The Uniform Scaling Method for Simplified Computation of the Key Tests of General Relativity

by

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Abstract

The method of uniform scaling of coordinates introduced by Schiff in 1960 is reviewed. It is shown that its application to the bending of light during solar eclipses assumes that the *light rays travel in perfectly straight lines.* It nonetheless obtains quantitatively the same angle of light deflection as General Relativity (GR). Schiff's failure to obtain similarly accurate results for the advancement of the perihelion of Mercury's orbit is traced to his ignoring the central role of the acceleration due to gravity g in these computations. When the appropriately scaled g factor is included in the theoretical treatment, the adjusted method obtains quantitative agreement with both GR and experiment for the angle of advancement. The scaling produces a value of g=0 for light by virtue of its moving at speed c in free space, thereby leading to the straight-line trajectory of the waves. However, g has a non-zero value for massive objects and its effect on the velocity of the planet needs to be taken into account explicitly to obtain accurate results. More generally, it is shown that there are two key scaling factors, Q for kinetic acceleration and S for the effects of gravity. These quantities can be evaluated on the basis of a minimum of information regarding the locations in a

gravitational field and the states of motion of any object-observer pair anywhere in the universe. The scaling of each physical property is characterized by a specific product Q^nS^p, where n and p are integers. One of the main advantages of the uniform scaling approach is that it is relatively simple to apply. The calculations for light bending and the advancement angle of the perihelion of planetary orbits are carried out with a computer program which differs by only a few statements from the standard one which applies Newton's classical method.

Keywords: Uniform co-ordinate scaling, General Relativity, gravitational redshift, light deflection during solar eclipses, advancement angle of the perihelion of planetary orbits, Shapiro's Fourth Test of General Relativity

I. Introduction

Recent measurements carried out for the star S2 near a massive black hole [1] have demonstrated that it exhibits a precession in its orbit that is comparable to that which occurs for Mercury and other planets in their orbits around the sun. This phenomenon was predicted by Einstein [2] in 1916 on the basis of his General Theory of Relativity (GR). The authors [1] point out in their Introduction that results for Mercury's orbit have previously been obtained using GR and its curved space-time methodology. They add that this experience shows that "General Relativity (GR) continues to pass all experimental tests with flying colors," citing Einstein's 1916 paper as well as work by Will published in 2014 [3].

There is another method for describing gravitational interactions, however, which gives quantitatively the same results for the Mercury orbit as does GR without making any assumptions about curved space-time [4]. It is based on a suggestion made by Schiff in 1960 in which he explored the idea that three "crucial tests" of relativity, including most especially the "deflection of light rays that pass close to the sun," *might be correctly inferred from* *weaker assumptions that are well established by other experimental evi*dence. The anomalous precession of the Mercury orbit was one of the other three tests, whereas the third was "the red shift of spectral lines emitted by atoms in a region of strong gravitational potential." After Schiff's paper had appeared, a "fourth test of general relativity" was suggested by Shapiro [6] to verify the GR prediction "that the speed of propagation of a light ray decreases as it passes through a region of increasing gravitational potential." All four of these predicted phenomena have been described quantitatively by the above method [4].

In the following, attention will be particularly centered on the details and results of calculations using Schiff's simpler method as they relate to the passage of light rays close to the sun and planets. The main question to be explored is whether light rays follow curved paths under these conditions.

II. Schiff's Method of Uniform Scaling

The stated purpose of Schiff's paper [4] was to show that the deflection of light rays by the sun, as well as the gravitational red shift can be obtained "in a valid manner without using the full theory." He added that he felt that his derivation "is probably well known," but that "there does not seem to be a publication that describes it." He emphasized that when future experiments are analyzed, "it is important to understand the extent to which they support the full structure of general relativity, and do not merely verify the equivalence principle and the special theory of relativity." It also should be noted that Schiff makes use of Newton's classical gravitation theory in arriving at his conclusions.

Schiff began by considering the periods of three clocks "in a gravity-free region, in which they are accelerated upward with acceleration g." He found that the times T_A and T_B satisfy the following approximate relationship:

$$T_B \approx T_A\left[1+\left(\frac{GM}{c^2 r_B}\right) - \left(\frac{GM}{c^2 r_A}\right)\right], \tag{1}$$

where G is the universal constant of gravitation, c is the speed of light in free space, M is the spherically symmetric mass from which the field arises, and r_A and r_B are the distances from the center of the gravitating mass. In his derivation, clock A is located at the higher gravitational potential ($r_A > r_B$), so that $T_B > T_A$. Consequently, the clock B at the lower potential is predicted to run slower than its counterpart A, which is in quantitative agreement with Einstein's original derivation of the gravitational red shift [7].

In applying Schiff's method, it is useful to employ notation which explicitly distinguishes between the location P of an event and that of the observer O. Toward this end, it is useful [8] to make the following definition for P using the notation of eq. (1):

$$A(P) = 1 + \frac{GM}{c^2 r_P}, \tag{2}$$

where r_P is the distance between location P and the center of the active mass M. An analogous definition holds for O, whereupon the following definition for their ratio

will also be useful:

$$S = \frac{A(O)}{A(P)} = \left(1+\frac{GM}{c^2 r_O}\right) / \left(1+\frac{GM}{c^2 r_P}\right). \tag{3}$$

Accordingly, the gravitational red shift for an object located at P as observed at O is expressed in terms of the respective times T(O) and T(P) read from clocks at these two locations as:

$$T(O) = S^{-1} T(P). \tag{4}$$

Since S<1 in eq; (3) when the observer is located at a higher gravitational potential than $P(r_O > r_P)$, it is clear from eq. (4) that the clock at P is running slower than that at O, as predicted by Einstein in his original definition of the equivalence principle (7). The utility of the scaling parameter S is demonstrated by considering the analogous proportional relationship for energies E(P) and E(O):

$$E(O) = SE(P). \tag{5}$$

In this case the exponent of S is +1 as opposed to -1 for times. The energy value observed at the lower potential is accordingly less than for the observer for the same object, but the proportionality factor is just the reciprocal of that in eq. (4) for elapsed times.

Schiff [5] next applied his analysis to distances. He distinguished between distances measured transverse L_{tr} and radial L_{rad} to the gravitational field on the basis of the Lorentz-FitzGerald length contraction relationships derived in the special theory of relativity:

$$L_{tr}(O) = L_{tr}(P) = S^0 L_{tr}(P) \tag{6}$$

$$L_{rad}(O) = SL_{rad}(P), \tag{7}$$

The latter two equations when combined with eq. (4) then give the corresponding proportionalities for the corresponding transverse v_{tr} and radial v_{rad} components of velocity:

$$v_{tr}(O) = Sv_{tr}(P) \tag{8}$$

$$v_{rad}(O) = S^2 v_{rad}(P), \tag{9}$$

A key assumption in Schiff's method [5] is that the local observer (P) always measures the speed of light to be c. The calculation starts with the light ray at a large distance away from the earth along the x axis. The light velocity is resolved into its transverse and radial components and then scaling proceeds in accordance with eqs. (8-9). The light trajectory over the entire distance to the earth is then computed analytically in Schiff's approach.

An alternative, and computationally equivalent, method [9] makes use of a finite differences approach. In each cycle, the light is assumed to travel over a short time Δt at the current velocity along the x axis, at which time the position of the light has changed by Δx. The new position is recorded and serves as the origin for further motion in the next cycle. At each stage of the calculation, the light velocity is directed along the x axis, so that the perpendicular distance Y_1 from the sun remains constant throughout. The calculation continues until the light has reached its final position at the surface of the earth. The sum of the distance changes in each cycle is then set equal to $X (Y_1)$.

The procedure is then repeated for a different lateral distance Y_2 from the sun. If $Y_2 > Y_1$, it is found that the corresponding distance travelled by the light $X (Y_2) > X (Y_1)$. This result is understandable since the damping of the light velocity decreases as the lateral distance from the sun increases, so the light can travel farther before the same amount of time has elapsed. The situation for a series of such passes is illustrated in Fig. 1. The line connecting the end points of the various light rays constitutes a *wave front*. The interpretation based on this diagram is simply that the gravitational effects have caused the wave front to rotate away from the sun at a definite angle Θ which is identified with the angle of light deflection. Both Einstein [2] and Schiff [4] employed Huygens' Principle to evaluate this angle:

$$d\Theta = \frac{1}{c'}\frac{dc'}{dy}dx\,. \qquad (10)$$

In this formula, c' is the speed of light measured by the observer (not the local value of c measured consistently by the observer at position P). It is obtained using the scaling relations in eqs. (8-9). The differential change $d\Theta$ is then obtained as the ratio of $(dc'/dy)/c'$ multiplied with the corresponding distance dx traveled by the light ray along the x axis in time dt.

Accordingly, *all that is required is that the speed of the light ray change with its lateral distance y from the sun*. To compute the derivative dc'/dy, it is clearly necessary to compare the speeds of two different light rays separated laterally by an amount dy. If it is assumed that the corresponding values of c' differ by dc', it is clear that the respective distances along the x axis in the two cases over time dt will also differ. As shown in Fig. 1, the angle which the line connecting the two rays makes with the corresponding one for their initial positions at infinity is thus $d\Theta = dc'\, dt/dy$. Since the total distance traveled is $dx = c'dt$, $d\Theta$ is seen to satisfy eq. (10). *There is nothing in this derivation which assumes that either light path is curved*, only that the speeds by which the light travels along them is different.

There is a simple interpretation of this result. The line connecting the current positions of the two light rays simulates a *wave front* in the terminology of Huygens. When the light reaches the observer, the direction from which it has come is judged by extending the normal to this wave front backward in space. Integration of $d\Theta$ in eq. (1) over the entire path therefore gives the amount by which the light *appears* to have been deflected from the straight-line path actually followed (Fig. 1). The finite differences approach [4] for the execution of Schiff's uniform scaling method [5] has shown that this angle has a value of 1".7517 for light coming from infinity which grazes the outer edge of the Sun's surface on its way to the Earth, identically the same value as obtained by Einstein [10] in 1915 using a method of successive approximations.

Schiff also notes that *exactly half this value* results when the scaling of radial distance in eq. (7) is ignored, the same result obtained by Einstein [11] in his early attempts at calculating the angle of deflection [12]. Schiff also points out that, in agreement with his scaling assumptions, Eddington [13] had shown that both the scaling of time and radial distance must be taken into account in order to successfully obtain the angle of light deflection. There is therefore little room for doubt that Shapiro's time-delay predictions can be obtained with Schiff's simpler computational method with the same level of accuracy as with the GR relations he used explicitly in his work [6, 14].

It is therefore reasonable to conclude that Schiff's assumption of a strictly straight-line trajectory is fully consistent with experience using GR. His method is just a simpler approach to applying GR in practice. What is far less clear is how this experience is *in any way compatible with the ubiquitous claims that GR relies on the principle of curved space-time to arrive at its predictions.*

III. Adapting Schiff's Method to the Third Crucial Test of Orbit Precession

Schiff gave two reasons why his scaling method cannot be extended to the crucial test of "the precession of the perihelion of the orbit Mercury" [5]. He quoted Einstein [10] to buttress his position on the first of these, specifically Einstein's conclusion that the accurate description of orbit precession requires *that the equation of motion* (the geodesic equation) of the planet be provided as input to the theory. Schiff also noted that Eddington [13] was in complete agreement on this point. In other words, Newton's Inverse Square Law (ISL), which spectacularly provided the first method for predicting planetary orbits in the 17th century, would not be useful in itself to supply the necessary information required to predict the precession anomaly, even though the latter amounts to only a minor correction to the classical theory.

Despite the above conclusion, it was decided to adapt Schiff's method [5] by including Newton's ISL explicitly by employing a finite differences approach [4] analogous to that used to obtain the angle of light deflection [9]. The following notation for the acceleration due to gravity g is given below, which is consistent with that used in Sect. II:

$$g = \frac{GM}{r^2} . \tag{11}$$

Significant encouragement for this approach was provided by some experimental results obtained a decade after Schiff's paper [5]. Hafele and Keating [15-16] placed identical atomic clocks onboard circumnavigating airplanes and measured the amount of time that elapsed before they returned to the airport of origin. They found that less time elapsed on the eastward-flying clock than on its counterpart left behind at the airport, which in turn was less than that recorded on the westward-flying clock. They were able to explain these results to a good approximation by assuming at each stage of a flight that the rate of the onboard clock was inversely proportional to $\gamma(v)=(1- v^2/c^2)^{-0.5}$, where v is the speed of the clock relative to the earth's center of mass (ECM). As a consequence, the eastward flying clock had the highest speed relative to the ECM, followed in order by the airport clock and its westward flying counterpart.

A correction was made at each stage of the flights to account for the effect of the gravitational red shift on the rate of each clock. This procedure is interesting in itself because it is inconsistent with the equivalence principle which was used extensively by Schiff, as well as Einstein originally [7], in obtaining the proportional relationships in eqs. (4-9). The basic idea behind the equivalence principle is that the effects of acceleration are the same as those that result because of changes in the gravitational potential of the object, a point made perfectly clear in Schiff's paper [5]. Hafele and Keating [15-16] by contrast found that these two effects on the clock rates are quite distinct and can simply be added to one another.

It is appropriate to refer to the above inverse proportionality relationship between elapsed times T(O) and T(M) as the Universal Time-dilation Law (UTDL):

$$T(O)\gamma(v_O) = T(M)\gamma(v_M), \tag{12}$$

where v_O and v_M are the corresponding speeds relative to the ECM. The same inverse proportionality [17] holds for the respective frequencies of an x-ray absorber and receiver mounted on a rotating disk, only in this case the relevant speeds are measured relative to the rotor axis and frequencies ν are defined as the reciprocal of the corresponding clock periods T.

To distinguish between the two cases, it is helpful to define a rest frame that is referred to as the Objective Rest System (ORS) [18] from which the relevant speeds are to be calculated. The ORS is the ECM for the Hafele-Keating results and the rotor axis for the Hay et al. x-ray frequency measurements. Einstein [19] gave a related example of clocks located respectively at the Equator and one of the earth's Poles in his original paper describing the special theory of relativity. More generally, the ORS is the rest frame in which force is applied to an object that causes it to be accelerated.

The Hafele-Keating results allow for a parallel scaling method for the effects of kinetic acceleration [8, 20] which is closely analogous to that first discussed for gravitational effects.

For this purpose, γ (v) serves the same purpose as $A_p \equiv A(P)$ in eq. (2):

$$\gamma\left(v_M\right) = \left(1 - \frac{{v_M}^2}{c^2}\right)^{-0.5}, \tag{13}$$

where v_M is the speed of the object relative to the ORS. As before, an analogous definition holds for the observer O. A ratio Q analogous to S in eq. (3) then serves as a common scaling factor for the effects of kinetic acceleration. It is obtained directly from the UTDL in eq. (12):

$$Q = \frac{\gamma\left(v_M\right)}{\gamma\left(v_O\right)} = \left(1 - \frac{{v_M}^2}{c^2}\right)^{-0.5}\left(1 - \frac{{v_O}^2}{c^2}\right)^{0.5}. \tag{14}$$

In analogy to eq. (4), the relationship between elapsed times in the two rest frames is:

$$T(O) = QT(M). \tag{15}$$

The corresponding relationship for energies E(O) and E(M) is then

$$E(O) = QE(M). \tag{16}$$

Because the speed of light relative to its source is equal to c in all rest frames,

it follows that the exponent of Q for *relative speeds* between any two objects is 0, i.e. the value is exactly the same in each rest frame:

$$v(O) = v(M) = Q^0 v(M) = v_M. \tag{17}$$

It is necessary for eqs. (15) and (17) to both hold that the corresponding distance scale as:

$$L(O) = QL(M). \tag{18}$$

In other words, time dilation is accompanied by length expansion, not the type of anisotropic

relationship (Lorentz-FitzGerald length contraction) that is predicted by the special theory of relativity [19]. Other proofs that Einstein's theory is invalid will be discussed subsequently in Sect. IV.

What about the acceleration due to gravity? Ascoli [21] anticipated this question and answered it as follows in the present notation:

$$g(O) = Q^{-2} g(M). \tag{19}$$

It can be noted that eq. (19) is consistent with eq. (18) if one assumes that G is a fundamental constant and the gravitational mass M is invariant between rest frames. i. e. the exponent of Q is zero in this case as well. By contrast, inertial mass m_I scales with Q, the same as energy and time:

$$m_I(O) = Qm_I(M). \tag{20}$$

Note that Einstein's mass/energy equivalence relation $E=m_I c^2$ takes exactly the same form in all rest frames as a consequence of eqs. (16, 17, 20), as required by Galileo's relativity principle (RP).

Ascoli's eq. (19) is quite illuminating with regard to Schiff's calculation of light deflection discussed in Sect. II. Light is the object in this case, so v(M)=c in eq. (17). As a consequence, $Q=\gamma(v_M)=\infty$, and therefore, $Q^{-2}=0$ in eq. (19). On this basis, one concludes that g(O)=0, that is, no acceleration due to gravitational forces is expected for the light waves. This result is therefore consistent with Schiff's assumption that the velocity of the light waves always remains the same in the local rest frame, i.e. c in the x direction.

It is important to see that eq. (19) is consistent with Galileo's unicity principle (Eötvös experiment), since this only requires that the inertial and gravitational masses of all objects always be *in the same proportion* for any given observer. The proportionality constant is γ. One consequence of this relationship is that the gravitational mass of a photon (or any other system with null proper mass) is zero for all observers, even though its inertial mass ($h\nu/c^2$ in free space) varies with the relative speed of the observer to the light source (Doppler effect). This result is thus consistent with Newton's Third Law, since it indicates that a photon is incapable of exerting a gravitational force on any other object on this basis. Since photons in free space always move with speed c for a local observer, according to Ascoli's result, their local acceleration due to a gravitational field is also always zero. Thus, there is neither action nor reaction in this case.

In order to successfully adapt Schiff's method [5] to the description of planetary orbits, it is necessary to explicitly include the effects of eq. (11), i.e. Newton's classical theory of gravitation, in the computational procedure. The first step is to take the current value of the planet's velocity $\mathbf{v_M}$ relative to the sun and resolve it into its transverse and perpendicular components, exactly as has been done in Sect. II to obtain the deflection angle for light waves. Gravitational scaling via eqs. (8-9) is then undertaken to obtain the corresponding velocity components in O's rest frame (**v_O**). For this purpose, one must first evaluate S in accordance with eq. (3).

The next step is to obtain the value of g (O). For this purpose, it is necessary to expand upon eq. (19) to include the effects of gravitational scaling on this quantity. As discussed elsewhere [4], the resulting combined scaling equation for both kinetic and gravitational acceleration is [Q = γ (v_M), consistent with eq. (14)]:

$$g(O) = Q^{-2} S^{-3} g(M,P) \qquad [21]$$

The change in the planet's velocity **Δv_O** is then obtained as g (O) Δt, where Δt is the elapsed time in O's units during the current cycle. It is directed radial to the sun in accordance with Newton's classical theory.

The final velocity **v_O'** in O's units at the end of the cycle is then obtained by vector addition of **Δv_O** and **v_O** employing the velocity addition rule (Relativistic Velocity Transformation RVT [22]). This is an important point since use of simple vector addition of **Δv_o** to the original value of **v_o** in each time cycle causes significant accumulation of error over a complete orbital period. More generally, all the computations discussed herein are done using quadruple precision in order to insure sufficient overall accuracy [4].

The distance Δs_o travelled by the planet in the current time cycle from O's perspective is computed by multiplying the average velocity **v_o^a=(v_o+v_o')/2** by Δt(O). The direction taken is that of the average *local* velocity **v_M^a=(v_M+v_M')/2**, however, not that of **v_o^a**. The final local velocity **v_M'** is obtained by "back-scaling" **v_O'** in accordance with eqs. (8-9).

Note that since there is no gravitational acceleration of light in Schiff's method for computing the angular displacement of star images [4], the magnitude of $\mathbf{v_M^a}$ is always equal to c in this case and its direction is constant as the light passes by the Sun. Taking the direction the light follows to be the same as that of $\mathbf{v_o^a}$ in that application leads to inaccuracies in both the trajectory and the displacement angle. The final location of the object **P'** at the end of the cycle is thus computed as

$$\mathbf{P'} = \mathbf{P} + \frac{\mathbf{v_M^a}}{v_M^a}\Delta s_o \qquad (22)$$

It is important to see that all observers who are *co-moving* with O must measure exactly the same value for **P'**. They will only disagree on the amount of elapsed time for this portion of the object's trajectory because their respective clocks run at different rates depending on their position in the gravitational field. In essence, O's location at infinity makes him the ideal neutral observer. He and he alone can apply Schiff's scaling procedure to obtain the object's trajectory in his system of units (A_o=1), and this information can then be converted to the units of any other observer simply by knowing the latter's value of A_p from eq. (2).

The above procedure has been applied to the calculation of the relativistic contribution to the advancement angle of the perihelion of planetary orbits around the sun. At the start of the calculation the position and velocity of the planet are taken from experiment (based on the observed values for the mean radius r and eccentricity e of a given orbit). The solar mass is taken to be 1.99×10^{30} kg and the mass of the planet is not required, consistent with the unicity principle. The time interval $\Delta t(O)$ for each cycle in the numerical procedure has been varied in all cases to insure that a proper degree of convergence is obtained for the calculated results (quadruple precision has been used in all computations).

The value of the advancement angle Θ of the perihelion of Mercury's orbit around the sun obtained from this treatment is 43".0033/cy, in good agreement with both the currently accepted experimental value for this quantity of 43".2±0".9/cy [23] and that computed by Einstein from GTR of 43".0076/cy. [2, 24]. In the latter work he obtained a closed expression [24-25] which indicates that the advancement angle in general is proportional to M_s and inversely proportional to both r and $(1\text{-}e^2)$. Tests have therefore been carried out for different values of the latter three quantities, and very good agreement with the predictions of GR has been found in all cases. Indeed, since the amount of computer time required increases with r, most of the tests carried out are for a hypothetical planet with one-thousandth of Mercury's radius and therefore a period of revolution around the sun of only 240 s. When the solar mass is increased by a factor of 10.0, it is found that the value of Θ is 10.0012 times greater. If the mean radius is cut in half, Θ is found to increase by a factor of 1.9990. Similarly good agreement with GR is obtained if the radius is changed by factors of 10 and 100. Finally, when e is changed from its experimental value of 0.2056 for Mercury to 0.10, the value of Θ is found to be 0.9677 times smaller, as compared to the predicted factor of 0.9674.

The A_p factors have been computed in the present treatment in two different ways: by means of eq. (2) in each time-step, or by making use of the proportionality relationship between the A_p and γ factors to obtain an initial value only [4]. The corresponding two values of Θ agree to within a factor of 1.000093, with that obtained with the latter definition being higher. This result thus clearly supports the conclusion that the whole concept of gravitational scaling is rooted in the conservation of energy principle.

IV. Failure of the Lorentz Transformation

The scaling factors that are critical in Schiff's method [5] were determined by assuming that both the equivalence principle and the special theory of relativity are valid. As discussed above, however, the experiments with atomic clocks carried out by Hafele and Keating [15-16] have proven that kinetic and gravitational acceleration are fundamentally different. Each has its own separate effect on the rates of clocks.

In recent work [26-27], it has also been shown that Einstein's special theory of relativity [19] is similarly deficient. This fact is evident from the following equation contained in the Lorentz transformation (LT) which is the cornerstone of the special theory:

$$\Delta t' = \left(1 - v^2 c^{-2}\right)^{-0.5} \left(\Delta t - c^{-2} v \Delta x\right). \tag{23}$$

Einstein used the example of two lightning strikes on a train moving at constant velocity relative to the platform to illustrate his position that events which are simultaneous for one observer may not be so for another (remote non-simultaneity RNS). It is clear from this equation that if both the distance Δx separating the lightning strikes and the train's speed relative to the platform v are both non-zero, then it is impossible for the time differences $\Delta t'$ and Δt separating the strikes measured by the two observers on the train and platform both be equal to zero (simultaneous observation).

This conclusion overlooks the fact that both of the above clocks are moving at constant velocity and thus are inertial systems [27-28]. According to the Law of Causality, it is impossible for an inertial clock to change its rate spontaneously, i.e. without the application of some external unbalanced force. Therefore, each clock rate must remain constant indefinitely. As a consequence, the ratio Q of the rates of the two clocks must also be a constant, and this means that the elapsed times measured by the two clocks for the same event must also be in the same fixed ratio ($\Delta t'=\Delta t/Q$). This relationship is in direct conflict with eq. (23) of the LT. In particular, it forces the conclusion that if one of the time differences is zero, so must also the other's. This state of affairs is the antithesis of RNS [19] and constitutes proof that the LT is contradicted by measurement. It therefore cannot reasonably be claimed to be a valid component of relativity theory.

It is therefore not surprising that a number of other predictions of the special theory prove to be incorrect. For example, it is claimed that measurements of time, distance and inertial mass are *symmetric* for pairs of observers. If this were true, it would mean that observers who exchange light signals would each find that their respective measured frequencies are red-shifted [29]. This prediction is violated by the experience with atomic clocks obtained by Hafele and Keating [15-16]. It shows conclusively that clock measurements are asymmetric, i.e. one observer finds that his clock is running slower while the other finds the opposite (reciprocal) relationship. The latter result is clearly consistent with the proportionality of clock rates that is responsible for the above $\Delta t'=\Delta t/Q$ relationship between elapsed times.

The LT is also consistent with the Lorentz-FitzGerald length contraction prediction. Accordingly, the lengths of moving objects should be contracted by varying amounts depending on their orientation to the observer. This claim was contradicted by the Ives-Stilwell experiment [30] in which the wavelength of light emanating from an accelerated light source was found *to increase* relative to its standard value, and by the same fraction in all directions. The corresponding light frequency is found to decrease [17], from which it follows that the speed of light remains constant relative to its source. Ultimately, what the experiments show is that the slowing down of clocks (time dilation) is accompanied by length expansion of accompanying objects. This result runs contrary to what must be assumed based on the LT [19], and is instead consistent with eqs. (15, 18) given above.

Another example of the false predictions of the LT concerns the question of whether the speed of light can exceed c under any circumstances. If $\Delta x/\Delta t > c$ in eq. (23), it follows that Δt and $\Delta t'$ can have opposite signs, which would mean that the time order of events is different for the two observers. No such difference is expected on the basis of the $\Delta t' = \Delta t/Q$ result which is demanded on the basis of the Law of Causality, since $Q > 0$ in all cases. The experimental relationship for anomalous dispersion indicates that if the index of refraction n of the medium through which the light moves is less than unity, the speed of the light c/n will exceed c. Experimental verification of this relationship has been reported [31,32], but the reaction of mainstream physicists [33,34] has been to ignore this possibility and claim that the definition of light speed itself must be changed in order to agree with the LT.

The fact that useful relationships can be derived on the basis of the LT and the equivalence principle should not be surprising. The fact that both theories are irreparably flawed does not rule out the possibility of experimental verifications. Logic merely requires that an experimental contradiction is proof that the corresponding theory is not correct and needs to be amended.

V. Transmission of Gravitational and Kinetic Interactions

One can summarize the procedures employed above in the extended Schiff method by noting a simple point. They are based on the assumption that proportionality relations exist between measured values of a given physical property obtained by two different observers. Eqs. (4-9) depend on a single parameter S, and they refer to observers who are located at different gravitational potentials, whereas eqs. (15-18) depend instead on a single parameter Q. The proportionality factors themselves are always integral powers of either S or Q. The latter two values are easily calculated on the basis of minimal information of the locations of the observers in a gravitational field and on their respective states of motion. A summary of the values of these exponents for any physical property may be found in earlier work of the author [8].

It is also possible to combine the two sets of factors in each case. For elapsed times, for example, the following relation is obtained:

$$T(O) = \frac{Q}{S} T(M,\ P). \tag{24}$$

This relationship is used to correct the rates of atomic clocks carried on board satellites of the Global Positioning System (GPS) are the same as for their counterparts on the earth's surface [35,36]. The corresponding relation for energy values obtained by the same two observers for the same object is:

$$E(O)=QS\,E(M,P). \tag{25}$$

The corresponding relation for angular momentum $X=m_I vr$ is:

$$X(O)=Q^2 X(M,P). \tag{26}$$

Since Planck's constant h has the same units (Js) as angular momentum, it is scaled in the same manner. The conversion factor for inertial mass m_I is also (Q/S), the same as for time in eq. (24).

To obtain the above results it is sufficient to know the composition of any physical property in terms of the fundamental units of time, inertial mass and distance. The Q kinetic factor exponents are each equal to 1, while those for S are respectively, -1, -1 and 0. Note that the latter value is chosen on the basis of eq. (4) for lengths measured translational to the gravitational field. *The exponents chosen for each property guarantee that all the laws of physics are invariant to coordinate scaling, in accord with the RP.* Consider Planck's energy/frequency relation $E=h\nu$, for example: E scales as QS on the left-hand side, whereas h scales as Q^2 on the right and $\nu=1/T$ scales as S/Q, so that their product scales as QS, as required. For $E=m_Ic^2$, the right-hand side scales as Q/S for m_I and as S^2 for c^2 (again using the translational speed formula of eq. (8) and not eq. (9) for radial velocity required exclusively in the above trajectory calculations).

The comprehensive treatment of physical relationships discussed above, which requires the use of only the two parameters S and Q, provide a justification for employing a coordinate system in Euclidean space in which all objects of the universe can be located uniquely. All observers *who are not in relative motion to one another* [8] must agree on this basis with regard to the instantaneous position of each of these objects. As long as one takes proper account of the fact that the units of time, velocity and acceleration due to gravity vary with one's state of motion and position in a gravitational field, it is then possible *to carry out trajectory calculations exclusively in Euclidean spa*ce. The necessary adaptation can be accomplished by inserting a small number of statements in a comparatively simple computer program which otherwise treats planetary motion strictly on the basis of Newton's inverse square law (ISL) shown in eq. (11).

The development of a comprehensive gravitational theory that relies on the local validity of the ISL inevitably raises questions about whether such forces can be transmitted instantaneously across long distances. Newton himself rejected such an interpretation in the strongest terms, but this did not keep him from using the ISL to solve longstanding problems in astrophysics. The fact remains, however, that the above computer program uses time intervals as small as 10^{-4} s to calculate the change in velocity of a planet caused by the Sun which is as much as $7x10^{10}$ m distant. It is a matter of opinion whether GR succeeds in eliminating the need for "action at a distance" by introducing the concept of "curved space-time."

The present work indicates that the units of physical quantities vary in a precisely predictable manner with the distance of a given location from the gravitational source, suggesting that something like a distance-dependent stationary field ("aura") exists at all times. Therefore, *it does not need to be transmitted with gravity waves at any speed* to have the observed effect on an arbitrarily chosen object located at that point in space. It has demonstrated that, with proper attention to detail, it is possible to obtain a level of accuracy in trajectory calculations that is comparable to that of GR by merging the ISL with equations inspired by both Einstein [7] and Schiff [5] for the kinetic and gravitational scaling of the above physical units. This experience speaks for the validity of the assumptions that form the basis for arriving at this synthesis, and at least underscores the practicality of the ISL that Newton so skillfully exploited during his lifetime.

VI. Conclusion

The computational approach employed by Schiff in 1960 [5] operates on the principle that observers located at different gravitational potentials will disagree in a well-defined manner about the velocities of objects, as well as on the values of elapsed times and distances travelled by them. This procedure of "uniform scaling" was used to quantitatively predict the angle by which light appears to be bent during solar eclipses. The reason that Schiff was unable to extend this method to the description of the advancement of the perihelion of the orbit of Mercury and other planets can be traced directly to his failure to recognize that Newton's classical gravitational theory needs to be considered directly in such calculations. In particular, it is necessary that the acceleration due to gravity g must also be scaled so as to take explicit account of its effect on the planetary trajectories. The pertinent scaling factor is shown in eqs. (19,21) and makes clear why g never occurs in the light bending treatment. It is because $Q=\gamma=\infty$ since the local value of the light speed is always c and therefore, the scaled value of g is equal to 0 in this case. This is of course not so with planets and thus their velocities must be augmented continuously by adding $g\Delta t$ to their current value. Once this is taken care of, the angle of advancement of the Mercury orbit is predcited with the same level of accuracy as is obtained with GR [2].

Uniform scaling is applicable to any pair of observer-object pairs in the universe. The conversion factors depend exclusively on two separate parameters in each case, Q for kinetic scaling and S for graviational. It is possible to compute these quantities on the basis of a minimum of information regarding the states of motion and locations in a gravitational field of both participants. The conversion factor is always a product of Q^n and S^p, where the exponents p and n are integers that are specific to each physical property. For example, the time T measured on a satellite needs to be multiplied with Q/S in order to convert it to the unit of time used by an observer on the earth's surface. An amount of energy E for the object is equal to QS E in the observer's units. The acceleration due to gravity g measured locally on a planet (or a light ray) has a value of $Q^{-2}S^{-3}$ g for the observer.

The proportionality relationships expressed in the conversion factors for each property are to be regarded as *laws of physics*. Just as with the Laws of Thermodynamics and Newton's Laws of Motion, these relationships cannot be derived on the basis of so-called "First Principles." Instead, they have been developed so as to agree with the results of all available experimental information. Their main purpose is to encourage the development of further tests to verify their accuracy. One quite positive feature of the present set of conversion factors is that they leave all accepted laws of physics invariant. This experience is closely connected with Galileo's RP. It can be modified as follows on this basis: *The laws of physics are the same in each inertial system, but the units on which they are based can and do vary from one rest frame to another.* From the vantage point of each observer, the rest frame of a given object is characterized by specific values of Q and S. It is interesting to note that both S and Q would be equal to 1 in all applications if the speed of light is assumed to be infinite. All of the relativistic corrections to Newton's gravitational theory are due to his failure to realize that the speed of light is finite.

The rationale behind the uniform scaling method is very simple. It assumes that when the observer sees an object move into a particular rest frame, the interactions which are required to produce the effects indicated by the respective Q and Z conversion factors *are already there.* They were there before the object arrived and they remain after it has left. There is an *aura* produced by each active mass that is responsible for the effects indicated via the pertinent S scale factor. The same holds true for each ORS from which the speed of the object is to be inserted in the UTDL of eq. (12) in order to evaluate Q. No gravitational waves are necessary for these conditions to be present at any given time. It is useless to claim that the aura does not exist, any more than it is to assert that a specific experiment supposedly proves that there are gravitational waves moving with finite speed.

Is the isotropic scaling method equal to that of GR? Despite the previous history of nearly universal belief in GR, there is only one way to answer this question *objectively*. It is necessary to find an experiment which clearly distinguishes between the predictions of the two theories. A good place to start such an investigation is to ask whether light travels a perfectly straight line in free space. Or does it instead follow a curved path in agreement with the ubiquitous diagrams produced by GR proponents that show a ball rolling into a well to illustrate the fundamental nature of "relativistic space-time?" That one uses Euclidean coordinates while the other employs their Riemannian counterpart should not make any difference whatsoever? Since when does the changing of coordinates in a differential equation lead to different results, and not just make it easier to obtain the unique solution.

In addition, however, Schiff has also outlined another such possible distinguishing experiment [37 38]. Schiff pointed out that a naive application of the kinematics of special relativity in the form of Thomas's precession [39] of the electron's orbit around a nucleus leads to a qualitatively different prediction for the rate of precession of the component of spin in the plane of the earth's orbit than is predicted by GR. The GR precession frequency is actually indicated *to be in the opposite sense* as that indicated by the Newtonian law of gravitation. The theory outlined above is perfectly in line with Thomas spin precession, so there is a clear distinction between it and GR in this respect.

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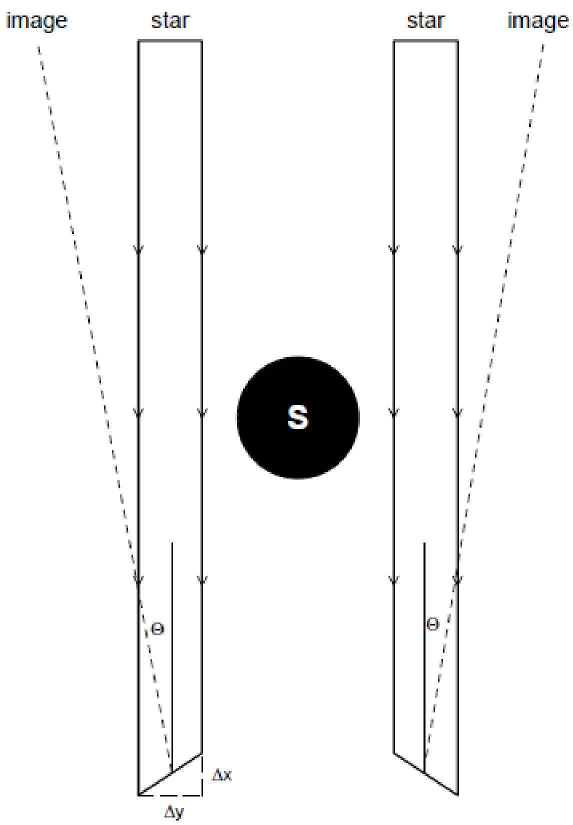
Fig. 1



$$\Theta = \frac{\Delta x}{\Delta y} = \int \frac{dc'dt}{dy} = \int \frac{1}{c'}\frac{dc'}{dy}dx$$

Schematic diagram showing light rays emitted by stars to follow straight-line trajectories as they pass near the sun. Because of gravitational effects, the speed of the light rays c' is known to increase with gravitational potential, with the effect that the corresponding Huygens wave front gradually rotates away from the sun. As discussed in the text, the normal to a given wave front points out the direction from which the light appears to have come, causing the star images to be displaced by an angle Θ during solar eclipses.

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