An Experimental Gravimetric Result for the Revival of Corpuscular Theory

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Abstract

Gravity measurements made in the Montreal area during the solar eclipse of 10 May 1994 show a weakening in the soli-lunar attraction at the time of the occultation. This gravitational anomaly of the eclipse seems to be explainable only within the framework of a corpuscular theory of gravitation. Calculations from two independent phenomena, the gravitational anomaly of the eclipse and the advance of the perihelion of the planets, lead to a satisfactory concordance of the attenuation of gravity through matter. In this study a quantitative connection is established between gravitation and the interaction of neutrinos with matter.

Key words: corpuscular theory, Newton's law, gravitation, solar eclipse, graviton, neutrino, interaction cross section, advance of perihelion, gravity anomaly

1. THE GRAVITATIONAL PHENOMENON AND THE CORPUSCULAR THEORY

The Newton theory and the Einstein theory of gravitation are founded, first of all, on mathematical considerations. One is based on an attraction law that molds itself on the results; the other is based on a geometric structural law where the Aristotelian notion of up and down is redefined in a modern mathematical language. For our modern gravity theory we are offered a mathematical universe where matter "alters" space and time. Without any real hope of being able to understand the nature or the cause of the interaction between matter and space and since the time is nothing other than the relativity of movement, we have the right to ask ourselves if the truth is not somewhere else.

Without falling into speculation, Newton mentions the explicative limits of his attraction law with these words: "That one body may act upon another at a distance through vacuum without the mediation of anything else is to me so great an absurdity that I believe that no man, who has in philosophical matters a competent faculty for thinking, can ever fall into it." A body acting at a distance certainly meant for him an influence by means of "something." Within the principle of inertia, fundamental in physics, two isolated bodies not acting on one another and on which no "forces" act stay in relative rest or keep the same relative velocity. The movement of a body can only be altered by the interaction of another body whose movement will in turn be altered (the action equals the reaction). It ensues that matter and the movement of matter are preserved. In concrete terms the notion of force is directly related to the action of a body onto another, and starting from this concept, it is easy to imagine that an accelerated body (gravitational acceleration) is in interaction with this "something" implicitly referred to by Newton (another undetectable body?). Could the gravitational acceleration imply the action of another body — of corpuscles? How can we explain attraction, when the shock of a body on another is a push and not an attraction? The objective explanation of a simple and understandable way of action is contained in a corpuscular theory formulated by Lesage in the middle of the 18th century.(1) This theory assumes that "in outer space, minute corpuscles circulate in all directions with great speeds. An isolated body will not be affected in its motion by the impacts of these corpuscles, as these impacts act in all directions. But if two bodies *A* and *B* are brought together, the *B* body will act as a screen and will intercept a part of the corpuscles, thus preventing some corpuscles from hitting *A*. Impacts received by *A* in the opposite direction of *B* will just be partially compensated and will push *A* to *B*" (Fig. 1).

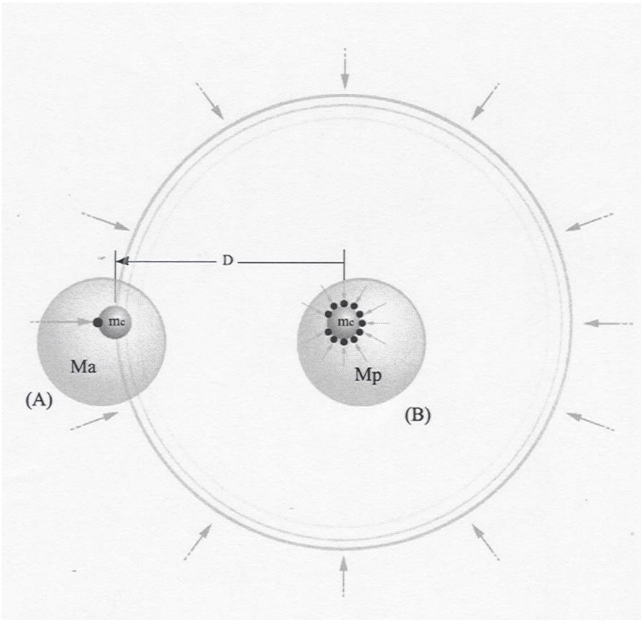

Figure 1. A body (B) of mass M_p, near a body (A) of mass M_a, is exposed to an unbalanced pushing by the gravitons. This figure represents the interaction between two constituents m_c having an interaction cross section σ and at distance D apart. (In fact, D is very large compared to σ, and m_c is the mass of a subquantum constituent in this interaction mechanism.)

This reasoning is not without its difficulties, but it is all the more interesting because it does not suppose new principles and tries to explain the mechanism that could lie behind the law of attraction. With respect to the laws of inertia, the gravitational phenomenon becomes the consequence of the interaction between the "palpable" matter of a body and the "undetectable" one of the corpuscular medium. The apparent attraction of a body onto another could result from neither a fictive force of attraction nor a geometrical alteration of space, but could be caused by the push (unbalanced action) of the corpuscular medium affected by the presence of the two bodies.

With a modern vision and knowledge of the internal structure of matter, the corpuscular model becomes clear. We are no longer referring to the action of corpuscles at the atomic level, as was interpreted by Poincaré,[(2)] but to an interaction at a more inward structural level of matter, presumably at the level of penetration and interaction of neutrinos. The capacity of penetration of matter by minute neutral particles was not known in Poincaré's times and on that basis he himself argued strongly against the corpuscular theory. With neutrinos, we know that the degree of penetration required by the corpuscular theory exists. This old concept is still, to this day, the more concrete explanation of what can be the true nature of the gravitational phenomenon. In this study the corpuscular theory has been developed on a quantitative basis in order to be compared with the experimental facts and actual data.

1.1 Calculation of the Gravitational Law

We set the basis of a theoretical description by simply assuming that the gravitational corpuscles, which we call gravitons, transfer their momentum to matter by absorption. In order to obtain an attraction effect, it is required that the impacts be partially inelastic. The simplest way is to consider that the absorption happens for each collision with the constituents of elementary particles (subquantum constituents) and that these "absorbing" constituents have a mass m_c and an interaction cross section σ with the gravitons.

The flux of impulsion (balanced flux) that reaches an absorbing constituent can be defined by

$$\vec{I}_o = \frac{\sum m_g \vec{v}_g / dt}{m_c}, \tag{1}$$

where m_g and v_g are respectively the mean mass and velocity of the gravitons coming from all directions and absorbed in m_c during the time interval dt. In this relation, where I_o has the dimensions of acceleration, we assume that the total mass of the absorbed gravitons per unit of time is insignificant compared to m_c; then $\sum m_g/dt << m_c$. Let's consider a body of "active" mass M_a at a distance D from another body of "passive" mass M_p. A constituent of M_p absorbs all the flux centered on it; thus it undergoes a set of impulsions under the effect of the impacts of the gravitons (Fig. 1). In the absence of M_a the global effect is nil ($\vec{I}_o = 0$) because the vectorial sum of the impulsions is nil, the impacts being uniformly distributed around m_c.

In the presence of an active mass M_a the global flux $\vec{I}_o$, susceptible to reach an absorbing constituent of M_p, will first be affected by the absorbing constituents of M_a. Each element of M_a at a distance D from M_p will produce a reduction $\sigma(\vec{I}_o/4\pi D^2)$ of the flux $\vec{I}_o$ directed toward a constituent m_c of M_p. Using $\vec{I}_o/(4\pi D^2)$, we are defining for all points of the sphere of radius D the surface density of the flux centered on the "passive" constituent. We can easily conceive that σ is a tiny point on this sphere. Thus the acceleration on M_p (or on each of its "passive" constituents m_c), because of the influence on the corpuscular medium of the (M_a/m_c) “active” constituents, sufficiently distant and grouped to be regarded as concentrated in one point at a distance D, will be

$$\vec{g} = -\left(\sigma \frac{\vec{I}_o}{4\pi D^2}\right)\left(\frac{M_a}{m_c}\right),$$

or, by reorganizing the terms of the expression,

$$\vec{g} = \left(\frac{-\vec{I}_o}{4\pi}\frac{\sigma}{m_c}\right)\left(\frac{M_a}{D^2}\right). \tag{2}$$

The influence of M_a on M_p being a subtracting effect to the external flux, the induced acceleration g is a vector directed toward M_a. The expression (2) is equivalent to Newton’s law, where the universal gravitational constant is

$$G = \left(\frac{I_o}{4\pi}\frac{\sigma}{m_c}\right). \tag{3}$$

In our relation G is proportional to the interaction cross section per mass unit for the gravitational interactions and is proportional to the density of the corpuscular flux intercepted by the active mass on its path to M_p.

1.2 Gravitational Attenuation and the Correction to Newton’s Law

By assuming that the subquantum constituents act independently, we have developed, in the previous section, a law of attraction in the inverse ratio to the squared distance. In fact, in the case of a very large mass, like the Sun, any part of the mass intercepts a flux already weakened by the presence of the others. In this case the effect of gravity will depend on the residual flux passing through the “active” constituent. The cumulative absorption that reduces more or less the density of the flux at the level of an “active” constituent, consequently the effective value of G, will bring a correction to the gravitational attraction law given by the relation (2).

Let’s take an element of mass dM contained in the solid angle $d\beta$ and located at a distance L from M_p; then we have $dM = \rho(\pi/4)L^2\, d\beta^2\, dL$, where ρ is the density of dM (see Fig. 2, where M_p is identified with a test particle, or with the center of mass of a planet). The number of “active” constituents in dM is dM/m_c. In order to find f, the attenuation of the flux due to dM,

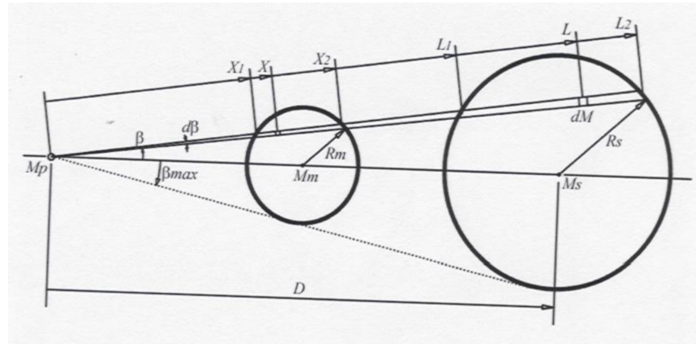

Figure 2. Geometric mapping of mass elements of the Moon and the Sun relative to a test particle at M_p. The points M_m and M_S correspond respectively to the mass centers of the Moon and the Sun.

we divide A, the sum of the cross sections of constituents, by S, the total surface of the incident flux, with $A = (dM/m_c)\sigma$ and $S = (\pi/4)L^2 d\beta^2$. We have after reduction

$$f = K\rho dL, \tag{4}$$

where K is the interaction cross section per mass unit for the gravitons:

$$K = \frac{\sigma}{m_c}. \tag{5}$$

For each mass element of the Sun (dM), if we know the fraction P of the flux I_o absorbed beforehand by the other mass elements located between L and L_2, then the effective attenuation relative to the flux I_o, in the considered direction, will be

$$f_r = f(1-P). \tag{6}$$

P is given by the sum of the f_r’s from the mass elements situated between L and L_2; then

$$P = \int_0^{L_2-L} f_r. \tag{7}$$

By combining (4), (6), and (7), we get

$$P = \int_0^{L_2-L} K\rho(1-P)dL, \tag{8}$$

which has for solution, supposing a uniform density,

$$(1-P) = e^{-K\rho(L_2-L)}. \qquad (9)$$

This last relation gives the necessary correction to obtain the residual flux I at the level of "active" dM constituents. The correction depends on the density ρ and the thickness ($L_2 - L$) of matter in which the exterior flux is passing through to the path to reach dM; it is applied relative to the flux directed at the passive mass (the test particle). The gravitational influence of dM will be reduced proportionally to the reduction of the flux. The relation (9) characterizes the attenuation of the corpuscular flux through matter. With a large "mass," like the Sun, we must account for the attenuation in the gravitational attraction calculations. Thus to obtain the Sun's attraction on a test particle we must calculate the sum of the gravitational effects of each mass element by multiplying G by $e^{-K\rho(L_2-L)}$, whose value depends on the position and the distribution of the solar matter relative to the test particle. The correcting term used in this study is only a first approximation, as it is based on the supposition of uniform density for the Sun and the Moon. For a rigorous calculation of the attenuation effect we should account for the variation of density using a solar model.

2. CORRECTION APPLIED TO THE ADVANCE OF THE PERIHELION OF THE PLANETS

Evaluating, in Fig. 2, the value that ($L_2 - L$) can have for any mass element dM, we find that this value becomes greater when M_p moves away from M_s. Consequently, the value taken by $Ge^{-K\rho(L_2-L)}$ will decrease when a test particle moves from the perihelion to the aphelion. This cumulative absorption effect on a Sun's mass element will produce a reduction of the attraction, with the distance slightly greater than the one predicted by the attraction in $1/r^2$. This result brings a correction that is in qualitative agreement with an advance of the perihelion of the planets. Before we rehabilitate the corpuscular theory, the decisive test that must be done is to verify if it can also take quantitative account of the advance of the perihelion of planets.

2.1 Calculation of the Interaction Cross Section *K*

The calculations to find the constant K are based on the experimental value of the advance of the perihelion of Mercury. In order to simplify our calculations and to compare our results of the corpuscular theory with Einstein's theory of gravitation, we have simply used an analogy. It is possible to absorb in G the corrections brought by the corpuscular theory or Einstein's theory of gravitation; so they were compared on the basis of an equivalent effect, the one caused by a linear variation of the gravitational "constant" G between the perihelion and aphelion of Mercury. If the variations of G with both theories are the same, it is logical to suppose that the effects on the advance of the perihelion will be the same. We can show that the linear approximation is acceptable between these two orbital positions.

In the following calculations we will use Newton's law with the correcting term for attenuation. For this first estimation of K we have used a uniform density for the Sun. Let's take dM, an annular portion of solar matter identified in Fig. 2 by its coordinates L and β. This solar matter is at an equal distance L from M_p, produces an effective component of attraction proportional to $\cos\beta$, and is affected by the same attenuation $e^{-K\rho(L_2-L)}$. To calculate the solar attraction we have to evaluate the thickness ($L_2 - L$) of crossed matter up to dM in the direction of the flux passing through dM and M_p. The point M_p is identified with the center of mass of the planet (see Fig. 2). The acceleration of M_p, due to the Sun, is found by adding the gravitational actions of all dM elements. The corrected law of attraction is

$$g = \int_0^{\beta_{\max}} \int_{L_1}^{L_2} \left[G\rho 2\pi L^2 \sin(\beta)\cos(\beta) \times \frac{1}{L^2} e^{-K\rho(L_2-L)} dL d\beta \right], \qquad (10)$$

where L is the distance between dM and M_p. The values L_1, L_2, and β_{max} are functions of β, R_s, and D (R_s is the solar radius and D is the distance between M_p and the center of the Sun). The acceleration without the attenuation effect (Newton's law) is

$$g_n = \int_0^{\beta_{\max}} \int_{L_1}^{L_2} \left[G\rho 2\pi L^2 \sin(\beta)\cos(\beta) \times \frac{1}{L^2} dL d\beta \right], \qquad (11)$$

which is equivalent to $g_n = GM_s/D^2$ for a spherical mass such as the Sun.

The variation ΔG of the gravitational "constant" between the perihelion and the aphelion caused by the attenuation effect will be

$$\Delta G = \frac{(g_p)D_p^2 - (g_{pa})D_p^2}{M_s}, \tag{12}$$

where g_p was calculated, with relation (10), for the distance D_p corresponding to the perihelion of Mercury and g_{pa} was obtained by changing, in the same relation, the attenuation values of the perihelion by those of the aphelion. The local attenuation effects in relation (10) prevent us from regarding g as a central force, so, in this manner, we may calculate the mean variation of G from the same solar distance, that of the perihelion. In general, we calculate ΔG by calculating the difference, for the same orbital distance, between the mean values of G with the attenuation of perihelion and aphelion. Whether we proceed from the perihelion or the aphelion, the computed values differ by less than 0.3%. We may assume that this calculation method is acceptable.

Einstein's correction $3GM_S/(c^2D^2)$ to study the path of a test particle in a Schwarzschild field[(3)] is also evaluated in comparison to a variation ΔG of the gravitational "constant" that it would introduce between the perihelion and the aphelion of a planet. Then, absorbing this term into G, we have

$$\Delta G = \frac{12G^2M_s}{c^2}\frac{e}{a(1-e^2)}, \tag{13}$$

where c is the speed of light, M_S is the mass of the Sun, e is the orbit eccentricity, and a is the orbit's semimajor axis.

Equalizing (12) and (13) for Mercury, we get through numerical calculation an interaction cross section

$$K = 3.25\times10^{-17}\ \text{m}^2/\text{kg}. \tag{14}$$

To evaluate K in a more rigorous manner we have to extract the correction term due to the attenuation (10) and to use the demonstration in Ref. 3 to find the advance of the perihelion of Mercury. The previous, simpler, method has been adopted in the present study.

This value of K, at first sight, strictly proportional to the mass, corresponds to a cross section of 5×10^{-40} cm^2/nucleon and 3×10^{-43} cm^2/electron. It is an outstanding result, because without theoretical link with quantum mechanics, it falls precisely into the range of neutrino interaction with matter. In the literature one finds interaction cross sections in these orders of magnitude for neutrinos of a few tens of mega electron volts.

2.2 Calculation of the Advance of the Perihelion of the Planets

The value of K being found in (14), we can calculate the advance of the perihelion of the other planets using (10) to (12). Multiplying ΔG by $(\pi/(2Ge))$, we get the advance of the perihelion in radians per revolution.

Table I gives the advance of the perihelion in seconds of arc per century. The values calculated with the corpuscular theory are in good agreement with the experimental values of the advance of the perihelion of the planets.

Table I: Advance of the Perihelion of the Planets

Planet	*Einstein*[(3)]	*ΔΩ/Century* *Corpuscular*	*Experimental*[(3)]
Mercury	43.03″	43.11″	43.11″ ± 0.45″
Venus	8.64″	8.65″	8.4″ ± 4.8″
Earth	3.84″	3.84″	5.0″ ± 1.2″
Mars	1.35″	1.35″	Not available

The Einstein correction is additive and related to the central mass of the Sun, while the corpuscular correction is subtractive and related to each part of the Sun. The corrections to Newton's law being very different, it is curious to note that both theories give exactly the same results for the advance of the perihelion. We have made new calculations by adding the effects of two layers of homogeneous density: the first one is a core of $0.25R_s$ containing 40% of the solar mass and the second one is a peripheral envelope for the residual mass. This calculation, which is closer to the standard solar model, gives again the values of Table I, but with a value of K of approximately half. One can reasonably believe that precise calculation using the variation of the radial density of the solar model will give us a constant K not very far from 10^{-17} m^2/kg.

2.3 The Corrected Law and Celestial Mechanics

With the gravitational attenuation, we have to make a small correction of about 0.0024% to the estimated mass of the Sun. Using this correction, we find the Newtonian value of the solar gravity at 1 AU. The attenuation term in (10) modifies the curvature and causes a shift relative to Newton's law; then when we have coincidence of (10) and (11) at 1 AU, the corrected law gives a solar gravity value a little higher at greater distances. In that case the difference with Newton's law increases rapidly toward its asymptotical value and remains lower than one part per ten billion for all the planetary distances. The corpuscular theory therefore accounts for the advance of the perihelion of the planets without introducing a discordance with the celestial mechanics.

3. GRAVITATIONAL ANOMALY BY OCCULTATION

During an eclipse, when the Moon passes in front of the Sun, it stands in a cone of influence where the corpuscular flux directed toward the eclipse zone has been reduced by the Sun. Since the attraction effect of the Moon is proportional to the flux that it affects, by intercepting a reduced corpuscular beam, the Moon will have a smaller attraction influence on an observer in the eclipse zone. The phenomenon being combined with Earth's tide, a precise calculation of this time-dependent effect is quite complex. A weakening of the soli-lunar attraction during a solar eclipse causes a local increase of gravity that normally would be conducive to a positive anomaly.

The lunar attraction is evaluated by taking the average densities, ρ_m for the Moon and ρ for the Sun, and by assuming an exact cover of their apparent disks during the eclipse. These parameters of maximal occultation and of homogeneous density largely facilitate our calculations and allow us to evaluate the size of the phenomenon. The lunar attraction at the time of the maximum of eclipse is

$$g_{me} = \int_0^{\beta_{\max}} \int_{X_1}^{X_2} G[e^{-K\rho_m(X_2-X)}][e^{-K\rho(L_2-L_1)}] \times \rho_m 2\pi X^2 \sin\beta\cos\beta \frac{1}{X^2} dX d\beta, \tag{15}$$

where X, X_1, X_2, L_1, L_2, and $\beta_{\max}$ are shown in Fig. 4. The attraction without the Sun attenuation is

$$g_m = \int_0^{\beta_{\max}} \int_{X_1}^{X_2} G[e^{-K\rho_m(X_2-X)}]\rho_m 2\pi X^2 \times \sin\beta\cos\beta \frac{1}{X^2} dX d\beta. \tag{16}$$

The lunar attraction will therefore undergo a relative diminution equal to $(g_m - g_{me})/g_m$. A numerical calculation with (14), (15), and (16) gives a local reduction of 0.005% for the lunar attraction, and consequently its vertical component, during a total solar eclipse. The phenomenon passes across the planet, but decreases toward the penumbra zone, so we assume that one can neglect its effect on the global attraction of Earth.

4. THE SOLAR ECLIPSE OF 10 MAY 1994[4]

When the Moon and the Sun are above the horizon, their influence on gravity is negative relative to Earth's attraction. In fact, at that moment, the vertical action of these heavenly bodies, for a terrestrial observer, is directed upward and acts in the opposite direction to Earth's attraction. At the time of the maximal phase of solar eclipse of 10 May 1994, at 13:38, near Montreal, at latitude 45°30′.00N and longitude 73°30′.00W, the vertical component of the gravitational acceleration due to the Moon was estimated at –2.66 mgal. This value is given by $G(M_m/D^2)\sin\alpha$, where M_m is the lunar mass, D is the distance between the Moon and the test site, and α is the Moon altitude. The lunar altitude varies from 62.2° to 49.2° during the eclipse,[4,5] while the distance D changes very little; therefore the vertical component of the lunar attraction stays between –2.7 and –2.0 mgal.

The diurnal variation of gravity must normally be considered in gravity surveys, so the Geological Survey of Canada (GSC) supplies the tidal correction tables for geophysical prospecting. The measurements of 10 May 1994 were made by a geophysical firm specializing in microgravity surveys, using a LaCoste & Romberg gravity meter, model D, fixed on a permanent station. In these ideal conditions the type of gravity meter allows one to take relative measurements with an error of accuracy[6] as low as ±0.5 μgal. Figure 3 gives the variation of gravitational acceleration (relative values in milligals) as a function of the time of the measure. A sinusoidal function fits the values from the tide correction tables for Montreal (between 11 h and 16 h, local time) supplied by the GSC. The broken-line curve, adjusted on the first point, is the Earth tide corresponding to these corrections. The curve-fitting function

$$115.4835 + 0.1135(\sin(0.429 H_r - 0.75)),$$

where H_r is the local time, was applied to the experimental points obtained outside the eclipse period. This regression function of the relative value of gravity as a function of the local time should contribute to bringing out the discontinuity that could result from the occultation of the Sun by the Moon and should absorb the instrumental drift that shows a continuous variation in the time. The instrumental drift is appreciated by comparing the two regression curves. The regression curve (continuous line) was superimposed on the experimental points. The vertical

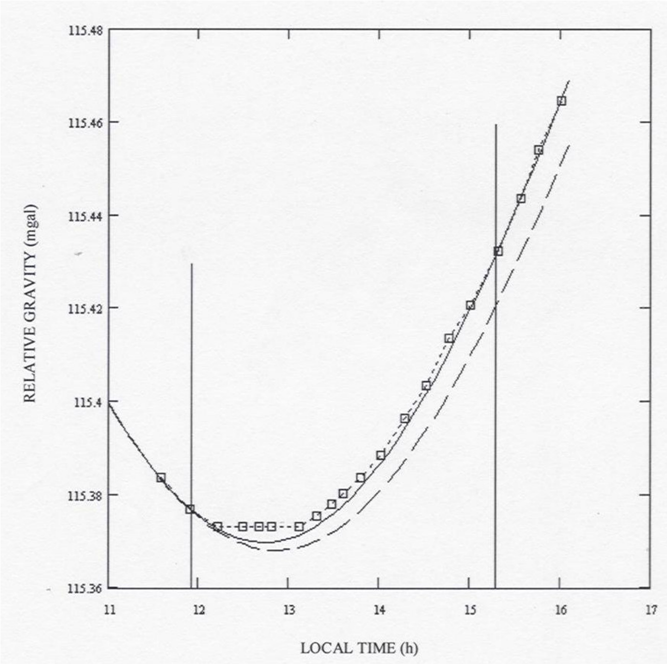

Figure 3. Relative values of gravity as a function of the local time during the annular solar eclipse of 10 May 1994, in Boucherville, Quebec, Canada. Vertical lines mark the start and the end of the visual eclipse. The solid line is the interpolation curve for the experimental measurements that fall outside the eclipse period. The broken-line curve corresponds to Earth's tide based on the correction tables of the GSC.

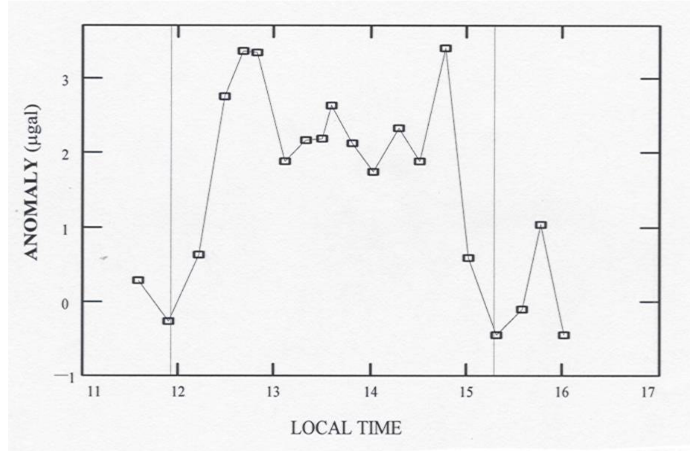

Figure 4. Gravitational anomaly of the annular eclipse of the Sun, 10 May 1994, in Boucherville, Quebec, Canada. The dots represent the difference, in microgals, between the experimental values and those given by the regression function. The period of visual eclipse is delimited by the vertical lines.

lines show the beginning and the end of the visual eclipse. The experimental values clearly show an anomaly that coincides with the eclipse period.

Figure 4 gives the difference in microgals between the experimental values and those calculated with the regression function. The estimation standard error is lower than 0.6 µgal for the adjusted points. The points corresponding to the eclipse period present a positive deviation of about four standard errors. From a statistics point of view an anomaly is present. Since the anomaly could not be related to an instrumental error caused by a variation of pressure or ambient temperature, it is reasonable to believe that it is imputable to a gravitational effect resulting from the occultation of the Sun by the Moon. Indeed, the gravity meter is maintained at 51°C in a closed box with a temperature variation of less than 0.3°C, so that the influence of the variation in outside temperature can be considered as negligible. The box is also sealed to isolate its mechanism from the effect of buoyancy due to atmospheric pressure variation. An influence of less than 0.4 µgal/mbar is reported for this type of instrument.(8) Table II shows the variation of atmospheric pressure, given by Environment Canada, for the region of Montreal. We can conclude that the atmospheric pressure cannot be responsible for the anomaly since the highest pressure variation observed, +0.7 mbar, does not coincide with the phenomenon and can only explain 1/10 of its value.

The average anomaly measured during the eclipse is $+2.4 \pm 0.5$ µgal. Its association with a gravitational phenomenon demands to be validated by other measures using more precise instrumentation, but its link to the eclipse is supported by the fact that the anomaly coincides perfectly with the eclipse period. The order of magnitude of the anomaly had initially been estimated(7) to a value slightly over the instrument accuracy, which is why a verification was done in May 1994. However, due to the planning of measurements just one month before the eclipse, we have done only a traditional gravity survey. The right conditions were present to highlight the phenomenon since the Moon was at its highest altitude during the eclipse; moreover, the annularity of the eclipse could only maximize the occultation effect because, from the point of view of the corpuscular theory, the Moon was almost totally in the cone of maximal influence of the Sun at Montreal's latitude. The vertical component of the lunar attraction during the eclipse being 2.66 mgal, we have theoretically evaluated to 0.13 µgal (0.005% × 2.66 mgal) the direct effect of the solar eclipse. Our gravity measurements on 10 May 1994 show a gravitational anomaly of about 20 times the theoretical value.

Table II: Variation in Atmospheric Pressure for Montreal on 10 May 1994

Local time (h)	10	11	12	13	14	15	16	17	18	19
Pressure (millibar)	1012.7	1012.7	1012.5	1012.5	1013.2	1013.2	1013.2	1013.1	1013.1	1013.8

4.1 Discussion

It is interesting to mention the gravity surveys made during the eclipses on 24 October 1995 and 9 March 1997.[9,10] In each case a LaCoste & Romberg gravity meter was used and an anomaly observed during the solar eclipse. The order of magnitude of the anomalies is comparable, but contrary to the one of 1994, the anomalies of 1995 and 1997 are negative. An important difference between these eclipses is the maximal altitude of the Moon at the anomaly observation sites, that is, a few degrees in 1995, 21° in 1997, and 62° in 1994. However, based on our previous theoretical evaluation, none of the used gravity meters having the precision to detect a direct effect of occultation of one tenth of a microgal, no anomalies should have been observed. If we admit that these anomalies are not fortuitous phenomena, the most logical interpretation is to associate them with a local gravitational effect. Among the conventional causes explaining a negative anomaly, the effect of the atmospheric attraction due to an augmentation in atmospheric density in the umbra over the test site was brought up, but the movements of air masses that this involves do not seem realistic, nor observed from the ground.[11] The most probable effect due to gravity is therefore associated with a light movement of Earth's crust (that is, a ground inclination, a change in level, or both combined) that would happen during the eclipse. The induced known causes by the eclipse, able to have such an effect on the crust, are related to a change in the pressure and temperature. Even if we assume that the atmospheric pressure may have a significant effect, there is no correlation between the atmospheric pressure and the anomalies in 1994 and 1997, whose influence of pressure changes was evaluated. The variation in temperature during an eclipse was put forward to account for the crust movements, but it is too weak and shallow.[10,11] It seems difficult to conceive that the variation in the surface temperature, generally affecting loose soils, may generate large enough constraints to be able to induce significant dilatations and distortions on Earth's crust. It is easy to assess the effect of a slight subsidence h of Earth's surface on which the gravity meter is posed. The gravity variation, which corresponds to a change in the distance from the center of Earth, is

$$GM_t\left[\frac{1}{(R_t-h)^2}-\frac{1}{R_t^2}\right],$$

where M_t and R_t are respectively the mass and the radius of Earth. If we use this formula with a local subsidence of 7 mm only, we find an increase in gravity of 2.1 μgal, which is of the order of magnitude of the anomaly in 1994. We may wonder if the theoretical acceleration of 0.13 μgal, according to the corpuscular theory, is able to produce a local subsidence significant enough to explain the anomaly. To answer this question we have evaluated the displacement of a free-falling object exposed to a gravitational acceleration of 0.065 μgal during 1 h and 43 min, which corresponds to the time spent between the first contact and the maximal phase of the eclipse. We have used half the theoretical acceleration, considering the fact that the acceleration will grow from zero to its maximal value. It is logical to believe that if an important portion of the planet is subjected to a differential acceleration in relation to the other portion, it can be assimilated to a free-falling object in this small acceleration field, especially if we consider displacements of a few millimeters. With the classical formula $h = at^2/2$, we find a displacement, toward Earth's center, of 12.5 mm, which is almost twice the subsidence required to produce the anomaly observed in 1994. In conclusion, even though the acceleration difference defined by the corpuscular theory is too weak to have been detected, it can produce some displacements able to generate measurable effects. Because the cone of influence goes through the planet, not only are displacements local and at the surface of the observation site but they extend inside Earth's mass, along the axis of umbra and penumbra. These tiny relative displacements of certain whole blocks of the planet are possibly responsible for the abnormal variation of gravity during the eclipse. The real effect will depend on the masses' displacements and on the distortions affecting the position and the tilt of the gravity meter in relation to the distribution of Earth's mass. This effect will depend, among others, on the following parameters: the latitude of the observation site, the longitude and duration of the eclipse, and the orientation of the shadow relative to the Earth-Moon axis. The design of the instrument and its orientation in space are also factors that can influence the gravity measurements. However that may be, the gravitational attenuation of the eclipse appears to be an excellent option to explain the gravitational anomalies. The dynamics of displacements combined with the rotation of Earth and the stiffness of the crust could, in part, be the cause of the disparity between the observations from one eclipse to the other. Calculation of the anomaly corresponding to a particular event, using the corpuscular theory, is a very complex task, but now we can start case studies. It seems that the most efficient way to settle the question between the remaining conventional causes and the unconventional ones to explain the anomalies would be to take gravity measurements with enough precision, in the same conditions, in the cone of influence, and on both sides of the planet. The induced displacements, defined by the corpuscular theory, go through the planet in the extension of the shadow and can also be found on the other side of the planet, which would be the ideal site for a gravity survey — far from the visual eclipse and with no disturbance from the Sun's rays.

5. CONCLUSION

The corpuscular theory proposed by Le Sage in the middle of the 18th century was summarily evaluated by the scientists of the early 20th century before it was set aside. The little development of the theory and the physical knowledge of this time were in favor of its opponents. Condemned on presumptions rather than on facts, the corpuscular theory is still valid and can be dismissed only if its predictions are irreconcilable with the experimental facts. The latest theoretical developments, in combination with the experiment of May 1994, strongly support the accreditation of the corpuscular theory.

The corpuscular theory, foremost an explicative theory, attempts to describe the nature of the gravitational field using only the laws of inertia. Indeed, the conservation of momentum in the interaction of matter with the corpuscular medium explains, in a natural way, the mechanism leading to an attraction law in inverse ratio to the squared distance.

We easily understand the apparent equality between the gravitational mass and the inertial mass if we suppose that the interaction cross section of our gravitons with matter is strictly proportional to the mass. But such a proportionality imposes that the scale in which the interactions happen is of subquantum level. We found a cross section for gravity interaction that is comparable to the neutrino interaction with matter. This connection, which brings the gravitational phenomenon closer to our knowledge in microphysics, is probably not a simple coincidence. Using a cross section of 10^{-17} m^2/kg, we can demonstrate that to reach the limit of validity of the principle of equivalence on a laboratory scale, as in Eötvös's experiments, we will need a relative accuracy better than 10^{-15}. Such a precision, which is very difficult to reach, has not been obtained in this kind of experiment.[12]

The corpuscular flux of impulsion is weakened in a classic way by going through matter, and the calculation of the attenuation effect gives us the correction that must be made to Newton's law. The attenuation effects that become appreciable for a large mass, like the Sun, are conducive to a quantitative agreement for the advance of the perihelion of the planets.

The present theoretical development gives a quantitative basis, sufficiently precise and self-consistent, to suggest experimental tests. It is conducive to such repercussions in physics that we cannot insist strongly enough that the scientific community should do validation tests not only on the gravitational anomalies of eclipses but also on the equivalence principle.

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Résumé

Les mesures gravimétriques prises dans la région de Montréal, pendant l'éclipse de Soleil du 10 mai 1994, montrent l`existence d'un affaiblissement de l'attraction soli-lunaire au moment de l'occultation. Cette anomalie gravitationnelle d'éclipse ne semble pouvoir s'interpréter que dans le cadre d'une théorie corpusculaire de la gravitation. Les calculs réalisés à partir de deux phénomènes indépendants, l'anomalie gravitationnelle d'éclipse et l'avance du périhélie des planètes, conduisent à un accord satisfaisant de l'atténuation de la gravité à travers la matière. Dans cette étude, un rapprochement quantitatif est établi entre la gravitation et les interactions des neutrinos avec la matière.

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