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RELATIVITY THEORY AND THE PRINCIPLE OF RATIONALITY OF MEASUREMENT

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ABSTRACT

One of the most basic principles in science is the objectivity of measurement of physical properties. According to the special theory of relativity (STR), this ancient principle is violated for observers in relative motion since it predicts that they generally will disagree on the ratios of the lengths of two objects and also on whose clock is running slower at any given time. It is pointed out that neither of these claims of the theory has ever been verified experimentally. On the contrary, one knows from experiments that have been carried out with circumnavigating airplanes that less time is recorded on an accelerated clock than on its identical counterpart whose state of motion has not changed. Moreover, measurements of the transverse Doppler Effect (TDE) have shown that wavelengths increase when light sources are accelerated, which fact is inconsistent with the Fitzgerald-Lorentz contraction effect (FLC), which predicts that the dimensions of a photographic plate co-moving with the light source should decrease by varying amounts depending on its orientation. If one insists on the other hand that the Principle of Rationality of Measurement (PRM) also hold for observers in relative motion, each of the above inconsistencies in relativity theory can be eliminated without coming into conflict with any previously confirmed experimental observations. Finally, it is pointed out that one can achieve a definitive test of the PRM by measuring Doppler-shifted light frequencies from the vantage point of an observer in an accelerated rest frame.

KEYWORDS: *Einstein's Symmetry Principle (ESP), Asymmetric Time Dilation, Clock-Rate Proportionality, Lorentz Transformation (LT), Alternative Global Positioning System-Lorentz Transformation (GPS-LT), Absolute Remote Simultaneity, Isotropic Length Expansion, Uniform Scaling of Physical Properties, Amended Version of the Relativity Principle (RP)*

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INTRODUCTION

One of the most interesting aspects of the history of civilization was the development of a system of weights and measures. In order to have fair trading practices, it was very important for different groups to agree on standards of length and weight and other quantities. Although this ideal has actually not been realized even to the present day, it still was possible to carry out business transactions in a relatively peaceful manner because a basic principle was recognized that is referred to below as the *Rationality of Measurement*.

The idea was quite simple to apply once one had grasped how to carry out basic arithmetical operations. The key point is that after one defines a standard unit for a given physical property, it is possible to assign a unique numerical value

for the amount of this property to be associated with any conceivable object. If two traders used a different unit, which was often the case, it was *only necessary to know the ratio of these two units* in order to compare their measurements for a given quantity, that is, convert one numerical value to that in another system of units.

When Einstein introduced his special theory of relativity (STR [1]), he broke with tradition and did not require that the Principle of the Rationality of Measurement (PRM) be valid for observers in different inertial systems. This is due primarily to the inclusion of the Fitzgerald-Lorentz contraction effect (FLC) in this theoretical framework. For example, according to STR the ratios of the lengths of two sides of a given triangle are generally different for two such observers in relative motion to one another. This state of affairs is ruled out by the PRM. It is important to see, however, that the FLC has never been observed in actual experiments, even though the literature is replete with Gedanken experiments that are consistent with it [2].

There is a more general feature of STR that also violates the PRM, however, namely the claim that measurement is symmetric for observers in relative motion to one another [1,3]. Accordingly, it is claimed that two clocks can both be running slower than one another at the same time, and also that the above contraction effect is just a matter of the perspective of each of the observers. After all, it is argued, two such observers each have the perception that it is the other that is moving. On this basis, it is claimed that it is only natural that each one will think it is the other's clocks that are running slower or the other's measuring rods that are contracted relative to his own. This point of view clearly requires that the observers cannot agree on *the ratios* of elapsed times of a given pair of events when they occur in different inertial systems. The same holds true for distances between objects in different inertial systems. As a result, all of these conclusions of STR are seen to be in direct conflict with the PRM.

It is generally claimed that the rest of Einstein's theory [1] is so firmly established that one must therefore accept all of its predictions as facts even in the complete absence of experimental verification. This conclusion is challenged in the discussion below. It will be shown that it is possible to satisfy Einstein's two postulates of relativity theory, the relativity principle (RP) and the constancy of the speed of light, without coming in conflict with the PRM.

RATIOS OF MEASURED QUANTITIES IN STR

Let us consider two inertial systems for the purposes of the present discussion. One is a laboratory on the Earth's surface and the other has previously been accelerated to speed v relative to it. The latter could be a rocket, for example, that has been shot from the Earth to attain its present state of constant motion. We shall refer to observers located in the two rest frames as O and M, respectively. Both observers have standard measuring rods and clocks that were identical when they were all located on the Earth's surface at the beginning of the experiment. In addition, each has a light source emitting the same *in situ* frequency ν and wavelength λ. A distance between two fixed points is marked off in both rest frames that is found in each case to have a length L equal to 1 m.

The value for each of these quantities is generally different for the two observers according to the FLC. To keep track of their respective measured values, the following notation is introduced. A subscript is used to designate the rest frame in which the object of the measurement is located, whereas the identity of the observer in each case is shown in parentheses. For example, when O measures the wavelength of light emitted on the rocket ship, this value is referred to as λ_M (O). Let us first consider the case when measurements are made *along the direction of relative motion* of the two inertial systems.

According to STR, the measured values for L and λ in the above example are

[$\gamma = (1\text{-}v^2/c^2)^{-0.5}$]:

$\lambda_O\,(O) = \lambda$ $\quad L_O\,(O) = 1$

$\lambda_M\,(O) = \gamma\,\lambda$ $\quad L_M\,(O) = \gamma^{-1}$

$\lambda_M\,(M) = \lambda$ $\quad L_M\,(M) = 1$

$\lambda_O\,(M) = \gamma\,\lambda$ $\quad L_O\,(M) = \gamma^{-1}$.

The measured wavelengths listed above are determined on the basis of the transverse (or second-order) Doppler effect (TDE) [4]. It is assumed thereby that this relationship is perfectly symmetric [3], that is, O measures the same value for the wavelength emitted in M's rest frame that M measures for that emitted in O's rest frame. The values for L on the other hand are specified by the FLC and they exhibit the same symmetry as the wavelengths discussed first. In all cases, the "diagonal" elements are simply the *in situ* values, in accordance with the RP.

It is easy to see that the above results do not satisfy the PRM. Consider, for example the ratio $R_M\,(O) = \lambda_M\,(O)/ L_M\,(O)$. It has a value of $\gamma^2\,\lambda$ in the present example. According to the PRM, M must measure exactly the same value for the corresponding ratio, $R_M\,(M) = \lambda_M\,(M)/$

$L_M\,(M)$. The latter is simply a ratio of the two *in situ* quantities and thus has a value of λ, however.

This conclusion of the orthodox version of STR [1] thus differs from our experience in daily life: one always finds that the ratio of two such quantities is the same in any system of units and therefore, by implication, is also the same for any two observers. For example, suppose that one observer (A) uses the meter as his unit, whereas the other (B) uses cm. If A measures the lengths of two objects to be $P_1\,(A) = 200$ m and $P_2\,(A) = 100$ m, he will report a value for their ratio R (A) of 2. Because B uses a different, smaller, standard of length the corresponding measured values for him are larger, $P_1\,(B) = 20000$ and $P_2\,(B) = 10000$, but their ratio R (B) is also 2, the same as for A. Because of the PRM, *in evaluating such ratios* it is wholly immaterial what unit a given observer adopts so long as it is used consistently for both measurements.

INCORPORATING THE PRM IN RELATIVITY THEORY

There has never been an *experimental* verification that the PRM is violated for observers in relative motion. It is therefore important to understand how relativity theory would have to be modified to make it compatible with this ancient principle. The most obvious condition is that the FLC would have to be discarded. Justification for this change in theoretical foundation must be found without violating either of Einstein's STR postulates since they are both well founded experimentally. For the moment, however, the emphasis will be placed simply on discovering how the relationships between measurements of a given quantity by different observers have to be altered in order to satisfy the PRM. However, there is an additional restriction, namely the results of the TDE experiments [5, 6] must be consistent with any new formulation.

To accomplish the above goal, it is clearly necessary to change one of the entries in the table given in the previous section, namely that for $L_M\,(O)$, in order for the ratios defined in the preceding section to be equal, i.e., $R_M\,(O) = R_M\,(M) = \lambda$:

λ_O (O) = λ L_O (O) = 1

λ_M (O) = $\gamma\lambda$ L_M (O) = γ

λ_M (M) = λ L_M (M) = 1

λ_O (M) = ? L_O (M) = ?.

In order for the theory to satisfy the PRM, the value of L_M (O) has been changed from γ^{-1} to γ. The last two entries in the table are left open at this point, as will be discussed subsequently. They are not needed to compute the key ratios, R_M (O) and R_M (M), discussed above. The latter values now become: R_M (O) = λ_M (O)/ L_M (O) = λ and R_M (M) = λ_M (M)/ L_M (M) = λ, in agreement with the PRM since they are equal. This amounts to assuming that there is *length expansion* in the accelerated rest frame of M rather than the contraction expected from the FLC.

It is also clear that the expansion must be *isotropic* in order for the PRM to be independent of the orientation of the objects to be measured because in the TDE the increase in wavelength is the same in all directions [4]. According to STR [1], L_M (O) in the transverse direction has a value of 1, so R_M (O) = $\gamma\lambda$, in this case, which is different than R_M (M) = λ.

RECIPROCALITY AND THE HAFELE-KEATING EXPERIMENT

The PRM is also quite specific on how to fill in the missing entries in the above table, however. As a result of the acceleration, M's meter stick is now larger than O's by a factor of γ, it follows that all his length measurements will be *smaller* in the same proportion, that is, there is a *reciprocal* relationship between them. This means that O's meter stick will appear to have contracted to a length of γ^{-1} m and also that the wavelength of light emitted from O's rest frame will also be smaller by this fraction for M than his *in situ* value for an identical source. The completed table is given below:

λ_O (O) = λ L_O (O) = 1

λ_M (O) = $\gamma\lambda$ L_M (O) = γ

λ_M (M) = λ L_M (M) = 1

λ_O (M) = $\gamma^{-1}\lambda$ L_O (M) = γ^{-1}.

According to the PRM, whenever they both measure the length of any object, their values must differ by the same ratio. Thus, from the table, λ_O (O) / λ_O (M) = λ_M (O) / λ_M (M) = L_O (O) / L_O (M) = L_M (O) / L_M (M) = γ. The reason that their values differ is because their standard unit of distance is different, *not because they are carrying out measurements on objectively different systems*. In the context of relativity theory, this means that two observers in relative motion can distinguish their state of motion on this basis, even though they are both moving at constant velocity. Quite the opposite is assumed in STR, however. The table in Section II is perfectly symmetric. It says that O thinks the light emitted from M's source has wavelength $\gamma\lambda$ (because of the TDE) at the same time that M thinks the light emitted from O's source also has this value. It is important to note that Einstein was of a different opinion in his original work [1], however.

To understand this, it is first necessary to see that the PRM requires that perfectly analogous relationships to those shown for wavelengths in the above table also hold for a number of other key physical quantities, namely energies, lifetimes and inertial masses. One knows from experiment that both the inertial mass m_I [7] and the lifetime τ [8] of accelerated particles increase in direct proportion to γ, just as the wavelength of the light source in the above example. In

the context of the PRM, this means that the unit of each of these quantities is greater by this amount (γ) in the rest frame of the accelerated objects. One can therefore replace λ in the above table by τ, m_I and also the rest energy E of the object and still have the same ratios of O and M's measured values as for wavelengths. Einstein [1] referred to the specific case of the periods of clocks in his work and argued that acceleration destroys the symmetry that otherwise exists for two inertial systems according to the RP. Von Laue [9] later reinforced this position with the following remarks: "Inertial systems are observable realities; our thought experiment decides which clock remained at rest in the same system, which in different ones." Their common conclusion was certainly in line with the PRM since it asserts that the accelerated clock always runs slower than an identical one left behind and therefore must record smaller elapsed times for the same event in every case.

A different interpretation [10,11] also became very popular, however, one that nonetheless insists on the symmetric relationship between the two clocks that is required by STR. In this view, it is critical to distinguish between portions of a journey in which the clocks are in constant relative motion to one another and those when they are not. In the first case, it is argued that it is somehow possible for each clock to be running slower than the other by the same fraction. In order for the accelerated clock to return back to its original position, it has to reverse directions, however. Using an argument from the general theory of relativity [12], it is then claimed that during this phase of the journey the clock "at rest" must speed up because of the gravitational field generated at its position.

The result of this interpretation is that, in agreement with Einstein's original conclusion [1], the accelerated clock has registered less elapsed time than its counterpart when they are reunited at the end of the journey. One of its key assumptions is that the time-dilation effect of STR should only be applied to truly inertial systems. By contrast, the interpretation dictated by the PRM assumes that the amount by which a clock has slowed down can always be determined on the basis of its instantaneous speed relative to its original rest system, whether it is currently undergoing acceleration or not.

The physical reality of time dilation was demonstrated in 1971 by a famous experiment with circumnavigating airplanes carried out by Hafele and Keating [13]. This study's decisive role in distinguishing between the orthodox STR and the PRM interpretation of this effect has been overlooked, however. The authors succeeded in making quantitative predictions of the rates of clocks carried in opposite directions around the globe as well as others that stayed behind at the airport of origin. The journey of each clock during the entire period of measurement was broken into small portions. The only information used to make the necessary calculations for a given clock was its altitude and its speed v relative to a hypothetical reference clock located on the Earth's polar axis. This means that at any stage of the journey, after making the appropriate gravitational correction, it is possible to compute the clock rate by assuming that it is γ (v) times slower than the reference clock. This procedure is perfectly consistent with the PRM, but it unequivocally contradicts the symmetric interpretation of Refs. [10,11]. The accelerated clock on the airplane always runs slower than its counterpart on the polar axis (see also ref. [6]). There is never a portion of the journey in which the reference clock runs faster once one excludes the effects of gravity.

OTHER EXPERIMENTAL EVIDENCE FOR THE PRM

As has already been noted in Sect. III, the FLC is not consistent with the PRM. Once one proves that the rates of clocks in relative motion satisfy the PRM, it is at least difficult to argue that the FLC is nonetheless a real effect in nature despite its contradicting the same ancient principle. The connection between time and distance is fixed in STR because of Einstein's second postulate, the constancy of the speed of light in free space at the same gravitational potential. Since 1983 the meter

has been defined as the distance travelled by light under vacuum conditions in $\Delta T = c^{-1}$ s. This definition must hold in any inertial system, and therefore it must be consistent with the time-dilation effect discussed in the preceding section. If such an experiment were carried out on the rocket ship introduced in Sect. II, for example, it is clear that ΔT (M) = c^{-1} s, since M is carrying out the measurement *in situ*. Because of the time-dilation effect, however, it is just as clear that ΔT (O) = c^{-1} γ s, that is, *γ times longer* (after making gravitational corrections [13]). Observer O does not even have to carry out this measurement explicitly, much less do it at the same time as M makes his determination. It is simply a matter of insisting that the time-dilation effect observed by Hafele and Keating must hold under these circumstances, that is, where M has been accelerated to speed v relative to O (this inference is essential to the workings of the Global Positioning System technology). To be consistent with the above definition, O must therefore conclude that the distance travelled by the light between the two fixed points on the rocket ship is γ m, even though his original measurement before the acceleration took place was the same as M's, namely exactly 1 m. This result is obviously consistent with *length expansion* in the accelerated rest frame, and the effect is *isotropic* because it is unaffected by a change in the orientation of the rocket ship. *It shows that one must either discard the FLC or give up the current definition of the meter.*

As already discussed in Sect. II, the TDE is also much easier to rationalize in the context of the PRM. This topic is discussed in more detail elsewhere [14], but the most important arguments can be illustrated with the following example. According to the FLC, a photographic plate will contract by varying amounts in different directions when it is accelerated. The TDE experiments demonstrate that the wavelength of light increases as the source is accelerated, and by the same fraction in all directions. The RP demands that the observer (M) co-moving with the light source and photographic plate not be able to detect any change in the wave pattern that he measures after being accelerated. If the PRM is valid, M would have to see that the wavelength along the direction of relative motion to O has increased by a factor of γ^2 relative to the dimensions of the photographic plate, and by a factor of γ in a perpendicular direction. A wavelength is just the distance between two maxima on the photographic plate. As such, it should be subject to the same contraction according to the FLC as any other distance. One has to come up with an argument why wavelengths are an exception for the FLC in order to remain consistent with the RP.

On the other hand, if one insists on the PRM, then the above results are easily understandable *by assuming isotropic length expansion in the accelerated rest frame*, contrary to the prediction of the FLC. The photographic plate increases by a factor of γ in all directions, so it is impossible for M to notice any change in the wave pattern that is deposited on it. The initially identical plate that is left behind naturally retains its dimensions throughout, and so the wavelength that O measures with it is observed to increase with the relative speed of the light source, regardless of orientation. All this is in perfect agreement with the experimental findings [5].

Measurements of the half-lives [8] of accelerated metastable particles also should be mentioned in the present discussion. Let us assume that observer M is traveling with the particles as they travel between fixed points A and B in O's rest frame. The *in situ* half-life of the particles is τ and they are traveling with speed v relative to O. The following argument has been given in standard texts [15,16] in support of the FLC. If M measures the elapsed time to be τ, then only half the particles will remain by the time he reaches B. Because of time dilation, O must measure a longer time, γ τ, but must also find that exactly half of the particles remain because this number is obviously a relativistic invariant. However, it is assumed that the speed v of the particles is the same for both O and M (we will return to this assumption subsequently). On this basis, one must conclude that M will measure the distance between A and B to be v τ, whereas O will find the

length of M's journey between the same two points is larger than this value by a factor of γ. It is then stated according to the above argument [15,16] that this is an example of length contraction in M's rest frame.

There are two problems with the latter argument, however. First of all, the FLC only claims that distances are contracted by this much along the direction of relative motion. The conclusions about respective distance measurements of the two observers are based solely on the time-dilation effect and thus are not affected by this detail. Thus, the argument is specious because it only applies for a particular direction of motion. That is not the only problem, however. The points A and B are the same for both observers and they can in no way be construed as being exclusively in M's rest frame. The only reason why the two observers disagree on the numerical value for this distance is because they reference their measurements to a different standard of length. The PRM allows one to explain these results by assuming that the measuring rod in M's rest frame is *γ times larger* than that employed by O, consistent with the table given in Sect. III, with the consequence that he measures the distance between A and B to be *γ times smaller* than O does. Moreover, this argument is independent of the direction travelled by M, consistent with what must be assumed on the basis of time dilation. Again, the FLC doesn't explain anything about these observations. To believe it, one has to suspend the logical deduction process that is essential in applying the PRM.

Finally, the aforementioned assumption that O and M both measure the same speed v for M's journey between A and B is also consistent with the PRM [17]. Speed or velocity is defined as a ratio of distance travelled to elapsed time. By assuming that the fraction of length expansion is the same as for time dilation, it follows immediately from the PRM that *the speeds of all objects between two fixed points*, not only for light pulses, will be the same for any two observers, regardless of their state of relative motion (the latter statement actually only holds if both observers are located at the same gravitational potential). A more general discussion about the way in which the units of physical quantities vary with the observer's state of motion and position in a gravitational field is given elsewhere [18, 19].

A DEFINITIVE EXPERIMENTAL TEST FOR THE PRM

As mentioned in Sect. IV, a detailed analysis of the results of the experiment with circumnavigating airplanes [13] shows not only that they support time dilation in accelerated rest frames but also that they contradict earlier claims [10,11] for the symmetric nature of this effect for purely inertial systems. They demonstrate instead that at each phase of the journey, after one has made the appropriate gravitational corrections [13], the clocks on the aircraft actually do run slower than reference clocks that are at rest on the Earth's polar axis. This result is a clear confirmation of the PRM since it proves that elapsed times measured on the airplanes are always less than those obtained using the reference clock.

The Hafele-Keating results suggest another experiment that is perhaps a more direct test of the two relativity theories. According to STR, the TDE should be perfectly symmetric for two observers in relative motion. There is another derivation [4,14] of the latter effect that suggests otherwise, however. It equates the second-order effect on frequencies and wavelengths with time dilation. According to the PRM, this means that the TDE is perfectly anti-symmetric, that is, reciprocal in nature.

To be specific, let us return to the general situation discussed in Sect. II in which the two observers, O and M, are in relative motion but only M has undergone acceleration. In order to make the argument more transparent, we can assume that they are both at the same gravitational potential and also that the effects of rotation about the Earth's polar axis can be neglected. Both observers have identical light sources of frequency ν_0. When O receives a light signal from M's source, he

measures its frequency to be $\gamma^{-1}\nu_0$ when they are moving in a transverse direction relative to their line of sight. This result is consistent with all previous TDE measurements and is explained by the fact that all clocks in M's accelerated rest frame run slower by a factor of γ than their identical counterparts used by O in his rest frame.

What one needs to test the PRM is to have M measure the frequency *emitted from O's light source*. According to STR [1], he should obtain the same value as O does, namely $\gamma^{-1}\nu_0$, because for M it is O who is moving with speed v. The PRM, on the other hand, does not expect this result. It requires that M always *measure higher frequencies for the same light source* because of the fact that his clock runs slower than O's. In agreement with Einstein [1] and von Laue [9], the PRM assumes that it is indeed possible to distinguish between the two inertial systems in this application because only one of them has been accelerated. On this basis, M should measure the transverse Doppler-shifted frequency from O's light source to be $\gamma\nu_0$, that is, he should find that *the frequency has been blue-shifted*, the opposite of what O finds when he receives signals from M's rest frame. There is thus a clear distinction between the predicted results of STR and those of the PRM in the proposed experiment. The ratio of the two Doppler-shifted frequencies should vary as γ^2 in the latter case and thus be dependent on the relative speed of the two observers, contrary to what is claimed in conventional STR.

More details concerning this version of the TDE experiment may be found elsewhere [20]. In order to obtain the frequency results to sufficiently high accuracy, it is necessary to eliminate the first-order Doppler effect, but this can be done electronically using a two-way transponder system [21]. If the experiment is carried out on an airplane, then the effects of rotation about the Earth's polar axis as well as of gravity on the measured frequencies would have to be taken into account to suitably high accuracy, as was the case in the original Hafele-Keating experiment [13]. The main question is clearly whether the frequency determinations can be stabilized to a sufficient degree to allow the TDE measurements to be of definitive accuracy in the airplane's rest frame. In reality, it is possible to carry out this experiment by using exclusively land-based laboratories situated at widely different latitudes, as is discussed in the companion article [20].

GLOBAL POSITIONING SYSTEM- LORENTZ TRANSFORMATION (GPS-LT)

Whenever the predictions of a theory are contradicted by experiment, there must be an incorrect assumption responsible for this failure. Especially since the main argument generally given for belief in the FLC and the symmetric character of time dilation is purely theoretical, it is especially important in the present case to try and identify such a weak point in the overall formulation of STR. To this end it is instructive to carefully examine the theoretical basis for these predictions, which is the Lorentz transformation (LT) of space-time coordinates.

Einstein [1] derived the LT by using the example of a light pulse moving from a common origin for two observers in relative motion. In this context it is clear that the space-time variables of the theory refer to the distance Δr travelled by the light pulse and the corresponding elapsed time Δt. This definition is crucial because of the need to satisfy the basic requirement of Einstein's second postulate, namely that the speed $v=\Delta r/\Delta t$ of the light pulse be equal to c for both observers. This identification is perfectly in line with that used by Newton and contemporaries in deriving the Galilean transformation. As discussed in previous work [22,23], however, the above condition can be satisfied with a different transformation than the LT, which is referred to as the alternative *Global Positioning System- Lorentz transformation* (GPS-LT) [24-26]:

$$\Delta x = \eta\,(\Delta x' + u\,\Delta t') \tag{1a}$$

$$\Delta y = \eta\,\gamma^{-1}\Delta y' \tag{1b}$$

$$\Delta z = \eta \gamma^{-1} \Delta z' \quad (1c)$$

$$\Delta t = \Delta t', \quad (1d)$$

In which γ has the same meaning as in the FLC/LT used above and η is defined as:

$$\eta = (1 + uc^{-2} dx'/dt')^{-1}. \quad (2)$$

The latter quantity appears in the relativistic velocity transformation (RVT [27]). Note that eq. (1d) is the same as in the Galilean transformation (GT) and does not involve any mixing of spatial and time coordinates, unlike the case for the LT. It is important to note that it is assumed in eqs. (1a-d) that both observers use exactly the same set of units. However, because of time dilation, this is not the usual case. If the clocks in the primed rest frame (S') run Q times slower than in the other (S), one has to alter *each* of the above equations by multiplying with Q on the right-hand side in order to insure that each observer uses his own set of proper units. For example, eq. (1d) becomes dt=Qdt'.

In the case of eq. (1d), it is assumed that both observers base their measurements on clocks that run at exactly the same rate. This requirement is satisfied in the GPS methodology [28, 29] by employing "pre-corrected" atomic clocks whose rates have been adjusted prior to launch so that upon reaching orbit they are exactly equal to those of their identical counterparts left behind on the Earth's surface.

This interpretation is perfectly consistent with the PRM and therefore has the advantage of eliminating the symmetry principle required by the LT and therefore the necessity of claiming that two clocks can both be running slower than one another at the same time. It also removes the FLC as an inevitable consequence of the theory, while still satisfying Einstein's postulate of the constancy of the speed of light in free space. In the last analysis, the LT must be rejected as a relativistic space-time transformation because it does not conform to the principle of simultaneity of events for observers in different inertial systems [21, 22, 30, 31]. Events that occur at the same time for an uncompensated clock on a satellite must also be simultaneous for the corresponding pre-corrected clock and therefore also for their counterparts on the Earth's surface. In predicting non-simultaneity, Einstein and others simply overlooked the possibility that the rates of clocks in relative motion can simply be adjusted to be perfectly synchronous with one another, as experiment has ultimately proven to be the case.

CONCLUSIONS

The ancient principle (PRM) of the strict proportionality (or rationality) of the measurements of different observers for physical quantities such as length, mass and time is violated in the special theory of relativity in two respects. First, STR claims that there is always a symmetric relationship between the measured values of two observers in relative motion: for example, each should find that the other's clock is running slower or that the other's standard of length has been contracted. Secondly, because of the Fitzgerald-Lorentz contraction effect (FLC), it asserts that two lengths measured along different directions will not generally be in the same proportion for two such observers. Despite the excellent achievements of STR over the past century, however, *there has been no experimental confirmation for either of the above features of this theory.*

The PRM is of inestimable value in everyday life because it allows one to introduce a rational set of units on which to base determinations of a given quantity. There is absolute certainty that the ratio of the lengths of two objects is the same for everyone regardless of the unit that is chosen on which to base such measurements. The transverse Doppler

effect (TDE) provides a good illustration of the problems that develop in trying to make logical deductions based on STR. One knows from the relativity principle (RP) that it is impossible for an observer to detect a change in the wavelength of a light source as it is accelerated as long as he is co-moving with it. Experiment has shown that an observer who stays behind in the laboratory does find that the wavelength increases by a factor of γ, however. At the same time, according to the FLC the same observer should find that the dimensions of the photographic plate he uses to measure the wavelength have contracted by varying amounts in the accelerated rest frame depending on its orientation to him. Normally, one would say that this is a contradiction, but by not subscribing to the PRM it is possible for STR to accept these results without further discussion. The question that remains, however, is what purpose the FLC serves if it is not possible to make logical deductions on its basis.

The modern definition of the meter does not allow such a liberal interpretation, however. It must be valid in every inertial system and this means because of time dilation that a rest frame whose clocks run slower must employ a larger standard for the meter, and this in all directions. This state of affairs is only consistent with *isotropic length expansion accompanying time dilation* in a given rest frame, not the FLC. This conclusion is also consistent with the results of the TDE discussed first. If the dimensions of the accelerated photographic plate increase by a factor of γ in all directions, it becomes perfectly understandable why the co-moving observer is unable to detect a change in the wavelength in his rest frame.

The importance of incorporating the PRM into relativity theory becomes even clearer when attention is directed to the Hafele-Keating experiments with circumnavigating airplanes. They provide evidence for more than just time dilation. They show unequivocally that clocks slow down upon acceleration and therefore that the effect is not symmetric for two observers in relative motion even when they are both traveling at constant velocity. In particular, they contradict the oft-quoted assertion that the asymmetry of time-dilation observations is caused solely by gravitational effects. This result is again perfectly consistent with the PRM, which demands that timing results obtained with any two clocks must always be in the same proportion for a given event.

This in turn suggests another experiment that is capable of distinguishing between relativity theory with and without the PRM. According to STR, the TDE is perfectly symmetric for two such observers when they exchange light signals from identical sources. The frequency should decrease for both of them relative to the *in situ* value. The PRM, on the other hand, requires that the accelerated observer measure an increase in frequency by a factor of γ because of the fact that his clock runs slower by this fraction than that of his counterpart whose state of motion has not changed. As noted above, this is the only result that is consistent with the observations in the Hafele-Keating experiment.

The FLC and also the symmetric character of STR and its corresponding rejection of the PRM are based on an incorrect assumption in Einstein's original work [1], namely that observers in relative motion generally will not agree on whether two events occur simultaneously or not. Experience with the GPS methodology in fact shows that this prediction is not fulfilled in actual practice. Time dilation only produces a change in the rate of an accelerated clock. Since its new rate is always strictly *proportional* to the old one, *it is impossible that events that are simultaneous for one of the clocks will not be simultaneous for the other as well*. This contradiction is easily removed from the theory by replacing the LT with a different space-time transformation, the GPS-LT [22-27], which also satisfies Einstein's two postulates of STR, but which is perfectly consistent with both the PRM and the principle of absolute simultaneity.

This fact destroys the oft-cited argument that the FLC and the symmetry principle of STR must occur in nature because the LT on which they are based works so well in other applications. The key advantage of the GPS-LT is that it allows one to ascribe a rational system of physical units to each observer at any point of time that enables him to easily convert his own measured values for a given event to those of a second observer who is in relative motion to him. In this way it is possible to return to the situation that existed in physics before the introduction of STR, *namely the belief that the measurement of physical quantities is perfectly objective.* The only reason that two observers can disagree on the numerical value for any such quantity *is because they employ a different system of units* on which to base their respective measurements.

REFERENCES

1. *A. Einstein, Ann. Physik 17, 891 (1905).*
2. *E. F. Taylor and J. A. Wheeler, Spacetime Physics, W. H. Freeman and Company, San Francisco, 1966.*
3. *H. Goldstein, Classical Mechanics, Addison-Wesley Publishing Co., Reading, Massachusetts, 1950, p. 193.*
4. *W. Rindler, Essential Relativity, Springer Verlag, New York, 1977, p. 55.*
5. *H. E. Ives and G. R. Stilwell, J. Opt. Soc. Am. 28, 215 (1938); 31, 369 (1941); G. Otting, Physik. Zeitschr. 40, 681 (1939); H. I. Mandelberg and L. Witten, J. Opt. Soc. Am. 52, 529 (1962).*
6. *H. J. Hay, J. P. Schiffer, T. E. Cranshaw, and P. A. Egelstaff, Phys. Rev. Letters 4, 165 (1960); W. Kuendig, Phys. Rev. 129, 2371 (1963); D. C. Champeney, G. R. Isaak and A. M. Khan, Nature 198, 1186 (1963).*
7. *A. H. Bucherer, Phys. Zeitschr. 9, 755 (1908).*
8. *D. S. Ayres, D. O. Caldwell, A. J. Greenberg, R. W. Kenney, R. J. Kurz, and B. F. Stearns, Phys. Rev. 157, 1288 (1967); A. J. Greenberg, Thesis, Berkeley (1969).*
9. *M. V. Laue, Relativitaetstheorie, Vol. 1, 7th ed. , Vieweg, Braunschweig, 1955, p. 36.*
10. *M. Born, Einstein's Theory of Relativity, revised edition with G. Liebfried and W. Biem, Dover, New York, 1962.*
11. *E. F. Taylor and J. A. Wheeler, Spacetime Physics, W. H. Freeman and Co., San Francisco, 1966, p. 94.*
12. *A. Einstein, Ann. Physik 49, 769 (1916).*
13. *J. C. Hafele and R. E. Keating, Science 177, 166 (1972); 168 (1972).*
14. *R. J. Buenker, "The Lorentz Transformation and the Transverse Doppler Effect," Berg. Univ.-Wuppertal Library, Item 50, pp. 1-14 (2017).*
15. *R. T. Weidner and R. L. Sells, Elementary Modern Physics, Allyn and Bacon, Boston, 1962, p. 410.*
16. *R. A. Serway and R. J. Beichner, Physics for Scientists and Engineers, 5th Edition Harcourt, Orlando, 1999, p. 1262.*
17. *R. J. Buenker, Apeiron 20, 73-83 (2015).*
18. *R. J. Buenker, Apeiron 20 (4), 1-31 (2018).*
19. *R. J. Buenker, Apeiron 15, 382 (2008).*

20. *R. J. Buenker, Apeiron 16, 203 (2009).*

21. *R. F. C. Vessot and M. W. Levine, General Relativity and Gravitation 10, No. 3, 181 (1979).*

22. *R. J. Buenker, Apeiron 15, 254 (2008).*

23. *R. J. Buenker, Apeiron 16, 96 (2009).*

24. *R, J, Buenker, Physics Essays 26 (4), 494-497 (2015).*

25. *R. J. Buenker, Relativity Contradictions Unveiled: Kinematics, Gravity and Light Refraction, Apeiron, Montreal, 2014, pp. 55-56.*

26. *R, J, Buenker, J. Astrophys. Aerospace Technol. 3, 115, 1-6 (2015).*

27. *R. D. Sard, Relativistic Mechanics, W. A. Benjamin, New York, 1970, p. 167.*

28. *C. M. Will, Was Einstein Right?: Putting General Relativity to the Test, Basic Books Inc. 2nd Ed., New York, 1993, p. 272.*

29. *T. Van Flandern, in: Open Questions in Relativistic Physics, ed. F. Selleri, Apeiron, Montreal, 1998, p. 81.*

30. *R. J. Buenker, 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).*

31. *R. J. Buenker, Adv. Theor. Comp. Phys. 1(2), 1-4 2018).*