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Reconciling Einstein's postulate with the objectivity of measurement: A reciprocal lorentz transformation

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Abstract
A review of Einstein's derivation of the Lorentz transformation (LT) discloses an unjustified assumption that leads to conflicts with experimental data. By taking advantage of a normalization condition, it is shown that a different version of the relativistic space-time transformation is obtained which allows the theory to be consistent with the ancient principle of objectivity of measurement while still satisfying Einstein's original postulates regarding the constancy of the speed of light and the equivalence of all inertial systems.

Keywords: Time dilation, remote non-simultaneity, lorentz transformation (LT), universal time-dilation law (UTDL), alternative global positioning system-lorentz transformation (GPS-LT)

1. Introduction

There has been a widespread consensus among physicists that the Lorentz transformation (LT) represents the only means of satisfying Einstein's two relativity postulates [1] while still reducing to the classical Galilean space-time transformation in the limit of low velocity. The resulting theory breaks with a number of long-established principles, particularly the belief that the measurement process is totally objective. It claims instead that the result of a measurement is a matter of perspective, for example, that observers in relative motion can objectively disagree as to which of two clocks is running slower or which measuring rod is shorter than the other. At the time that Einstein gave his derivation of the LT, there were no experiments that were in conflict with this conclusion, but that situation has changed over the past 65 years with the availability of highly accurate measurements of the frequencies of atomic lines and the development of atomic clocks. In a companion paper [2] it has been shown that the blue shift obtained in transverse Doppler experiments with ultracentrifuges [3-5] is incompatible with predictions based on the LT. On this basis it becomes advisable to reexamine Einstein's derivation of this set of equations. The goal is to remove the above contradiction from the existing theory, while still remaining consistent with the relativity principle and the constancy of the speed of light in free space.

2. Derivation of an Objective Version of the LT

In order to completely specify a linear transformation connecting two sets of space-time coordinates, (x,y,z,t) in inertial system S and (x',y',z',t') in inertial system S', it is necessary to specify the values of 16 coefficients/matrix elements. Lorentz [6] and Einstein [1] showed that all but three of these can be eliminated on the basis of considerations of the isotropy and homogeneity of inertial frames [7]. Without loss of generality, we can assume that the two sets of axes are always parallel to one another, i.e., x with x', y with y' and z with z', and that the direction of relative motion of S and S' is along their respective (coincident) x and x' axes with speed u. We adopt the following notation for the remaining three undetermined parameters in the transformation equations:

$$\begin{aligned} t' &= A\,(t + Bx) \\ x' &= A\,(x - ut) \\ y' &= \varepsilon\, y \\ z' &= \varepsilon\, z. \end{aligned} \qquad (1)$$

The values of A and B are then determined by invoking Einstein's second postulate, the constancy of the speed of light c in free space. If the light pulse travels along the x,x' axis (y=z=0), it follows from eq. (1) that x'/t' = x/t = c and thus that $B=-u/c^2$. In order to have the same condition fulfilled when the light pulse travels in an arbitrary direction, it is necessary that $A = \gamma\,\varepsilon$, with $\gamma = (1 - u^2/c^2)^{-0.5}$.
At this point in the derivation, Einstein made a critical assumption (see p. 900 of Ref. 1). He claims without discussion that the remaining coefficient ε (φ in his notation) can only be a function of the relative speed u of S and S', and then goes on to show based on symmetry arguments that the latter condition leads unequivocally to a value of unity for this quantity. Lorentz had pointed out earlier [6] that the electromagnetic field equations remain invariant to the above transformation independent of the choice of ε, and it is clear that the same holds true for Einstein's light speed condition. Consequently, it is possible to obtain the corresponding relativistic velocity transformation (RVT) without specifying the value of ε. This is significant because the main empirical verifications of the resulting theory [8], namely the Fizeau light drag experiment and the aberration of light from stars at the zenith, are based directly on Einstein's RVT and only indirectly on the LT itself. Upon making the above substitutions for A and B in eq. (1) and defining the velocity components as $v_x=x/t$, $v_{x'}= x'/t'$ etc., we obtain:

$$\begin{aligned} v_x' &= (1 - uv_x/c^2)^{-1}(v_x - u) = \eta\,(v_x - u) \\ v_y' &= (1 - uv_x/c^2)^{-1}\, v_y/\gamma = \eta\, v_y/\gamma \\ v_z' &= (1 - uv_x/c^2)^{-1}\, v_z/\gamma = \eta\, v_z/\gamma, \end{aligned} \qquad (2)$$

with $\eta = (1 - uv_x/c^2)^{-1}$, in agreement with Einstein's original result [1].
At this stage in the present derivation, the transformation equation for t' still has an undetermined parameter ε:

$$t' = \gamma\varepsilon\,(t - ux/c^2) = \gamma\varepsilon t/\eta. \qquad (3)$$

As already mentioned, Einstein assumed that ε could be a function of at most the relative speed u of S and S'. However, in so doing he overlooked the fact that the quantity η in the RVT of eq. (2) is a function of both u and v_x, the parallel component of the object's speed. On this basis, there is no reason to assume that ε might not also depend on v_x as well. By excluding the latter possibility, Einstein was led unequivocally to the value of ε = 1 that produces the LT version of eq. (3). One of the main consequences of this choice is that the resulting theory is only consistent with a subjective interpretation of the measurement process whereby observers in S and S' must disagree as to whose clock is running more slowly. In actual practice, this means that when the two observers exchange signals from an identical light source, the theory predicts that they will each find the frequency to be Doppler-shifted to the red.
The ultracentrifuge experiments [3-5], as pointed out in a companion publication [2], found a blue shift when the observer/absorber of the radiation moves at a higher speed (v) than the light source (v') relative to the rotor axis. In other words, the experimental results contradict the latter prediction of a red shift in all cases. The empirical data [3-5] indicate the following relation to hold between elapsed times measured at the positions of the absorber (t) and light source (t'):

$$t' = \gamma\,(v)\, t \,/\, \gamma\,(v') = t/Q. \qquad (4)$$

In other words, the rate of a given clock decreases with its speed relative to this axis [4]. It is therefore not a question of perspective as to which clock is running slower at any given time. Because eq. (4) is satisfied in all experimental tests of time dilation as yet carried out, it will be referred to in the following as the Universal Time Dilation Law (UTDL) [9-10].
If v>v', as in the above experimental arrangement [3-5], then $Q = \gamma\,(v') \,/\, \gamma\,(v) < 1$ and an observer in S will therefore measure a smaller elapsed time/period t for the radiation, and thus a higher frequency (blue shift), than the value t' measured at the radiation source. The opposite result occurs when the light source is moving faster than the absorber relative to the rotor's axis. The latter situation (Q>1) occurs in the Ives-Stilwell transverse Doppler measurements [11], in which case the light source moves at high speed in the laboratory in which the measurements are carried out and a red shift is observed. Measurement is objective rather than subjective. There is no disagreement in either set of experiments as to which clock is running slower. Instead, the experimental data demonstrate that clock rates are strictly proportional to one another as long as the relative speeds v and v' retain the same values. This result is consistent with eq. (4) but not with the LT obtained from eq. (3) by setting ε=1.
Moreover, it is possible to obtain eq. (4) directly from eq. (3) by making the substitution:

$$\varepsilon = \eta/\gamma Q. \qquad (5)$$

This choice requires that ε be a function of both u and v_x because of the definition of η, and thus was excluded by Einstein's assertion [1] that ε could only be a function of at most the former variable. Since any value for ε leads to the RVT of eq. (2), it is therefore clear that the principle of objectivity of measurement implied by eq. (4) is perfectly compatible with Einstein's second postulate of the constancy of the speed of light in free space. Whether it is also consistent with the relativity principle is the subject of the following section.

3. Lorentz Invariance and Reciprocal Measurement
One of the primary motivations for Einstein's derivation of the LT was his belief in the essential symmetry characteristics of natural processes. Neither eq. (4) nor eq. (5) would appear to satisfy this criterion, at least not in an obvious way. The situation can best be illustrated with reference to the Lorentz invariance condition of the LT. The general transformation of the space-time coordinates given in eq. (1) satisfies the following relation:

$$x'^2 + y'^2 + z'^2 - c^2t'^2 = \varepsilon^2\,(x^2 + y^2 + z^2 - c^2t^2). \qquad (6)$$

The relativity principle, Einstein's first postulate, demands that this equation hold for all observers. This is easily accomplished in the LT by setting ε = 1, in which case eq. (6) is symmetric with respect to interchanging the primed and unprimed coordinates of the same type, so that it is equally valid for observers in both S and S'. However, this choice is by no means unique in this respect. All the relativity principle actually requires is that the two observers agree on the general form of this invariance relation, each from his own perspective. It is wholly sufficient if an equivalent relationship to eq. (6) holds for the "other" observer from his vantage point for the same process. In the present instance this means that a second equation must be equally valid:

$$x^2 + y^2 + z^2 - c^2t^2 = \varepsilon'^2 (x'^2 + y'^2 + z'^2 - c^2t'^2), \qquad (7)$$

that is, one in which corresponding primed and unprimed quantities are interchanged with respect to eq. (6). The only thing the relativity principle demands is therefore that the definition of ε' in eq. (7) for the observer in S must be completely equivalent to that of ε in eq. (6) for his counterpart in S'. In other words, Einstein's choice of ε = ε' = 1 in the LT is far too restrictive.

There is another condition that needs to be imposed on the values of ε and ε' based on eqs. (6-7) if one makes the assumption that carrying out successive transformations in the forward and reverse directions must lead to the original set of space-time coordinates. This is tantamount to insisting that one be allowed to use the ordinary rules of algebraic manipulation in working with the above equations. It should be pointed out, however, that this concept implies compliance with the general principle of the objectivity of measurement, which has been deemed expendable in other instances in the existing theory, for example, in the case of time dilation. Applying it in the present instance leads to the following equation:

$$\varepsilon\varepsilon' = 1, \qquad (8)$$

which has also been used in Einstein's derivation of the LT [1].

The question thus arises as to whether the definition of ε in eq. (5) satisfies the above relation. To see that it does, it is helpful to first go back and examine eq. (4) and the physical significance of the proportionality factor Q contained in it. It arises because of the experimental fact that the rates of clocks differ from one rest frame to another. This has been demonstrated in a most convincing fashion with the atomic clocks carried onboard circumnavigating airplanes in the Hafele-Keating experiments [12], as well as in the transverse Doppler measurements employing ultracentrifuges [3-5] mentioned in the Introduction. Ordinary algebraic manipulation of eq. (4) leads to the equivalent result:

$$t = \gamma (v')\, t' / \gamma (v) = Qt' = t'/Q'. \qquad (9)$$

It is necessary to assume that Q' = 1/Q in the last expression, so that interchanging the primed and unprimed variables in eq. (9) leads back directly to the original equation, as required by the relativity principle. In conclusion, objectivity of the measurement process demands that the two proportionality factors be inversely proportional to one another, not that they be equal. The resulting theory thus has a reciprocal feature that is totally absent in the LT.

The rest of the new version of the Lorentz transformation can be obtained by applying the definition of ε in eq. (5) to the spatial relations of eq. (1), with A=γε = η/Q:

$$\begin{aligned} x' &= (\eta/Q)(x - ut) \\ y' &= \eta y/\gamma Q \\ z' &= \eta z/\gamma Q. \end{aligned} \qquad (10)$$

The same result is obtained by multiplying the three equations of the RVT of eq. (2) by both sides of the corresponding temporal relation in eq. (4), i.e. t'=t/Q, and recalling that $v_x = x/t$ etc. The inverse relations are obtained in the usual way by changing the sign of u and interchanging the respective primed and unprimed variables in each case [$\eta' = (1 + uv_x'/c^2)^{-1}$ upon applying the same operations to η as defined below eq. (2)]. As before, this procedure is required by the relativity principle, and the inverse relations are thus:

$$\begin{aligned} x &= (\eta'/Q')(x' + ut') \\ y &= \eta' y'/\gamma Q' \\ z &= \eta' z'/\gamma Q'. \end{aligned} \qquad (11)$$

Note that γ (u) is unchanged in this procedure and that QQ'= 1 [see eq. (9)].

It is important to see that, as before with eqs. (4,9) for t and t', one can also obtain the spatial relationships in eq. (11) by algebraic manipulation of eq. (10), that is, without making any assumptions based on the relativity principle. To this end, it is important to prove the following relationship [13]:

$$\eta\eta' = (1 - ux/tc^2)^{-1} (1 + ux'/t'c^2)^{-1} = \gamma^2. \qquad (12)$$

This can be done by using the expressions for x' and t' in eqs. (4, 10). As a result, we can rearrange eq. (10) to give

$$y = \gamma Q y'/\eta = \eta' y'/\gamma Q', \qquad (13)$$

in agreement with eq. (11). The corresponding result for z and z' can be obtained in the same manner, as well as the verification of eq. (8) by using the definition in eq. (5):

$$\varepsilon\varepsilon' = (\eta Q/\gamma)(\eta' Q'/\gamma) = 1. \qquad (14)$$

Finally, rearrangement of the relation for x' in eq. (10) gives:

$$\begin{aligned} x &= Qx'/\eta + ut = \eta' x'/Q'\gamma^2 + \eta' u\, t'/\eta' Q' \\ &= (\eta'/Q')\, [x' (1 - u^2/c^2) + ut' (1 + ux'/t'c^2)] \\ &= (\eta'/Q')(x' + ut'), \end{aligned} \qquad (15)$$

the remaining inverse relation in eq. (11).

The transformation of space-time variables in eqs. [4, 10] thus satisfies both of Einstein's postulates of relativity. It also reduces to the Galilean transformation in the limit of low velocities, since each of the quantities, η, γ and Q, approaches a unit value under these conditions. However, while the LT insists on the inextricable mixing of space and time, the present transformation (which we will refer to as the Global Positioning System- Lorentz transformation or GPS-LT [14, 15]) remains consistent with the Newtonian view that space and time are completely distinct entities. Its eq. (4) simply incorporates the experimental fact that the unit of time is not the same for all observers because of the phenomenon of time dilation. The rates of clocks depend on their state of motion as well as their position in a gravitational field, and thus two observers can and do disagree on the amount of time a given process requires. The ratio of their elapsed times is independent of the event under consideration, however, and this quantity therefore must appear explicitly in each of the equations of the transformation. The relationship for any two observers is *reciprocal* rather than symmetric, as exemplified by the QQ' =1 relationship inherent in eqs. (4, 9) and (10, 11), respectively. This reciprocal relationship is a consequence of the principle of the objectivity of measurement that is implied by the results of the transverse Doppler measurements discussed in a companion publication [2]. It leaves open the possibility that observers can disagree on the value of a certain measurement because of the different units they employ to express their respective results, but it rules out any disagreement about whose measured value is greater or less in any given case.

The form of the RVT in eq. (2) suggests that it is also valid when the relative speed u and velocity component v_x are not constant, which is to say that we can apply it on an instantaneous basis even when either the object of the measurement or one of the observers is being accelerated. When the same assumption is made in eqs. (4,10), the result is the differential form of the RLT given below:

$$\begin{aligned} dx' &= (\eta/Q)(dx - udt) \\ dy' &= \eta dy/\gamma Q \\ dz' &= \eta dz/\gamma Q \\ dt' &= dt/Q, \end{aligned} \tag{16}$$

where Q is also taken to be the instantaneous value of the clock-rate ratio for the two observers. It reduces to the RVT upon appropriate division of dx', dy' and dz' by dt' if we use the standard definitions for the corresponding velocity components, i.e. v_x=dx/dt etc. The corresponding inverse transformation is then

$$\begin{aligned} dx &= (\eta'/Q')(dx' + udt') \\ dy &= \eta' dy'/\gamma Q' \\ dz &= \eta' dz'/\gamma Q' \\ dt &= dt'/Q'. \end{aligned} \tag{17}$$

In both sets of equations, the instantaneous values for η, η' and γ are assumed and we also require that the clock-rate ratios Q and Q' bear a reciprocal relationship to one another. Employing a differential form for the transformation has several simplifying features. It removes the necessity of having a common origin for the coordinate systems employed for S and S' at some particular time since only changes in the space-time variables appear in the transformation. It also downplays the role of inertial systems in relativity theory and claims instead that the GPS-LT can be successfully applied on an instantaneous basis even when one or both observers are being accelerated, which after all is almost universally the case in actual experiments.

4. Hamilton's Principle and Objectivity of Measurement

The failure of Einstein's LT to correctly predict the sign of the transverse Doppler frequency shifts observed in ultracentrifuge experiments [3-5] has far-reaching consequences in relativity theory. The conversion factor Q in eq. (4) of the GPS-LT also appears in the corresponding spatial equations [eq. (10)], for example. This is clearly necessary to satisfy Einstein's second postulate of the constancy of the speed of light in free space. In order for two observers to measure the same value for the speed of light using clocks which have different rates, it is obvious that their respective units of length/measuring rods must also differ by the same factor. Since the observer with the slower clock must report a smaller value for the elapsed time for the light to move between two points, it follows unequivocally that he obtained a correspondingly smaller value for the distance traveled. For this to happen, however, he needs a *larger* measuring rod than his counterpart, not a smaller one. Moreover, the lengthening effect cannot depend on the rod's orientation in space, because both the speed of light and the rate of his clock are the same in all directions. The conclusion is that time dilation is accompanied by isotropic length expansion [16], not by the type of anisotropic (Fitzgerald-Lorentz) length contraction foreseen with the LT.

The same conclusion follows from the modern definition of the meter as the distance traveled by light in free space in 1/c s. Accordingly, the unit of length must be proportional to the period of the standard clock used to carry out the timing measurement, which clearly means that it increases when the clock is slowed by time dilation. Einstein's original theory [1] does not subscribe to the principle of objectivity of measurement, and thus is free from making such a straightforward connection. In effect, it claims that the above definition of the meter is only valid when the object of the measurement is at rest with respect to the observer, even though the speed of light is postulated to be the same even when this is not the case. The GPS-LT of eqs. (4,10) has no such problem with describing the interconnections of clock rates, units of length and light speed. It insists that relativity theory be consistent with the objectivity principle so that the ordinary rules of algebra can be applied to determine such relationships.

We next turn to measurements of energy E, inertial mass m and momentum p in relativity theory. The Maxwell electromagnetic field equations are invariant to a Lorentz transformation for any value of ε [6] in eq. (1), so there is no distinction between the LT and the GPS-LT on this basis. Einstein concluded from his analysis [1] that the inertial mass m of an accelerated charged particle is different in the longitudinal and transverse directions relative to its velocity vector v. He later agreed [17] with Planck [18] that the supposed mass anisotropy is removed when one uses Newton's Second Law in the definition of force

(F = dp/dt) instead of F=mdv/dt as in his original derivation [1]. This led to the presently accepted definition in terms of the proper or rest mass μ:

$$m = \gamma (v) \mu. \tag{18}$$

The latter relation is analogous to that used for lifetimes of accelerated particles, which, as we have seen above, is not generally valid. This raises the question of what would be the result of an experiment with an ultracentrifuge in which the mass of object A, located close to the rotor axis, is compared with that of an identical object B near its rim. According to eq. (18), the mass of B would be greater because it is moving faster relative to the rest frame of the laboratory. If the observer is co-moving with B, it seems inescapable that a similar result would be found as for the Doppler-shifted frequency in the ultracentrifuge experiments [3-5], namely he would find that m(A) is less than the (proper) value he measures for B, i.e., m(B) = μ > m(A). This is the only possibility if one assumes that the physical measurement process is objective, which one can take as an additional postulate for relativity theory. On this basis, one is led to a general relation between the measured values of a given mass obtained by observers in two different rest frames that is entirely analogous to eq. (4) for elapsed times:

$$m' = m/Q, \tag{19}$$

where Q has the same value as in the latter relation. Accordingly, eq. (18) is assumed to be of limited validity, holding only for the situation in which the object is accelerated to speed v from the laboratory (S) in which the observer is at rest. In this case (as in the Ives-Stilwell experiment [11], for example), $m' = \mu$ in S' and $Q = \gamma(v)$, so that the observer in S measures a value of $m = \gamma\mu$. For a meta-stable particle, this means that the ratio of its lifetime τ and inertial mass m is the same for all observers (after correcting for gravitational effects [19-21]). In the high-speed rotor studies [3-5], $Q= \gamma(v')/ \gamma(v)$, in accord with the UTDL of eq. (4). Since $Q<1$ in this case with $v'<v$, as discussed in Sect. II, the observer in the rest frame of the absorber (S) finds that his value for the inertial mass m of the object at rest in S' is less than $m'=\mu$ according to eq. (19).

It is instructive to examine the way in which the dependence of a particle's kinetic energy K on its speed v in order to show that the above conclusion regarding eq. (18) is reasonable. This derivation is achieved by assuming that Hamilton's relation holds for the dependence of energy E on momentum p, namely $dE/dp = v$ (with $p = mv$):

$$K = \int_0^v v\,dp = \int_0^v v\,d\,[\gamma(v)\,\mu\, v] = (\gamma - 1)\,\mu\, c^2 = (m-\mu)\, c^2, \tag{20}$$

where eq. (18) has been assumed in the definition of $p = mv$. This result is closely related to Einstein's famous $E=mc^2$ relation [1], which has been verified in many experiments. However, the point which needs to be emphasized in the present context is that Hamilton's relation itself is only valid under very specific conditions: It is assumed that the particle was initially at rest and that its final speed v was reached by virtue of the application of a force at this rest position. Returning to the centrifuge example above [3-5], this means that eq. (20) can only be used directly to compute the energy of the particle located at a given distance from the rotor axis from the vantage point of an observer who is at rest in the laboratory. When the observer is also accelerated, the unit of energy on which he bases his measurements is greater than its corresponding value when he was at rest in the laboratory, causing him to find that the energies of objects that remained at rest in the laboratory have decreased by the same fraction. The corresponding relation for energies measured in two rest frames S and S' has the same form as for masses and elapsed times:

$$E' = E/Q. \tag{21}$$

Hamilton's relation can also be used to obtain an energy-momentum transformation, but again subject to the same restrictions as above. In this case, we assume on the basis of Einstein's second postulate [1] that $dE/dp = dE'/dp' = c$. Using essentially the same arguments as for the LT, one arrives at the following well-known result (with $\varepsilon=1$) [16]:

$$\begin{aligned} dE' &= \gamma\,(dE - u\,dp_x) \\ dp_x' &= \gamma\,(dp_x - u\,dE/c^2) \\ dp_y' &= dp_y \\ dp_{z'} &= dp_z\,. \end{aligned} \tag{22}$$

If the object is at rest in S', it follows that $dp= dp_x' =0$ and that $dp_x = udm = udE/c^2$ and hence $dm=dE/c^2$. The result is clearly consistent with the $E=mc^2$ formula, which enjoys general validity, but the corresponding invariance relation, $dE^2 - c^2\, dp^2 = dE'^2 - c^2\, dp'^2$ only holds if $dE = \gamma dE'$ and $dp'=0$. This occurs whenever the conditions for Hamilton's relation are satisfied, but it does not hold for an experiment in which both the observer and the object are rotating at high speed on an ultracentrifuge. In that case one needs to know the ratio Q of the two γ factors in eq. (4) in order to successfully predict the value of the object's energy from the vantage point of the observer by applying eq. (21). Hamilton's relation is thus a means to an end in the general case, but it leads to false predictions if u is not the velocity of the accelerated object relative to the point at which an external force was applied to it, i.e. $dp'=0$. This restriction is clearly consistent with the principle of the objectivity of measurement. Above all, it stands in contradiction to the oft-repeated assertion that the measured inertial mass of an object is always greater than its rest mass μ.

5. Conclusion

The only valid reason other than experimental error that two observers can disagree on the value of a given physical quantity is because they express this result in a different set of units. This is the principle of objectivity of measurement. Since the clock rates and inertial masses that scientists depend on to define these units vary with acceleration, it is essential that they take these systematic differences into account when comparing the results of their observations. Einstein disavowed the above principle in deriving his special theory of relativity [1] because he felt that it came into conflict with his two postulates, the relativity principle and the constancy of the speed of light in free space. The hallmark of his theory is the Lorentz transformation (LT) and its characteristic Lorentz invariance. It leads to the conclusion that two observers in relative motion must find that it is the other's clock that is running slower or the other's measuring rod which is shorter. The experimental data for transverse Doppler shifts contradict this position, however, as has been discussed in a companion publication [2]. If the LT were the correct space-time transformation, a red shift would have to be observed independent of whether the observer or the light source was moving faster in the laboratory, but this position was disproven by the ultracentrifuge experiments carried out in the 1960s [3-5]. This fact went unnoticed at the time because it was possible to obtain the correct prediction by using Einstein's equivalence principle between acceleration and gravity. The latter is an objective theory, however, since it assumes that there is a definite relationship between the rates of clocks at different gravitational potentials, and it is for this reason that it succeeds whereas the original LT-based theory of the Doppler effect does not.

The present work has shown that one can take advantage of a degree of freedom in the definition of the original LT to obtain a different space-time transformation that still satisfies Einstein's two postulates while being perfectly consistent with the objectivity of measurement principle. Its definition requires knowledge of the ratio of the clock rates employed by the two observers whose measurements are being compared, in accordance with the Universal Time Dilation Law (UTDL) of eq. (4). The resulting transformation in eqs. (4,10) is referred to as the Global

Positioning System-Lorentz transformation or GPS-LT. It recognizes that the above ratio (Q) for one observer must have the reciprocal value for the other (Q' = 1/Q). The inverse transformation can be obtained by straightforward algebraic operations and the resulting set of equations has exactly the same form as the original, as required by the relativity principle.

The GPS-LT is neither Lorentz-invariant nor does it lead to Fitzgerald-Lorentz contraction, both of which predictions of Einstein's LT-based theory have never been verified experimentally. It is also consistent with the principle of absolute remote simultaneity, since there is no space-time mixing in eq. (4). Accordingly, when observers disagree on the elapsed time of a given event, it is only because their clocks are not running at the same rate.

Perhaps the main advantage of the objectivity principle is that it allows one to not only employ a rational set of units in each rest frame but also to have a precisely defined procedure for converting from one set to another between rest frames by using the UTDL. Helpful in this respect is the observation that the units of energy, time and inertial mass all vary in the same proportion when standard reference objects undergo acceleration, in agreement with Einstein's original version of the theory. The fact that the light speed is the same for all observers necessarily means that the unit of distance must vary in strict proportion to that of time, which is completely consistent with the modern definition of the meter as the distance traveled by light in free space in 1/c s. This conclusion has found practical application for the Global Positioning System (GPS) satellites with their precise measurements of distances on the earth's surface. Objectivity also leads to a number of other theoretical predictions which await experimental verification. For example, the fact that the energy of an accelerated light source increases by the same factor Q that its frequency decreases is only commensurate with the conclusion that Planck's constant varies as Q^2 [19-21]. Precise measurement of the photoelectric effect for high-energy radiation from moving light sources would therefore offer another test of the objectivity principle in future investigations.

In summary, while it forever remains impossible to prove a scientific theory in the strict logical sense, it can be disproven by a single experiment. When such an experiment presents itself, as in the determinations of the transverse Doppler frequency shifts obtained with ultracentrifuges [3-5], the only recourse is to modify the existing theory in such a way as to remove the contradiction. To be achieved in a convincing manner, this must be done without in any way affecting other results of the existing theory that are in agreement with observation. The GPS-LT accomplishes this objective by insisting that the principle of objectivity of measurement holds for all observers, not just for those who are not moving relative to one another. It stands in contradiction to the belief that time and space are inextricably mixed, and replaces it with the experimentally observed fact (UTDL) that observers in relative motion typically employ clocks that run at different rates. An important goal of relativity theory is therefore to show how the ratios of all types of physical units vary with acceleration. By appropriate conversion it then becomes possible to show that the results of a given experiment have absolute character and are not just a matter of a given observer's perspective. (Jan. 28, 2016)

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