad of characteristics for radial velocity curves. They range from falling curves to flat curves to rising curves [13]. For non asymptotic distances, the rotation curves depend on many other factors. Such factors include the type of galaxy, detailed knowledge and distribution of the Baryonic matter, bars effect in the galaxy disks, and mass to light ratios, etc. At non-asymptotic distances, observed galaxy rotation curves also depend on their morphological types; early-type galaxies have rotation curves that begin to fall down, while late-type and dwarfs have not yet reached their maximum velocity at the farthest observed radial distances.

2. Hubble's Law

Whatever the behavior of the radial velocity profiles in the non-asymptotic distances, our prediction in equation 7 is that the asymptotic behavior for velocity curves is for them to rise linearly with distance.

The asymptotic statement made by equation 7 is equivalent to the statement of Hubble's Law. This is an important result of our theory, namely the equivalence of the asymptotic rotation curves and Hubble's Law, as outcomes from one and the same equation. Effectively, Hubble's Law and the behavior of the galactic rotation curves are manifestations of the same equation. Using the terminology that we have abolished in this paper, both DE and DM originate from a common source, namely the hamost, thus obviating their separate postulations.

To make it explicit, we rewrite Equation 6 as follows.

$$V(r) = H_0(t)\, r \qquad (8)$$

where $H_0(t)$ is the parameter of proportionality with the following value.

$$H_0(t) = \sqrt{\frac{4}{3}\pi G\, \rho_0(t)} \qquad (9)$$

Equation 8 is Hubble's Law, which holds for asymptotic distances. Hubble's parameter is defined in equation 9 as a function of $\rho_0(t)$. It means that Hubble's parameter and hamost density vary together in equilibrium.

Historically, Hubble's Law was first inferred via the study of radial velocities [**Error! Bookmark not defined.**]. Our equations 7 and 8 show that all velocities observe Hubble's Law in asymptotic regions. It becomes even clearer when the galactic bodies break free from the galactic center and travel in open orbits. Such a flight into open orbits continues to follow Hubble's Law. All galaxies and galactic bodies, together, constitute a network of orbits.

Our theory establishes connection between the radial velocities and what is usually called recession velocity using the language of expanding universe. Our theory presents them as manifestations of the same equation, namely equation 6, in non asymptotic and asymptotic regions, respectively.

To have some idea about what asymptotic means in this cosmological context, and what is the extent of distances and mass, let us calculate the radius, r, when the two terms in equation (4) become comparable. The condition is expressed by equation 10 below.

$$\frac{M}{\rho_0(t)} = \frac{4}{3}\pi r^3 \qquad (10)$$

In this equation it is not obvious what value to use for M. Let us illustrate and take it to be the mass of Sagittarius A* black hole at the center of our Milky Way galaxy, which is around 4.3 Million Solar masses. For the $\rho_0(t)$ we can take 2.2×10^{-27} kg/m^3 from 2018 Plank experiment. Equation (10) then yields r to be around 32 kpc, indicating that asymptotic distances where the hamost force would dominate are far off. The hamost mass enclosed in this radius would be around a quarter trillion solar masses.

3. Acceleration

Oour theory throws light on the acceleration experienced by the receding bodies. Dividing the force in equation 4 by mass m, gives the acceleration as follows.

$$A(r) = -G[\frac{M}{r^2} + \frac{4}{3}\pi\rho_0(t) r] \qquad (11)$$

At large r, the first term in equation 11 vanishes and the acceleration changes linearly with r as follows.

$$A(\mathrm{r}) \approx -\frac{4}{3}\pi G\rho_0(t)\, r \qquad (12)$$

using equation 9, we obtain

$$A(r) \approx -H_0^2(t)r \qquad (13)$$

This predicts that acceleration is oppositely directed than distance r and its magnitude increases linearly with r. The constant of proportionality is $H_0^2(t)$. Precise measurements with, for example, James Webb Telescope can test this prediction.

Another look at equation 13 shows that *it represents a harmonic oscillator* in which the force is oppositely directed from the direction of motion. Viewed as a harmonic oscillator, H_0^2(t) represents the angular frequency in equation 13.

4. Intergalactic Voids

Consider the effect of a galactic scale void in the universe. It is empty of Baryonic matter, though the void is filled with mass due to hamost and manifests through equation (4) with M=0, which can be rewritten as below.

$$F(r) = Gm[\tfrac{4}{3}\pi r\rho_0(t)r] \qquad (14)$$

Our theory predicts that such a large void exerts gravitational force F(r) on a probe body of mass m. The force due to the void is proportional to its radius r, the radius of the spherical void. This force can be observed through gravitational lensing experiments [14]. Such a void is actually observed in A520 galaxy cluster. The study [15] discovered a large void filled with mass in the galaxy cluster center. These observations were initially made with Canada-France-Hawaii Telescope, and were confirmed using Hubble Wide Field Planetary Camera 2. The observation discovered a giant mass core where there is little Baryonic matter. This gravitational effect due to the void is predicted by our theory, while under the current standard model of cosmology this observation remains an unexplained challenge [15]. Large voids are abundant in the universe, because the amount of Baryonic matter is small compared to that of the mass due to hamost. Such voids are there as a rule, rather than an exception, per our theory. They can be experimentally discovered as in the case described above, and we suggest such experiments be conducted.

5. Mass at the Galactic Center is Variable

A prediction of equation (4) is that galactic bodies at different radii, r, will experience a different amount of mass, $M + m_h(r)$, at the galactic center. It is because the force contribution of the mass $m_h(r)$ increases linearly with r. Further, the Baryonic matter enclosed in the sphere also varies with its radius r. For example, the Sun mass as seen by the Earth is smaller than what is seen by Neptune. These distances are small on cosmological scale, yet the effect may be experimentally detectable on Satellite trajectories, like NASA missions Voyager 1 and 2 trajectories.

Conclusions

We have added a mass term, representing the mass due to hamost, into the formulation of our theory of gravitation. This new term dominates at asymptotic distances, while being negligible at small distances due to the smallness of hamost density. The theory introduces one parameter, namely the density of mass due to hamost, and explains, rather predicts, solutions to the nagging problems in cosmology, namely that of DM and DE. The theory derives the Hubble law and parameter H_0 (t) as a function of the mass density due to hamost, $\rho_0(t)$. Either of these parameters can equivalently describe the dynamics representing the linearly rising velocity with distance, and its acceleration.

The theory also makes additional predictions, like the abundance of large empty voids which manifest as chunks of gravitational masses. Our theory presents a different picture for the universe versus the currently used standard model of cosmology that employs DM and DE.

In future research we will construct a detailed model for the nature of hamost, and calculate further predictions based on such a model, as well as their relativistic extensions. We will also explore the time dependence of hamost mass density $\rho_0(t)$, and its relativistic treatment.

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