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Article

Information Theory of Gravity

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Abstract: A new model of gravity is presented here that is similar to MOND and Chameleon theory but uses an Entropic Gravity approach that is not based fundamentally on the First Law of Thermodynamics. Instead, the Second Law of Thermodynamics will be mainly used here as it was applied in Black Hole Physics via the Area Theorem and the Holographic Principle. The Area Theorem was considered here to imply, not only that the total area of the event horizon will never shrink when entropy increases, but also that the mass or energy content within the black hole will always be greater than the original mass-energy input, though not necessarily violating the energy conservation law. This black hole property will be extended to include even a non-black hole setting. Moreover, the approach does not use the Equipartition Theorem to relate energy to temperature ($E = Nk_bT$) instead we used Vopson's Energy-Mass-Information Equivalence Principle ($E = k_bT\ln(\Omega)$). The theory uses $E = NE_p$, for the total energy of a massive object where E_p is the Planck Energy and N is the number of Planck Energy to represent the amount of information within the limit set at the Planck scale. It is shown here that gravity emerges whenever information is updated within a given volume of space with a magnitude that is defined not only by the gravitating matter but also by the energy generated in space within the vicinity of the gravitating matter. The model is the first to consider the role of both spacetime and matter as a medium to store information and apply it to describe gravity in a fundamental way.

Keywords: other theories of gravity; MOND; Chameleon theory; emergent gravity; information

PACS: 04.50.-h; 05.70.-a; 98.10.+z

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1. Introduction

In Verlinde's Entropic Gravity (EG), it was conjectured that ordinary surfaces are holographic screens that obey the First Law of Thermodynamics (tFLT) [1]. The theory primarily used tFLT equation, $F\Delta r = T\Delta S$, where Δr is the distance of the test particle from the holographic screen, T is the temperature in the screen and ΔS is the change in entropy S. It was argued that as $\Delta r \to 0$, i.e., as the test particle touches the screen and increases the entropy, it induces gravitational force as a kind of entropic force [2]. Thus in EG, a test particle that enters a gravitational field is likened to a polymer molecule that enters a region immersed in a thermal bath. Such a condition gives rise to an entropic force at molecular and atomic levels. According to EG, a test particle that enters a gravitational field also undergoes a similar condition where the entropic force is the gravitational force itself. This analogy was heavily criticized [3,4]. In the paper of Wang and Braunstein [5], it was shown that for surfaces away from horizons, tFLT fails and therefore undermines the key thermodynamic assumption of the EG program.

In this paper, it will be shown that there is no need to use tFLT but instead, one can fully develop an Entropic Gravity model that purely uses the Second Law of Thermodynamics alone as it was originally used in the seminal works in Black Hole Physics. In retrospect, the basis of Entropic Gravity is the Holographic Principle based on the conjecture of Bekenstein [6] in the 1970s that the entropy of a black hole is proportional to the surface area of the black hole, i.e., $S = \gamma A$, where S is the entropy within the black hole, $A = A(r_s)$ is the surface (horizon) area of the black hole with radius r_s and γ is a constant of proportionality. Subsequently, the value for γ was established to be the Planck Length [7] such that,

$$S = A/4l_p^2 = A/A_p = N_a \tag{1}$$

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where $l_p = \sqrt{\hbar G/c^3}$ is the Planck length and A_p is the Planck area. This result was interpreted by many as the quantity N_a or the number of cells in the holographic screen is a measure of entropy within the volume of space enclosed by the holographic screen. The question that Verlinde wanted to answer in his version of EG is how can this be applicable to describe gravity in a non-black hole setting. However, the relation $A = N_a A_p$ seems to be the only central argument in Verlinde's work and by using it, separates the role of other quantities like the mass or energy content in a holistic way. In Verlinde's approach to the derivation of Newton's gravity law equation, the role of the mass enters via the use of tFLT and the Equipartition Theorem. In this paper, although tFLT and the Equipartition Theorem will not be used, a modified Newton's law of gravity will be derived that is similar to a Modified Newtonian Dynamics (MOND) theory [8]. Our motivation is derived from the fact that the changes in the strength of gravity are proportional to the matter density. In Poisson Equation, $\nabla^2\phi = 4\pi G\rho$, the strength of gravity is given by the scalar potential ϕ and proportional to the density $\rho = \rho(r)$. In Gauss' Theorem of gravity, $A\Delta F = -4\pi GV\Delta\rho$, the strength of gravity given by F is proportional to the changes in matter content or density for a constant volume and area. It gives us,

$$\frac{dF}{d\rho} = -\frac{4}{3}\pi G r \tag{2}$$

Hence, we suggest here that this fundamental result in the description of gravity should be integrated into the EG approach by not just using the quantity N_a, but via the quantity,

$$N_d = \frac{\rho}{\rho_{pl}} = \frac{M/r}{M_p/L_p} = \frac{M/M_p}{r/L_p} = \frac{N}{N_l} \tag{3}$$

as a measure not only of the number of the smallest possible units of density but also as a measure of the density of information or entropy of the system. It is defined by the Planck (linear) density $\rho_{pl} = M_p/L_p = \sqrt{c^4/G^2}$, where M_p is the Planck Mass and L_p is the Planck Length. Notice that N_d can also be written in terms of quantities $N_l = r/L_p$ and $N = M/M_p = Mc^2/M_pc^2 = E/E_p$. This will be shown to be aligned with the earlier work of Vopson [9] with his extended Landauer's Principle that relates mass and energy with the entropy of a system,

$$E = mc^2 = k_b \cdot T \cdot \ln(\Omega) = N \cdot k_b \cdot H(X) \cdot \ln(2) \tag{4}$$

where the information corresponds in observing N set of event X such that $H(X)$ is the information entropy function $H(X)$, T is the temperature at which the bit of information is stored and k_b is the Boltzmann constant. Thus, the main difference of our work with Verlinde's and others [10] that also derived a model of MOND via the EG approach, is that the Energy Equipartition Principle, $E = \frac{1}{2}k_b NT$, will not be used here but to be replaced by the expression, $E = NE_p$, as a quantized representation of energy in terms of the Planck energy $E_p = M_p c^2$. This is consistent with the fact that everything is expressed in terms of the Planck scale units rather than with quantities that are emergent or within the macroscopic and quantum scale. Moreover, the use of N_d is consistent also with what had been suggested above that the magnitude of gravity is proportional to the density and not just to mass or to (properties of) space alone. In a way, the intrinsic relation of matter and space in the description of gravity is still maintained by using a simple mathematical approach that measures the mass and information density of the system at the fundamental level. Lastly, the consequence of the Area Theorem which shows the relation of entropy to the mass, via the equation, $S = 4\pi M^2$, will be emphasized here. It is considered here as a key result that relates the mass to the information that can reside inside a black hole. This, of course, is a simplification since other quantities such as the electric charge and the spin can also increase the entropy of a black hole. Hence, if only the mass-entropy relation is to be considered, the questions we set to answer here are: "Can we still use this result in a non-black hole setting?" and "Can the Area Theorem in Black Hole Physics be applied to a galactic setting in which a relatively large magnitude of gravity is also involved?".

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In the end, the main objective of this paper is not to derive Newtonian Gravity as Verlinde had done in his original paper on EG but to derive a new model of gravity similar to MOND or to a Chameleon Theory as a possible alternative to the Dark Matter hypothesis. The paper is organized as follows: In Section 1, a modified Newtonian gravity equation was derived, and in Section 2 Vopson's Energy-Mass-Information Equivalence Principle was discussed. Then in Sections 3, 4, 5, and 6, we showed that the model predicts the MOND equation, the Tully-Fisher Relation, the External Field Effect, and the observation on Wide Binary Stars, respectively. In Section 7, a relativistic version of the model, consistent with Special Relativity, is discussed leading to a modified Kepler's Third Law. This is different from the TeVeS model of Bekenstein which extensively uses Tensor and Lagrangian Formalism within the framework of General Relativity (GR). In Sections 8, 9,10, and 11, topics such as the Horizon Mass, Mercury's Perihelion Shift, Light Deflection, and Equivalence Principle, were all derived from the model.

2. Information in a Given Mass

In the previous section, we have mentioned that the mass ratio, $\frac{m}{mp}$, can serve as a measure of the amount of information in an object such that N_d can be considered as a measure of the density of information in a system where a gravitating mass occupies a certain volume of space. We also mentioned that this idea is aligned with Vopson's seminal work on the relation of mass and energy with information. What he called as the "Extended Landauer's Principle" or his "Mass-Energy-Information Equivalence Principle" [9] expressed via Eqn.(4), can be written in Planck scale units. By simply rewriting Eqn.(4), it can be shown that the mass ratio m/m_p can be considered as a measure of information contained within a gravitating matter. First is to rewrite Eqn.(4) as follows,

$$m = \left(\frac{k_b}{c^2}\right) \cdot T\ln(2) \tag{5}$$

where we consider the simple case of a "digital information" with $N = 1, X = \{0,1\}$, such that $H(X) = 1$. Notice that the constant $\frac{k_b}{c^2}$ serves as a constant of proportionality and a conversion factor. We can make the equation above unitless and express it in Planck scale units, by inserting other constants and showing that,

$$\frac{k_b}{c^2} = \sqrt{\frac{k_b^2}{c^4}} = \sqrt{\frac{\frac{\hbar c}{G}}{\frac{\hbar c^5}{Gk_b^2}}} = \frac{\sqrt{\frac{\hbar c}{G}}}{\sqrt{\frac{\hbar c^4}{Gk_b^2}}} = \frac{m_p}{T_p} \tag{6}$$

where T_p is the Planck temperature. Substituting this in Eqn.(5) and rearranging,

$$\frac{m}{m_p} = \left(\frac{T}{T_p}\right) \cdot \ln(2) \tag{7}$$

which is just the unitless version of Vopson's equation for his mass-energy-information equivalence principle. This is the reason why it is suggested here that the mass ratio, m/m_p, can be used fundamentally to measure the amount of information in a gravitational system. In the work of Vopson, it was postulated that the information mentioned can only be stored in particles that are stable and have a non-zero rest mass, while the force carrier bosons can only transfer information in a waveform [11]. He added that "information could also be stored in other forms, including on the surface of the space-time fabric itself, according to the holographic principle". Thus, for the first time in this paper, those two methods of storing information are combined to describe gravity. This was already hinted by Vopson when he conjectured the possible role of information in the Dark Matter Problem and called Information the "Fifth State of Matter" [11]. Most recently, he proposed a way to experimentally verified his "mass-energy-information equivalence principle" via a particle annihilation experiment [12]. He also

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previously used the principle to quantify the amount of information contained in the visible matter in the entire Universe [13].

3. Modified Newtonian Gravity Equation

The dimensionless form of Newton's Law of Gravity in terms of Planck scale units can be expressed as follows,

$$N_F = \frac{F}{F_p} = \frac{\left(\frac{M_1}{M_p}\right)\left(\frac{M_2}{M_p}\right)}{r^2/l_p^2} = \frac{N_1 N_2}{N_a} \tag{8}$$

where, $F_p = c^4/G$, is the Planck Force. The expression above must be modified in cases when the magnitude of gravity is large. However, the modification must be done such that the expression above will become a special case when gravity is relatively weak. One such particular case where modification is needed for a large magnitude of gravity is the case of a black hole. Another one is the case of the magnitude of gravity by a large number of objects that collectively generate a gravitational effect like in the case of a galaxy or a galaxy cluster. The modification of Eq.(8) for both cases was attempted, historically, by GR and by MOND theory respectively. As mentioned in Section 1, the proposed modification here is similar to Verlinde's EG but does not primarily using the quantity, N_a. It is argued that N_a is a quantity that measures only the entropy of virtual particles generated in the vicinity of gravitating matter. This generation of virtual particles is considered to happen only at the Planck scale. However, one must also consider the information associated with the real particles. These particles are either free or bound within the atoms of gravitating matter. It is suggested here that this distinction of entities that contribute to the total entropy of the system must also be true not only for black holes but also for non-black hole settings. For example, the maximum density of information given by all real particles in a 2-body system can be represented by the quantity $N = \frac{M_1}{M_p} + \frac{M_2}{M_p} = N_1 + N_2 = M/M_p$, where M_1, M_2 are the masses of the two gravitating objects and M being the total mass. The quantities, $N_1 = M_1/M_p$, and $N_2 = M_2/M_p$, represent the maximum possible density of information that can be stored for each real particles inside each of the gravitating matter. A purely information-theoretic approach to gravity would be that the magnitude of gravity is dependent solely on the amount of information that resides in space and matter within a gravitational system. If gravity is strong enough that it can generate virtual particles within the vicinity of the gravitating objects, those particles must be included in the description of entropy within the system. Hence, what we mean by a "purely information-theoretic approach" is that the magnitude of gravity F should only be dependent or quantifiable by the value of N and N_a. The former represents the amount of information that resides in a gravitating matter and the latter represents the amount of information within the space in the vicinity of gravitating matter. We wanted then to have a quantity that measures the intensity of the gravitational effect within a system that is proportional to the information density. We posit here that such quantify is N_d and we consider the square of it to be proportional to N_F, that is, $N_F = \epsilon N_d^2$, for some unitless constant of proportionality ϵ. It must be proportional to the density of Information since $S = 4\pi M^2$. Thus we have,

$$F = \frac{2c^4}{G}\frac{N_1 N_2}{N_l^2}\epsilon + \frac{c^4}{G}\left(\frac{N_1^2 + N_2^2}{N_l^2}\right)\epsilon = F_{NG} + F_{HG} \tag{9}$$

where it can be shown that,

$$F_{NG} = \frac{2c^4}{G}\frac{N_1 N_2}{r^2/L_p^2}\epsilon = 2\hbar c\frac{M_1 M_2}{r^2 M_p^2}\epsilon = G\frac{M_1 M_2}{r^2} \tag{10}$$

which is the expression for the magnitude of gravity in Newtonian Gravity (NG) where we set $\epsilon = 1/2$. Hence, the quantity F, must be an expression also for the magnitude of gravity while, the

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quantity, $F_{HG} = \frac{c^4}{2G}\left(\frac{N_1^2+N_2^2}{N_l^2}\right)$, can be interpreted as the magnitude of an excess gravity i.e., a "Hidden Gravity"(HG), in addition to what is already given by the Newtonian part of the equation. In terms of masses, M and m, for a two-body system, we can rewrite Eqn. (9) as follows,

$$F = G\frac{Mm}{r^2}\epsilon + G\left(\frac{M^2+m^2}{r^2}\right)\epsilon \tag{11}$$

which can be simplified further as follows,

$$F = G\frac{Mm}{r^2}f\epsilon \tag{12}$$

where $f = f(M/m) = 1 + \left(\frac{M}{m} + \frac{m}{M}\right)$.

This result is similar in a black hole setting where the addition of mass in the vicinity of the black hole does not necessarily imply the addition of individual entropy. The increase in mass M in a black hole by introducing a test object with mass $m \leq M$, i.e., $M \to M + m$, increases the entropy within the volume occupied by M but with total entropy greater than the sum of the individual entropy S_M and S_m of the masses. Using the entropy-mass relation, $S = 4\pi M^2 \to 4\pi(M+m)^2$, which is greater than the sum, $S_M + S_m$, since the total entropy would become,

$$S = 4\pi(M^2 + 2Mm + m^2) > 4\pi(M^2 + m^2) \tag{13}$$

4. MOND Equation

In Observational Astronomy, one can never calculate the mass ratio by getting the individual masses of the gravitating objects since the mass of one celestial object can never be known separately from the other mass of a celestial object that is gravitationally bound to it. However, one can express the function f in terms of other quantities and not just the individual masses of the gravitating objects. One such set of quantities is the accelerations of the two gravitating objects toward each other. For simplicity, let $M >> m$ which gives as, $f = 1 + \frac{M}{m}$. Using Newton's second and third law, $f = 1 + \frac{a}{a_0}$ which then gives the familiar modification of MOND theories to Newton's gravity equation,

$$F = G\frac{Mm}{\mu(a/a_0)r^2} \tag{14}$$

where $\mu(a/a_0) = (\epsilon f)^{-1} = \frac{1}{\epsilon\left[1+\frac{a}{a_0}\right]}$ and a is the acceleration of the test object. In MOND theories, it was originally suggested by Milgrom that $a_0 \approx 1.2 \times 10^{-10}\ m/s^2$ and would serve as the optimal value based on his analysis of rotation curve data. Here, the quantity, a_0, is not arbitrarily added without any physical meaning or justification. It is not a new fundamental constant that marks the transition between the Newtonian and deep-MOND regimes. It is interpreted here as the acceleration of the gravitating matter towards the test object orbiting it. However, there are complications in knowing the exact value of a_0, especially if the gravitating matter is a collection of smaller bodies with spaces in between like in the case of galaxies where there are different density distributions within the galaxy. Such variation leads to various shapes and configurations of galaxies making the corresponding range of the gravitational influence within and outside of the visible part of the galaxy unique for every galaxy and therefore the value of a_0 as well. The details of this will be further discussed in Section 6. This scenario for galaxies is very different in the case of a black hole in which there are no pockets of different density distributions within the black hole since all of its mass is concentrated at its center. However, the magnitude of the gravitational effect should be relatively the same with a galaxy especially if the black hole is a supermassive black hole. In Section 5 and 6, this new approach of directly relating the magnitude of gravity to entropy will be applied to larger systems that involve a large number of gravitating objects. In summary, the difference between the model presented here

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with other MOND theories [14] is that the so-called "interpolating function", $\mu(x)$, was identified and derived here to be a product of the function f and the unitless constant ϵ. The said function was originally added by Milgrom to Newton's equation, arbitrarily, to fit in the flat rotation curve data from which the value of the parameter x is based. Here, it has a specific physical interpretation and is not just added arbitrarily since the correction term $f = f(M/m)$ is a function of the mass ratio.

5. Tully-Fisher Relation

In Observational Astronomy, there are already known methods that can be used to measure the mass ratio of two objects in a two-body system. For non-luminous objects, the distances R_1 and R_2 from the barycenter can be used. Since each force felt by both objects acts only along the line joining the centers of the masses and both bodies must complete one orbit in the same period, the centripetal forces can be equated using Newton's 3rd law, such that we can have the relation $\frac{M}{m} = \frac{R_1}{R_2}$. However, this can only be used for nearby objects where the distances can be directly measured otherwise we can only get the mass ratio by indirectly getting the distances through the estimated value of the luminosity of each object. Hence, to get the mass ratio of distant luminous objects in a two-body system like in a binary star, one can use an approximation [15] via the mass-luminosity relationship, $\frac{M}{m} \approx \left(\frac{L_M}{L_m}\right)^{\gamma}$, where $1 < \gamma < 6$. The value, $\gamma = 3.5$, is commonly used for main-sequence stars. For a galaxy with halo mass M and a star with mass, $m_\odot$, equal to one solar mass and revolves along the halo mass, we can use the work of Vale et.al. [16] that relates the observed luminosity of the galaxy L and the halo mass of the galaxy via a double power law equation, i.e., $\frac{M}{m_\odot} \approx \left(\frac{L}{L_\odot}\right)^{\frac{1}{b}}$ where the range $0.28 \leq b \leq 4$ for exponent b, is for galaxies with galactic halo mass that ranges from high-mass to low-mass. The mass-luminosity relation above will yield,

$$v^2 = \frac{\epsilon GM}{r}\left(1 + \frac{M}{m_\odot}\right) \approx \frac{\epsilon GM}{r}\left[1 + \left(\frac{L}{L_\odot}\right)^{\frac{1}{b}}\right] \tag{15}$$

by equating F with the magnitude of the centripetal force mv^2/r. This implies that $L \sim v^{2b}$ where for the average, $b = 2$, the equation give us the Tully-Fisher relation $L \sim v^4$. Thus, by evaluating the correction term $f(M/m)$, we were able to derive the Tully-Fisher Relation just like in MOND theories.

6. External Field Effect and Chameleon Theory

In most MOND theories [17], it was suggested that any local measurement of the magnitude of gravity is not "absolute". It will always depend on the external gravity of other masses. This is known as the External Field Effect (EFE) which according to [18] implies that "the internal dynamics of a system are affected by the presence of external gravitational fields". Note, however, that the effect or magnitude of gravity from a source varies depending on the density or distribution of matter in its vicinity. In the galactic scale in particular, one must consider the variation of density from its bulge, to the galactic disk, and up to the galactic halo. Although MOND theories were the first to suggest the existence of EFE, as far as we know, it was never translated into concrete mathematical terms. Here, the model of gravity is more similar to the so-called "chameleon theories" of gravity that consider the density of the environment since the amount of information is dependent on the density of matter that serves as the medium to contain the information. The main difference, however, is that there is no need to consider the existence of an additional "fifth force" for a low-density environment but simply to consider the amount of information within the environment and the apparent "fifth force" will emerge. For large-scale gravity which involves a larger group of gravitational sources we now have, as a measure of the density of the information, the quantity, $N = N_1 + N_2 + \ldots + N_k$, for k number of gravitating objects. Squaring N, we have, $N^2 = (N_1)N_1 + (N_1 + N_2)N_2 + \ldots (N_1 + N_2 + \ldots + N_k)N_k$.

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By distributing and rearranging terms, we can have a more compact expression using the summation symbol, i.e.,

$$N^2 = \sum_{i<j}^{k} N_i N_j + \sum_{i}^{k} N_i^2 = \left(\sum_{i<j}^{k-1} N_i N_j + N_k \sum_{i}^{k-1} N_i \right) + \left(\sum_{i}^{k-1} N_i^2 + N_k^2 \right)$$

By using Eq.(9) and the convention $\epsilon = G = \hbar = c = 1$, the magnitude of the gravity of a galaxy, F_G, acting on kth star, would be,

$$F_G = \left(\frac{M_k \sum\limits_{i}^{k-1} M_i}{r_{cg}^2} \right) + \left(\frac{\sum\limits_{i<j}^{k-1} M_i M_j}{r_{cg}^2} \right) + \left(\frac{\sum\limits_{i}^{k-1} M_i^2}{r_{cg}^2} \right) + \left(\frac{M_k^2}{r_{cg}^2} \right) = F_{NG} + F_{HG} \tag{16}$$

where r_{cg} is the distance of separation of the kth object from the center of gravity of all other stars within the galaxy. The number of stars with their gravitational influence acting on the kth star is given by $k - 1$. The "stars" mentioned here include the supermassive black holes at the center of the galaxy which usually contribute the greatest to the overall gravity of the galaxy. The first term in Eq.(16) is the usual Newtonian gravity with magnitude given by F_{NG}, while the last three terms constitute the quantity, F_{HG}, as a measure of the magnitude of a "Hidden Gravity" (HG). The additional gravity given by F_{HG} will make the gravity of the galaxy extend not just on stars at the edge of the visible part of the galaxy but even beyond it, up to the edge of the galactic halo that surrounds the visible part of the galaxy. The observed flat rotation curve of galaxies is explained here not by an unobservable additional matter within the galactic halo but by an excess gravity that was unaccounted for when calculating the magnitude of gravity using only classical theories of gravity. The three terms of F_{HG}, make the measurement of its value complicated for every galaxy. It varies from one galaxy to another since it depends not only on the number of gravitating objects that can contribute to the magnitude of gravity but also on the distribution of the objects in a given volume of space. The same can be said in the case of galaxy clusters. Hence, the observation of the behavior of the Bullet Cluster does not in any way pose a significant challenge to the proposed model here.

7. On Wide Binary Systems

The most recent update on the status of MOND is the publication of three papers last year on the study of wide binary stars. These are the work of Chae [19], Hernandez [20], and Pittordis et.al. [21]. All of them seem to be giving three different results. One is very Newtonian, the other is very much aligned with MOND, while the third one is somewhere in between. In our model, this "MOND Tension" is what is expected even if there is no issue with the quality of data obtained or the measurement process used to estimate the mass and the velocity of the binary stars. There will always be variations in the result since each of the binary systems is subjected to the influence of different matter and energy density in its vicinity within the Milky Way galaxy. The different orientations and eccentricities of the orbits of the binary stars are an indication that these binaries are acted upon by an external source of gravity coming from different matter distributions in their vicinity. To quantify the magnitude of gravity that acts upon a binary system, we use Eq. (16) where we set $M_k = m$ as the

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mass of the kth star and M as the mass of the other star, both in a binary system with the second star at r_{k-1} distance away from the center of gravity. It yields us,

$$F_G = \frac{mM}{(r+r_{k-1})^2} + \frac{m\sum_i^{k-2} M_i}{r_{cg}^2} + \frac{\sum_{i<j}^{k-2} M_i M_j}{r_{cg}^2} + \frac{\sum_i^{k-2} M_i^2}{r_{cg}^2} + \frac{M^2}{r_{k-1}^2} \tag{17}$$

$$= \frac{mM}{r_{k-1}^2[1+2\frac{r}{r_{k-1}} + (\frac{r}{r_{k-1}})^2]} + \frac{m\sum_i^{k-2} M_i}{r_{cg}^2} + \frac{\sum_{i<j}^{k-2} M_i M_j}{r_{cg}^2} + \frac{\sum_i^{k-2} M_i^2}{r_{cg}^2} + \frac{M^2}{r_{k-1}^2}$$

where $r = r_{cg} - r_{k-1}$ is the distance between the two stars with a range that is just above 1000AU for wide binary stars. Such distance is an extremely minimal distance compared with r_{k-1} and r_{cg}, even if these distances are for nearby star clusters within the same host galaxy. Thus, the magnitude of gravity acting on the system would be,

$$F_G \approx \frac{mM}{r_{k-1}^2} + \frac{m\sum_i^{k-2} M_i}{r_{cg}^2} + \frac{\sum_{i<j}^{k-2} M_i M_j}{r_{cg}^2} + \frac{\sum_i^{k-2} M_i^2}{r_{cg}^2} + \frac{M^2}{r_{k-1}^2} \tag{18}$$

Now, the mass of any of the stars considered will have a wide range of possible values within the known observable range. However, if there is a massive star or a cluster of stars within the host galaxy, say with a mass far greater than the combined masses of the binary stars and happens to be nearby, it could greatly affect the dynamics of the system. In such a possible scenario, we have the possibility that

$$F_G > G\frac{mM}{r^2} = F_N \tag{19}$$

The excess $F_f = F_G - F_N$ would quantify as the magnitude of an apparent "fifth force" acting on the binary system and affecting not just its inclinations and eccentricities, but also the over-all magnitude of the gravitational field acting on the system. Moreover, the external gravitational influence acting on a binary system could also be the gravitational influence of other galaxies or clusters of galaxies outside of the host galaxy. Although these galaxies are already very far, there could be a possibility that an ultra-massive galaxy exists and may still exert gravitational influence on the system. Thus, it will make the dynamics of every binary star complicated since an apparent "fifth force" emerges. This "fifth force" is not associated with some exotic entity like a "dark particle" or a "chameleon particle" but associated only with all the matter in the vicinity with a magnitude that is not necessarily reflective of the actual number of matter associated with it. This is clearly shown by the last three terms in Eqn. (18) that mainly contributed to the magnitude of what would be perceived as the "excess force". The consensus today, however, such "excess force" corresponds to the existence of dark matter.

8. Relativistic Form of the Model and Modified Kepler Equation

The most commonly used approach in introducing a relativistic new theory of gravity is to generalize the Einstein-Hilbert action, $S = \int \sqrt{-g}Rd^4x$, by imposing additional parameters into the action, such as scalar, vector, tensor, and spinor fields, and then making it conformally invariant to produce a new field equation for gravity. One of the well-known examples of such an approach is the Tensor–Vector–Scalar (TeVeS) gravity theory by Bekenstein [8] as a relativistic generalization of the MOND paradigm of Milgrom [22]. This method will not be used here since the model presented here will focus more on the relation of gravity with the information density within a gravitational system rather than on its energy density. Instead, a relativistic approach to the model using Special Relativity (SR) only will be discussed here as part of the postdiction of the model. It will be shown here

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that the consequences of SR are enough to derive the predictions made in GR. However, it should be noted that being compatible with Special Relativity is not enough for any new theory of gravity to be correct. In addition, any new theory of gravity must be able to show that, not only that at a weak field, it can derive Newton's theory of gravity, but also it should correctly describe the effect of gravity when there is a very strong field. Like in the case of GR, it attempts to explain the case of Mercury where its orbit precess whenever it is affected by the Sun's strongest gravitational effect at the perihelion. The same thing for the case of light from the stars bending when it grazes near the Sun. In this section and suceeding sections, we will show how our model can also predict the outcome of some of the so-called "classical tests" that had been known to pass by GR with flying colors. This had been done by not necessarily going geometric in the formalism and interpretation of how gravity operates in Nature.

Using Special Relativity, in a frame of reference where the Sun is at rest and of a planet that is moving towards the Sun from aphelion (i.e. at slow velocity) towards at the perihelion, the rest energy $E = M_0 c^2 \gamma$ of the Sun and the Kinetic Energy $E_k = m_0 c^2(\gamma - 1)$ of the planet will give us the correction term,

$$f = 1 + \frac{M_0}{m_0} = 1 + \frac{E/c^2\gamma}{E_k/c^2(\gamma - 1)} \approx 1 + \alpha\frac{v^2}{c^2} = 1 + \alpha\beta^2 \tag{20}$$

where $\alpha = \frac{E/2}{E_k}$, $\beta = v/c$ and $\gamma = 1/\sqrt{1 - v^2/c^2}$. At the frame of reference where the relative velocity v is zero or its value is relatively very small in comparison to the speed of light c, such that $\beta \approx 0$, then Eq.(12) becomes the usual Newtonian gravity equation. On the other hand, at perihelion where β attain a non-zero value, we can set $\alpha \to 1$, such that Eqn. (12) becomes,

$$F \approx \frac{GM_0 m_0}{r^2}\left[1 + \frac{v^2}{c^2}\right] \tag{21}$$

where $M_0 >> m_0$ and we have set the constant of proportionality $\epsilon = 1$. The immediate consequence of this is a modified Kepler's Third Law equation becomes,

$$P^2 \approx \frac{4\pi^2}{GM_0}\left[1 + \frac{v^2}{c^2}\right]^{-1} r^3 \tag{22}$$

by combining Eqn.(21) with the equation for centripetal force $F_c = m_0 v^2/r = (m_0/r)(2\pi r)^2/P^2) = m_0 r/P^2$ where P is the orbital period for a simplest path of a circular orbit. Note that for a very slow object like a planet, the equation above becomes the usual Kepler's Third Law. Hence, the modified Newtonian gravity equation derived from the model is consistent with all known experiments made to test Newtonian gravity theory since the velocities of most of the planets are relatively slow. The advantage of the model, therefore, is that not only it apply on the Solar System scale but also the galactic scale as shown in the previous sections.

9. Horizon and Irreducible Mass

The result of the last section leads to the notion of irreducible mass, M_{irr}, and the horizon mass, M_h, similar to what was derived for black holes using GR [23],

$$\frac{v^2 r}{G} \approx M_0\left[1 + \frac{v^2}{c^2}\right] = M_{irr}\left[1 + \frac{v^2}{c^2}\right] = M_h = M_h(r) \tag{23}$$

where the rest mass M_0 acts as the irreducible mass, M_{irr}, and M_h is the horizon mass. Horizon mass is dependent on where the observer is. At infinity or at the edge of the Hill's Sphere, where the gravitational influence is too weak and therefore the test object's linear velocity ($v = \omega r$) or angular

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velocity, ω, is so small such that $v^2/c^2 \approx 0$, which gives us $M_h = M_0$. However, in the case of a strong gravitational field, we rewrite Eqn. (20),

$$f = 1 + \frac{M_0}{m_0} = 1 + \frac{E/c^2\gamma}{E_k/c^2(\gamma - 1)} = 1 + \frac{E}{E_k}(1 - \sqrt{1 - \beta^2}) \tag{24}$$

such that we have,

$$M_h(r) = \frac{v^2 r}{G} = M_0\left[1 + \frac{E}{E_k}\left(1 - \sqrt{1 - \beta^2}\right)\right] \tag{25}$$

Instead of considering the possiblity of $E_k \to E/2$, we consider the case of $E_k \to E$ and $\beta \to 1$. This can only happen for a black hole at the event horizon which gives us,

$$M_h = 2M_{irr} \tag{26}$$

Thus for black holes, the horizon mass becomes twice the irreducible mass. This statement is known in Black Hole Physics as the Horizon Mass Theorem [23]. This concept of the mass of the gravitating object being observer-dependent or an asymptotic mass will be used later in the succeeding section where one must distinguish the mass of the planet at aphelion and perihelion. For the observable mass, it must be the difference between the horizon mass and the irreducible mass which then gives as the total energy contained within a radius at coordinate r,

$$E(r) = (M_h - M_0)c^2 = M_0 c^2\left(\frac{E}{E_k}\right)\left(1 - \sqrt{1 - \beta^2}\right) \tag{27}$$

Setting $E_k \to E/2$ and $v^2 = 2M_0 G/r$, which can be substituted on the righthand side of the equation to yield,

$$E(r) = 2M_0 c^2\left(\frac{E/2}{E_k}\right)\left[1 - \sqrt{1 - \beta^2}\right) = \frac{rv^2c^2}{G}\left(1 - \sqrt{1 - \frac{2GM_0}{rc^2}}\right] \tag{28}$$

For a black hole, where M_0 is the mass of the black hole observed at infinity, it was shown [23] that,

$$E(r) = \frac{rc^4}{G}\left[1 - \sqrt{1 - \frac{2GM_0}{rc^2}}\right] \tag{29}$$

which is an equation that also emerged in studies trying to find the exact energy expression of a Schwarzchild black hole in the quasilocal energy approach [24], in the so-called teleparallel equivalent formulation of general relativity [25], and in the gravitational redshift approach [26].

10. Perihelion Shift of Mercury

Historically, the so-called ''anomalous precession shift of Mercury", being predicted by GR, is contested by some authors. They argue that the correction applied to Newton's equation by Einstein was not a direct consequence of his geometrization of gravity in his GR but simply from what was previously derived from Special Relativity [27]. This relatively unknown controversy is rooted in the fact that there is a slight error in the Einstein calculation from Schwarzchild's metric to derive the correct formula for Mercury's perihelion shift [28,29]. Nowadays, this error in the calculation does not in any way tarnish the reputation of GR since there are other ways now to derive Mercury's perihelion shift using GR. However, such known ''best" derivation based on GR [30] is still on ''shaky ground" or founded on some assumptions which are usually not explicitly shown, especially in the algebraic approach of the derivation like in the work of Taylor and Wheeler [31]. Hence, in the end, the status quo at present is that any new theory that deviates from GR is said to be very ''tight", i.e., it must be able to explain all of the so-called successes of GR and not just one part of it. In this section, we focus on achieving this by showing that our model can also derive the precession shift of Mercury and the

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deflection of light using the modified Newtonian gravity equation given by Eqn. (21). Our approach is similar to the earlier work of Kou [32] but we added some corrections and clarifications. We start with the standard Newtonian dynamical theory of planetary motion for comparison which is given by two equations below,

$$\frac{d\varphi}{dt} = \frac{L}{r^2} \tag{30}$$

$$\frac{1}{2}\left(\frac{dr}{dt}\right)^2 = E + \frac{GM}{r} - \frac{L^2}{2r^2} \tag{31}$$

These equations show the planet's angular momentum and energy conservation laws, respectively, wherein the first equation, L is the angular momentum and φ is the angle of the angular polar coordinate while in the second equation, E is the energy of the system and r is the distance of the planet. In our model, using Eqn. (21), it will lead to the modification of the last equation, i.e.,

$$\frac{1}{2}\left(\frac{dr}{dt}\right)^2 = E + \frac{GM}{r}\left(1 + \frac{v^2}{c^2}\right) - \frac{L^2}{2r^2} \tag{32}$$

where v is the velocity of the planet toward the host star in a stellar system. This velocity can be written as a combination of tangential and radial velocity,

$$v^2 = v_{tan}^2 + v_{rad}^2 = \left(\frac{dr}{dt}\right)^2 + \left(r\frac{d\varphi}{dt}\right)^2 = \left(\frac{dr}{dt}\right)^2 + \left(\frac{L}{r}\right)^2 \tag{33}$$

Using this, we can write Eqn.(32) as follows,

$$\left(\frac{1}{2} - \frac{GM}{rc^2}\right)\left(\frac{dr}{dt}\right)^2 = E + \frac{GM}{r} + \frac{GM}{c^2}\frac{L^2}{r^3} - \frac{L^2}{2r^2} \tag{34}$$

To simplify, we set $\frac{1}{2} >> \frac{GM}{rc^2}$, and ignore the $\frac{GM}{rc^2}$ term at the left-hand side of the equation which yields us,

$$\left(\frac{1}{2}\right)\left(\frac{dr}{d\varphi}\frac{d\varphi}{dt}\right)^2 = \left(\frac{L^2}{2}\right)\left(\frac{1}{r^2}\frac{dr}{d\varphi}\right)^2 = E + \frac{GM}{r} + \frac{GM}{c^2}\frac{L^2}{r^3} - \frac{L^2}{2r^2} \tag{35}$$

by subsituting Eqn.(30) in the equation. Taking the derivative of both sides of the equation in terms of φ and noting that $\frac{d}{d\varphi}\left(\frac{1}{r}\right) = -\frac{1}{r^2}\frac{dr}{d\varphi}$ where $r = r(\varphi)$, we have,

$$\frac{L^2}{2}\frac{d^2}{d\varphi^2}\left(\frac{1}{r}\right) + \frac{L^2}{r} = GM + \frac{3GML^2}{r^2c^2} \tag{36}$$

By setting $u = GM/r$, and substituting this to the last equation, we finally have the expression,

$$\frac{d^2u}{d\varphi^2} + u = \left(\frac{GM}{L}\right)^2 + \frac{3u^2}{c^2} \tag{37}$$

This result is similar to the relativistic correction of General Relativity to the Newtonian formula by a factor of $3u^2/c^2$. In the case of Mercury and the Sun, $u^2 = 2.3 \times 10^6\ m^2/s^2$, where we plugged in the measured value of the distance of Mercury from the Sun at aphelion, $r = 5.79 \times 10^{10}$m, and we initially set the mass to be $M = 2 \times 10^{27}$kg, to get the value for u such that the order of the correction factor is,

$$\frac{3u^2}{c^2} \sim 10^{-4} \tag{38}$$

Note that in the Newtonian formula,

$$\frac{d^2u}{d\varphi^2} + u = \left(\frac{GM}{L}\right)^2 \tag{39}$$

the solution of this is given by,

$$u = \left(\frac{GM}{L}\right)^2 (1 + e\cos\theta) \tag{40}$$

Since $3u^2/c^2$ is relatively very small, the Newtonian solution above can be considered as the zero-order solution of Eqn.(37). Substituting it to Eqn.(37), we have,

$$\frac{d^2u}{d\varphi^2} + u = \left(\frac{GM}{L}\right)^2 + \frac{3}{c^2}\left(\frac{GM}{L}\right)^4 + \frac{6}{c^2}\left(\frac{GM}{L}\right)^4 (e\cos\varphi) + \frac{3}{c^2}\left(\frac{GM}{L}\right)^4 (e\cos\varphi)^2$$

Since for the case of Mercury, the eccentricity is very small ($e << 1$) and $\left(\frac{GM}{L}\right)^2 >> \frac{3}{c^2}\left(\frac{GM}{L}\right)^4$, we can consider the others terms negligible and rewrite Eqn.(37) to be,

$$\frac{d^2u}{d\varphi^2} + u \approx \left(\frac{GM}{L}\right)^2 + \frac{6}{c^2}\left(\frac{GM}{L}\right)^4 (e\cos\varphi) \tag{41}$$

where the right-hand side is all just constants. To find the solution, we use the ansatz: $u = u_1 + u_2$ to have two separate equations:

$$\frac{d^2u_1}{d\varphi^2} + u_1 = \left(\frac{GM}{L}\right)^2 \tag{42}$$

$$\frac{d^2u_2}{d\varphi^2} + u_2 = \frac{6}{c^2}\left(\frac{GM}{L}\right)^4 (e\cos\varphi) \tag{43}$$

This will give us two solutions:

$$u_1 = \left(\frac{GM}{L}\right)^2 (1 + e\cos\theta); \qquad u_2 = \frac{3}{c^2}\left(\frac{GM}{L}\right)^4 (e\varphi\sin\varphi) \tag{44}$$

which can be combined into,

$$u = \left(\frac{GM}{L}\right)^2 \left[1 + e\cos\theta + \frac{3}{c^2}\left(\frac{GM}{L}\right)^2 e\varphi\sin\varphi\right] \tag{45}$$

to serve as solution to Eqn.(41). We can simplify the expression inside the square bracket by factoring out e and using the auxiliary angle formula:

$$a\sin\varphi + b\cos\varphi = \sqrt{a^2 + b^2}\cos(\varphi + \theta) \tag{46}$$

where $a = 1$, $b = \frac{3}{c^2}\left(\frac{GM}{L}\right)^2$. Then using the following approximations:

$$\theta = arctan\left(\frac{a}{b}\right) \approx \frac{a}{b} = \frac{1}{b}, \qquad b^2 \approx 0, \qquad \frac{1}{1+x} \approx 1 - x \tag{47}$$

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Finally we have the expression,

$$u \approx \left(\frac{GM}{L}\right)^2 \left\{1 + e\cos\left[1 - 3\left(\frac{GM}{cL}\right)^2\right]\varphi\right\} \tag{48}$$

as the solution for the planet orbit equation that came out of the modified Newtonian equation of the model. Looking at this, one can see that after one turn $\varphi = 2\pi$, that planet can't return as its orbit will precess a small angle. The cycle T of the orbit will no longer be at $\varphi = 2\pi$ but,

$$T = \frac{2\pi}{1 - 3\left(\frac{GM}{cL}\right)^2} \tag{49}$$

Each time the planet will orbit around the perihelion, it will turn an angle,

$$\varphi_n = \frac{2n\pi}{1 - 3\left(\frac{GM}{cL}\right)^2} \approx 2n\pi\left[1 + 3\left(\frac{GM}{cL}\right)^2\right] \tag{50}$$

From this, we can compute,

$$\Delta\varphi_n = (\varphi_{n+1} - \varphi_n) - 2\pi = 6\pi\left[\frac{GM}{cL}\right]^2 = 6\pi\left[\frac{GM}{c \cdot r \cdot v}\right]^2 \tag{51}$$

where we use $L = r \cdot v$, such that the quantity in square bracket is unitless. Substituting now the orbital velocity at perihelion, 6.9×10^4m/s, $G = 6.67 \times 10^{-11} Nm^2/kg^2$, the perihelion distance $r = 4.6 \times 10^{10}$m and setting the mass at perihelion to be $M = 2 \times 10^{30}$kg, we finally have,

$$\Delta\varphi_n = 6\pi \cdot \left(\frac{6.67 \cdot 2}{2.9 \cdot 4.6 \cdot 6.9} \times \frac{10^{-11} \cdot 10^{30}}{10^8 \cdot 10^{10} \cdot 10^4}\right)^2 = 3.96 \times 10^{-7} \approx 0.1'' \tag{52}$$

which means for every year, there are $0.1''$ turn of the precession angle, giving us the total precession angle,

$$\sum \Delta\varphi_n \approx 43'' \tag{53}$$

within a century.

11. Deflection of Light

Another so-called test of GR is the deflection of light which is usually observed nowadays in gravitational lensing of galaxy clusters. This can also be predicted by the present model of gravity in the case of a light grazing around the Sun as also shown in the works of Kou [32]. Using again the modified orbital or dynamical equations,

$$\frac{d\varphi}{dt} = \frac{L}{r^2} \tag{54}$$

$$\frac{1}{2}\left(\frac{dr}{dt}\right)^2 = E + \frac{GM}{r}\left(1 + \frac{v^2}{c^2}\right) - \frac{L^2}{2r^2} \tag{55}$$

Combining both equations by expanding $\frac{dr}{dt} = \frac{dr}{d\varphi}\frac{d\varphi}{dt}$, setting $v = c$ and using $dr = -r^2 d\left(\frac{1}{r}\right)$, we get,

$$\frac{L^2}{2}\left[\frac{d\left(\frac{1}{r}\right)}{d\varphi}\right] = E - \frac{L^2}{2r^2} + \frac{2GM}{r} \tag{56}$$

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Getting the derivative and multiplying with $\frac{GM}{L^2}$ on both sides of the equation and defining $u = GM/r$, the equation above can be simplified as follows,

$$\frac{d^2u}{d\varphi^2} + u = 2\left(\frac{GM}{L}\right)^2 \tag{57}$$

where $L = Rc$, R being the radial of the Sun. To find the approximate solution, we make the righthand side of the equation negligible by defining $\tilde{u} = 1/r$ such that $u = GM\tilde{u}$ and dividing both sides with GM, yielding us,

$$\frac{d^2\tilde{u}}{d\varphi^2} + \tilde{u} = \frac{2GM}{(Rc)^2} \tag{58}$$

The approximate solution of this is a line,

$$\tilde{u}_0 = R^{-1}\cos\varphi \tag{59}$$

while the general solution is a line with a deflection term,

$$\tilde{u} = \tilde{u}_0 + \frac{2GM}{(Rc)^2} = R^{-1}\cos\varphi + \frac{2GM}{(Rc)^2} \tag{60}$$

For a straight line, it can be extended to infinity ($r \to 0$) which makes $\tilde{u} \to 0$ while the azimuth angle is $\varphi = \pm\frac{\pi}{2}$. We can reverse this by setting that at infinite where $\tilde{u} \to 0$, and we set $\varphi = \pm\left(\frac{\pi}{2} + \theta\right)$ giving us,

$$0 = R^{-1}\cos\left[\pm\left(\frac{\pi}{2} + \theta\right)\right] + \frac{2GM}{(R^2c^2} = R^{-1}\sin\theta + \frac{2GM}{R^2c^2} \tag{61}$$

From this we can derive for θ,

$$\sin\theta \approx \theta = \frac{2GM}{c^2R} \tag{62}$$

which finally gives us the light deflection angle,

$$\Delta\varphi = 2\theta \approx \frac{4GM}{c^2R} \tag{63}$$

For solar mass 1.988×10^{30} kg, and radial $R = 6.955 \times 10^8$m, we can predict that,

$$\Delta\varphi = \frac{4 \cdot 6.67 \cdot 1.988}{(2.9979)^2 \cdot 6.995} \times \frac{10^{-11} \cdot 10^{30}}{10^{16} \cdot 10^8} = 0.8436 \times 10^{-5} = 1.74'' \tag{64}$$

which is the value that has been confirmed since the time of the famous 1919 eclipse observation of Eddington.

12. Equivalence Principle

Unknown to many, Eqn. (21) is a form of a modified Newtonian equation that has appeared in various papers but is derived in different ways. The variety of ways that Eqn. (21) was derived due to the fact that there had been various motivations or physical bases that have been used by different authors just to derive it. For example, one of such motivations is the use of the concept of velocity-dependent mass in Special Relativity [27]. Another paper used the velocity-dependent gravitational potential energy [33] while others assumed the existence of a ‘‘cogravity" force [34] or a general perturbing potential force [35]. Regardless of the different derivations and motivations, one can fully derive the correct perihelion shift formula for Mercury and also for the deflection of light in a strong gravitational field by using Eqn. (21), as it was shown in the previous sections. Thus, the model here is fully grounded on Special Relativity and can even pass the test of GR without necessarily going geometric in its interpretation of the nature of gravity. Despite this, the model is still compatible with

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Einstein's Equivalence Principle but in a limited way, i.e., only with the Weak Equivalence Principle. To show this, consider a test object that is orbiting from a more massive object with an angular speed ω, we can use the relation $v = \omega r$ in Eqn. (21), and gives us,

$$F \approx \frac{GM_0 m_0}{r^2}\left[1 + \frac{\omega^2 r^2}{c^2}\right] = \frac{GM_0 m_0}{r^2} + GM_0 m_0 \frac{\omega^2}{c^2} = F_N + F_I \quad (65)$$

The last term can be considered as a fictitious force, i.e. the so-called ''inertial force'' that appears only when the test object is in rotational or accelerated motion. In cases where there is no angular speed, Newton's Law of Gravity is applicable while for the case of non-zero angular speed, such fictitious force must be added. In a frame of reference where $F_N = F_I$, it will appear that there is no gravity acting on the test object, i.e., $F = 0$ and the observer will experience ''weightlessness" or zero-gravity. The equality can be interpreted as implying the equivalence of a gravitational force with inertial force in terms of its magnitude or its corresponding gravitational and inertial mass, the so-called Weak Equivalence Principle. However, the model will be incompatible with Einstein's version or extension of the Weak Equivalence Principle or even with a Strong Equivalence Principle since the model considers the effect of other matter in the Universe that has the proximity and gravitational influence in the system. The model therefore is perhaps more compatible with the notion of the so-called ''fifth force" of a Chameleon Theory and will probably be inconsistent with a geometric interpretation of the nature of gravity. This is because, in most cases, the gravitational field will not be similar to an accelerated frame of reference since the model will always fully account for all other gravitational influences within the vicinity or ''environment" of the gravitating matter. This is in stark contrast to General Relativity, in which gravitational force is treated as a constant while in our model the effects of gravity can fluctuate and change based on the environment.

13. Conclusions

A new theory of gravity is presented here with a basis that is similar to Verlinde's entropic theory of gravity but with a result that is similar to a MOND or Chameleon theory. Gravity here is not described by the amount of curvature of spacetime (*à la* Einstein) nor described as an entropic force that emerges in a thermal bath (*à la* Verlinde), but solely described by the density of information that can be contained within a gravitational system. Also, the theory neither introduced a new baryonic particle as suggested by the Dark Matter hypothesis nor introduced a new field as suggested by a TeVeS version of MOND theory. It modifies Newtonian gravity by emphasizing the fundamental role of information and entropy in the description of gravity as suggested by the Holographic Principle and Vopson's Mass-Energy-Information Equivalence Principle. It is the first time these two fundamental methods of storing information, in spacetime and matter, were combined and used to describe gravity. In succeeding papers, we will attempt to apply the model to Quantum Mechanics. We conjecture that only by rewriting QM as an emergent theory, using perhaps the information-theoretic approach that we used here for its mathematical formalism, unification with gravity is possible. In such an approach it could be possible that the notion of gravity waves can also be integrated into the model which is currently lacking in most EG and MOND theories.

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