Review Article

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The kinetic relativity theory – hiding in plain sight

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Abstract: A question in physics is whether Special Relativity (SR) is the only theory that explains relativistic behavior. SR measures time dilation by a relative velocity between two frames. Laboratory experiments with a single moving body fit this concept. However, GPS satellites and their ground clocks measure time dilation by a velocity relative to a common non-rotating Earth inertial frame. To better understand the conceptual difference, an experimental survey was undertaken. The survey analysis showed that laboratory experiments also fit into the non-rotating Earth frame concept. The laboratory experiments only need to add the Earth rotational velocity to both the laboratory frame and the moving frame. The analysis also revealed that the relative velocity calculation was astonishingly close to the common Earth frame calculation. The common Earth frame then becomes the explanation for all experimental types. And it signifies that a gravity field – moving body interaction causes relativistic effects. The experimental record also contained enough data to draft an empirical kinetic theory different than SR. The "no preferred reference frame" of SR is replaced by "there is a preferred reference frame." And the preferred frame is the nearby Earth gravity field.

Keywords: special relativity, time dilation, general relativity, Lorentz factor, kinetic relativity

1 Introduction

A non-rotating Earth-centered frame (ECF) theory is the focus of this experimental review. The theoretical goal is to develop an empirical theory that describes the Earth's gravity field–moving body interaction. The experimental results define relativistic behavior for time and length. The math used by the experimenters is copied to become the math of the new theory. Some harmonization is required, and conceptual preference is given to higher-resolution experiments. Fortunately, there is sufficient experimental evidence to do this.

Thirty-one experiments were reviewed to clarify how the Lorentz factor of Special Relativity (SR) was applied and to identify fixed frames and moving bodies. A select group of five is presented to shorten the discussion and still provide the larger picture. That picture reveals that all experiments do indeed fit into the relativistic order of Earth-based velocities. A higher velocity in Earth's gravity field results in higher relativistic effects. Relativistic dilation was always predictable, and it was clear which body dilated.

The select group looks at airplane trips around Earth, GPS satellite motion, relativistic Doppler shifting in laboratories, and muon particle life. These measurements clarify what is experimentally known.

Most importantly, multi-body atomic clock experiments provide clear support for an alternative kinetic theory.

2 Experimental review and discussion

2.1 The Hafele and Keating (HK) experiment (1972) [1,2]

The theory begins with an experiment report by HK in 1972. They flew four atomic clocks around the world in eastward and westward directions. After each round trip, they compared the clock times to the Naval Observatory atomic clocks.

They measured relativistic time changes for both elevation (gravity) and kinetic motion (velocity). The relativistic velocity was computed by combining the airplane's ground speed with Earth's rotational speed. They collected the speed and elevation data from the flight staff for each flight segment. Their atomic clocks were capable of

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measuring time down to a level of 10^{-13}–10^{-14} due to atomic clock stability over time.

They wrote:

> ... For low coordinate speeds ($u^2 \ll c^2$), the ratio of times recorded by the moving and reference coordinate clocks reduces to $(1 - u^2/2c^2)$, where c is the speed of light. Because the earth rotates, standard clocks distributed at rest on the surface are not suitable in this case as candidates for coordinate clocks of an inertial space. Nevertheless, the relative timekeeping behavior of terrestrial clocks can be evaluated by reference to hypothetical coordinate clocks of an underlying nonrotating (inertial) space (6).
>
> For this purpose, consider a view of the (rotating) earth as it would be perceived by an inertial observer looking down on the North Pole from a great distance. A clock that is stationary on the surface at the equator has a speed $R\Omega$ relative to nonrotating space, and hence runs slow relative to hypothetical coordinate clocks of this space in the ratio $1 - R^2\Omega^2/2c^2$, where R is the earth's radius and Ω its angular speed. On the other hand, a flying clock circumnavigating the earth near the surface in the equatorial plane with a ground speed v has a coordinate speed $R\Omega + v$, and hence runs slow with a corresponding time ratio $1 - (R\Omega + v)^2/2c^2$. ...

Importantly, both the airplane and laboratory clocks moved relativistically to the hypothetical ECF.

For the airplane clocks, the kinetic time dilation used the small velocity approximation of ($u^2 \ll c^2$), resulting in a time ratio of

$$\frac{t_{\mathrm{m}}}{t_{\mathrm{f}}} \approx 1 - u^2/(2c^2) \approx 1 - (R\Omega + v)^2/(2c^2), \tag{1}$$

where t_{m} and t_{f} are the respective times recorded by the moving planes and the ECF during flight, respectively, R is the Earth's radius, Ω is the Earth's rotation speed, and v is the airplane ground speed. They explicitly stated that the airplane clocks had a time that "runs slow," meaning time dilation.

If the small number approximation of

$$\sqrt{1 - a} \approx 1 - a/2 \tag{2}$$

is used in reverse, their calculation becomes

$$\frac{t_{\mathrm{m}}}{t_{\mathrm{f}}} = \sqrt{1 - u^2/c^2}, \tag{3}$$

where u is the total velocity of the laboratory or airplane moving relative to the ECF.

HK compared the airplane clock time against the Naval Observatory clock time. They measured a kinematic *time gain* in the west direction and a kinematic *time loss* in the east direction. The time dilation due to gravity potential was similar in each direction. Their experiment clearly showed that motion is neither relative between planes nor relative to the Naval Observatory. The East/West directions clarified that time was relativistic to the ECF.

The HK experiment empirically establishes time dilation. Based only on their experiment, one might conclude that every plane, satellite, car, train, walking person, and building moves relative to the ECF.

To clarify this possibility, GPS satellite results are mentioned.

2.2 GPS satellite reports

The GPS description of relativistic time by Ashby and Spilker [3] and Ashby [4,5] agrees with the HK result and calculation method for satellites instead of airplanes. Both the satellites and ground-based clocks move relativistically to the ECF.

In a 2006 paper, the GPS expert Ashby [6] described GPS time dilation by:

> "... so the time of the "moving" clock at the top end of the rod, and the "rest" clock at the same location are related by (4):
>
> $$t' = \sqrt{1 - \frac{v^2}{c^2}}\, t. \tag{4}$$
>
> Thus, a clock moving relative to a system of synchronized clocks in an inertial frame beats more slowly. The square root in Eq. (4) can be approximately expanded using the binomial theorem (5):
>
> $$\sqrt{1 - \frac{v^2}{c^2}} \approx 1 - \frac{1}{2}\frac{v^2}{c^2}. \tag{5}$$
>
> In the GPS, satellite velocities are close to 4,000 m/s, so the order of magnitude of the time dilation effect is (6)
>
> $$-\frac{1}{2}\frac{v^2}{c^2} \approx -8.35 \times 10^{-11}. \tag{6}$$
>
> This is also a huge effect. A reference clock on earth's equator is also in motion, but with a smaller speed, of order 465 m/s. To obtain the fractional frequency difference between a GPS satellite clock and a reference clock on the equator, we have to compute the difference (7):
>
> $$\frac{\Delta f}{f} = -\frac{1}{2}\frac{v^2}{c^2} - \left(-\frac{1}{2}\frac{(\omega a_1)^2}{c^2}\right) = -8.228 \times 10^{-11}. \tag{7}$$
>
> If not accounted for, this would build up to contribute a navigational error of order 2.13 km/day. Because of these frequency offsets, it is best to view the GPS satellite constellation and the reference clocks on the rotating earth from the point of view of the ECI frame."

Ashby's math symbols were: t' is the moving body time, t is the fixed frame time, v is the moving body velocity, Δf is the frequency change between the satellite and a clock on the equator, and f is the reference frequency on the equator. The term ωa_1 is the velocity of the reference clock due to Earth's rotation ω at equator radius a_1, and ECI is the same as ECF.

The main point of [Eqs. (6) and (7)] is that a laboratory clock also moves relativistically to Earth and the smaller velocity reduces the difference in dilation between the equator clock and the satellite clock.

Ashby attributed the laboratory dilation to the Sagnac effect. However, the GPS report by Denker *et al.* [7] merely called it centrifugal potential. HK only mentioned it as motion. Regardless of attribution, HK, Ashby, and Denker *et al.* agree that laboratory clocks also experience time dilation based on Earth's rotation.

The cited GPS references confirm time dilation when moving relative to the ECF in orbit and when rotating on Earth's surface.

Next, a relativistic Doppler shifting experiment in a laboratory will be discussed to determine how relativistic length changes.

2.3 The Mandelberg–Witten experiment (1962)

Mandelberg and Witten [8] set up an experiment to improve the accuracy of earlier Ives and Stilwell [9,10] and Otting [11] experiments. Mandelberg–Witten used a similar apparatus to measure the change in the emitted wavelength from moving hydrogen atoms, which was the result of relativistic movement in a laboratory. They used a spectrograph to separate the spectral lines and took pictures of them.

They described their measurement by:

> "The experiment consisted in measuring λ_R and λ_B, the wavelengths observed with and opposite to the beam, and taking the average to determine λ_Q and hence $\lambda_0\beta^2/2$. By a subtraction,
>
> $$2\lambda_D \equiv \lambda_R - \lambda_B = 2\lambda_0\beta\cos\theta. \quad (8)$$
>
> β was determined by measuring λ_R, λ_B, λ_0, and θ. The velocity was thus obtained by direct measurement without assuming a precise knowledge of the accelerating voltage and without making assumptions regarding the collision mechanism which produced the atom. To give an idea of the magnitudes of the parameters involved, a typical run was made with an accelerating voltage of 63.70 kV which produced a beam of excited atoms whose measured velocity corresponded to $\beta = 0.008176$. For a wavelength $\lambda_0 = 6562.793$, we measured $2\lambda_D = 107.317$ A and $\delta\lambda \equiv {}^1/_2\,\lambda_0\beta^{\,2} = 0.219$ A."

They combined their results with those of Ives–Stilwell and Otting and plotted them in Figure 6 of their paper. Mandelberg–Witten viewed their Doppler shift experiment as being predicted by SR. They reported an overall precision of 5% for velocities up to 2.8×10^8 cm/s.

In addition to linear Doppler shifting, Mandelberg–Witten measured a tiny relativistic wavelength change created by moving hydrogen molecules. The change was measured by laboratory instruments. Photographic plates showed spectral lines shifting to numerically longer wavelengths, which is called "red shift." The red shift increased for higher particle velocities.

Their red shift calculation, $\delta\lambda \equiv {}^1/_2\,\lambda_0\beta^{\,2}$, where β is the particle velocity as a fraction of c, is an additional amount that is added to the hydrogen spectral line wavelength λ_0. This is illustrated in Figure 1.

In Figure 1, both the laboratory and moving body have rulers that measure the same light beam wavelength. The moving frame ruler and the laboratory frame fixed ruler are aligned at the left, as illustrated. In this case, the moving body ruler is longer due to length dilation.

By only looking at the relativistic effect and ignoring linear Doppler shifting, a light beam with wavelength λ_0 is created by the moving body source (emitter) at 1 unit length. The wavelength is observed (measured) at λ_{Obs}. The wavelength measured by the laboratory ruler is longer than one unit. This agrees with a red-shifted beam as measured in the laboratory frame.

In contrast, a change in source is shown in Figure 2, and the two scales remain the same.

As illustrated, the laboratory source frame creates a shorter beam length (called "blue shift") as measured by the moving body frame. Regardless of which frame is the source, length dilation is shown for the moving body.

Figures 1 and 2 illustrations of red shift and blue shift agree with well-known relativistic doppler shifting effects.

The Mandelberg–Witten experiment measured length in the *direction of motion*. This result, along with HK's time

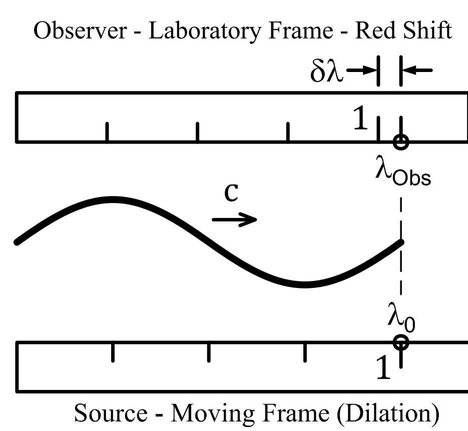

Figure 1: Illustration of relativistic length dilation by a moving light emitter.

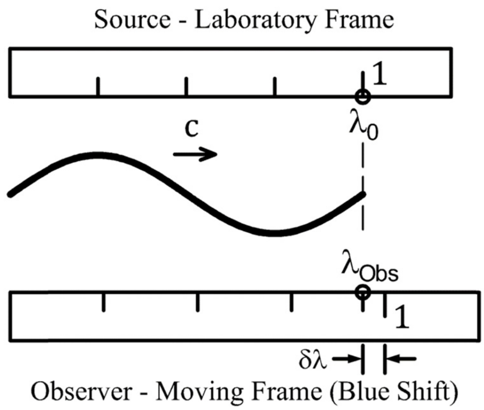

Figure 2: Illustration of relativistic blue shift from a fixed source light emitter.

dilation, means that the relativistic effects for both length and time use the same small-number approximation.

The experiments thus far have established relativistic time dilation to an ECF and relativistic length dilation to a laboratory frame.

This raises the question: Is the same relativistic length change measured *perpendicular* to the direction of motion? That is, does length change in all directions?

2.4 The Hasselkamp, Mondry, and Scharmann experiment (1979)

This question was answered by Hasselkamp *et al.* [12]. Their experiment also measured light from high-speed hydrogen atoms. The equipment was set up to measure the emitted wavelength perpendicular to the direction of motion. They focused the light on the entrance of a monochromator and measured the position of specific spectral lines by a photomultiplier. They measured red shift, like the Mandelberg–Witten results.

Their experiment used higher particle speeds up to 3.1% of the speed of light, and their error was about 6%. They described their calculations as follows:

> "We consider a light source emitting photons of wavelength λ_0 that is moving with a velocity v with respect to a detector located at an angle θ with respect to the direction of the source. The detector measures a wavelength λ' which is given by the Doppler formula (9).
>
> $$\lambda' = \lambda_0 \frac{1 - \frac{v}{c}\cos\theta}{\sqrt{1 - \left(\frac{v}{c}\right)^2}}, \qquad (9)$$
>
> c is the velocity of light.
>
> Eq. (9) is a consequence of the Lorentz-transformation of time. The experimental confirmation of the validity of (9) is therefore a verification of time dilatation. If $v/c \ll 1$, we find for the Doppler-shift $\Delta\lambda = \lambda' - \lambda_0$ with neglection of higher order terms (10):
>
> $$\Delta\lambda \cong -\lambda_0 \frac{v}{c}\cos\theta + \frac{\lambda_0}{2}\left(\frac{v}{c}\right)^2. \qquad (10)$$
>
> Besides the classical Doppler term $-\lambda_0 \frac{v}{c}\cos\theta$ (retardation) we have on the right-hand side of (10) a second term as a consequence of the Lorentz transformation of time. This relativistic term is called the "second order Doppler-shift." It is always positive and independent of the observation angle θ, therefore always causing a red shift of the measured wavelength (or, what is the same, causing a decrease of the frequency of the moving "clock" in the system of the observer, *i.e.* a time dilatation)."

The wavelength calculation of [Eq. (9)] when the beam is perpendicular to motion ($\theta = 90°$) is similar to the HK Eq. (3) calculation for time. The wavelength detector was in the laboratory frame and therefore measured wavelength λ' in the fixed laboratory frame. λ_0 is the spectral wavelength emitted by hydrogen atoms. The similarity to Eq. (3) comes from the square root position of $(1 - (v/c)^2)^{1/2}$; it is underneath the moving body wavelength λ_0 which conceptually agrees with the HK calculation.

Hasselkamp *et al.* also acknowledged SR by:

> "The results of the present experiment are therefore in agreement with the theory of SR and especially with the prediction of time dilatation."

Because the laboratory measured red shift perpendicular to the direction of motion, the experimental conclusion is that red shift occurs in all directions. That is, wavelength dilation occurs in all directions.

The experiments so far have established relativistic time dilation to an ECF and a relativistic wavelength red shift in all directions to a laboratory.

The next question is to clarify that the square root function of Eq. (3) is needed. The experiments so far have used the small number approximation of Eq. (2). A high-speed experiment will confirm it is needed.

2.5 The Bailey *et al.* muon experiment [13]

A 1977 laboratory time dilation experiment by Bailey *et al.* used an extremely high speed.

In the CERN Muon Storage Ring, the lifetimes of both positive and negative muons were measured in circular motion using a 14 m diameter ring. The muons moved at a speed of 0.9994 c, and the muon lifetime τ as measured by the laboratory frame was longer than the moving frame τ_0. The experimental error was 0.2%, with 95% confidence. They noted that the muons experienced a tangential acceleration of 10^{18} g. They viewed their results as in accordance with SR.

They described the lifetime of muons (both positive and negative) by:

> "... If the muon sample has a velocity v then the lifetime of the sample as measured in the laboratory is given by
>
> $$\tau = \tau_0/[(1 - (v/c)^2)^{½}] = \gamma\tau_0,$$
>
> where τ_0 is lifetime for the particle at rest."

Since moving particles do not include a clock instrument, the experimental understanding is that muons experience their lifetime as though they are at rest. Thus, the moving frame time τ_0 has a lower numerical value than the laboratory measurement time of τ. This equates to time dilation by the moving body frame, and their equation is also similar to Eq. (3). However, they used the laboratory as the fixed frame, not the ECF.

If moving/laboratory notation is added to their equation, the agreement with the HK calculation is easier to see.

$$(\tau_0)_{\text{moving}} = \left(\sqrt{1 - (v/c)^2}\right)(\tau)_{\text{laboratory}}. \tag{11}$$

The experiment broadly confirmed time dilation by moving particles in a laboratory and confirmed the square-root function at high speeds.

The extreme tangential acceleration of $10^{18}g$ is higher than the gravity acceleration at a black hole event horizon. The accurate adherence to Eq. (11) appeared to be only from relative motion in a laboratory. Extreme acceleration had no measurable effect.

The experiments so far have established relativistic time dilation to both an ECF and a laboratory, and a relativistic wavelength red shift in all directions to a laboratory.

The next question becomes, can relativistic doppler shifts in frequency and length be combined with time and length dilation for a consistent view?

2.6 Consistency in relativistic doppler shifting

Relativistic Doppler shifting can be analyzed by isolating the relativistic effect from linear Doppler shifting. This is done by illustrating transverse relativistic Doppler shifting in Figure 3.

In Figure 3(a), an emitter (source) moves in a perfect circle relative to a detector (observer) at the circle's center. The emitter creates a beam wavelength based on its relativistic length and time dilation. The detector is positioned in a laboratory frame. Similarly, Figure 3(b) flips the position of the emitter and detector, and the detector moves in a circle around the emitter in the laboratory frame. The detectors are colored to indicate a red shift or a blue shift wavelength measurement.

Since only a relative velocity was used in Doppler shifting experiments, this analysis only uses a relative velocity, not an ECF velocity.

Again, the question is whether both time and length dilation predict the measured relativistic effects. The question is answered by adding time and frequency scales to Figures 1 and 2, resulting in Figures 4 and 5.

To draw the additional scales for time and frequency, both the source and observer measure the speed of light according to

$$c = \lambda_O f_O \quad \text{and} \quad c = \lambda_S f_S, \tag{12}$$

where c is the speed of light, λ_O, λ_S and f_O, f_S are the wavelength and frequency as measured by the observing and

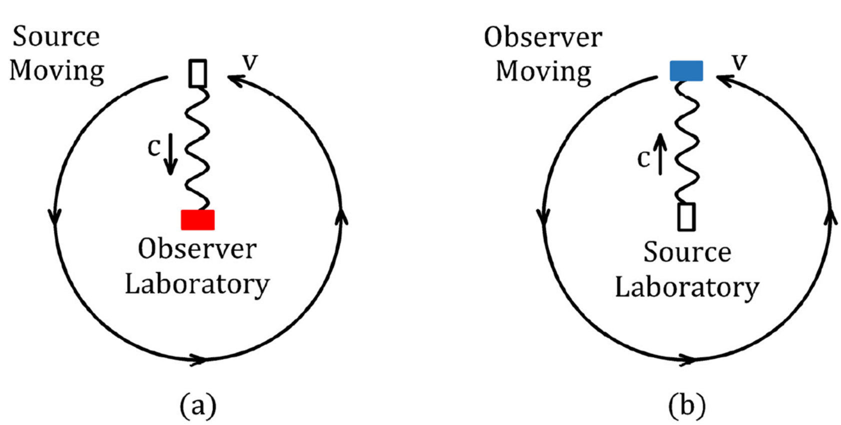

Figure 3: Idealized transverse Doppler effect for the source moving (a) and the observer moving (b).

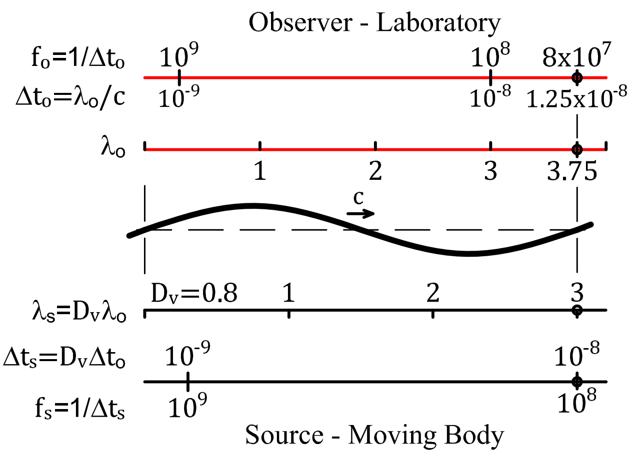

Figure 4: Relativistic Doppler shifting (source: moving body frame).

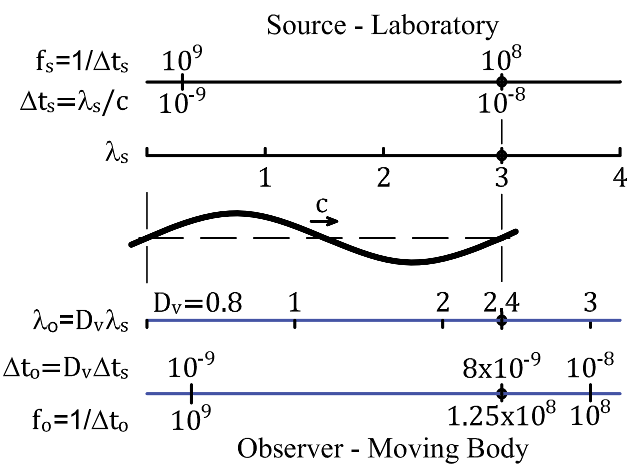

Figure 5: Relativistic Doppler shifting (source: laboratory).

source frames. Eq. (12) is correct regardless of which frame is the source.

The Figure 4 time and length scales are aligned at zero on the left, and infinite frequency is also aligned to the left. The equations on the left indicate how the scales are illustrated. In this case, the illustration assumes an observed laboratory wavelength λ_O and a known dilation factor D_v to create the illustrated scales.

To simplify the illustration, an example of a 3 m long radio beam is created by a moving emitter source, and the moving frame scales use $v/c = 0.6$, resulting in a dilating factor D_v of

$$D_v = \sqrt{1 - (v/c)^2} = \sqrt{1 - 0.6^2} = 0.8. \quad (13)$$

The scales of the moving frame dilate (*i.e.* become longer) equally for time and length. This results in scales that are numerically smaller than the fixed laboratory scales, according to Eq. (3).

Similarly, Figure 5 shows the results when the laboratory is the light source. The scales are the same as Figure 4.

These two figures are based on the understanding that the light beam does not change in length or frequency after it is emitted. It is the emitter and detector that experience relativistic effects, as mentioned by Cranshaw *et al.* [14].

An inspection of Figures 4 and 5 results in Table 1.

Table 1 agrees with current and well-known textbook equations [15,16] for relativistic doppler shifting and are posted on numerous web pages.

To summarize, Figures 4 and 5 and Table 1 all agree with the concept of time and length dilation experienced by the moving body relative to the fixed laboratory frame. The moving body time Δt_m and length ΔL_m are calculated according to

$$\Delta L_m/\Delta L_f = \sqrt{1 - (v/c)^2} \text{ and } \Delta t_m/\Delta t_f = \sqrt{1 - (v/c)^2}, \quad (14)$$

where ΔL_f and Δt_f are the fixed laboratory frame length and time, and v is the moving body velocity. The two figures provide a compelling case that time and length dilation in all directions correctly describes transverse relativistic doppler shifting.

2.7 The question of an ECF or laboratory frame

However, another question arises. Both HK and GPS used relative velocities to the ECF. Laboratory experiments used a moving body velocity relative to the laboratory frame. Why is there a difference? Is there a way to reconcile the two?

Table 1: Equations for relativistic Doppler shifting (excluding linear Doppler shift)

Source	Frequency	Wavelength	Observer	Color shift
Laboratory	$f_o = f_s/\sqrt{1-(v/c)^2}$	$\lambda_o = \sqrt{1-(v/c)^2}\,\lambda_s$	Moving body	Blue shift
Moving body	$f_o = \sqrt{1-(v/c)^2} f_s$	$\lambda_o = \lambda_s/\sqrt{1-(v/c)^2}$	Laboratory	Red shift

The answer is simple. Moving body velocities relative to a laboratory frame are an astonishing approximation of moving body velocities relative to the ECF. A moving body in a laboratory only appears to move relativistically to the laboratory frame.

HK's experiment and GPS operating experience make it clear that all laboratory clocks move relativistically to the ECF. And HK's airplanes used a combination of ground speed plus Earth's rotation to determine the total plane velocity to the ECF. The HK and GPS results are the guiding experiments because their atomic clocks have higher resolution.

By using their calculating method, laboratory velocities are mathematically cleared up by adding Earth's rotational velocity to both the laboratory and the moving body. Then, the Eq. (3) method applies instead of a relative velocity calculation.

Surprisingly, there is only a tiny difference between an ECF velocity calculation and a relative velocity calculation. Figures 6–8 show this.

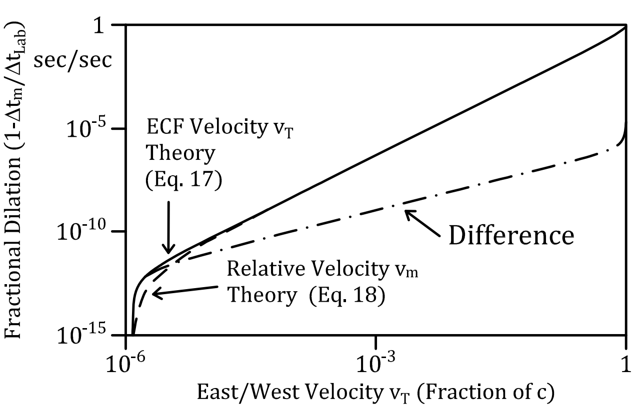

Figure 6: Time dilation comparison for linear motion East/West.

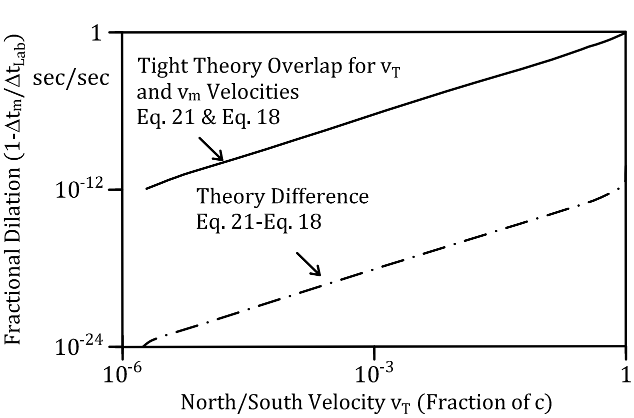

Figure 7: Time dilation comparison for North/South motion.

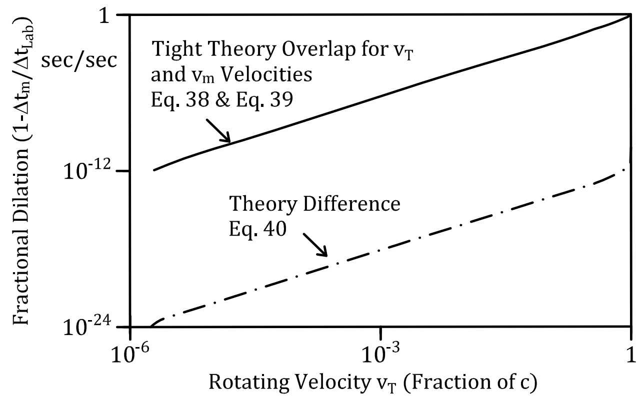

Figure 8: Comparison of time dilation for circular motion.

To create the figures, the mathematical comparison of relative motion vs ECF motion will be derived. Both linear and rotational motion in a laboratory will be addressed.

2.8 Theory comparison – linear motion east/west

Figure 6 compares moving body time dilation by using a relative laboratory velocity v_m (dashed line) and a moving body velocity v_T relative to the ECF (solid line).

At higher velocities, the solid and dashed lines overlap tightly. The dashed-dotted line shows the difference between the two theories.

In Figure 6, the time ratio for a moving body time according to an ECF total velocity v_T is

$$\Delta t_m/\Delta t_f = \sqrt{1-(v_T/c)^2} = \sqrt{1-(\beta_{Lat}+\beta_m)^2}, \tag{15}$$

where Δt_m is the moving body time, Δt_f is the ECF time, v_{Lat} is the laboratory latitude velocity of Earth's rotation, v_m is the moving body velocity relative to the laboratory, $v_T = v_{Lat} + v_m$, $\beta_{Lat} = v_{Lat}/c$, and $\beta_m = v_m/c$.

And the ratio of laboratory time Δt_{Lab} to the ECF time Δt_f is

$$\Delta t_{Lab}/\Delta t_f = \sqrt{1-(\beta_{Lat})^2}. \tag{16}$$

So the moving body time Δt_m ratio to the laboratory time Δt_{Lab} is the ratio of Eqs. (15) and (16):

$$\frac{\Delta t_m}{\Delta t_{Lab}} = \frac{\sqrt{1-(\beta_{Lat}+\beta_m)^2}}{\sqrt{1-(\beta_{Lat})^2}}. \tag{17}$$

Eq. (17) is the solid line in Figure 6 as a fractional dilation by subtracting from 1.

The time ratio for a moving body time Δt_{m} to the laboratory time Δt_{Lab} according to the relative velocity β_{m} is

$$\frac{\Delta t_{\mathrm{m}}}{\Delta t_{\mathrm{Lab}}} = \sqrt{1 - (\beta_{\mathrm{m}})^2}. \tag{18}$$

Eq. (18) is the dashed line in Figure 6 by subtracting from 1. The dashed line represents SR.

The dashed-dotted line is the difference between Eqs. (17) and (18).

Figure 6 also represents length dilation as it is equal to time dilation.

North/south motion is next.

2.9 Theory comparison – linear motion north/south

Similarly, a time comparison for north/south longitudinal motion is shown in Figure 7. The two theories tightly overlap for all velocities. Figure 7 begins when the theory difference is above 10^{-24}.

In this case, the total instant velocity is the combination of the Earth's rotation velocity v_{Lat} at a laboratory latitude. The moving body has a north/south ground velocity v_{m} and the total velocity v_{T} comes from a right triangle sum of the squares:

$$v_{\mathrm{T}}^2 = v_{\mathrm{Lat}}^2 + v_{\mathrm{m}}^2. \tag{19}$$

The ratio of the moving time Δt_{m} to the ECF time Δt_{f} is

$$\begin{aligned} \Delta t_{\mathrm{m}}/\Delta t_{\mathrm{f}} &= \sqrt{1 - v_{\mathrm{T}}^2/c^2} = \sqrt{1 - (v_{\mathrm{Lat}}^2 + v_{\mathrm{m}}^2)/c^2} \\ &= \sqrt{1 - \beta_{\mathrm{Lat}}^2 - \beta_{\mathrm{m}}^2} \end{aligned} \tag{20}$$

and using the ratio $\Delta t_{\mathrm{Lab}}/\Delta t_{\mathrm{f}}$ of Eq. (16) gives

$$\Delta t_{\mathrm{m}}/\Delta t_{\mathrm{Lab}} = \frac{\sqrt{1 - \beta_{\mathrm{Lat}}^2 - \beta_{\mathrm{m}}^2}}{\sqrt{1 - \beta_{\mathrm{Lat}}^2}}, \tag{21}$$

where $\beta_{\mathrm{Lat}} = v_{\mathrm{Lat}}/c$ and $\beta_{\mathrm{m}} = v_{\mathrm{m}}/c$.

Figure 7 compares Eqs. (18), (21), and their difference. In this case, the agreement between the two theories is higher.

Figure 7 applies to laboratory velocities in the North/South direction and points out the difficulty in seeing Earth's rotational velocity in a laboratory experiment.

However, an experiment outside of a laboratory, such as a round trip to/from an origin airport to a destination airport, is a different calculation. In this case, the origin clock has a fixed velocity, but the moving body has a variable velocity due to Earth's variable rotation.

Rotating motion is next.

2.10 Theory comparison – rotating motion

A rotating laboratory velocity is a different mathematical study. The instant velocity is not in a single direction and combines differently with Earth's rotation.

Figure 8 shows a comparison of the rotating Earth-based velocity v_{T} and a rotating relative velocity v_{m}. Similarly, Figure 8 begins when the theory difference is above 10^{-24}.

As you can see, Figure 8 is the same as Figure 7. Though the derivation is different, the mathematical result is the same as Eq. (21). Details are in the supplemental material.

Again, length dilation is equal to time dilation, so Figure 8 represents both.

Figures 6–8 are a compelling case that the ECF explains relative velocity laboratory experiments.

The main point of Figures 6–8 is the astonishing agreement between a relative laboratory frame and the ECF. Above the difference line, low-resolution experiments cannot differentiate between the two theories. High-resolution experiments below the dotted line see the difference if designed for it.

Figures 6–8 explain why SR remains a widely accepted theory.

Another question arises from the experimental survey. The cited experiments acknowledge or affirm agreement with SR and often cite the Lorentz factor. However, experimenter math used Eq. (14), which positions the square root function differently. Why would the experiments state support for SR?

2.11 Experimenter comments supporting SR

The answer to this question is uncomplicated. The SR Lorentz factor γ for time change Δt is written as

$$\Delta t_{\mathrm{m}} = \Delta t_{\mathrm{f}}/\sqrt{1 - (v/c)^2} = \gamma \Delta t_{\mathrm{f}}, \tag{22}$$

where the subscripts m and f refer to the moving and fixed frames, respectively. Because there is "no preferred reference frame," SR permits an equal interpretation of Eq. (22) as either:

$$\text{(a) } \Delta t_{\mathrm{m}} = \gamma \Delta t_{\mathrm{f}} \quad \text{or} \quad \text{(b) } \gamma \Delta t_{\mathrm{m}} = \Delta t_{\mathrm{f}}. \tag{23}$$

An experimenter can correctly assume that the Lorentz factor position is an option from two.

Surprisingly, all experiments used option (b) for both high and low resolutions. Therefore, option (b) was used in the comparisons of Figures 6–8, and the position of the square root function in Eq. (24).

2.12 Relativistic behavior is orderly

The cited experiments clarify that relativistic effects follow a normal sense of motion relative to the ECF. That is, a faster ECF velocity causes higher relativistic effects.

In a review of 31 experiments, no experiment contradicted this relativistic order. The experiments are listed in the supplemental material.

To provide clarity of what was measured and not measured in the relativistic order, important results of the experiments are:

1. It was *always* the case that the moving body in a laboratory experiment was the moving frame, and the laboratory was the fixed frame.
2. It was *always* the case that experimenters in a laboratory experiment calculated relativistic time and length according to Eq. 23(b). It was *never* the case the experimenters used Eq. 23(a), even if the Lorentz transformation equations or the Lorentz factor was mentioned.
3. It was *always* the case that the moving body in a laboratory experiment emitted and measured red shift/blue shift according to Table 1.
4. Atomic clocks in the GPS system *always* experienced time dilation by their velocity to the ECF, whether the clock was in a satellite or in a ground laboratory.
5. It was *always* the case that similar and later experiments measured the same effects and used the same moving and fixed frames.
6. It was *always* the case that Earth's gravity field was an explanation for relativistic effects, even if not measured or considered.

This well-ordered behavior also answers many perplexing questions inherent to a relative velocity theory. These include the twin paradox and the speed at which high-speed particles move past each other. Because a causal frame is clearly identified, there is no twin paradox, and high-speed particles may move past each other up to twice the speed of light. They are only limited by c relative to the ECF.

This well-ordered and predictable behavior supports a view that a common celestial frame for nearby moving bodies is universal.

3 A tangible causality – gravity field moving body interaction

Relativistic effects have been observed between large celestial objects [17] and small particles in a laboratory. The effects are measurable for linear, rotating, and orbital motion. It is also measurable by the gravity potential difference relative to a large celestial object. It is also measured for moving masses that do not fit the concept of an inertial frame.

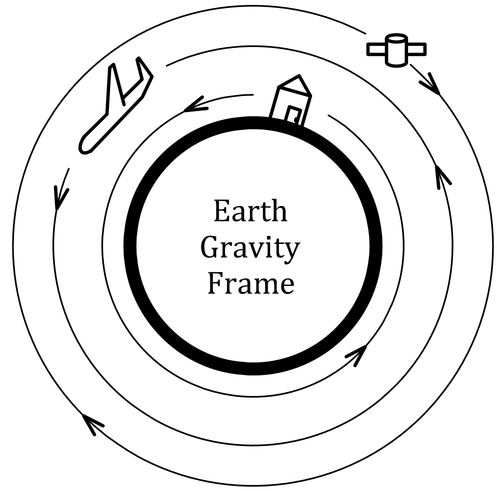

Figure 9: Circular motion causes constant dilation.

Notably, both gravity potential and kinetic dilation effects are at a constant rate for constant circular motion around an idealized planet (Figure 9). The instant velocity of the moving body through the non-rotating planet gravity field causes relativistic effects.

Relativistic dilation occurs for both Earth contact and non-contact. It is well known that Earth's gravity field moves with the Earth and does not rotate with it. This strongly supports causality originating from a gravity field interaction. And position and motion in a gravity field cause time and length dilation.

Based on this, relativistic effects will be better understood through gravity field interaction experiments and measurements in the future. Before that, there is a need to create a suitable sensor.

The gravity field interaction is tangible and measurable. Also, field interaction is clearly part of observed relativistic effects in a high-speed particle accelerator. This provides a basis for an improved understanding of particle motion.

A future atomic clock experiment that moves from an Earth ECF to a Sun ECF could use time dilation to characterize how the Earth and Sun gravity fields relativistically interact. It would allow an understanding of how the two celestial fields combine during the transition.

No experiments have been conducted to confirm that a moving body contracts or enlarges. This is an open matter for now. In any case, the gravity field interaction effect is dilating because a moving emitter produces a longer (red shifted) light beam. This is further discussed in the supplemental material.

4 The kinetic theory of relativity

Based on the cited experimental results, a consistent interpretation of relativistic Doppler shifting, the equal measurement of the speed of light by wavelength/frequency in any frame, and the common ECF gravity frame for multiple moving bodies, it is clear that a moving body's position and motion in a gravity field causes field time and length dilation. The kinetic relativity theory is then:

> In addition to position in a celestial gravity field, a moving body experiences a gravity field change according to:
>
> $$\begin{aligned} dx_m &= D_v dx_f \\ dy_m &= D_v dy_f \\ dz_m &= D_v dz_f \\ dt_m &= D_v dt_f \end{aligned}, \quad (24)$$
>
> $$D_v = \sqrt{1 - (v/c)^2}$$
>
> by its instant velocity v relative to a celestial gravity field. dx_m, dy_m, dz_m, and dt_m are incremental time and length changes to the field. dx_f, dy_f, dz_f, and dt_f are incremental field time and length without moving body motion. Cylindrical or spherical coordinates are similarly used for curved motion.

A posteriori relativistic behavior is based on experimental results and Eq. (14).

Again, field length dilation is based on direct measurement of relativistic Doppler "red shift" by a moving source.

The letter c in the square root function is more likely the propagation speed of gravity than the speed of light.

The definition of a moving body is fundamentally based on the experimental results. A summary is:

> A moving body has a mass and is capable of a variable velocity.

5 Experimental prediction

The kinetic relativity theory predicts the results of a round-trip experiment east (or west) at a constant latitude and velocity between two airports. Three atomic clocks are required. One clock is at each airport and the third clock is on the plane.

Kinetic dilation for an outgoing trip from the starting airport to the destination airport is calculated by Eq. (17). The return trip to the starting airport is similarly calculated. However, the round trip is also accurately calculated by Eq. (18). That is, ground speed only.

Gravity dilation for the two legs is calculated by the change in gravity potential using well-known equations, such as those used by HK.

In short, each trip leg looks like the HK experiment, but the round trip looks like SR.

This prediction is based on a combination velocity term ($\beta_{Lat}\beta_m$), which is included in Eq. (17). By using a small number approximation and ignoring fourth-order and higher terms, the time ratio for each leg is

$$\Delta t_m/\Delta t_L \approx 1 - \beta_m^2/2 - \beta_{Lat}\beta_m (\text{Flying Eastward}), \quad (25)$$

$$\Delta t_m/\Delta t_L \approx 1 - \beta_m^2/2 + \beta_{Lat}\beta_m (\text{Flying Westward}). \quad (26)$$

6 The Michelson–Morley experiment [18]

Interpretation of the null Michelson–Morley experiment has been discussed for well over a century. In SR, a postulate for light's time-of-flight (TOF) behavior is based on a particular interpretation of their experiment.

The kinetic theory does not use light's TOF behavior as a basis for describing relativistic effects. The TOF behavior of light was neither measured, nor a part of any cited experiment. The TOF behavior of light is considered an unrelated matter to be resolved in the future. Light has light properties, and mass has mass properties.

The only important behavior of light is its speed at c when measured by wavelength and frequency. This is important for relativistic Doppler shifting and is not a controversial matter.

7 Conclusion

The experimental record supports an alternate kinetic relativity theory. Near-Earth relativistic motion is based on the non-rotating Earth gravity frame. The record also supports orderly and predictable relativistic behavior.

The experimental record indicates relativistic field dilation for both time and length in all directions, according to Eq. (24).

The well-known and accepted relativistic Doppler shifting equations in Table 1 are developed by using time and length dilation, as illustrated in Figures 4 and 5.

The relative laboratory velocities are shown to be an astonishingly close approximation of the underlying Earth-centered frame as shown in Figures 6–8.

An experiment was proposed to clarify the existence of an ECF for all nearby motions.

No postulates are needed. The kinetic relativity theory is simple to understand.

Finally, experimental results convincingly point to a tangible effect: body motion and position in a gravity field cause time and length dilation.

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