CRITIQUE OF THE TREATMENT OF EINSTEIN'S SPECIAL THEORY OF RELATIVITY IN ISAACSON'S BIOGRAPHY[1]

[1]W. ISAACSON, EINSTEIN: HIS LIFE AND UNIVERSE (SIMON & SCHUSTER PAPERBACKS, NEW YORK, 2007)

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Abstract: Consideration is given to the properties expected for inertial systems, that is, objects which are not subject to unbalanced external forces. Isaacson points out correctly that Einstein based his version of relativity theory on the motion of such inertial systems. It is overlooked, however, in both his discussion and also the original work of Einstein himself that, consistent with Newton's First Law of Motion (Law of Inertia), the rates of inertial clocks must remain constant so long as no unbalanced force is applied to them. As a consequence, it can be safely concluded that the ratio of any two such rates must also be constant. This in turn leads to a prediction about the relationship between elapsed times measured by two inertial clocks (Newtonian Simultaneity), namely they must always occur in strict proportion to one another ($\Delta t=Q\Delta t'$). The latter result is shown to stand in direct contradiction to the predictions of the Lorentz transformation derived by Einstein in his famous 1905 paper, namely the occurrence of space-time mixing and remote non-simultaneity (RNS). It is furthermore pointed out that the frequency of sound waves is independent of the state of motion of the source because, as Einstein argued in a 1907 paper in which he derived the gravitational red shift, the number of wave crests emitted by the source per unit time is not changed thereby. This fact has a definite bearing on Einstein's postulate of relativity according to which he assumed that the speed of light in free space is independent of the state of motion of both the observer and the source. It indicates instead that the postulate must be reformulated to state that the speed of light relative to its source is always the same in free space, a version that Einstein also carefully considered, as clearly mentioned in Isaacson's narrative. Accordingly, it becomes clear that Einstein was incorrect in his claim that the classical (Galilean velocity transformation) is not applicable to light. His relativistic velocity transformation only has validity for specific cases in which the speed of light is measured under different circumstances by a single observer, such as in the famous Fresnel/Fizeau light-drag experiment in which the motion of light waves in refractive media is investigated. The failure of the Lorentz transformation necessitates a rethinking of some of its well-known predictions such as time dilation and Lorentz-FitzGerald length contraction. Experimental evidence is presented which indicates instead that the slowing down of clocks upon acceleration is accompanied by isotropic length expansion. The applicability of these theoretical developments for the Global Positioning System of navigation is discussed. Opportunities for carrying out new experiments on this basis are also outlined in the present critique.

Keywords: Lorentz transformation; remote non-simultaneity; Galilean velocity transformation; gravitational red shift; time dilation; transverse doppler effect; global positioning system (GPS)

1. Introduction:

Relativity theory is a key subject in Isaacson's biography of Albert Einstein. The centerpiece of this discussion is the landmark paper which was published in Annalen der Physik in 1905. The author states correctly that Einstein's theory is based on two postulates, or basic assumptions, both of which deal with what are known as *inertial systems*. These are objects which are not subject to any external force and they form the basis for Newton's First Law of Motion, otherwise known as the Law of Inertia.

In order to have a proper understanding of Einstein's version of relativity theory, it is important to recognize that there is an overriding principle which governs all physical theories, namely they must be free of any and all contradictions. *They must be internally consistent, but must also conform to all existing credible theories which* *bear a definite relation to them.* In the present case, this includes the Law of Inertia. The latter states that an inertial system must move at the same speed and direction indefinitely in lieu of the application of some external force upon it.

Since Einstein's theory is intimately connected with relationships of time and space, one needs to ask the question of whether Newton's First Law has any bearing on the *properties of inertial systems* beyond their speed and direction. Consider an inertial clock, for example. If it is used to measure the elapsed time of a dependably recurring event such as a complete rotation of the earth about its polar axis, it seems inescapable to conclude in the context of Newton's First Law that *its value would always be the same* over an indefinite period of time. On this basis, it is reasonable to infer that *the rate of any inertial clock is constant*. In the following discussion, it will be shown that this property of inertial clocks, as well as the requirement of formulating theories which are free of internal contradictions, will have a direct bearing on the analysis of Einstein's theory of relativity.

2. Galileo's relativity principle and the speed of light:

The subject matter of relativity theory centers around the question of what is the speed of light in free space. Isaacson correctly points out that there were a number of experimental results in the 19^{th} century that caused physicists to doubt whether the motion of light waves could be described successfully on the same basis as conventional atoms and molecules. These included first and foremost the Fizeau/Fresnel light-drag experiment in which the light speed was measured in refractive media which are themselves in motion relative to the laboratory. Extrapolation of these results to a medium consisting of perfectly free space seemed to indicate that the speed of light under this circumstance is completely independent of the state of motion of the observer.

Perhaps, even more influential was Maxwell's theory of electromagnetism which was published in 1864. It indicated that the speed of electromagnetic waves, and therefore also light, has the same value c in all inertial systems. In an effort to explain this state of affairs, it became popular to hypothesize that there is an absolute frame of reference relative to which light travels at the speed c. This reference frame was thought to be filled by a "luminiferous ether" which somehow explained the propagation of electromagnetic wave motion. Isaacson points out on p. 111 that "all of this led to the great ether hunt of the late nineteenth century." On this basis, it was theorized that an observer moving relative to the absolute frame of the ether would measure different light speeds for different directions of travel of the light. Michelson and Morley carried out experiments with their newly developed interferometer in 1887 that disproved this theory, however.

Einstein therefore set about the task of developing a "postulate" involving the speed of light which would preclude any notion of an ether. Isaacson notes on p. 119 that Einstein was presented with at least two options to accomplish this objective. In one case he could assume that light particles can just "zoom through emptiness" and would be described by the conventional laws of classical physics. That would mean that the speed of light depends on the state of motion of the observer relative to the light source. There would be no need for an ether and there would be plenty of examples from everyday life to compare in order to compute the velocity of the light particles for any given observer.

In the second case, Einstein envisioned a theory in which the speed of light in free space was always the same, completely independent of the states of motion of either the light source or the observer. It is here that at least Isaacson, if not Einstein himself, makes a false conclusion based on the theory of sound waves to justify making this assumption. Before discussing this point, however, it is well to note that Isaacson then gives a detailed discussion of why both of the above two possibilities seemed to be eliminated from the realm of possibility. As for the second case, for example, Einstein fretted over the idea as described in the following quote: "And he puzzled over the apparent dilemma that an observer racing up a track toward a light would see the beam coming at him with the same velocity as when he was racing away from the light – and with the same velocity as someone standing still on the embankment would observe the same beam." In any case, Einstein was convinced that the correct theory must be consistent with Galileo's Relativity Principle.

3. Colliding with newton over simultaneity:

At some point, Einstein settled on two "postulates" which he felt had to be rigorously satisfied in order to arrive at a viable theory. One was the above relativity principle, while the other he defined in the following citation from Isaacson's narrative (p. 120): "Light always propagates in empty space with a definite velocity V that is independent of the state of motion of the emitting body." He was nonetheless hesitant to accept this assumption. The insight that definitively changed his mind was (see p, 123) "that two events that appear to be simultaneous to one observer will not appear to be simultaneous to another observer who is moving rapidly."

It is imperative to see the connection between the simultaneity issue on the one hand and Einstein's relativity postulate on the other. To do this satisfactorily, it is necessary to consider the Lorentz transformation (LT). It is the set of equations Einstein derived in his 1905 paper that relates the space and time relationships of two observers of the same event who are in relative motion to one another. It is noteworthy that exactly the same equations had been derived in the 1890s by Lorentz (as the name implies) and Larmor, who arrived the same result sometime before Lorentz. Indeed, there was a precursor derived by Voigt in Göttingen, Germany in 1887, which was a reaction to the pivotal Michelson-Morley experiment carried out in the same year, that embodies the same connection. In the following LT equation, the respective elapsed time results are denoted by Δt and $\Delta t'$, whereas the corresponding measured values of the spatial separation of the two events are given by Δx and $\Delta x'$ (v is the speed of separation of the two observers and c is the speed of light, i.e. what Einstein denotes as V in his paper):

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

In Einstein's train example mentioned by Isaacson on. p.123, Δx and $\Delta x'$ are the distances between the two lightning strikes measured by the observers on the platform and the train, respectively, and Δt and $\Delta t'$ are the corresponding elapsed times between the strikes they have recorded. It is clear that if the events occur simultaneously for the platform observer ($\Delta t=0$) and both v (the speed of the train relative to the platform) and Δx are different from zero, they cannot occur simultaneously, i.e. $\Delta t' \neq 0$, for the observer riding along on the train. This state of affairs is commonly referred to as "remote non-simultaneity" or simply RNS.

There is a critical problem with this equation, however. To see this, it is necessary to understand that, by construction, both observers whose timing results are compared in the above LT equation are *inertial systems*, i.e. they are not subject to any unbalanced external force. In the Introduction, it was pointed out that, consistent with Newton’s Law of Inertia, the rate of any stationary clock in such a rest frame does not change over time. While this detail does not help us to determine the actual rates in a given situation, it does tell us something of critical importance in the present context, namely that the *ratio of the rates of two inertial clocks must also be time-independent.* As a consequence, if two such clocks are used to measure the time difference between two events, their respective measured values Δt and $\Delta t'$ must also have the same constant value in all cases, i.e.

$$\Delta t / \Delta t' = \text{constant} = Q.$$

Comparison of this relationship with the above LT equation shows quite clearly that they are completely inconsistent with one another. For example, the above proportionality relationship does not allow for any situation in which the two events are found to be simultaneous on the basis of one of the clocks ($\Delta t=0$), without the same holding true for the other ($\Delta t'=0$). That finding directly contradicts the prediction of RNS that is obtained when the LT equation is used. As a consequence, it must be concluded that the LT is not physically valid since, as discussed in the Introduction, it fails the essential test of avoiding contradiction with established theory. It does not matter how many successful predictions have otherwise been made using the LT. *The fact that it is contradicted in the above manner outweighs all other considerations.*

Indeed, the LT is not even internally consistent because the above equation leads to another well-known prediction of Einstein's theory: *time dilation*. Accordingly, the elapsed times of the two observers also always occur to be strictly proportional. Thus, in Einstein's famous example of two lightning strikes on a train, which was alluded to on p. 123 of Isaacson's biography, it is also impossible on this basis for the platform clock to find that the two strikes occur at the same time without the same being true on the other inertial clock located on the train.

It also needs to be noted that the LT equation in question is responsible for the widely held belief among physicists that *space and time are incontrovertibly mixed* with one another. We will return to this subject when *experimental* evidence for time dilation is discussed subsequently.

4. Re-examining the role of the Galilean transformation:

The failure of Einstein's solution to finding a suitable light-speed postulate opens up the discussion once again to the alternative idea that light can be considered to be just another form of matter and thus that its speed is subject to the same laws as sound. As mentioned above, Isaacson makes a false statement on p. 119: "If the source of sound is rushing toward you, the waves will not get to you any faster." He then goes on to give a correct statement about the wavelength λ, however, pointing out that because of "the Doppler effect, the waves will be compressed and the interval between them will become smaller." This is true. Quantitatively, this means that λ is proportional to the difference in the speed of the sound v_S and the speed of approach v of the observer, i.e. v_S - v. But in the next sentence, he makes another error, claiming that "the decreased wavelength means a higher frequency." This is certainly not true because the frequency ν of the waves is completely independent of the speed of the observer. *The source keeps spewing out waves at the same rate no matter how fast the observer approaches it.* Pais notes in his biography that Einstein made the very same assertion in his 1907 paper when introducing the "gravitational red shift." As a consequence, *the speed of the waves relative to the observer is also proportional to v_S - v,* i.e. the product of the frequency and wavelength, which is the speed of the wave, is equal to $\lambda\nu = v_S - v$. In other words, *the proportionality constant between the speed and wavelength of sound waves is the period,* i.e. the reciprocal of the frequency.

Once this is realized, one can go about the task of computing the speed of the sound without bringing the complication of wave properties into the discussion. To do this we merely need conventional vector addition. One vector is $\mathbf{v_S}$, which points away from the source toward the observer, while the other is the velocity **v**, which points *toward the source and away from the observer.* From the observer's vantage point, it is the source that is moving while he remains stationary. The resultant velocity is therefore $\mathbf{v_S + v}$ pointing from the source of the sound to the observer.

It should be noted that his result is not consistent with the previous calculation for the speed of the waves, however. That's because two different types of speed are involved and they are not identical. The formula "$v=\lambda\nu$" is not a true measure of the actual speed of sound relative to the observer. Take, for example, the case when the observer moves relative to the source with speed v_S. In that case the $v=\lambda\nu$ formula gives *a value of zero* for the speed of the waves, whereas the correct value obtained by vector addition from the vantage point of the observer ($v_S + v_S$) is 2 v_S, i.e. by adding the distances traveled in unit time by the source and that of the sound relative to the source as viewed by the observer. What the λν formula tells us instead is that the wavelength is zero under these circumstances, whereas the frequency of the sound waves is the same as it is when the observer remains stationary throughout. This is clearly something quite distinct from the actual speed of sound.

There is every reason to treat light waves in exactly the same manner. One simply must change Einstein's postulate to: *the speed of light relative to its source is a constant c.* This is true in every rest frame and is therefore also perfectly consistent with Maxwell's electromagnetic theory. This version is also consistent with the relativity principle. The rest frame of the light source is unique in any given case. The corresponding law of physics simply states that a local observer in that rest frame will always measure the speed of the light to have a value of c. It is not so, as Einstein incorrectly assumed, that it is a law of physics that the local observer in every rest frame must always find a value of c no matter what the state of motion of the light source. *The above analysis shows on the contrary that the measured light speed does indeed depend on the relative velocity of the source to the observer.*

It should be recognized that the procedure of vector addition employed above is what is meant by the classical (or Galilean) space-time transformation used by Newton in the 17^{th} century. Einstein in his version of relativity theory had relegated it to the position of simply being the low-velocity limit of his LT. The present application is only to collinear vectors but there is no reason to restrict it to this extent. It can also be used to combine vectors which are perpendicular to one another.

A prominent example thereof occurs in the phenomenon of aberration of starlight from the zenith discovered by Bradley in 1727. Accordingly, the angle of deviation Θ for light emanating from the sun when the astronomer is moving at speed v in the earth's orbit is given by $\tan \Theta = v/c$. Einstein added a factor of $(1-v^2c^{-2})^{-0.5}$ in the numerator in order to obtain consistency with his light-speed postulate, but the present analysis indicates that Bradley's original formula is correct. The orbital speed of the earth is such that it has thus far been impossible to obtain an experimental verification of the proposed distinction in the two formulas.

5. The role of Einstein's velocity transformation (RVT):

It cannot be denied, nonetheless, that the Fizeau/Fresnel light-drag experiment cannot be explained on the basis of the Galilean transformation. Einstein was right about this. As mentioned above, this experiment indicates that the speed of light is independent of the speed of the medium through which it passes. This fact is consistent with either of the light-speed postulates that have been discussed herein. The derivation of the LT is certainly in agreement with this conclusion, but, as has been discussed above, its prediction of RNS rules it out as a suitable instrument of relativity theory. It is important to note, however, that von Laue's derivation of the light-drag effect does not actually make use of the LT, but rather the closely related velocity transformation (RVT). The latter is obtained from the LT in a very simple manner just by dividing each of its spatial coordinates by the corresponding time coordinate.

Lorentz pointed out, however, that there is a degree of freedom most conveniently determined in terms of a single parameter which allows the RVT to be derived from a whole family of space-time transformations. The original Voigt transformation also possesses this characteristic, for example, but it too leads to the RNS prediction. It has recently been noted, however, that the above parameter can be chosen to have a different value so as to avoid RNS while still adhering to both of Einstein's postulates. One merely has to combine the RVT with the Newton First-Law clock relation discussed above, namely in the form given below (Newtonian Simultaneity):

$$\Delta t = Q\Delta t'.$$

It is surprising that the resulting transformation also satisfies the relativity principle, but it is easily shown that this is the case. One can speculate that the reason Einstein and his predecessors Larmor and Lorentz chose another value for the parameter is because they believed that only in this way could the relativity principle be satisfied. They were willing to give up the long-held Newtonian doctrine of the total separation of space and time to arrive at their desired result. The alternative transformation based on Newtonian Simultaneity does not have this problem and has heretofore been named the Newton-Voigt transformation in recognition of the concepts on which it is based. It is also perfectly consistent with the results of the light-drag experiment by virtue of its direct relation to the RVT.

The question that needs to be answered is therefore in what situations the two transformations can be applied. The answer is quite simple. The NVT and RVT describe events in which a single observer measures the space and time coordinates of the *same event under two different conditions.* In the light-drag experiment the two conditions are the different speeds of the medium through which the light passes. The same (laboratory) observer makes the measurements in both cases. The same holds true for the experiment in which charged particles are subjected to different amounts of acceleration in an electromagnetic field. The RVT is consistent with the fact that no amount of force can cause the speed of the particles to exceed c. Again there is only a single observer carrying out the two sets of measurement. Another important example occurs in the phenomenon of the Thomas spin anomaly. Two paths of the electron or atom are observed at different times in the orbital motion by a single observer.

None of these events can be described successfully by the Galilean transformation. The latter must be used instead whenever the results of *two different observers are to be compared for the motion of a single object.* This occurs with sound waves reaching observers standing on a street corner and another racing toward it in an automobile. The same hold true for light waves emanating from the sun and stars at speed c approaching respective observers in an astronomy laboratory and stationed on a satellite in outer space. There is qualitatively no difference between these two cases and what happens when observers on a speeding train and the station platform both see a truck moving down an adjacent highway. In turn, none of these events can be successfully described with the RVT.

6. Time dilation and length variations:

Two of the most famous predictions of Einstein's theory are time dilation and FitzGerald-Lorentz length contraction. In view of the failure of the LT on which these predictions were based, it is important to examine the experimental evidence that has been obtained that is relevant to both issues. The experiments of Hafele and Keating with atomic clocks carried onboard circumnavigating airplanes provide quite clear evidence for the slowing down of clocks as a result of their motion. These authors found that the rate of any given clock was determined by two factors, one of which is due to gravity. When the gravitational effects on the rates are subtracted, it is found that a given rate is inversely proportional to the speed of the clock relative to the earth's center of mass (or non-rotating polar axis in their words). Qualitatively, this meant that the clocks moving in an easterly direction returned to the point of origin with less elapsed time than those that remained behind. In turn, the latter had less elapsed time than their counterparts that moved in the westerly direction.

These results differ in at least two significant ways from what was expected based on the LT. First of all, it is always possible through the duration of the flight to say which of two clocks runs slower (asymmetric time dilation). The LT on the contrary leads to the prediction of *symmetric* time dilation, whereby it is supposedly a matter of perspective of the observer which clock runs slower. In addition, the rate of the clock should always be determined by the speed of a given clock relative to the observer. Neither LT effect is observed. This is naturally consistent with the conclusion that the LT is not a physically valid transformation. The earlier results of experiments with rotating x-ray absorbers are quantitatively consistent with the atomic clock findings. In the latter case it was the speed of a given timing device relative to the rotor axis which is rate-determining.

The timing results can be conveniently summarized in a simple manner referred to as the Universal Time Dilation Law (UTDL). It describes an inverse proportionality involving the speeds of clocks relative to a particular rest frame (Objective Rest System or ORS for short). The latter is the earth's center of mass in the atomic clock study with airplanes, the axis of the rotor in the x-ray investigations, and more generally, the rest frame in which force is applied to cause the object to accelerate. The UTDL compares time differences (elapsed times) Δt and $\Delta t'$ for a given pair of events measured by two observers in relative motion to one another. All that is needed for input are the respective speeds v and v' of the corresponding clocks relative to the ORS. The formula is given below [$\gamma(v) = (1 - v^2 c^{-2})^{-0.5}$]:

$$\Delta t \, \gamma(v) = \Delta t' \, \gamma(v').$$

There is a wealth of experimental evidence to support the UTDL and there are no known exceptions to it.

The UTDL is useful in another theoretical context as well. By forming the ratio of the elapsed times in any given case, one obtains a unique value for the parameter Q in the Newton Simultaneity expression, namely as:

$$Q = \Delta t / \Delta t' = \gamma(v') \gamma(v).$$

The same parameter appears explicitly in the NVT system of equations. A convenient way to look upon Q is as a *conversion factor* between the respective units of time in the two rest frames. Note that the reciprocal of Q serves as the corresponding conversion factor in the opposite direction, exactly as is the case for their counterparts conventionally used for physical quantities in general. *The UTDL therefore enables one to determine this conversion factor for time between any two rest frames.* Note that it is not possible to have a parallel development in Einstein's version of relativity theory because of its prediction that each observer must find that the other's clock runs slower than his own.

Experimental evidence indicates that the speed of light relative to its source is equal to c for both the local observer as well as his counterpart in another rest frame. On this basis one can conclude that no conversion factor for the unit of velocity between different rest frames is required, i.e. the corresponding factor is unity. Since the unit of speed is equal to the ratio of the units of distance and time, one can therefore also conclude on this basis that the conversion factor for distance/length is also equal to Q. In other words, changes due to acceleration in the units of distance and time merely cancel each other out.

This is another example in which Einstein's version of the theory has misled the physics community. Ever since the 1905 paper, it has been widely believed that (Lorentz-FitzGerald) contraction occurs in an accelerated rest frame. Moreover, the effect was supposedly different depending on the orientation of the object. The experiment carried out by Ives and Stilwell in the late 1930s showed on the contrary that the wavelength of light emanating from an accelerated light source is *greater* than when it is generated in the rest frame of the laboratory. Moreover, the clear indication is that the increase in wavelength is the same in all directions. Instead of accepting this result at face value, scientists came up with explanations which defended the length contraction theory. In reality the situation is quite clear: *the lengths of objects expand whenever the rates of clocks are slowed by acceleration.*

Experiments with electrons in electromagnetic fields carried out by Bucherer in 1909 indicate that their inertial mass changes in exactly the same proportion as the lifetimes of meta-stable particles. On this basis one can further conclude that the conversion factor for inertial mass is also equal to Q. Furthermore, since the units of all other physical properties can be expressed in terms of the fundamental units of space, time and inertial mass, it follows that the corresponding conversion factors are simply powers of Q. For example, the angular momentum of an object is given as the product of its inertial mass, orbital speed and radius, i.e. with units of kg $m^2 s^{-1}$ in the mks system of units; accordingly, its conversion factor is Q^2 (the exponent of Q is determined as the sum of 1+2-1). The same exponent applies to Planck's constant h since it also has units of angular momentum. Note that this circumstance guarantees that Planck's seminal $E=h\nu$ relation holds in every inertial frame (the energy E scales as Q, the same as inertial mass, while the frequency ν scales as Q^{-1}, i.e. the reciprocal of the unit of time).

7. Gravitational scale factors:

There is an analogous system for gravitational measurements. In this case the quantity that is analogous to γ (v) in the conversion is A (r) = 1 + GM_s/c^2r, where G is the universal gravitation constant, M_s is the gravitational mass of the active source (such as the sun for planetary motion), c is the speed of light, and r is the distance of a given location to the active mass. The conversion factor analogous to Q is equal to S= A_O/A_P, where r_O is the distance of the observer to the active mass and r_P is the distance of the object to the active mass. If the object is at a higher gravitational potential than the observer, i.e. $r_O<r_P$, this means that S>1. The basis for these definitions is Einstein's gravitational red shift which he defined in a 1907 paper.

The exponents of S for conversions of various physical quantities are different than for Q discussed above. The conversion factor of both time and inertial mass is S^{-1} while that for distance is S^0=1. As before with the determination of exponents of Q for motion, the value can be obtained in this case from the composition of a given quantity in terms of the fundamental units of time, distance and inertial mass. For example, energy has a conversion factor of S^1 = S since it has units of kgm^2s^{-2}; hence the exponent in this case is determined to be -1 + 0 -(-2) = 1. This means that if an energy value of E (P) is measured for the object at location P in the gravitational field, the corresponding value for O is equal to E(O)= SE(P).

As before with motion, one can most easily understand these results in terms of the units of a particular quantity. For example, the unit of energy is S times larger at location P if it is at a higher potential than location O. This result is in quantitative agreement with Newton's inverse square law for small potential differences, i.e. ΔE=mgh at the higher potential. The corresponding unit of time is S times smaller at P than at O, i.e. clocks run S times faster at P than at O. This prediction has been verified quantitatively by experiments in which an atomic clock is moved to the top of a mountain and allowed to stay there before being brought back later to its original location. The results indeed show that the clock was running faster on the mountain by the predicted amount than its counterpart below.

The formalism discussed above for determining conversion factors can be tested by carrying out measurements of elapsed times using stationary atomic clocks in different rest frames. For example, one could measure the time separating two laser emissions with a clock located on the earth's surface and a second clock located on a satellite orbiting the earth. The values of the Q and S conversion factors from the standpoint of the ground station can be computed on the basis of the relative speeds of the ground and satellite clocks to the earth's center of mass (ORS) and their respective locations in the gravitational field of the earth. The time difference Δt_G measured with the ground clock should be equal to (Q/S) times the corresponding time difference Δt_S recorded on the (uncorrected) satellite clock. This procedure is completely equivalent to that used in the airplane experiment of Hafele-Keating.

A more ambitious experiment involves a clock located on a satellite orbiting the moon. In that case, one needs to know both the speed of the satellite relative to the moon's center of mass (which is the ORS in this case) and the speed of the moon relative to the earth's center of mass. The overall conversion factor Q for the earth-bound observer is obtained as the product of the above two partial Q factors. The value of the corresponding gravitational conversion factor S is again obtained by comparing the respective A (r) values, that of the satellite A_P, in the moon's field in this case, and that of the observer A_O in the earth's (S= $A_{O/}$ A_P). Again, the time difference Δt_E measured with the earth-bound clock should be equal to (Q/S) times the corresponding time difference Δt_M recorded on the (uncorrected) satellite clock.

A similar procedure based on conversion factors between different rest frames was first used by Schiff in 1960 to predict the angular displacement of star images during solar eclipses. The interesting fact about this calculation is that it assumes that light rays are not actually bent by the sun, rather that they are simply slowed down by various amounts as the pass by the sun but continue throughout in perfectly straight lines. This is in accordance with Einstein's conclusion in the aforementioned 1907 paper in which he stated that the speed of light is decreased as it passes through regions of lower gravitational potential. It is also consistent with the above discussion which indicates that the speed of an object scales as S. Even more significantly, this assumption was confirmed in experiments carried out by Shapiro in his study of the time delays of radio waves as they pass close to planets such as Venus and Mercury. The most interesting aspect of these studies, however,

is that they stand in contradiction to the claim that the light rays travel through "curved space." This experience shows at the very least that there is more than one way to obtain a given result. It is also consistent with the main argument mentioned at the beginning of this report, which is that, because of the properties of freely translating systems (Newtonian Simultaneity), it is unreasonable to expect that events occurring simultaneously for one observer will not be so for another. This state of affairs places considerable doubt in the concept of "space-time," that is, that the coordinates of space and time are inextricably mixed with one another.
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References:

[1] A. Einstein, *Ann. Physik* 322 (10), 891 (1905).
[2] A. Pais, in '*Subtle is the Lord*…' *The Science and the Life of Albert Einstein* (Oxford University Press, Oxford, 1982), p. 115.
[3] R. D. Sard, in *Relativistic Mechanics* (W. A. Benjamin, New York, 1970), pp. 49-51.
[4] T. S. Jaseja, A. Javan, J. Murray, and C. H. Townes, *Phys. Rev.* 133, A1221 (1964).
[5] H. Müller and A. Peters, *Phys. uns. Zeit* 35, 70 (2004).
[6] R. J. Kennedy and E. M. Thorndike, *Phys. Rev.* 42, 400 (1932).
[7] C. Braxmaier, H. Müller, O. Pradl, J. Mlynek, A. Peters and S. Schiller, *Phys. Rev. Lett.* 88, 010401 (2002).
[8] 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).
[9] 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).
[10] D. S. Ayres, D. O. Caldwell, A. J. Greenberg, R. W. Kenney, R. J. Kurz, and B. F. Stearns, *Phys. Rev* .157, 1288 (1967).
[11] E. F. Taylor and J. A. Wheeler, in *Spacetime Physics* (W. H. Freeman and Co., San Francisco, 1966), p. 16.
[12] D. Hils and J. L. Hall, *Phys. Rev. Letters* 64, 1697 (1990).
[13] J. C. Hafele and R. E. Keating, *Science* 177, 166 (1972); 168 (1972).
[14] R. J. Buenker, *Apeiron* 17, 99 (2010).
[15] R. J. Buenker, *Apeiron* 15, 254 (2008).
[16] R. J. Buenker, *Apeiron* 16, 96 (2009).
[17] R. J. Buenker, in *The Relativity Principle and the Kinetic Scaling of the Units of Energy, Time and Length* (Apeiron, Montreal, 2014), pp.55-56.
[18] R. J. Buenker, *J. App. Fundamental Sci.* 4 (1) 6 (2018).
[19] R. J. Buenker, *Apeiron* 15, 382 (2008).