A Push to Understand Gravity: A Heuristic Model

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I present a new version of the Le-Sage-Brush-Tommasina hypothesis of gravitation that emphasizes a two-fold role of the baryons in a particular region of a celestial body that I call the effective volume. I do not treat the celestial bodies as point-like masses. Instead I propose that only the baryons in an effective volume of a spherical celestial body participate in the gravitational response. The baryons in the effective volume are accelerated vectorially as a result of an asymmetrical impact of quantized low frequency electromagnetic waves I describe as gravitons. In a baryonic analogue of Compton scattering, the baryons in the effective volume also induce an asymmetry in the distribution of gravitons. This asymmetry caused by the baryons in the effective zone not only causes the baryon-containing body to accelerate, but it also causes another baryon-containing body to accelerate towards it. Only the baryons in the effective volume participate in the gravitational attraction since the momentum transfer to each baryon outside the effective volume is neutralized by the momentum transfer to one other baryon outside the effective volume. With the recent detection of gravitational waves, it is timely to bring back a modernized view of the Le Sage-Brush-Tommasina hypothesis of gravitation as an alternative to the general theory of relativity for describing the mechanism of gravitational attraction in Euclidean space and Newtonian time. According to the general theory of relativity, the detected gravitational waves are a result of ripples in the four-dimensional space-time continuum caused by the spiraling of black holes before they collide. According to a modernized view of the Le Sage-Brush-Tommasina gravitational hypothesis presented here, the waves that were detected are pulses of low frequency gravitons that were directed towards earth as the spiraling black holes acted like a chopper, alternately producing a window and a shutter, for the gravitons propagating towards the earth from the neighborhood of the black holes.

"*I feel much diffidence in presenting the foregoing rough draft of a theory of gravitation; but I can not avoid the belief that it contains some germs of truth, perhaps the real key to the great mystery, though, if this be true, I have, no doubt, used the key clumsily and imperfectly.*"

Charles F. Brush [1]

1. Introduction

According to the general theory of relativity, the attraction between two bodies is a consequence of the warping of space-time by the two masses which reciprocally create geodetic lines in four-dimensional space-time through which the other mass moves [2]. With the widespread acceptance of the general theory of relativity, the concept of gravity being a force that operates in Euclidean space and Newtonian time has been relegated to the category of occult qualities and metaphysical fictions. However, it is possible that this categorization is premature. Recently, I have shown that the fundamental observations that gave rise to and subsequently confirmed the general theory of relativity, such as the precession of the perihelion of Mercury [3], the deflection of starlight [4,5], the gravitational red-shift [4,5] and the global positioning system (GPS) [4,5] can be explained by a gravitational force that propagates through Euclidean space and Newtonian time.

Newton's [6] law of universal gravitation mathematically characterized the gravitational force but it did not explain in a mechanistic manner how the gravitational force acted between two distant bodies. Newton wrote "…*hitherto I have not been able to discover the cause of those properties of gravity from phenomena, and I frame no hypothesis*." However, in a letter to Richard Bentley, Newton [7] postulated that the force of gravity is probably propagated through some kind of contact.

A horse that is assumed to be pulling a carriage can be thought of as a horse pushing against its breastplate with the attached carriage following by necessity. Likewise, the force of gravity, which causes two bodies to accelerate towards each other, can be formally considered to be either a pulling force exerted between the two bodies or a pushing force that pushes the two bodies towards each other. Both mechanisms result in the reciprocal acceleration of the two bodies towards each other. The idea of a pushing force was developed by Georges-Louis Le Sage [8] in terms of ultra-mundane corpuscles, and by Charles Brush [1,9-16] and Thomas Tommasina [17,18] in terms of ethereal waves. According to the pushing theories of gravity, the particles or waves are uniformly and ubiquitously present throughout all space and propagate isotropically. However, their distribution becomes non-uniform in the gravitational shadow of massive bodies. As a result, the pushing force on a body coming from the direction of the gravitational shadow is less than the pushing force coming from any other direction. Consequently, the two bodies accelerate towards each other as if they were attracted to each other. As long as the corpuscles or the ethereal waves are able to penetrate through a massive body so that they have a chance of interacting with any massive component, the pushing force will be proportional to the product of the masses of the two bodies and inversely proportional to the square of the distance between the two bodies [19-22]. How the particles/waves could interact with the matter that made up the bodies without heating them up presented a challenge at the time to the gravitational theories involving pushing forces, however, no better theories were proffered [23-33].

With the spectacular success of the general theory of relativity in predicting the deflection of starlight, gravitational theories involving pushing forces in Euclidean space and Newtonian time fell by the wayside. Richard Feynman [34], in the 1964 Messenger Lectures given at Cornell University said, "*the only trouble with this scheme is that it does not work, for other reasons. Every theory that you make up has to be analysed against all possible consequences, to see if it predicts anything else. And this does predict something else. If the earth is moving, more particles will hit it from in front than from behind…So, if the earth is moving it is running into the particles coming towards it and away from the ones that are chasing it from behind. So more particles will hit it from the front than from the back, and there will be a force opposing any motion. This force would slow the earth up in its orbit, and it certainly would not have lasted the three or four billion years (at least) that it has been going around the sun. So that is the end of that theory*." However, Feynman's objection is no longer valid as I have shown that such a tangential velocity-dependent counterforce results in the precession of the perihelion of the planets in Euclidean space and Newtonian time, bringing observation in line with a theory based on a tangential velocity-dependent correction to Newton's law of universal gravitation [3].

The heavy particles in the atomic nucleus were named "baryons" by Abraham Pais [35] in 1953. Here I reframe Le Sage's, Brush's and Tommasina's mechanistic model of gravitation by considering the possibility that the gravitational pushing force is due to Compton-like scattering of low frequency electromagnetic waves by baryons. This would explain the proportionality of the Newtonian gravitational potential to the mass of a body. If the baryons in each body scattered the low frequency electromagnetic waves isotropically in a manner that would shield the other body from the pushing force on the side closest to the shielding body, there would be a mutual acceleration of the two bodies towards each other in a manner that would appear to be an attractive gravitational force that was proportional to the product of the masses and inversely proportional to the square of the distance.

As early as 1669, Gilles de Roberval wrote that weight may reside in a heavy body, weight may depend reciprocally on the two bodies that show mutual attraction, and/or weight may be a result of a third body that pushes the two bodies closer together [36]. Here I will show that if we take all three possibilities into consideration, it is possible to picture a mechanistic hypothesis of gravity that involves a pushing force. I will give the name gravitons to the ultra-mundane corpuscles of Le Sage and ethereal waves of Brush and Tommasina. Briefly, each body acquires momentum through the interaction of gravitons with its baryons. By interacting with the gravitons, not only does each body acquire momentum, but each body also scatters the gravitons in a manner that provides an asymmetry in the pushing force on the other body. This graviton-baryon analogue of the Compton scattering of photons by leptons, causes the two bodies to accelerate towards each other in a manner that is proportional to the product of the masses and inversely proportional to the square of the distance between them.

Recently, Abbott et al. [37] detected gravitational waves that were predicted by Einstein [38, 39] a century ago. The detection of gravitational waves supports the general theory of relativity as the theory of universal gravitation that applies to high velocity, strong field regimes as well as low velocity, weak field regimes [40]. Here I suggest the possibility that pulses of gravitons that exert a pushing force on massive bodies in Euclidean space and Newtonian time may be the entities that were detected as gravitational waves at the Laser Interferometer Gravitational-wave Observatory (LIGO).

2. Results and Discussion

According to the second law of thermodynamics, thermal energy cannot be extracted from a single source no matter how hot it is. It is a difference in thermal energy that is necessary to provide a motive force. Likewise gravitational energy, in the form of gravitons that exert a pushing force force, cannot be extracted from a single source no matter how forceful it is, and it is the difference in gravitational energy that is necessary to provide a motive force. Thus gravitational energy only becomes useful energy in accelerating matter when the homogeneity is broken as a result of a massive body and the symmetry is broken as a result of two or more massive bodies. I claim that the carriers of the gravitational force known as gravitons that originated from the fragmentation of the primeval atom at the onset of the big bang became distributed throughout the universe in an analogous way that the photons that make up the cosmic microwave background radiation became distributed throughout the universe. In the absence of matter, the gravitons are distributed uniformly and propagate isotropically (Fig. 1), while in the presence of matter, the distribution is no longer uniform (Fig. 2). The distribution of gravitational energy becomes asymmetric in a predictable manner that is proportional to the product of the masses of the bodies and inversely proportional to the square of the distance between them. As such, the asymmetry in the gravitational radiation results in a gravitational force that accelerates two bodies towards each other.

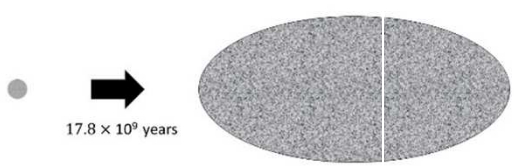

Fig. 1: The gravitons that split off from the primeval atom at the time of the big bang 17.8 billion years ago became uniformly distributed throughout the universe.

For the pushing model of gravity to be correct and universal, in any region of the universe, the number of gravitons originally produced in the big bang must be sufficient to cause the observed gravitational accelerations between the most massive of gravitating bodies known as black holes. The

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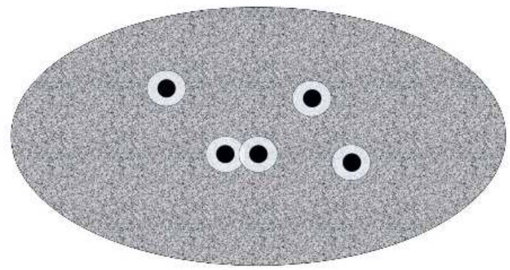

energy density of gravitons should be added to the thermal energy cannot be energy density of baryons and photons when determining the total energy density of the universe.

Fig. 2: The uniformity in the distribution of gravitons became altered by matter. The distribution of gravitons becomes asymmetric by the presence of two massive bodies.

The baryons that are in the nuclei overwhelmingly make up the mass of a body. Consequently, in order for the gravitational potential to be proportional to the mass of a body, and for the gravitational force to be proportional to the product of the masses of two bodies, the carriers of the gravitational force must interact with the baryons. There would be no net gravitational pushing force on a nucleus if the gravitons struck the nucleus equally from all directions. However, if there were a paucity of gravitons from a given direction as a result of gravitational shielding by another body, there would be a net gravitational pushing force. The nucleus would no longer undergo Brownian motion but would accelerate in the direction of the paucity of gravitons, which is towards the shielding body.

We can begin to characterize the properties of the gravitons that carry the gravitational force. Firstly, in order to interact with the baryons, the gravitons must have energies that resonate with the nuclear energy states [41, 42]. We know from the success of nuclear magnetic resonance (NMR) spectroscopy in chemistry and magnetic resonance imaging (MRI) in medicine that the protons and neutrons in atomic nuclei act as small rotating, spinning magnets that can interact with low frequency electromagnetic radiation. However, since the interaction of low frequency electromagnetic radiation with atomic nuclei is normally very weak, powerful magnets are necessary to put the nuclei in quantum states where the magnetic dipole moment resulting from the intrinsic angular momentum of the nucleus is oriented relative to the magnetic field. This ensures that there is a sufficient interaction cross section to produce an image with MRI or a spectrum with a nuclear magnetic resonance spectrometer. However, under natural conditions where strong magnetic fields do not exist, the nuclear spins will be randomly arranged and low frequency electromagnetic waves coming from each and every direction will have an equal probability of interacting with a baryon. Moreover, the interaction between low frequency electromagnetic radiation and the atomic nuclei will be weak enough to allow the low frequency electromagnetic radiation to penetrate deeply into a gravitating body [43]. This fulfills a second condition that ensures that the gravitons can move through the body in such a way that the gravitational potential will be proportional to the mass of the body and the force of gravity will be proportional to the product of the masses of two bodies.

In order for low frequency electromagnetic waves to function as gravity waves they must have a frequency that is high enough to have a probability of interacting with a baryon and low enough to penetrate a body so that each and every baryon has a probability of interacting with the gravity waves. For this reason, the gravity waves must be electromagnetic waves that have a very low frequency and a very long wavelength. In an MRI, frequencies on the order of 25 MHz are typically used to produce an image of the distribution of hydrogen nuclei. I am assuming that the gravity waves are electromagnetic waves with a lower frequency, say 100 Hz, so that they have a probability of both interacting with the baryons and penetrating through a heavenly body. Because they are electromagnetic waves, such gravity waves would travel at the speed of light (3×10^8 m/s) and have a wavelength of approximately 3×10^6 m. As a quantized entity known as a graviton, its total energy ($E = \frac{hc}{\lambda_{graviton}}$) would be 6.63×10^{-32} J, and its mass ($m = \frac{E}{c^2}$) would be 7.37×10^{-49} kg. These values are only guesses but serve as an ansatz. By contrast, the LIGO Scientific Collaboration and Virgo Collaboration gives a lower bound on the wavelength of the graviton to be 10^{16} m [40]. By assuming that the momentum of a graviton is inversely proportional to its wavelength (see below), the effects of gravitons with any wavelength can be analyzed with the following equations.

Assume that the wavelength ($\lambda_{graviton}$) of the gravity waves is 3×10^6 m, the linear momentum (p) of each quantized gravity wave or graviton would be 2.2×10^{-40} Ns according to the following formula:

$$p = \frac{E}{c} = \frac{h}{\lambda_{graviton}} \tag{1}$$

In order to estimate the transfer of momentum from the graviton to the nucleus, I assume that the gravitons impart momentum to a nucleus in the same way that X-ray photons impart momentum to an electron through the Compton effect. If we assume that on the average, gravitons scatter from their targets isotropically, we can determine the difference in the number of gravitons[1] pushing two bodies together and the number of gravitons pushing the same two bodies apart in order to produce the observed gravitational force. First we equate the gravitational force (F_g) calculated with Newton's law of universal gravitation with the inertial force (F_i) calculated with his second law of motion:

$$F_g = G\frac{Mm}{r^2} = F_i = \frac{dp}{dt} \tag{2}$$

Where, G is the gravitational constant equal to 6.67×10^{-11} m^3 kg^{-1} s^{-2}, M and m are the masses of the two bodies and r is the center-to-center distance between them. Let the total differential force between the gravitons pushing the two bodies together and pushing the two bodies apart be given by:

$$\frac{dp}{dt} = \frac{dn_{gravitons}}{dt}\left[\frac{h}{\lambda_{graviton}}\right] \tag{3}$$

Where, $n_{gravitons}$ is the differential number of gravitons pushing the two bodies together and pushing the two bodies apart. In the case of the sun-earth system, in which the mass of the sun (M) is 1.99×10^{30} kg, the mass of the earth (m) is 5.98×10^{24} kg, and the distance between the two is 1.50×10^{11} m, the gravitational force is 3.53×10^{22} N. Assuming that the wavelength ($\lambda_{graviton}$) of the gravitons is 3×10^6 m, the differential number of gravitons ($n_{gravitons}$) per second needed to exert the observed gravitational force is given by the following formula:

$$G\frac{Mm}{r^2} = \frac{dn_{gravitons}}{dt}\left[\frac{h}{\lambda_{graviton}}\right] \tag{4}$$

[1] The calculated difference in the number of gravitons needed to push two bodies together depends on the nature of the interaction between baryons and gravitons. If the baryons totally reflected the gravitons, the linear momentum exchanged between the graviton and the baryon would be twice as great and half the number of gravitons would be needed to provide the gravitational force (although no gravitational force would be generated between two bodies). If the baryons were completely transparent to the gravitons, there would be no momentum transfer and an infinite number of gravitons would be needed to provide the gravitational force.

A difference of 1.60 × 10^{62} gravitons/s pushing the two bodies together and pushing the two bodies apart would provide the observed gravitational force.

The combined mass of the earth and the sun is 1.99 × 10^{30} kg. Since the mass of a baryon is 1 amu or 1.67 × 10^{-27} kg, then there are 1.19 × 10^{57} baryons ($n_{baryons}$) in the sun-earth gravitational system. Thus, in order to cause the observed gravitational force, 1.60 × 10^{62} gravitons/s must interact with 1.19 × 10^{57} baryons. That is, 1.34 × 10^5 gravitons/s must interact with each baryon.

The differential number of gravitons per second pushing the two bodies together and pushing the two bodies apart that is needed to produce the gravitational force depends on the mass of the system. In the earth-moon system, in which the mass of the earth (M) is 5.98 × 10^{24} kg, the mass of the moon (m) is 7.34 × 10^{22} kg, and the distance between the two is 3.84 × 10^8 m, the gravitational force is 1.99 × 10^{20} N. The differential number of gravitons/s pushing the two bodies together and pushing the two bodies apart that is needed to interact with the earth and the moon to provide the observed gravitational force in the earth-moon system is 9.00 × 10^{59} gravitons/s. Given that the combined mass of the earth and moon is 6.05 × 10^{24} kg, there are 3.62 × 10^{51} baryons ($n_{baryons}$) in the earth-moon gravitational system. Thus, in order to cause the observed gravitational force, 9.00 × 10^{59} gravitons/s must interact with 3.62 × 10^{51} baryons. That is 2.49 × 10^8 gravitons/s must interact with each baryon.

The number of gravitons/s interacting with each baryon in the sun-earth system and the earth-moon system is 1.34 × 10^5 and 2.49 × 10^8 gravitons/s respectively. This 1858-fold difference is too great to conclude that the interaction of gravitons with each baryon is the universal mechanism that causes gravitational acceleration between the sun and the earth and the earth and the moon. However, the difference in the number of gravitons/s interacting with baryons in the two systems can be reduced by eliminating the assumption of a point-like mass and taking into consideration the effective volume, which depends on the inverse square of the distance between the two bodies.

When one body is reciprocally shielded from the other body, there are two cone-shaped regions in each body that are composed of baryons that experience an asymmetry in the momentum transfer from gravitons (Fig. 3; blue regions) that cannot be neutralized by other baryons. It is only the baryons in these conic regions that contribute to the net momentum transfer from graviton to baryon. We can calculate the number of baryons in this effective volume. The volume of a cone is given by the product of the cross sectional area and one third of its height. In the case of the sun-earth system, the volume (V_{sun}) of each cone in the sun composed of the effective baryons is:

$$V_{sun} = \pi x^2 \frac{R_{sun}}{3} \quad (5)$$

Where, $x = \frac{R_{sun}R_{earth}}{r_{se}}$ and R_{sun} is the radius of the sun, R_{earth} is the radius of the earth and r_{se} is the distance between the two. In the case of the sun-earth system, the volume (V_{earth}) of a cone in the earth that has the effective baryons is:

$$V_{earth} = \pi y^2 \frac{R_{earth}}{3} \quad (6)$$

where $y = \frac{R_{sun}R_{earth}}{r_{se}} = x$.

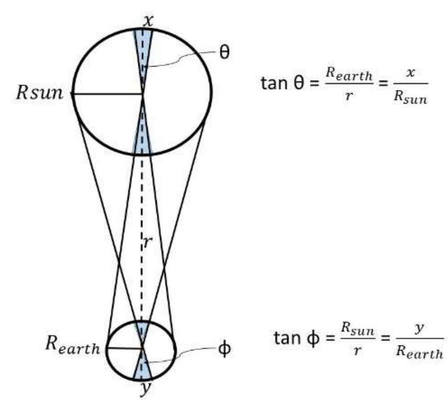

Fig. 3: Effective volumes are created by the mutual shielding of two or more massive bodies. When one body is reciprocally shielded by the other body, two cone-shaped regions (blue) are formed in each body. These cone-shaped regions contain the baryons that experience an asymmetry in the momentum transfer from gravitons. Because the momentum transfer to the baryons in these regions cannot be neutralized by the momentum transfer from gravitons to baryons in any other region of the body, only the baryons in these conic regions contribute to the net momentum transfer from graviton to baryon.

In the sun-earth system, the total effective volume ($V_{effective}$) of baryons is given by:

$$V_{effective} = 2\,\frac{\pi}{3}\frac{R_{sun}^2 R_{earth}^2}{r_{se}^2}[R_{sun} + R_{earth}] \quad (7)$$

and is equal to 1.29 × 10^{18} m^3. Since the total volume of the sun and the earth is 1.41 × 10^{27} m^3, the proportion of the effective volume to the total volume is 9.10 × 10^{-10}. The proportion of the 1.19 × 10^{57} total baryons in the sun-earth system that compose the effective volume is equal to 1.08 × 10^{48} effective baryons. Thus, in order to cause the observed gravitational force, the 1.08 × 10^{48} effective baryons must interact with 1.60 × 10^{62} gravitons/s. That is, 1.47 × 10^{14} gravitons/s must interact with each effective baryon.

Using the same logic to characterize the earth-moon gravitational system, where the mass of the moon is 7.34 × 10^{22}, the radius of the moon is 1.74 × 10^{6} m and the distance (r_{em}) between the earth and the moon is 3.84 × 10^{8} m, the total volume and the total effective volume of the earth-moon system are 1.10 × 10^{21} and 1.41 × 10^{16} m^3, respectively. The proportion of the effective volume to the total volume in the earth-moon system is 1.28 × 10^{-5}. The proportion of the 3.62 × 10^{51} total baryons in the sun-earth system that compose the effective volume is equal to 4.63 × 10^{46} effective baryons. In order to cause the observed gravitational force, the 4.63 × 10^{46} effective baryons must interact with 9.00 × 10^{59} gravitons/s. That is, 1.94 × 10^{13} gravitons/s must interact with each effective baryon.

The gravitons, which are quantized versions of low frequency electromagnetic waves that travel at the speed of light, are assumed to provide a pushing force on the baryons in the effective region of each body that results in the falling of the earth towards the sun, the falling of the moon towards the earth, the falling of an apple from a tree, and the falling of a protoplast within a cell wall when a plant senses gravity [44-46]. The acceleration of these bodies towards each other would all be a result of a differential pushing force on the baryons in the effective volume of each body. Such a pushing force, which ensures *what goes up must come down*, and which would account for Kepler's three laws of planetary motion, would be proportional to the products of their masses and inversely proportional to the square of the distances between them.

Given the proposed mechanism, the ratio of gravitons/s to effective baryons in the sun-earth system (1.47 × 10^{14} gravitons/baryon s) and the earth-moon system (1.94 × 10^{13} gravitons/baryon s) is only 7.58-fold. By taking the effective baryons into consideration the ratio has been reduced from 1858, which was calculated from the total baryons to 7.58, which was calculated from the effective baryons. While this ratio is not small, it is small relative to many astrophysical predictions, suggesting that the proposed interaction of gravitons with the baryons that make up the effective volume may be a candidate for the universal mechanism that causes the gravitational acceleration between two gravitating bodies. Certainly this is just a start, and the model requires refinement in order for the predicted difference between the sun-earth system and the earth-moon system to vanish.

The model predicts that the baryonic mass has two roles in the gravitational attraction between two bodies—the ability to scatter gravitons and the ability to accelerate in response to gravitons. The contribution of the baryons to the effective mass in one celestial body depends on that celestial body's relative position to another celestial body. Likewise the contribution of a baryon in one non-homogeneous celestial body may depend on its position relative to the other baryons in the same celestial body.

Since the celestial bodies are considered to be homogeneous and point-like, the determination of their mass using Newton's law of universal gravitation depends on the invariance of the gravitational constant (*G*). Could it be possible that the gravitational field along a given radius of the earth along which the gravitational constant is measured is influenced by internal heterogeneities? It turns out that the gravitational constant, which was originally determined from Henry Cavendish's measurement of the density of the earth [47-50], is not as constant as I had assumed [51, 52]. Thus, the calculated mass of a celestial body is dependent on the assumed value of *G*, and the 7.58-fold discrepancy in the graviton to effective baryon ratio in the sun-earth and earth-moon gravitational systems may be a result in part of too simplistic assumptions about mass. Differences in *G* may be due to differences in the interaction of gravitons with baryons within each celestial body. It may also be due to the differences in the distribution of quantized spin states (n) of the nuclei, which depend on temperature:

$$\frac{n_{high\,energy}}{n_{low\,energy}} = e^{\frac{-\Delta E}{kT}} - 1 \qquad (8)$$

and/or the magnetic field generated by the celestial body. It is possible that the discrepancy in the sun-earth and earth-moon gravitational systems could be eliminated by taking into consideration thermodynamic and "geological" factors such as any distribution of mass that is not spherically symmetrical, as well the temperature and intrinsic magnetic field of the bodies.

Each effective volume is associated with an area on the surface of a celestial body. The surface areas of the sun (S_{sun}) subtended by a single cone and the earth (S_{earth}) subtended by a single cone are given by:

$$S_{sun} = 2\pi R_{sun}^2 \theta \sin\frac{\theta}{2} \quad (9)$$

and

$$S_{earth} = 2\pi R_{earth}^2 \phi \sin\frac{\phi}{2} \quad (10)$$

Where, θ is 4.25×10^{-5} rad and ϕ is 4.64×10^{-3} rad as defined in Fig. 3. While the angles differ, in the sun-earth gravitational system, the surface area of the sun subtended by a single cone of the effective volume and the surface area of the earth subtended by a single cone of the effective volume as defined in Fig. 4 are both equal to 2.74×10^9 m^2. Likewise, in the earth-moon gravitational system, the surface area of the earth subtended by a single cone of the effective volume and the surface areas of the moon subtended by a single cone of the effective volume as defined in Fig. 4 are both equal to 2.62×10^9 m^2. In the two gravitational systems, the effective surface areas, which represent the entrance point of the gravitons that push the two gravitating bodies towards each other or the entrance point of the gravitons that push the two gravitating bodies apart from one another differ only by a factor of 1.05-fold. The mechanism of gravitational acceleration can be looked at anew when one considers the gravitating bodies in terms of their effective volume and effective surface area instead of assuming them to be point masses that warp a four-dimensional space-time continuum.

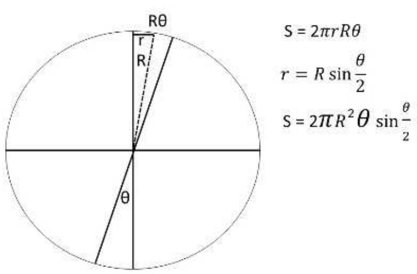

Fig. 4: Calculation of the surface area (S) that covers the effective volume of a single cone using Pappus's centroid theorem.

It may be possible to characterize the properties of the low frequency electromagnetic waves that I postulate to be synonymous with gravity waves or gravitons by measuring the attenuation coefficients of a spectrum of extremely low frequency (ELF) electromagnetic waves propagating through the earth. This could be accomplished by setting up a generator at one location on earth and a receiver at a location directly opposite the transmitter. The graviton hypothesis could be tested directly by generating extremely low frequency isotropic electromagnetic radiation in a large cavity and see if two small bodies suspended side-by-side gravitate towards each other once the power is turned on.

The vast majority of the gravitons that carry the force of gravity reside in free space and are present in the highest concentration in space that is far from the presence of material bodies. The concentration of gravitons is depleted in regions where gravitational acceleration can be detected. It is possible that the resulting distribution of gravitons near the surface of the earth due to the shielding by the sun can be detected. If differential pushing by gravitons on the baryons in the effective volume is the mechanism of universal gravitation, it should be possible to measure the difference in the net pushing force on a detector at noon when the earth is at perihelion and the net pushing force at midnight when the earth is at aphelion (Fig. 5). Due to shielding of gravitons, there should be fewer gravitons coming from the direction of the sun at noon when the earth is at perihelion, than from the direction of free space at midnight when the earth is at aphelion. Of course, the effect of the proposed difference due to an asymmetrical distribution of gravitons would not be any different than a detectable effect caused by the warpage of space-time. The detection of differences in the graviton flux density only provides evidence for a reasonable alternative to the general theory of relativity for the low velocity, weak field regime. It may also be possible to detect differences in the graviton flux density in the high velocity, strong field regime created by orbiting black holes.

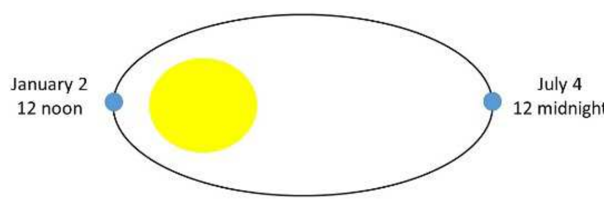

Fig. 5: The concentration of gravitons is depleted in regions where the gravitational force is evident. It is possible that the difference in the distribution of gravitons on the surface of the earth due to the shielding by the sun can be detected. If differential pushing by gravitons on baryons is the mechanism of universal gravitation, it may be possible to measure the difference in the net pushing force on a detector at noon when the earth is at perihelion and the net

pushing force at midnight when the earth is at aphelion. A detectable difference caused by an asymmetrical distribution of gravitons would not be different from a difference caused by the warpage of space-time, but it would just provide an alternative explanation.

Abbott et al. [37], using a Laser Interferometer Gravitational-wave Observatory (LIGO), discovered gravitational waves with frequencies between 35 and 250 Hz that were consistent with the hypothesis that the gravitational waves were produced by an spiraling binary system composed of a black hole[2] with 36 solar masses and a black hole with 29 solar masses. Abbott et al. [37] consider the gravitational waves they detected to result from a rippling of the fabric of space-time itself.

There is another way to account for the detection of gravitational waves that does not posit a four-dimensional space-time continuum. It is possible that the two massive black holes orbiting around each other alternately created a time-varying window and shadow. The window would freely allow 100 Hz gravitons (Fig. 6, blue arrows) to reach the earth from a given direction and when the window closed due to the orbiting of the black holes, the shadow formed would reduce the number of 100 Hz gravitons that reached the earth from same direction. As the two black holes got closer and closer, the alternating pulses of gravitons would get closer and closer to each other giving a strobe light effect with the alternating "brightness" and "darkness" of gravitons as the two black holes become one. Once the two black holes became one, the time-varying window would close and the time-varying signal would stop.

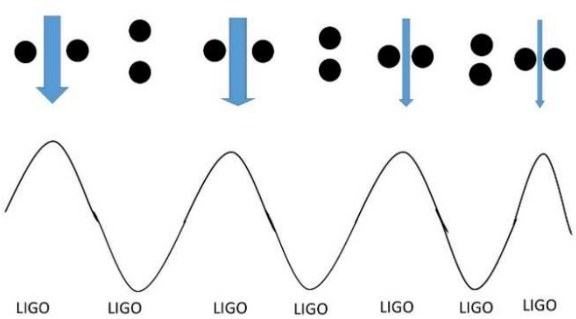

Fig. 6: A time sequence of two black holes orbiting around each other. During the inspiraling of two black holes, there will be sequence of pulses resulting from a pulse of gravitons that reach the earth after passing between the two black holes followed by a dearth of gravitons reaching the earth as a result of the shielding caused by the black holes. The pulses of gravitons would be detected by the Laser Interferometer Gravitational-wave Observatory (LIGO).

If gravitons are ubiquitous and uniformly-distributed throughout the cosmos, they could only be detected when their symmetrical distribution is broken by matter and they are no longer uniformly distributed in Euclidean space and Newtonian time. The LIGO detector can detect a strain amplitude of 10^{-21}, which would require gravitational radiation with an energy density (u) of 1.34×10^{-11} J/m^3 [53], a gravitational irradiance $(I = u\frac{c}{4})$ of 1.01×10^{-3} J m^{-2} s^{-1}, and a radiation pressure $(p = \frac{u}{3})$ of 4.47×10^{-12} N/m^2. If the energy of a graviton were 6.63×10^{-32} J, the detectable energy density would represent 2.02×10^{20} gravitons per cubic meter and the detectable graviton flux density would be 1.52×10^{28} gravitons m^{-2} s^{-1}. If the graviton flux density decreased with the inverse square of the distance, the graviton flux density at the site of the two black holes would be enormous.

While photons are spin-1 particles, gravitons are usually considered to be spin-2 particles since the gravitational force is thought only to be attractive. However, previously I have suggested a charge-parity-mass (CPM) symmetry as an alternative to charge-parity-time (CPT) symmetry that states that if time is unidirectional and irreversible, and matter is considered to have a positive mass and antimatter is considered to have a negative mass, then the gravitational force acting in Euclidean space and Newtonian time may be either attractive or repulsive [54-57]. If this is so, then the graviton would be expected to be a spin-1 particle just like the photon. Thus the gravitational force and the electromagnetic force would be similar and gravitons would differ from photons only in their wavelength. The gravitons with their very long wavelengths would interact with baryons, and the photons with their much shorter wavelengths would interact with leptons. The fact that the carriers of the electromagnetic force and the carriers of the gravitational force both exert mechanical force [18, 58, 59] and both obey the inverse square law would be understandable. Maxwell [23], Thomson [24] and Poincaré [33] worried that the gravitational pushing mechanism would cause a celestial body to become white hot. However, if the total energy of a graviton is more than a billion times less than the total energy of a thermal photon with a wavelength of 10^{-4} m $(E =$

[2] I do not consider black holes to be massive bodies that twist space-time but massive stars whose emitted light is red-shifted out of the visible range as a result of it propagating against the massive gravitational force produced by massive stars [4, 5].

$\frac{hc}{\lambda_{thermal}} = 1.99 \times 10^{-21}$ J), then, even if we postulate nonlinear events, the incineration hypothesis becomes unlikely.

The question arises as to whether the gravitons lose energy over time as they get scattered by matter. In previous publications I have interpreted exotic entities such as dark matter and dark energy in terms of known entities, such as antimatter [56] and photons [57]. I have suggested that antimatter has a negative mass and as such acts as an absorber of thermal energy just as matter at the same temperature acts as an emitter. I have also characterized the gravitational behavior of antimatter based on it having a negative mass. By combining the proposed thermodynamic and gravitational characteristics of antimatter, I have interpreted dark matter to be antimatter. The proposed absorption of thermal radiation from the cosmic microwave background by antimatter could in principle be reemitted as gravitational radiation, thereby replenishing the gravitational radiation in the cosmos that may be degraded by matter.

3. Historical and Philosophical Discussion of Le Sage's Hypothesis

Solomon wrote in Ecclesiastes 1:9, "*What has been will be again, what has been done will be done again; there is nothing new under the sun*." The hypothesis presented here is in essence a blossoming of the fruitful idea put forth centuries ago by the Swiss natural philosophers Nicolas Fatio de Duillier [60], Gabriel Cramer [61] Georges-Louis Le Sage [8,62,63] that provide a mechanical mechanism to explain Newton's law of universal gravitation. The three theories, which are essentially the same [24, 64-66], substitute mechanical contact for action at a distance. There is no disagreement that the mechanical hypothesis is capable of explaining Newton's law of universal gravitation—but is it the best explanation or should it be relegated to the trash bin containing fantastical ideas such as phlogiston, caloric and phrenology? According to Laudan [67], the mechanical hypothesis has been subjected to a steady stream of abuse and was dismissed as mere hypothesis at a time when great scientists, such as Isaac Newton, were thought to "*frame no hypotheses*." However, Newton [6], who framed many hypotheses throughout his career, did not use the statement "*frame no hypotheses*" as a general proposition of philosophical reasoning but only as a specific statement regarding the mechanism of gravitational attraction. Nevertheless, Le Sage was ridiculed for framing a hypothesis concerning the mechanism of gravitational attraction. Thus Le Sage's hypothesis was initially dismissed for epistemological reasons by Newton's acolytes solely because it was a hypothesis [67]. James Clerk Maxwell [23] knowing full well that there is no royal road to science wrote tongue-in-cheek that, Le Sage's hypothesis "*seems to be a path leading towards an explanation of the law of gravitation, which, if it can be shown to be in other respects consistent with facts, may turn out to be a royal road into the very arcana of science*." After I discuss the marginalization of Le Sage's hypothesis for epistemological reasons, I will discuss the facts presented by many eminent physicists that seem at first blush to challenge the hypothesis but become immaterial after further deliberation.

Today, Le Sage's hypothesis [63] is at once difficult to read because it is presented in terms of reshaping the Epicurean atomistic philosophy that was based on a flat earth and, it is easy to picture because it is based on a modern view of quantized entities that transfer linear momentum. In order for the reader of *The African Review of Physics* to get a readily accessible and true understanding of Le Sage's hypothesis and the atmosphere in which his hypothesis was considered, I am going to quote a long passage written by Thomas Thomson [68], which was published in the *Annals of Philosophy* in 1818.

"*Although Le Sage did not publish any connected or complete view of his theory, yet it has been brought forward, in a more or less perfect form, by his friends or pupils. Its great object was to give a mechanical explanation of the cause of gravity, or physical attraction, and to refer all the phenomena to the effect of impulse. When Newton had explained the laws of the system of the world by attraction, he was aware that there might be some mechanical cause for attraction itself; but neither he nor any of his contemporaries or pupils were able to reveal the mystery. Indeed for some time the attempt was entirely abandoned, either as hopeless, or as useless; and no theory that had been offered on the subject was regarded as of any value, when Le Sage undertook to solve the problem, and devoted all his energy, and a large portion of his life, to the attempt. The agents which produce these grand effects are styled by our author gravific corpuscles, or atoms; and it must be admitted that if we once allow for their existence, and conceive then to possess the properties that he assigned to them, the actual phenomena of attraction and gravitation must be the necessary result. These atoms, which are supposed to be indefinitely small, traverse through space in all directions, each atom moving in a straight line in a* *determined direction, and with a velocity much superior to that of light. The directions of these atoms are various, and their velocity is so great, that although they follow at an immense distance from each other, so that space may be considered almost as a vacuum, yet they abound everywhere. To comprehend this apparent paradox, we must bear in mind that the atoms pass through every point of space in all directions in an indefinitely short interval of time; so that every point may be regarded as the centre of an innumerable assemblage of atoms, both converging and diverging; or we may conceive that, at every instant, a multitude of atoms arrive at this point from all parts of space, and that, at the same instant, a number of atoms pass from it to all parts, in every possible direction. Having formed to ourselves this idea of a gravific fluid, let us now conceive a solid body immersed in it, bounded by convex surfaces, or by projecting angles, and much larger than an atom of the fluid. This body will remain immovable, or, at least, it will not be urged by any constant motion; it can only be tossed about by the inequality of the currents, so as to make regular oscillations. But if we now immerse into the fluid a second body, at some distance from the first, the two bodies will approach each other. For one will now serve as a kind of guard, or skreen to the other; and the opposite currents, having no antagonists, become positive in their operations upon the bodies, and produce a constant motion in them towards each other. And we shall find, by considering the circumstances under which these bodies are placed, and the supposed nature of the fluid, that this motion must be uniformly accelerated, and in the inverse ratio of the square of the distance, as all the forces which are conceived to depend upon Newtonian attraction.*

If bodies were all equal in the quantity of matter which they contained, or if the quantity of matter was always in proportion to their bulk, their attraction would be in the same proportion. The quantities of matter are, however, unequal in proportion to their bulk; and if we suppose that the gravific fluid can pass through the pores of the bodies, and that it is only stopped by the actual particles which they contain, we shall find that a body must always intercept a number of the atoms exactly in proportion to the number of its particles, or that the attraction of bodies must be in proportion to the quantity of matter which they contain. Hence we arrive at the explanation of the great law, that its power with which bodies attract each other, or to use Le Sage's expression, with which they are impelled towards each other, is in the direct ratio of the quantity of matter, and the inverse ratio of the distance. This may be regarded as the essential fact of Le Sage's theory, the base upon which he attempted to erect the grand edifice, and the master key with which he proposed to unlock the secret recesses of nature's operations."

The author then begins to analyze Le Sage's hypothesis in the way that any scientific hypothesis should be analyzed: "*In considering any theory of this description, the first question that we ought to ask is, whether we have any actual evidence of its truth; whether there be any positive fact, or any independent phenomenon, which can really lead us to conclude that this gravific fluid exists? To this question we are obliged to answer in the negative; it is not the object of any of our senses, and, in short, there is nothing which in any way indicates its presence, or announces its existence. We are then to regard it simply as a hypothetical body, called in to explain a set of phenomena; and here, then, two new questions present themselves: Does it explain all the phenomena? And does it in any degree tend to generalize them, or to reduce them to a form which is more consonant to the ordinary operations of nature? If it fail in the first of these respects, it is palpably false; if in the second, it is useless. As far as we are able to judge of the theory, it will be found to be correct in all its applications, and, therefore, it is not to be rejected on the first account; but the question of utility is, perhaps, more doubtful. On the subject of generalization there are two main points which Le Sage professes to have accomplished; first, to reduce all the motions of attraction and repulsion to the influence of one agent, or to show that they are exactly reducible to the same laws; and, secondly, to prove that all motion, of whatever kind, is merely a mode of impulse. Of the existence of the communication of motion by impulse, we have innumerable examples always before our eyes; we also see frequent instances of what we call attraction; but it is supposed that this latter is a more incomprehensible operation than the former, and one with which we are less familiar and less able to trace the steps by which it is produced. So far, therefore, Le Sage's theory may be useful, and so far it seems to advance us a step nearer to the ultimate object of all our researches.*"

However, the author concludes that Le Sage's hypothesis, like any other speculation, has no utility: "*It must, however, be acknowledged, that there are, on the contrary, some considerations which lead us to doubt the utility of all speculations of this kind. And, in the first place, it is a circumstance of no small import to the makers of systems, that no theory which proceeds upon the assumption of any* *imaginary agent, like the gravific atoms of Le Sage, has ultimately kept its ground, however ingenious they may have appeared, and whatever applause such speculations may have obtained from contemporary writers, they have ultimately fallen into oblivion, or have only been remembered as appendages to the other productions of their respective authors. So far indeed from adding to their celebrity, they generally operate in the directly contrary manner, they are tolerated rather than admired and we view them with regret, as a melancholy misapplication of labour and genius. And, if we apply these reflections to the subject of our memoir, when we consider what a large portion of his intellectual existence was spent on the construction of this system, when we estimate the number of hours and days which he devoted to it, and inquire what is the result, compared to what might have been accomplished by the same expenditure of time and labour, had he devoted them to the direct advancement of either mathematical or experimental science, we cannot but regret the choice which he made. It may be further observed that the influence of such systems is often very unfavourable on the state of science, at least on the minds of many of those who cultivate it. They are too apt to mistake the nature of the advantage which alone ought to be expected from these speculations: they do not regard them as the means of acquiring knowledge; as affording a commodious nomenclature, which may enable us to express our ideas with greater clearness; or as a species of algebraic notation, by which we may designate these ideas in a precise manner, where, however, there is no natural resemblance or relation between the idea and the mode of expressing it, but they suppose them to be an actual detail of facts; they reason concerning the atoms, and ethers, and subtile fluids, as if they were real existences, and build upon a thousand whimsical notions, which never entered into the contemplation of their original framers. We are therefore inclined to doubt whether any real benefit would be conferred upon philosophy by any further elucidation, or illustration, of Le Sage's theory of gravity that it has hitherto received from his friends or pupils. It is treading upon a kind of enchanted ground, where we have at all times to maintain a constant struggle between the imagination and the judgment, a contest in which the latter is too apt to be finally vanquished.* "

The idea that hypotheses are useless unless they can be generalized to other phenomena besides that which generated the hypothesis was codified by John Herschel [69] in his *A Preliminary Discourse on the Study of Natural Philosophy* and William Whewell [70] in his *Philosophy of the Inductive Sciences.* Herschel wrote that even if a hypothesis can explain known phenomena, it cannot be accepted until it succeeds "*in extending its application to cases not originally contemplated*" and Whewell wrote that, "*The hypotheses which we accept ought to explain phenomena which we have observed. But they ought to do more than this: our hypotheses ought to foretel phenomena which have not yet been observed….*" Whewell went on to say "*the cases in which inductions from classes of facts altogether different have thus jumped together, belong to the best established theories which the history of science contains. And as I shall have occasion to refer to this peculiar feature in their evidence, I will take the liberty of describing it by a particular phrase; and will term it the Consilience of Inductions."* Until this year, Le Sage's hypothesis was only able to explain the known appearances of gravitational attraction. Here Le Sage's hypothesis is extended to explain gravitational effects observed by LIGO [37] that were "*not originally contemplated*" and were "*altogether different*" from the original gravitational phenomena used to establish Le Sage's hypothesis. Thus on the basis of epistemology, Le Sage's hypothesis is vindicated on epistemological grounds and we are reminded by John Stuart Mill [71] and Paul Feyerabend [72] of how important it is for a healthy science to ensure that nothing and no one is beyond question.

With the development of atomic theory, thermodynamics and the kinetic theory of gases in the nineteenth century, there was a resurgence of interest in Le Sage's hypothesis of gravitation because of the similarity between how gaseous atoms exert pressure and how the ultra-mundane corpuscles exert a gravitational force. William Thomson [24], who later became Lord Kelvin and Samuel Tolver Preston [19,20], a student of Ludwig Boltzmann, restated Le Sage's hypothesis of cage-like atoms and extremely small ultra-mundane corpuscles in terms of the concepts that characterize the kinetic theory of gases. That is, the interactions between the cage-like atoms that made up the heavy bodies and the extremely small ultra-mundane corpuscles as well as the interactions between the ultra-mundane corpuscles themselves were described in terms of indivisible atoms and mean free paths. The long mean free paths traveled by the ultra-mundane corpuscles outside the heavy body ensured the rectilinear propagation of these corpuscles and the shorter but still long mean free paths traveled by the ultra-mundane corpuscles within the heavy bodies ensured that only a small percentage of the ultra-mundane corpuscles would be intercepted by the indivisible atoms that made up the heavy body.

Thomson [24] concluded that all the suppositions of the laws of gravity, both sublunary and universal, could be deduced from Le Sage's hypothesis and the "*only imperfection of his theory is that which is inherent to every supposition of hard, indivisible atoms*."

Thomson [24], one of the founders of the second law of thermodynamics, realized that if "*the gravific corpuscles leave…with less energy than they had before collision, their effect must be to continually elevate the temperature throughout the whole mass. The energy which must be attributed to the gravific corpuscles is so enormously great, that this elevation of temperature would be sufficient to melt and evaporate any solid, great or small, in a fraction of a second of time*." Thomson [24] could solve this paradox by assuming that the gravific corpuscles were not mathematical points but were capable to carrying with them significant amounts of rotational and vibrational energy.

In an *Encyclopedia Britannica* article on the "Atom," Maxwell [23] wrote, "*The explanation of gravitation, therefore, falls to the ground if the corpuscles are like perfectly elastic spheres, and rebound with a velocity of separation equal to that of approach. If, on the other hand, they rebound with smaller velocity, the effect of attraction between the bodies will no doubt be produced, but then we have to find what becomes of the energy which the molecules have brought with them but have not carried away. If any appreciable fraction of this energy is communicated to the body in the form of heat, the amount of heat so generated would in a few seconds raise it, and in like manner the whole material universe, to a white heat.*" Discounting Thomson's gambit that the ultra-mundane corpuscles were more than a mathematical point and thus could carry away excess energy in their vibrational and rotational modes, Maxwell [23] could not find a solution to the heat paradox. He went on to say, "*We have devoted more space to this theory than it seems to deserve, because it is ingenious, and because it is the only theory of the cause of gravitation which has been so far developed as to be capable of being attacked and defended. It does not appear to us that it can account for the temperature of bodies remaining moderate while their atoms are exposed to the bombardment. The temperature of bodies must tend to approach that at which the average kinetic energy of a molecule of the body would be equal to the average kinetic energy of an ultra-mundane corpuscle.*"

As wave theories eclipsed corpuscular theories in describing many physical phenomena, J. J. Thomson [73], Charles Brush [1] and Thomas Tommasina [18] independently recast Le Sage's ultra-mundane corpuscles as ethereal waves. Henri Poincaré [32] considered the possibility that light-like waves played the part of the ultra-mundane corpuscles and dismissed Le Sage's hypothesis for the same reason Maxwell did—the heat paradox. Poincaré [32] deduced that the ultra-mundane corpuscles, if they existed, would cause the temperature of the earth to increase 10^{26} degrees per second—yet the temperature of the earth was relatively stable.

The ultra-mundane corpuscles are a source of energy and if the ultra-mundane corpuscles enter a heavy body with more energy than which they leave, one must question what happens to the difference in energy. Maxwell [23], J. J. Thomson [73] and Poincaré [32] assumed that it was converted into heat. Heat can be described as thermal energy with wavelengths in the infrared range when bodies are as hot as the sun and in the micrometer range when the bodies are as hot as the earth. If we consider the wavelength of heat to be 10^{-4} m, the energy of a thermal photon would be $E = \frac{hc}{\lambda_{thermal}} = 1.99 \times 10^{-21}$ J. Thermal wavelengths are substantially shorter and the thermal energies of the associated photons are substantially greater than the energy of the Le Sage-like gravitons postulated here that have wavelengths of about 3×10^{6} m and energies of about 6.6×10^{-32} J.

Given quantum theory, 30×10^{9} gravitons would have to be absorbed simultaneously in a nonlinear or "multi-graviton" process and totally transformed into heat to give rise to a single thermal photon. If we consider the ultra-mundane corpuscles to be gravitons distributed like black body electromagnetic radiation with a peak wavelength of 3×10^{6} m, then we can use Wien's displacement law to estimate the average temperature (T) of the gravitons to be:

$$T = \frac{2.8977729 \times 10^{-3} \text{m K}}{3 \times 10^{6}\ \text{m}} \approx 10^{-9}\ \text{K} \qquad (11)$$

Which, is about a trillion times less than the average temperature of a white hot body (≈ 6000 K) or the earth (≈ 300 K), ensuring that all the matter in the whole material universe is not at risk of incinerating!

This explains why Freeman Dyson [74] considered gravitational energy to have the highest merit. According to Dyson [74], "*The laws of thermodynamics decree that each quantity of energy has a characteristic quality called entropy associated with it…Gravitation carries no entropy and stands first in order of merit. It is for this reason that a hydroelectric power station converting the* *gravitational energy of water to electricity can have efficiency close to 100 percent, which no chemical or nuclear power station can approach.*"

In Le Sage's time, particles that carried a force were considered to be unobservable with occult properties and thus outsiders in a positivistic science that celebrated Newton's mathematical description of the world that was based on action at a distance. It seems to me that Le Sage was marginalized for being ahead of his time. Indeed it can be seen that as late as 1913, quantum force carriers were considered speculative as demonstrated in the letter in support of Albert Einstein's membership to the Prussian Academy of Sciences where Max Planck, Walther Nernst, Heinrich Rubens and Emil Warburg [75] wrote, "*That he may sometimes have missed the target in his speculations, as for example, in his hypothesis of light quanta, cannot really be held against him*." By 1921, following the detection of the double deflection of starlight, Einstein won the Nobel Prize [76] "*for his services to Theoretical Physics, and especially for his discovery of the law of the photoelectric effect*." Quantum force carriers were no longer beneath contempt.

It is instructive to compare and contrast long wavelength, low frequency quantized gravitational force carriers that act on baryons with short wavelength, high frequency quantized electromagnetic force carriers or photons that act on electrons. Firstly, a single energy quantum can interact with an electron and the energy quantum that interacts with the electron is highly energetic compared with the energy ($E = mc^2$) of the electron, which is a lepton with a small mass [77]. In general, electrons that absorb the high energy quanta radiate thermal quanta and heat up their surroundings [78]. By contrast, the energy quanta that interact with a baryon are not energetic at all compared with the energy ($E = mc^2$) of the heavy particles known as baryons [35] and many low energy quanta must interact with each baryon in order to accelerate it.

The two types of energy quanta are similar in that both can be considered in terms of their particle-like and wave-like characteristics and both types of energy quanta can be considered to provide mechanical contact forces that accelerate either baryons or electrons. It is thus possible to look at Le Sage's hypothesis as a generalization of the Compton effect[3] [79] where the interaction of the energy quanta with the appropriate material particle results in an acceleration of the particle and a coincident lengthening or Dopplerization of the wavelength of the energy quantum. Had the Compton effect been discovered before the double deflection of starlight became the *experimentum crucis* in favor of the general theory of relativity [4,5], Le Sage's hypothesis of quantized contact forces might have been generalized to explain the Compton effect. It is also possible that Le Sage's hypothesis might have been a contender in developing a quantum theory of gravity that had no need to try to be consistent with the general theory of relativity [80].

Le Sage's hypothesis was not only rejected because the ultra-mundane particles had not been observed but it was also rejected by James Croll [26] in 1878 based on the idea that "*it is a necessary condition of Le Sage's theory, in order that gravity may be proportional to mass, that the total volume of the free spaces in a substance in the form of interstices between the molecules must be great compared with the total volume of matter contained in the molecules themselves*." Le Sage [8] had to postulate that the ultra-mundane gravitational atoms traverse the bodies as freely "*as light passes through diamond and magnetic matter through gold* [and] *thus the number of atoms which are intercepted by the first layers of a heavy body would be absolutely insensible relatively to the number of those which pass through the last layers. Nevertheless, the relatively small number intercepted would produce a sensible action upon the body, since they have, in virtue of an immense velocity, the force of impact which they would lack by reason of their small mass*."

Croll [26] countered Le Sage's hypothesis by citing calculations done by William Thomson that "*the mean spaces between the molecules are therefore less than the diameter of the molecules themselves*." C. Coleridge Farr [28] voiced the same objection in 1898 as Croll had twenty years earlier. Had Le Sage's hypothesis that atoms consisted of mostly empty space been taken more seriously, it is possible that in 1911 Lord Rutherford would not have been surprised at the relative size of the atomic nucleus to the size of the atom—the ratio he described as the fly in the cathedral [81]. Again, I think that Le Sage was marginalized for being ahead of his time.

Another criticism against Le Sage's theory came when William Thomson [24,82] realized that the gravitational force was isotropic while much of matter is anisotropic and thus the gravitational force on matter should be anisotropic. However, since the anisotropy of matter depends on the electrons [83],

[3] Ironically, it was the demonstration of the Compton effect that led to the wide-scale acceptance of the photon as a quantized carrier of force and linear momentum [5].

not on the baryons, this criticism can be discounted when Le Sage's hypothesis is framed in terms of baryons, as it is here.

The final criticism against Le Sage's hypothesis is that if the ultra-mundane particles existed, they would provide a resistance to the orbital motion of the planets [23,24,34,84]. Such a resistance caused by sunlight [3] and supplemented by gravitons may explain the precession of the perihelion of Mercury that was discovered by Urbain Le Verrier [85] and characterized more accurately by Simon Newcomb [86]. Le Sage already realized that the resistance provided by the ultra-mundane corpuscles would depend on the ratio of the orbital velocity of the planets to the velocity of the ultra-mundane corpuscles. To Pierre-Simon Laplace [84], this meant that, in order to be consistent with astronomical observations, the velocity of ultra-mundane corpuscles would have to be seven million times greater than the speed of light. By assuming that the resistance is proportional to the square of the ratio of the orbital velocity of the planets to the velocity of the ultra-mundane particles and not to the ratio itself, Laplace would have concluded that the speed of light and gravity were the same—a very modern assumption.

By framing Le Sage's hypothesis in terms of long wavelength, low frequency quantized electromagnetic quanta known as gravitons as a substitute of ultra-mundane corpuscles and baryons as a replacement for cage-like atoms with which the gravitons interact, the criticisms against Le Sage's hypothesis have been overcome and weight and gravitational acceleration can be understood in terms of Euclidean space and Newtonian time—a commonsense alternative to the general theory of relativity.

4. Conclusion

The hypothesis presented here is admittedly incomplete although I hope that it does contain some germs of truth in describing gravity in terms on Euclidean space and Newtonian time. The hypothesis requires: 1) the transfer of linear momentum from gravitons, which are the quantization of long wavelength, low frequency electromagnetic waves, to the nuclear baryons of matter; 2) the introduction of asymmetry in the transfer of linear momentum from gravitons to matter as a consequence of the scattering of low frequency electromagnetic waves by the baryons in the effective volume of gravitating bodies; and 3) a pushing force that is caused by gravitons asymmetrically pushing on the baryons in the effective volume of the gravitating bodies. By looking at gravitating bodies as having extension in the same way I look at photons as having extension [5], and by looking at the pushing force of gravitons on baryons in the same way as I look at the pushing force of photons on electrons [87], I have modified the Le Sage-Brush-Tommasina hypothesis to explain the acceleration of massive bodies towards each other in Euclidean space and Newtonian time. If we accept the modified Le Sage-Brush-Tommasina hypothesis to include long wavelength electromagnetic quantized particles, we can also understand why Newton's law of universal gravitation and Coulomb's law of electricity have the same mathematical form. The gravitational waves recently observed by LIGO[4], which are considered to be ripples in the fabric of space-time itself, can be interpreted to be pulses of gravitons that arrive on earth through a shutter made of rotating massive stars known as black holes that function as a chopper for gravitational radiation.

Two centuries ago, the Edinburgh Review [88] published the following statement concerning the cause of gravitation: "*The result of all this is, to throw considerable uncertainty over all our speculations concerning the cause of gravitation, and, what is more, concerning the essence of body, and the substratum in which its properties are conceived to be united. To know the laws of phenomena of body, is all that science has yet attained with certainty,—perhaps is all that it is ever destined to attain. What lies beyond that point, may exercise the ingenuity, and amuse the fancy of speculative men; but whether it will lead to more substantial acquisitions, must be left for futurity to determine. In the mean time, the objects to be aimed at are, to leave the matter open to inquiry; to abstain from dogmatizing; and to avoid whatever can narrow the field of philosophical investigation.*" Today's science should be no different.[5]

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