Review Article

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Global Positioning System Confirmation of a Contradiction between Einstein's Predictions of Time Dilation and Remote Non-Simultaneity: Failure of the Lorentz Transformation

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Abstract

Time dilation and remote non-simultaneity are two of the most famous predictions derived from the Lorentz transformation. As a simple example, consider two lightning strikes which occur at different positions in space. According to Einstein's special theory, the time differences Δt and $\Delta t'$ measured by two observers between the two strikes must satisfy a strict proportionality relation (time dilation): $\Delta t'=X\Delta t$. However, it is also claimed, by virtue of the corresponding prediction of remote non-simultaneity, that the two events can occur simultaneously for one of them ($\Delta t=0$) without doing so for the other ($\Delta t'\neq 0$). It is pointed out that it is impossible to satisfy both of the above conditions because that would mean having to violate the algebraic axiom which states that multiplication of any finite number, in this case X, by zero (Δt) must have a product ($\Delta t'$) of zero as well. Only by violating this axiom is it possible to avoid a direct contradiction of the prediction of remote non-simultaneity.

As a result, the Lorentz transformation itself is shown to be invalid since it is responsible for both of the above predictions. A different space-time transformation is therefore presented which also satisfies both of Einstein's postulates of relativity without requiring that space and time be mixed. The Hafele-Keating experiments with atomic clocks carried onboard circumnavigating airplanes confirm that time dilation is a real effect, but they also show that the prediction of Einstein's theory that observers can disagree in principle which of two clocks runs slower is not correct. The Global Positioning System makes use of the observed proportionality relationship between elapsed times to adjust the rates of atomic clocks carried onboard its satellites so that they run at the same rate as identical clocks located on the earth's surface. This practice also serves as a confirmation that remote non-simultaneity has no basis in fact. Otherwise, it would make no sense to have the two clocks running at the same rate in order to measure elapsed times for laser beams to travel between the satellite and the ground position.

Keywords: Global Positioning System, Lorentz Transformation, Remote Non-Simultaneity, Time Dilation

Introduction

The Lorentz transformation (LT) revolutionized the way physicists looked upon space and time. Its precursor was suggested by Voigt in 1887 [1]. He introduced the idea that space and time coordinates might be mixed in an extension of the classical Galilean transformation needed to account for recent experiments involving the speed of light. This approach clashed with the long-held position of Newton and his collaborators that space and time were completely separate entities.

Poincaré was the first to notice that the space-time mixing characteristic of the LT indicates that two events which occur simultaneously for one observer might not do so for another [2,3]. He pointed out that existing experiments did not contradict this supposition of *remote non-simultaneity*.

Einstein agreed with this possibility and used an example of two lightning strikes on a speeding train to justify his position [4,5]. He went a step further, however, by using the LT to also predict the phenomenon of time dilation, according to which the rates of clocks are slowed by motion. It is nonetheless easy to show that time dilation and remote non-simultaneity are actually mutually exclusive, as will be discussed below.

Comparison of the Predictions of Remote Non-simultaneity and Time Dilation

The starting point in the derivations of both time dilation and remote non-simultaneity is the following LT equation:

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

It relates the values of time intervals Δt and Δt' measured for the same pair of events by two observers O and O', respectively, who are moving with speed v (c is the speed of light in free space: 299792458 ms^{-1}) relative to each other along a common x-x' axis [$\gamma=(1-v^2c^{-2})^{-0.5}$ and $\eta = (1-vc^{-2}\Delta x/\Delta t)^{-1}$]. The prediction of remote non-simultaneity stems from the fact that if both v and Δx are not equal to zero in this equation, it follows that $\Delta t' \neq 0$ if $\Delta t=0$.

In other words, if the two events occur at different positions along the x axis and the two observers are moving with respect to each other, they cannot be simultaneous for both of them. Einstein's example (5) involves lightning strikes that occur at the front and back of a train while it is moving past the platform. One of the observers is located there, whereas his counterpart is riding on the train. Another popular illustration of remote non-simultaneity is intended to show that it is impossible for two businessmen to sign a contract at the same time when they are moving with respect to each other ($v\neq 0$) and not momentarily at the same position ($\Delta x\neq 0$).

The derivation of time dilation is more complicated [6]. It begins by squaring eq. (1) and each of the other three LT equations and adding them to form the following relationship known as Lorentz invariance:

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

An important fact about the latter equation is that it makes explicit Einstein's light-speed constancy postulate [4]. Accordingly, the square of the distance traveled by light in any direction is equal to the square of the product of c with the corresponding time of travel for both observers.

A general situation is then considered in which two clocks move along the x axis. One of them is stationary in the rest frame of observer O', while the other is moving with speed v away from it. In terms of the variables in eq. (2), this means that $\Delta x'=\Delta y'=\Delta z'=0$ on the one hand, and $\Delta x=v\Delta t$, $\Delta y=0$ and $\Delta z=0$ on the other. Substitution therefore leads to the relation below:

$$-c^2\Delta t'^2 = v^2\Delta t^2 - c^2\Delta t^2 \qquad (3)$$

Division of both sides by $-c^2$ then gives the desired result for time dilation, namely

$$\Delta t' = \left(1 - v^2c^{-2}\right)^{0.5}\Delta t = \gamma^{-1}\Delta t , \qquad (4)$$

i.e. the elapsed time measured by the clock in the rest frame of O' is less than the corresponding elapsed time measured by that in O's rest frame by a factor of $\gamma>1$.

The same situation as viewed from the rest frame of O can be described by interchanging the primed and unprimed symbols and changing the sign of v, with the result:

$$\Delta t = \left(1 - v^2c^{-2}\right)^{0.5} = \gamma^{-1}\Delta t' \qquad (5)$$

The latter two equations are not algebraically equivalent, as has often been discussed in the literature. This is because changing the sign of v does not change the value of γ.

There is another point about eqs. (4) and (5) that has received far less attention, however. In both cases, the elapsed times of the two observers are predicted by the LT to be *strictly proportional to another*. This means that if one of the values is zero, the other must be zero as well. In other words, this result of the LT clearly states that events such as the two lightning strikes on a train can indeed occur simultaneously for both the observer on the platform and his counterpart on the train. *To claim otherwise requires that one ignore the axiom of algebra which requires that the result of multiplying a finite number with zero is zero itself*. Yet, as already discussed, the LT also predicts by virtue of its eq. (1), that the two events will not occur simultaneously for the observers since both v and Δx are not equal to zero in this example. This result is true for any pair of events that occur at different locations, hence the term "remote non-simultaneity," as long as the observers are not stationary in the same rest frame. Proportional time dilation is therefore seen to be incompatible with remote non-simultaneity. Since both predictions are clearly derived from the LT, the only possible conclusion is that *this space-time transformation is not viable as a possible component of relativity theory* [7].

The reason that the LT fails in its description of timing relationships for moving clocks is clearly because of the space-time mixing characteristic of its eq. (1). There are strong indications from both theory and experiment, by contrast, that *proportional time dilation*, which therefore eschews such mixing, actually occurs in all relevant observations of natural processes.

This is evident from the derivation of time dilation discussed above, for example. There, one has two "inertial" clocks moving away from each other at constant speed along the x axis, consistent with Newton's First Law of Motion. The tacit assumption about the rates of these two clocks is that their rates are also constant, consistent with the Law of Causality [7]. There are no unbalanced external forces which could possibly lead to a change in this situation. As a consequence, the *ratio of the two rates* must also be assumed to be constant, i.e. as expressed in the following equation:

$$\Delta t' = \Delta t/Q, \qquad (6)$$

where Q is a proportionality constant which is unique for the two rest frames in which the clocks are located. This relation is clearly inconsistent with remote non-simultaneity since it is impossible for Δt to be equal to zero without the same being true for Δt'.

It is possible to confuse eq. (6) with eq. (4), but there is a clear distinction. This can be seen by reversing the roles of the observers by applying the same procedure employed above to obtain the latter's inverse. When the interchange between primed and unprimed variables is made in this case, the result is:

$$\Delta t = \Delta t'/Q', \qquad (7)$$

where Q' remains to be defined. If the value of Δt in this equation is substituted in eq. (6), the result is:

$$\Delta t' = \Delta t/Q = \Delta t'/QQ'. \qquad (8)$$

The conclusion is therefore that in order for eq. (7) to be the inverse of eq. (6), as demanded by the Relativity Principle when the variables interchange is applied; all that is required is that:

$$Q'=1/Q, \qquad (9)$$

i.e. that Q' must simply be the reciprocal of Q. Note that it is impossible to perform a similar operation to cause eqs. (4) and (5) to be the mutual inverses of one another. This is because the change from v to -v required in the accompanying interchange of variables does not result in a change in γ, as already mentioned above.

It is convenient to look upon Q in eq. (6) as a *conversion factor between the different units of time* employed in the two rest frames. Its reciprocal Q' in eq. (7) is the corresponding factor in the reverse direction. A completely analogous (reciprocal) relationship holds for all conversion factors in normal practice, such as between m and cm or lbs and kg, for example. Note that it is meaningless to speak of units of time based on eqs. (4) and (5) derived from the LT. This is impossible because in that *symmetric* version of time dilation, there is not even agreement as to which of two clocks runs faster or slower, much less by how much.

Experimental Verification of the Mutual Exclusion of Space and Time

The results of experiments are in complete agreement with the type of *asymmetric* time dilation indicated in eqs. (6) and (7). The following inverse proportionality relation is obtained for elapsed times in all cases, namely

$$\Delta t \gamma(v) = \Delta t' \gamma(v') \, , \tag{10}$$

where v and v' are the speeds of the clocks relative to some specific rest frame [8]. The latter is the earth's center of mass in experiments carried out with atomic clocks carried onboard circumnavigating airplanes, and it is the axis of the rotor employed in x-ray frequency measurements [9,10]. The constant in eq. (6) can be obtained directly from eq. (10) as:

$$Q = \frac{\gamma(v')}{\gamma(v)} \tag{11}$$

The corresponding constant in eq. (7) is also obtained directly from eq. (10) as:

$$Q' = \frac{\gamma(v)}{\gamma(v')} = \frac{1}{Q} \tag{12}$$

in agreement with the reciprocal relationship assumed in eq. (9). The experimental relationship in eq. (10) is also used in the operation of the Global Positioning System (GPS). The rates of atomic clocks are adjusted accordingly in order to insure that they are equal to those of their counterparts at rest on the earth's surface [11,12].

Finally, it is possible to obtain a replacement for the LT by insisting that elapsed times satisfy eq. (6), as given in eqs. (13a-d) below:

$$\Delta t' = \eta \frac{\Delta t - vc^{-2}\Delta x}{Q} = \frac{\Delta t}{Q} \tag{13a}$$

$$\Delta x' = \eta \frac{\Delta x - v\Delta t}{Q} \tag{13b}$$

$$\Delta y' = \left(\frac{}{} \right) \Delta y \tag{13c}$$

$$\Delta z' = \left(\frac{\eta}{\gamma Q} \right) \Delta z \tag{13d}$$

This set of four space-time equations is referred to as the Global Positioning System-Lorentz Transformation (GPS-LT) to emphasize its direct relationship to the navigation system [7,13-16]. It also satisfies both of Einstein's postulates of relativity, but does so without requiring either the space-time mixing characteristic of the LT or its prediction of remote non-simultaneity [4].

Conclusion

The Lorentz transformation predicts both remote non-simultaneity and proportional time dilation. It is impossible that both effects can occur together, however, because this would require that multiplication of one number, in this instance the ratio of two clock rates, with zero *leads to a result which is not equal to zero*. This logical argument therefore proves that the Lorentz transformation is not valid, including eq. (1) with its claim of the inevitability of space-time mixing. Space and time are not mixed, exactly as Newton argued over 300 years ago.

The only real question about the above observation is why it has taken so long for mainstream physics to acknowledge it. It is astonishing to think of the great scientists of the past century, such as von Laue, Pauli, Madame Curie, Heisenberg, Born, Oppenheimer, Schrödinger, Dirac, Wigner, Fock, Landau, Dicke, Schiff, Bethe,Wheeler and Feynman, who have never made it an issue. If there is actually something wrong with the argument presented in the present work, it is surely time for this to be demonstrated in a strictly rational manner. A significant part of Einstein's legacy is at stake.

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