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TOWARDS DETERMINATION OF THE LAPLACE GRAVITY PARAMETER h

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Abstract

We review a compressive model for material inertia and the effect of gravitation which follows naturally from it. We show that this model is consistent with the relativity principle, and suggest how a slight departure in the observed advance of the perihelion of the orbit of Mercury could put an upper limit on the Laplace screening parameter h.

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1 Introduction

It can be argued that relevant sections in the *Physics* of Aristotle (∼350 BCE) – particularly Book 7 – point to an intuitive understanding of the cause of material inertia in terms of the effect of pressure from a matter-surrounding medium. Gravitation would be a natural consequence of such an effect (cf. Budding, 2005, 2007). Such concepts are often referred to in connection with the thesis of Le Sage (1784), that was updated and re-adressed in the series of papers in the book *Pushing Gravity* (Edwards, 2002). An impression can arise, however (e.g. van Flandern, 2002; Schilling, 2004), that such older, intuitive models are at variance with the formalized discussion of Einstein in the general theory of relativity (GTR — cf. also Eddington, 1920). But it is not difficult to show – on general physical arguments – that this is not necessarily the case. Indeed, the Schwarzschild metric for a stationary 'attracting' point mass follows naturally in its normal form if the velocity of gravity-mediating particles ('gravitons') is the same as that of electromagnetic radiation – at least to the zeroth order in the Laplace absorption parameter h for gravitational force.

The next section reviews this point. A short third section considers the well-known practical test of the advance of perihelion of Mercury. This could provide an upper limit to the value of the h, but that result appears unlikely to be able to give an actual determination for some considerable time yet.

2 Inertial compression and relativity

A simplified physical picture can be produced in which the material inertia of moving objects is discussed along lines typically given for (special) relativity. Consider first the situation in the y-direction for a small object moving with constant velocity v parallel to a given x-direction (Fig. 1). For convenience, this elementary object is taken to be of rectangular shape, with sides parallel to the co-ordinate axes. The compressive model for inertia posits a uniform and isotropic surrounding field of particles ('gravitons') energized to an energy density U, that penetrate the object, the vast majority of which emerge without any significant material interaction. However, the absorption of some small proportion of the energy of the field produces a *compression* of the object, proportional, and scalably equivalent, to its inertia I_u that is its reluctance to acceleration (cf. Budding, 2005).

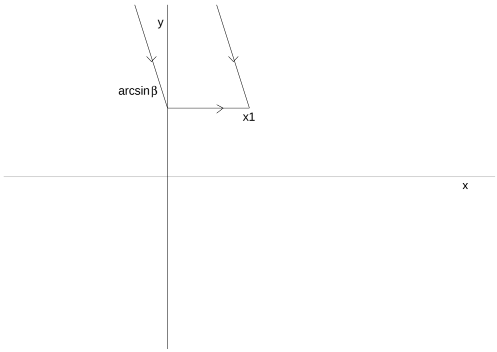

Figure 1: Linear motion in x direction (schematic). The arrowed rays incident on the moving object of length x_1 in the reference frame are seen as normally incident in the moving frame.

In the 'rest' frame of reference, it would seem that there is no difference between the compression in the y-direction experienced by a moving object and a similar object that is at rest. Any graviton missed at the back of the object as a result of the forward motion is effectively made up for by another one further forward that would have been missed if the object had not been moving.

In the moving frame, however, any graviton perceived to be coming directly from the positive y-direction must actually be coming with a component of its (constant) speed c (in the rest frame) in the positive x-direction equal to that of the object (Fig. 1). Hence its impact momentum in the y-direction is reduced in the ratio $\sqrt{1-\beta^2}$, where $\beta = v/c$. But this applies to all microscopic interaction components in the y-direction of the moving frame mediated by c-speed interactions, including those in a reference 'clock' moving with the object (cf. Larmor, 1897). The main function of such an idealized (proper) clock is that it produces a repetitive reference motion essentially orthogonal to the changes of position being timed (those in the x-direction). A conceptual pendulum, say, moving in the yz plane corresponds to such a clock. In effect, the interval between swings for a pendulum, powered by y-direction graviton interactions, would slow down, so that the same amount of graviton momentum transfer would occur in the same *measured* time interval. The same net compressive y-force would in this way be independently measured in both frames.

The situation in the x direction can be considered in terms of the communication of microscopic interactions of elastic particles, of which it is taken to be composed, set in motion from one yz section to its particular neighbour. This model is minimalistic: we do not enquire into the detailed nature of the particles of the body, only that their motion is rapidly communicated from one to another and that they have some response to the graviton field. Conservation of momentum continues in the same way as for this same object when nearly at rest in the rest frame only when the neighbouring yz sections are compressed in the x-direction in the same ratio $\sqrt{1-\beta^2}$ as above. Newton's second law holds for such a model of material motion started from rest (Budding, 2005), and from that we deduce that an impulse large enough to propel an object forward with discernible velocity v has a potential energy of compression

$$E = k(x_1^2 - x_2^2)/2 \ , \tag{1}$$

where x_1 is the natural length in the rest frame and x_2 is that in the moving frame. The full energy of the motion is made up of the potential energy of compression as well as the kinetic energy of the impulse. Again from the law of motion, it follows that the modulus k scales in terms of the compression in the reference frame, i.e. $k = I_u c^2/x_1^2$, where c is the speed of the impulsive wave through the object. Since the potential energy equals the kinetic energy for this motion, we must have

$$v^2 = \frac{c^2}{x_1^2}(x_1^2 - x_2^2) \ . \tag{2}$$

Equation (2) expresses the well-known contraction of moving objects (Fitzgerald, 1889). The compression implies an increased overall inertia of the moving object in the same proportion as its deceased length. The measured velocity of gravitons in the moving frame turns out the same in both x and y directions, and still the same as in the rest frame, thus confirming the principle of relativity (Einstein, 1920;

with reference to the potential energy of compression, see also Fayngold, 2008).

At the level of individual material particles, their inertia is measured by any impulse they receive ΔJ, divided by the square root of the product of their cross-section and rigidity $\sqrt{\sigma\kappa}$. The former measures an interaction length, which, from the foregoing, contracts in the direction of motion, thereby increasing the inertia of the material particle. Any period of response of such particles to an impulse of given mean magnitude ΔJ is scaled by $I/\sqrt{\kappa}$: the moving particle becoming more 'inert', its response time correspondingly dilated. Although the general compression of objects is regarded as coming from the supposed cosmic field as the principal source of local inertia, conservation of momentum among individual particles is somewhat more general, and I can take a more basic meaning as the mechanical mass M of the particle. It can be countenanced, though, that if the contraction approaches the scale of the material particle's interaction length itself, the particle may reach some microscopic equivalent of a 'yield point', beyond which there is increasing difficulty in holding itself together. The limiting case of $x_2 = 0$ implies the potential energy would rise to $\frac{1}{2}Mc^2$ from (1), so, for the total energy of such a particle, we find Einstein's famous expression

$$E_{\text{tot}} = Mc^2 \ . \tag{3}$$

Although the discussion so far refers directly to special relativity (constant uniform velocities), the arguments extend to the general case. Since, following Eqn (2), uniform linear motion is equivalent to a compression in the direction of motion, acceleration, or the rate of change of velocity (of a body), corresponds to a rate of change of this compression.

The relationship of gravitation to acceleration in GTR is associated with an idea of Mach, i.e. that physical laws are ultimately derive from clearly recorded perceptions of events by systematic observers. A passenger on a (horizontally) cornering vehicle feels a force pushing him away from the centre of turning. At the time when his relative movement is towards the side of the vehicle, immediate perceptions suggest only this 'centrifugal' effect. Perhaps later, when still, but pushed against the side of the vehicle, he may think that it was the car that turned, while his body's inertia kept him in the direction he took to be outwards. At this point, he is in equilibrium relative to the car: the acceleration from his inertia relative to the moving frame now balanced by the 'centripetal' inward push of the vehicle wall. Could the idea of 'falling' be due to an upward accelerating surface of the Earth, and our coming to rest against this a comparable balance of an imposed acceleration and an inertial tendency?

A key point is that we are regarding inertia as proportional to a general compression. The free movement of an inert body would then only be uniform and linear in a region where the universal compressive field is isotropic and uniform. Near a very massive body, such as the Earth, this is not the case. A compressive strain is thus set up across a body of finite vertical size, with a consequent proportional differential stress. The vertical integral of this stress differential corresponds to a net mechanical action on the body. It then accelerates, as a consequence of a differential loss of inertia (a relatively very slight loss of compression) in the downward direction. Relative to the falling observer the Earth is, of course, accelerating upwards; but as with the cornering car passenger, it seems much more natural to regard the observer as moving relative to fixed surroundings. Structural stability of the Earth implies that objects on its surface equilibriate. The imposed acceleration, analogous to the cornering car's wall, now associates with the restoring upthrust that maintains this equilibrium against the inertial tendency to keep falling.

If a falling object continues to very high speeds it will again increase its overall inertia according to Eqn (2). Continued acceleration towards a centre of gravitational attraction would then tend to depart from a simple Newtonian prescription. Since that acceleration is expressed as a rate of changing distances in successive time intervals, and depends almost entirely only on the mass of the attracting body, one may expect an appropriate form for the modified acceleration to be devisable in terms of appropiate modifications to space and time co-ordinates to be applied to any falling body. The setting up of such modifications for a manifold of space and time pervaded by a gravitational field is a main objective within GTR.

The principle of relativity referred to above can be dealt with in the setting of changing velocities with the aid of the Minkowsky construction for differential elements of space and time together, i.e.

as in a 4-dimensional 'space-time' continuum. This is written as

$$ds^2 = c^2dt^2 - dx^2 - dy^2 - dz^2 \ . \qquad (4)$$

Eqn (4) implies that events observed to be separated by dx, dy, dz in space and dt in time, that actually occur simultaneously, have been properly timed when the increment ds is zero. A special meaning attaches to the quantity c, that remains constant for moving observers. This propagation velocity, introduced above in connection with the apparent linear motion of material bodies, represents the maximum velocity with which events can be communicated from one particle to another. It is well known that this is generally identified with the velocity of electromagnetic radiation: the 'speed of light'. The form of the Minkowsky construction, by setting the second power of $ds^2 = 0$ for a light beam travelling between two points with constant locally measured velocity c, also implies that its propagation follows the shortest path between two locations.

Let us consider the gravitational field around an idealized, point-like mass. Symmetry suggests the appropriateness of spherical polar co-ordinates centred on the mass-point, and at distances so large that the cosmic field becomes uniform and isotropic, Eqn (4) will take the form

$$ds^2 = c^2dt^2 - dr^2 - r^2d\theta^2 - r^2 \sin^2\theta \, d\phi^2 \ . \qquad (5)$$

More generally, however, we should expect a form such as

$$\begin{aligned} ds^2 \quad = \quad & g_{11}{x_1}^2 + g_{12}x_1x_2 + g_{13}x_1x_3 + g_{14}x_1x_4 + \\ & + g_{21}x_2x_1 + g_{22}{x_2}^2 + g_{23}x_2x_3 + g_{24}x_2x_4 + \\ & + \ldots(\text{etc.}), \end{aligned} \qquad (6)$$

where we have replaced the familiar x, y, z and ct co-ordinates in (4) by the standardized x_1, x_2, x_3, x_4, and $g_{\alpha\beta}$ make up the metric coefficients of the co-ordinate transformation. Dimensional arguments, stemming particularly from the coefficient of the second-order time increment, indicate that the g's have the physical character of generalized force potentials.

A 'law of gravitation' can be understood as a relationship affecting the g's, that would hold for values of such coefficients observed in practice. Since these g's define any given system of co-ordinates, the implication is that a gravitation law would connect systems of co-ordinates applicable to real cases. As and when new co-ordinates become relevant, there obtain corresponding values of the g's, where the differential equations connecting the new g's and new co-ordinates continue *covariantly* from what held between the old g's and old co-ordinates.

It can be shown (cf. Eddington, 1920) that very general conditions for a source-free gravitational field are equivalent to the vanishing of the fourth rank Riemann-Christoffel tensor (large to write out in full), but this is reduced, in Einstein's formulation, to the second rank symmetric tensor equation

$$G_{\sigma\tau} = 0 \ , \tag{7}$$

the indices σ and τ running from 1 to 4. This is the four-dimensional counterpart to the Laplace equation for a classical field. The 10 separate conditions thus expressed provide the basis of the GTR formulation of gravitation. Any set of values of the 10 independent metric coefficients $g_{\alpha\beta}$ that satisfy (7) will correspond to a possible set of co-ordinates applying to a source-free field.

These reduced Riemann-Christoffel conditions can be spelled out as

$$\begin{aligned} G_{\sigma\tau} = & \frac{-\partial}{\partial x_\alpha}\{\sigma\tau,\alpha\} + \{\sigma\alpha,\beta\}\{\tau\beta,\alpha\} + \frac{\partial^2}{\partial x_s \partial x_t}\log\sqrt{-g} + \\ & -\{\sigma\tau,\alpha\}\frac{\partial}{\partial x_\alpha}\log\sqrt{-g} \ , \end{aligned} \tag{8}$$

where $\{\alpha\beta,\gamma\}$ represents the Christoffel 3-index symbol appearing in the covariant differentiation of the $g_{\alpha\beta}$ tensor, defined as $\{\alpha\beta,\gamma\} = \frac{1}{2}g^{\gamma\epsilon}(\partial g_{\alpha\epsilon}/\partial x_\beta + \partial g_{\beta\epsilon}/\partial x_\alpha - \partial g_{\alpha\beta}/\partial x_\epsilon)$, and the right hand side is summed in the repeated index ϵ (Einstein index convention).

Symmetry and other simplifications applying to the elementary situation considered permit

$$ds^2 = -e^\lambda dr^2 - r^2 d\theta^2 - r^2 \sin^2\theta d\phi^2 + e^\nu dt^2 \tag{9}$$

as an exploratory form, whose g's may satisfy (8), where λ and ν are arbitrary functions of r. We thus have, $g_{11} = e^\lambda$, $g_{22} = -r^2$, $g_{33} = -r^2\sin^2\theta$, $g_{44} = e^\nu$, and $g_{\sigma\tau} = 0$, when $\sigma \neq \tau$. The co-ordinate system remains orthogonal, but there appear scaling factors in the radial and time dimensions relative to a given spatial extension in the angular co-ordinates. The determinant g of the g-coefficients reduces to its leading diagonal, so that $-\mathrm{g} = e^{\lambda+\nu} r^4 \sin^2\theta$, and its cofactors $g^{\sigma\sigma} = 1/g_{\sigma\sigma}$. This allows considerable simplification of the general experession (8) — only 9 of the 40 possible independent Christoffel symbols are non-zero, for example — and, after some manipulation, it is found that the conditions (8) require the trial form (9) to reduce to

$$ds^2 = -\gamma^{-1}dr^2 - r^2 d\theta^2 - r^2 \sin^2\theta d\phi^2 + \gamma dt^2 \ , \tag{10}$$

with $\gamma = 1 - b/r$, where b is a constant of integration. The resemblance of γ to a gravitational potential will become clearer with an appropriate physical interpretation of b.

We can show that (10) is consistent with a generalization of the transforms of special relativitiy by setting x in (2) to be in a given radial direction of acceleration r. We have, for two different positions along the path, r_1 and r_2, say, (and these positions can be regarded independently of time),

$$\delta r_2^2 - \delta r_1^2 = \delta r_1^2 \frac{2E}{I_u c^2} \ , \tag{11}$$

or

$$\delta r_2^2 = \delta r_1^2 (1 + \frac{2E}{I_u c^2}) \ , \tag{12}$$

where E is the increase in potential energy of a point mass moving in the positive direction from r_1 to r_2. In the simple limiting case considered, one single large ‘attracting mass’ $\mathcal{M}$ at the fixed origin is regarded as the source of changes of potential for the moving particle, so that the second item in the parentheses in (12) can be replaced by the conventional form $-2G\mathcal{M}/rc^2$. The natural length δr_1 in a local frame of reference is equivalent to a proper time $\delta s_r/c$, while δr_2 gives the corresponding variation of this length applying to the purely spatial component of radial separation r, so that, generally,

$$\delta r^2 = -\delta {s_r}^2 (1 - \frac{2G\mathcal{M}}{rc^2}) \ , \tag{13}$$

or

$$\delta {s_r}^2 = -\delta r^2 / (1 - \frac{2G\mathcal{M}}{rc^2}) \ . \tag{14}$$

Relative changes of material compression are also associated with changes in the local elapsing of measured time intervals δt_1, compared with intervals δt_2, at some other position, as argued before. In the present situation, these changes relate to variations of radial separation from the centre of attraction, and are in exact proportion to the compression, so that

$$c^2 \delta {t_2}^2 = c^2 \delta {t_1}^2 / (1 - \frac{2G\mathcal{M}}{rc^2}) \ . \tag{15}$$

We can write again, in the manner of (9)

$$\delta {s_t}^2 = c^2 \delta t^2 (1 - \frac{2G\mathcal{M}}{rc^2}) \ . \tag{16}$$

Taking into account both the spatial contraction and time dilation effects from (14) and (16), we can rewrite (6) for the situation at distance r from the mass centre $\mathcal{M}$ as

$$ds^2 = c^2 (1 - \frac{2G\mathcal{M}}{rc^2}) dt^2 - dr^2 / (1 - \frac{2G\mathcal{M}}{rc^2}) - r^2 d\theta^2 - r^2 \sin^2\theta \, d\phi^2 \ . \tag{17}$$

It is noteworthy that b, that enters into (10) through γ, is equivalent to $2G\mathcal{M}/c^2$ in (17). The law of gravitation, expressed through Einstein's field equation (7), thus supports the expression for the potential used in (13) and confirms conventional physical interpretation of gravitational potential energy in this context. Since there are no changes of angular momentum in this model, there are no effects on ds^2 associated with differential changes in the increments $d\theta$ and $d\phi$.

Eqn(17) expresses the well-known Schwarzschild metric (Schwarzschild, 1915), that figures in most practical tests of GTR. It can be seen from this discussion that nowhere does a compressive model of inertia and gravitation, in the zeroth order in h, given as Equations (9) and (16) in Budding (2005), depart from standard relativity theory in its main testable findings when graviton velocity is the same as that of light.

3 Practical test

What would be the effect on the Schwarzschild metric for an accelerated object of finite size? We now note the consequence of the compression theory that gravitational attraction (weight) is slightly inefficient as an accelerative effect when converted into a series of momentum changes throughout a body having appreciable matter content (Budding, 2005).

The absence of angular momentum variation in Schwarzschild (central mass) attractions means that one of the angular variables, θ say, can be eliminated: orbital motion is in the 'equatorial' plane $\theta = \pi/2$ with no rotation about a horizontal axis. The constant angular momentum vector about the axis $\theta = 0$ and constancy of observed effects in the proper frame (the relativity principle) similarly allows the integral

$$r^2 \frac{d\phi}{ds} = \eta \ , \tag{18}$$

whereupon (10) can be arranged as

$$\gamma^{-1} \frac{dr}{ds}^2 + r^2 \frac{d\phi}{ds}^2 = c^2 \gamma \frac{dt}{ds}^2 - 1 \ , \tag{19}$$

This can be further tailored to something like the normal expression for a Keplerian orbit by multiplying the left side by γ and moving a small part of the term in the rate of angular variation over to the right side, thus

$$\left(\frac{dr}{ds}\right)^2 + \left(r^2 \frac{d\phi}{ds}\right)^2 = \gamma \left[c^2 \gamma \left(\frac{dt}{ds}\right)^2 - 1\right] + (1-\gamma)\frac{\eta^2}{r^2} \ . \tag{20}$$

The left side of (20) now looks like the regular kinetic term v^2, but we should divide by c^2, if regarding s as measuring proper time. From (16), the coefficient of $(dt/ds)^2$ in the square parentheses would seem to cancel out, but there is an element of arbitrariness about the selection of the constant position, applying to the time intervals δt_0, to which the orbit is referred. This involves again the same factor given in (2), so that we end up on the right side with

$$\left[\gamma \left(\frac{1}{1 - {v_0}^2/c^2}\right) - 1\right] + (1-\gamma)\frac{\eta^2}{r^2} \ .$$

If we write $v_0^2 = G\mathcal{M}/a$ in this, insert the full expression for γ and ignore higher orders than the first in small terms, (20) now reduces to

$$v^2 = G\mathcal{M}\left[\left(\frac{2}{r} - \frac{1}{a}\right) + \frac{2\eta^2}{r^3c^2}\right] \ , \tag{21}$$

which looks like the familiar Keplerian form for the orbital velocity, except for the small additional term involving the angular momentum constant η on the right.

It can be shown (cf. e.g. Eddington, 1920) that this small extra term leads, for an elliptic orbit of eccentricity e, to a slow rotation of the orbit as a whole (advance of perihelion) which, per orbit, amounts to

$$\Delta\phi = \frac{3\eta^2}{a^2(1-e^2)} \ . \tag{22}$$

$\Delta\phi$ is measured in the combination $e\Delta\phi$, which for the planet Mercury amounts to some 8.82 arcsec per century. The measured value falls short of this by 0.07 arcseconds, however, i.e. some 0.8% of its value (Shapiro et al., 1972), although this is within the standard error of the measurement.[1] This can be understood physically as the fall of potential energy for unit amount of matter E/I_u in (12) not being quite up to the same level as the substituted form $-G\mathcal{M}/r$ in (13), that would apply uniformly to all matter in the zeroth approximation of the compressive model. The reduction of effective gravitational force applying to a spherical body of radius R and density ρ is $3\rho hR/4$ (Budding, 2005, Eqns 18, 26), in the first order of the Laplace screening parameter h. With the mean density of Mercury as 5.427 and radius 2.440×10^8 (cgs), the value of h required to explain the discrepency turns out to be a high 8×10^{-12}, that should have been measured by other means (cf. Edwards, 2002). The estimate of $h \sim 10^{-15}$ speculated on by Budding (2005) appears another two or three orders of magnitude below what is currently measurable by radar delay measurements.

[1] The quantity actually determined to have a 0.5% excess by Shapiro et al. (1972) is a parameter λ that linearly combines both the relativistic coefficients β and γ, written as β' and γ', say, such that β' and γ' are both unity when β and γ have their regular GTR meanings. The compressive theory of gravity referred to in the present article has no direct effect on β, but it causes the observed value of γ to become slightly greater than the γ of GTR. This would increase λ by 2/3 of the same proportion.

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Comment on TOWARDS DETERMINATION OF THE LAPLACE GRAVITY PATAMETER h

M. Przanowski

The paper is devoted to a compressive model of inertia and gravity. The problem with this paper is that no mathematical model has been done at all. Instead, the authors describe this model in the vague way. Consequently, with such a theory you can prove anything you want. The journal Concepts of Physics, as I understand it, is open to new ideas in physics, but the considerations should respect the methodology of physics and mathematics. Therefore, any new model should have clear mathematical representation. (According to famous words by P.A.M.Dirac: *"Physical theory should have mathematical beauty"*). The model presented in the paper does not fulfill that criterion. Hence, I do not recommend it for publication.

Authors' response

We have been considering how best to deal with the general relativity subsection of the previously submitted paper, given its relatively simple and direct main aims.

We have thus added an additional page to the text and five new equations (6-10). The new part summarizes the conventional tensor approach to Einstein's law of gravitation, leading up – in Equation (10) – to the expected Schwarzschild form, that re-appears as Equation (17). We had justified this previously through Equations (13)-(16), simply by considering local incremental modifications to the metric from Special Relativity. What this approach did not do explicitly was to show that the resulting formulae are consistent with the field equations for a generalized four-dimensional continuum and covariant force transformation. I believe we have now established this point, by spelling out the relevant equations and citing appropriate references.

But another point, of special relevance to our model for gravitation, is that the potential coefficients that appear in Equation (17) and introduced in Equations (13) and (14) are identical to the formulae (11) and (12) in the zero'th order of the compression model. The very slight difference in (11) and (12) that will appear when gravitational screening is taken into account can be treated as a linear perturbation, certainly to the order of accuracy that is currently measurable, and probably for quite some time to come.

We thus hope that we have (a) interpreted the comments of your referee appropriatley, and (b) dealt with them in a suitable way so as to allow that there is no contradiction between the GTR law of gravitation and a compressive model in the zero'th order, and a very slight difference in the first order. We therefore resubmit the article with this in mind. Of course, we are ready to consider any further comments that may arise.

Edwin Budding and Oktay Yilmaz