Simplified Computation of the Key Tests of General Relativity

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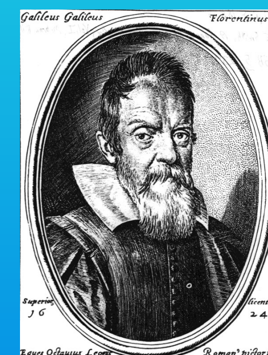

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Recent measurements carried out for the star S2 near a massive black hole have demonstrated that it exhibits a precession in its orbit that is comparable to that which occurs for Mercury and other planets in their orbits around the Sun. This phenomenon was predicted by Einstein in 1916 on the basis of his General Theory of Relativity (GR). The theory is characterized by its curved space-time methodology.

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. 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," can be explained with weaker assumptions than GR uses.

L. I. Schiff, "On Experimental Tests of the General Theory of Relativity", *Amer. J. Physics* **28,** 340-343 (1960).

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 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."

In the following, attention will be 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.

The stated purpose of Schiff's paper 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 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:

$$T_B = T_A \, [1 + GM/c^2 r_B - GM/c^2 r_A].$$

In this equation, 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

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 to make the following definition for P using the notation of the above equation:

$$A(P) = 1 + GM/c^2 r_P$$

(r_P is the distance between location P and the center of the active mass M). An analogous definition holds for O. Next define

$$S = A(O)/A(P) = (1 + GM/c^2 r_O)/(1 + GM/c^2 r_P).$$

Accordingly, $T(O) = S^{-1} T(P)$.

Since $S<1$ in the above equation when the observer is located at a higher gravitational potential than P ($r_O > r_P$), it is clear from this equation that the clock at P is running slower than that at O, as Einstein had predicted on the basis of his Equivalence Principle.

The utility of the scaling parameter S is demonstrated by considering the analogous proportional relationship for energies E(P) and E(O):

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$$E(O) = SE\,(P).$$

In this case the exponent of S is +1 as opposed to -1 for times. The energy value observed by O for an object at the lower potential is accordingly less than for the observer P for the same object. The proportionality factor is just the reciprocal of that for elapsed times.

Schiff 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:

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

$$L_{rad}(O) = SL_{rad}(P).$$

The latter two equations when combined with the equation for time then give the corresponding proportionalities for the transverse v_{tr} and radial v_{rad} components of velocity:

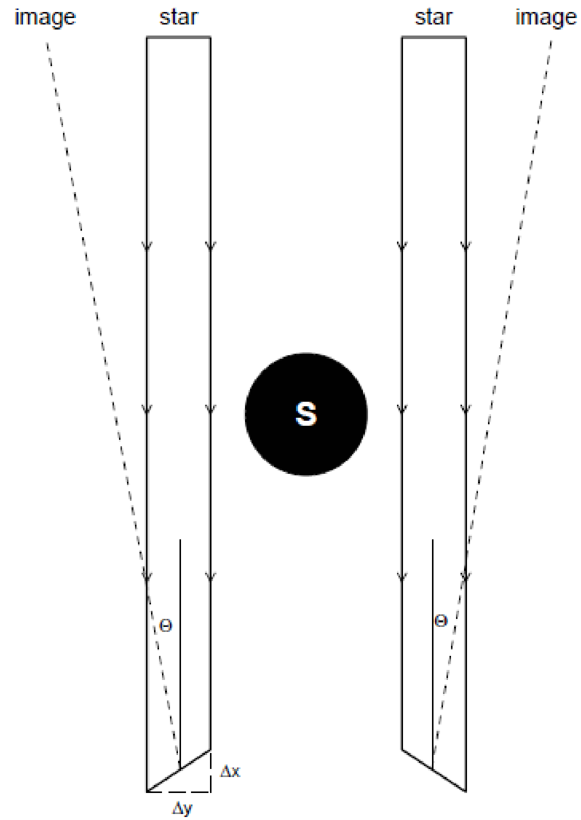
$$v_{tr}(O) = Sv_{tr}(P)$$

$$v_{rad}(O) = S^2 v_{rad}(P).$$

A key assumption in Schiff's method 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 the scaling proceeds in accordance with the above equations. The light trajectory over the entire distance to the Earth is then computed analytically in Schiff's approach.

An alternative, and computationally equivalent, method 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 the following diagram.



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

The line connecting the end points of the various light rays constitutes a *wave front*. The interpretation based on this diagram is 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 and Schiff employed Huygens' Principle to evaluate this angle:

$$d\Theta = dc' \, dx/c'dy = (dc'/dy)dt$$

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 the above equations. The differential change dΘ 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 the diagram, 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 Huygens' equation. 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 dΘ over the entire path therefore gives the amount by which the light appears to have been deflected from the straight-line path actually followed.

The finite differences approach for the execution of Schiff's uniform scaling method 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 in 1915 using a method of successive approximations.

Schiff also notes that *exactly half this value* results when the scaling of radial distance is ignored, the same result obtained by Einstein in his early attempts at calculating the angle of deflection. Schiff also points out that, in agreement with his scaling assumptions, Eddington 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.

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.

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". He quoted Einstein 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 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 by including Newton's ISL explicitly by employing a finite differences approach.

The following notation for the acceleration due to gravity g is given below, which is consistent with that used above:

$$g = GM/r^2$$

Significant encouragement for this approach was provided by some experimental results obtained a decade after Schiff's paper. Hafele and Keating placed identical atomic clocks on board 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 redshift 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, in obtaining the proportional relationships for properties mentioned above. 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 clear in Schiff's paper. Hafele and Keating by contrast found that these two effects on the clock rates are quite distinct and can simply be added to one another.

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

$$T(O)\,\gamma\,(v_O) = T(M)\,\gamma\,(v_M),$$

where v_O and v_M are the corresponding speeds relative to the ECM.

The same inverse proportionality 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) 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 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 which is closely analogous to that first discussed for gravitational effects. In this case, $\gamma\ (v_M)$ serves the same purpose as $A_p \equiv A(P)$:

$$\gamma\ (v_M) = (1 - v_M^2\ c^{-2})^{-0.5}$$

where v_M is the speed of the object relative to the ORS. A ratio Q analogous to S for gravity then serves as a common scaling factor for the effects of kinetic acceleration. It is obtained directly from the UTDL as:

$$Q = \gamma\ (v_M)\ /\gamma\ (v_O)$$

In analogy to the gravity equation, the relationship between elapsed times is:

$$T(O) = QT(M).$$

The corresponding relationship for energies is

$$E(O) = QE\,(M).$$

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:

$$v(O) = v(M) = Q^0 v(M).$$

It is then necessary that the corresponding distance scales the same as time:

$$L(O) = QL\,(M).$$

In other words, time dilation is accompanied by length expansion, not the type of anisotropic relationship (Lorentz-FitzGerald length contraction) that is predicted by Einstein's special theory of relativity. Other proofs that his theory is invalid will be discussed subsequently

What about the gravitational acceleration factor g? Ascoli anticipated this question and gave the following answer:

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

It can be noted that this is consistent with the distance proportionality relationship and Newton's Inverse Square Law (ISL) 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:

$$m_I(O) = Qm_I(M).$$

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, as required by Galileo's Relativity Principle (RP).

Ascoli's relation is quite illuminating with regard to Schiff's calculation of light deflection. Light is the object in this case, so $v(M)=c$. As a consequence, $Q=\gamma(v_M)=\infty$, and therefore, $Q^{-2}=0$ in Ascoli's formula. 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 Ascoli's equation 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 to the description of planetary orbits, it is necessary to explicitly include the effects of Newton's ISL, i.e. the classical theory of gravitation, in the computational procedure. The first step is to take the current value of the planet's velocity $\mathbf{v}_{\mathbf{M}}$ relative to the Sun and resolve it into its transverse and perpendicular components, exactly as has been done to obtain the deflection angle for light waves. Gravitational scaling is then undertaken to obtain the corresponding velocity components in O's rest frame ($\mathbf{v}_{\mathbf{O}}$). For this purpose, one must first evaluate S.

The next step is to obtain the value of g (O). For this purpose, it is necessary to extend Ascoli's equation to include the effects of gravity. As discussed elsewhere [R. J. Buenker, "Extension of Schiff's gravitational scaling method to compute the precession of the perihelion of Mercury," *Apeiron* **15**, 509-533 (2008)], the resulting combined scaling equation for both kinetic and gravitational acceleration is [$Q = \gamma\ (v_M)$], consistent with the UTDL is:

$$g(O) = Q^{-2} S^{-3} g\,(M,P).$$

The change in the planet's velocity $\mathbf{\Delta v_O}$ 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 $\mathbf{v_O}$' in O's units at the end of the cycle is then obtained by vector addition of $\mathbf{\Delta v_O}$ and $\mathbf{v_O}$ employing the velocity addition rule (Relativistic Velocity Transformation RVT). This is an important point since use of simple vector addition of $\Delta\mathbf{v_o}$ to the original value of $\mathbf{v_o}$ 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.

The distance Δs_o travelled by the planet in the current time cycle from O's perspective is computed by multiplying the average velocity $\mathbf{v_o^a}=(\mathbf{v_o}+\mathbf{v_o}')/2$ by $\Delta t(O)$. The direction taken is that of the average *local* velocity $\mathbf{v_M^a=(v_M+v_M')/2}$, however, not that of $\mathbf{v_o^a}$. The final local velocity v_M' is obtained by "back-scaling" $\mathbf{v_O}'$ in accordance with the rules for the radial and transverse components.

Note that since there is no gravitational acceleration of light in Schiff's method for computing the angular displacement of star images, 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:

$$\mathbf{P'} = \mathbf{P} + (\mathbf{v_M}^{\mathbf{a}} / v_M{}^{a})\Delta s_{\mathbf{O}}'$$

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.

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.[i]

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 and that computed by Einstein from GTR of 43".0076/cy. In the latter work he obtained a closed expression which indicates that the advancement angle in general is proportional to M_s and inversely proportional to both r and $(1-e^2)$.

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 the above formula 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. 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.

The scaling factors that are critical in Schiff's method 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 have proven that kinetic and gravitational acceleration are fundamentally different. Each has its own separate effect on the rates of clocks.

In recent work, it has also been shown that Einstein's special theory of relativity is similarly deficient.

R. J. Buenker, "The global positioning system and the Lorentz transformation," *Apeiron* **15**, 254-269 (2008).
R. J. Buenker, "The clock puzzle and the incompatibility of proportional time dilation and remote non-simultaneity," *J. App. Fundamental Sci.* **4 (1)**, 6-18 (2018).

This fact is evident from the following equation contained in the Lorentz transformation which is the cornerstone of the special theory:

$$\Delta t' = (1-v^{2}c^{-2})^{-0.5}(\Delta t\text{-}c\text{-}2v\Delta x)$$

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. 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 the above equation 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 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. This prediction is violated by the experience with atomic clocks obtained by Hafele and Keating. 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 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, 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, and is instead consistent with the scaling equations discussed 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 the LT equation, 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, but the reaction of mainstream physicists 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.

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. These equations depend on a single parameter S, and they refer to observers who are located at different gravitational potentials, whereas the other equations 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.

R. J. Buenker, "Gravitational and kinetic scaling of physical units," *Apeiron* **15**, 382-413 (2008),

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

. $T(O) = (Q/S)T(M,P).$

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. The corresponding relation for energy values obtained by the same two observers for the same object is:

$$E(O) = QS\,E(M,P).$$

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

. $X(O) = Q^2 X(M,P)$

.

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.

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 the equation 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 also scales as QS, as required. For $E=m_I c^2$, the right-hand side scales as Q/S for m_I and as S^2 for c^2

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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 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 space. 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 (ISL).

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 7×10^{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 and Schiff 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.

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R. J. Buenker, "Extension of Schiff's gravitational scaling method to compute the precession of the perihelion of Mercury," *Apeiron* **15**, 509-533 (2008).
L. I. Schiff, "On Experimental Tests of the General Theory of Relativity", *Amer. J. Physics* **28,** 340-343 (1960).
I. Shapiro, "Fourth test of general relativity," *Phys. Rev. Letters* **13,** 789 (1964).