Frame-Independent Synchronization for a Theory of Presentism

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Abstract

We introduce a synchronization scheme that reconciles presentism with special relativity. Specifically, we address the challenge of defining in special relativity a global present of an observer at a particular location that is independent of reference frame. This is achieved by postulating that the coordinate time that elapses for light to propagate from emitter to absorber is a fundamental constant of nature and is independent of the separation distance and also independent of the reference frame of the absorber. We show that the proposed theory predicts cosmological redshifts consistent with observation if an asymmetry exists between the emitter's and absorber's perceptions of time.

KEY WORDS: presentism, relativity, one-way speed of light, photon, electromagnetic wave, cosmology, cosmological redshift

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1 Introduction

It is often stated in both the popular and the scientific literature that light received from distant objects provides a glimpse into the past. The prevailing point of view maintains that the duration of time elapsed during light propagation from emitter to absorber is determined by dividing the propagation distance by the two-way speed of light. For example, it is generally believed that light from the moon takes approximately 1.3 seconds on average to reach the earth and light from the sun takes approximately 8.3 minutes on average to reach the earth. Thus, once concludes that light received from the moon was emitted approximately 1.3 seconds prior to absorption and light received from the sun was emitted approximately 8.3 minutes prior to absorption. In fact, this belief is so ingrained in contemporary physics that cosmological distances are often measured in light-years, the time it takes for light (in units of years) to reach an observer multiplied by the one-way speed of light. For example, the radius of the observable universe is believed to be 13.8 billion light-years.

However, this way of thinking is based on an unproven assumption, namely, that the one-way speed of light is equal to the measured two-way speed of light. As is well known, Einstein recognized in his groundbreaking paper on special relativity [1] that the one-way speed of light is in fact conventional and must be stipulated in order to determine distant simultaneity. Therefore, there is no difference between stipulating the one-way speed of light and adopting a particular synchronization scheme [2]. Einstein's assertion has indeed been upheld throughout the years; even though more than a century has passed since Einstein's seminal paper, all experimental efforts to measure the one-way speed of light independent of a synchronization scheme have failed.

Therefore, the numerous claims regarding the amount of time it takes for light to propagate from distant objects are in fact equivalent to mere assumptions regarding the adoption of a particular synchronization scheme in a chosen reference frame. While such claims have not been proven to be incorrect, they should be accompanied by a disclaimer such that they are not given factual priority over other equally valid claims. For example, it is equally valid to claim that light takes approximately 2.0 seconds on average, rather than 1.3 seconds, to reach the earth from the moon, as long as the time attributed to the propagation in the reverse direction preserves the experimentally-measured two-way speed of light.

Whereas the popular literature can be forgiven for its lack of scientific rigor, it is quite surprising that an entire scientific discipline, such as cosmology, carelessly adopts an unproven assumption without qualification. This is even further surprising, given that modern cosmology claims to be in the midst of a golden era that seeks to achieve unprecedented experimental rigor, and has even adopted the term 'precision cosmology'. Indeed, almost all cosmological measurements involve one-way light propagation and therefore the bulk of modern cosmology tacitly adopts the same unproven assumption.

In a seemingly unrelated development, there has been a growing interest in presentism, a theory of time that maintains that only the present exists and the past and future are not real. Such a view is in conflict with the traditional block universe of contemporary science, where the past, present, and future are each given an equal ontological status and the flow of time is regarded as an illusion based on our limited perspective of four-dimensional spacetime. In addition, presentism purportedly conflicts with relativity theory because relativity maintains that simultaneity is dependent on the observer's motion. Therefore, the two theories taken together suggest that reality depends on an observer's inertial frame. In fact, reality would be defined differently by multiple observers at the same location that undergo different relative motion through a common point.

In the following, we seek to reconcile presentism with relativity by adopting a synchronization scheme that defines simultaneity globally for each absorber independent of each absorber's reference frame. Our proposed solution includes defining the interval of coordinate time for light to travel from the emitter to absorber as a fundamental constant of nature that is independent of the emitter-absorber separation distance and also independent of the absorber's motion relative to the emitter. This suggests a significant departure from the current viewpoint, resulting in a null-cone structure that depends on the observer's role in the emission-absorption process. We will show that if an asymmetry in this emitter-absorber relationship exists, then the proposed model predicts cosmological redshifts, even in a static universe.

2 Frame-Independent Synchronization

To address the conflict between presentism and relativity, we define a global present for each absorber that is independent of the absorber's reference frame. This is achieved by postulating that the present of any absorber (i.e., observer) is defined by a duration of time, T_0, that is a fundamental constant of nature. We further assume that T_0 is the time for light to propagate from emitter to absorber, independent of the separation distance and independent of the motion of the absorber relative to the emitter. In other words, we postulate that according to any arbitrary observer, the coordinate time for light to propagate from any point in space to the observer is the same coordinate time for light to propagate from any other point in space to the observer. Consequently, the time $T_A - T_0$ defines global simultaneity, where T_A is the time of arrival at the absorber. The one-way speed of light thus becomes a function of the distance between the emitter and the absorber. In addition, all absorbers thus define reality in the present as the total absorption in a waveband from all emitters throughout the universe.

In the following, we restrict ourselves to a generalization of special relativity, namely, a space-time with constant metrics terms. We consider one-dimensional light propagation using a line element with one time coordinate, $x^{(0)}$, and one spatial coordinate, $x^{(1)}$:

$$ds^2 = g_{00} dx^{(0)2} + 2 g_{01} dx^{(0)} dx^{(1)} + g_{11} dx^{(1)2}, \tag{1}$$

where $g_{\mu\nu}$ are the metric components, with $\mu = \{0, 1\}$. The time to travel a distance $dx^{(1)}$ is determined by equating the line element to zero and using the quadratic equation, resulting in:

$$dx^{(0)}_{+,-} = \left[-\frac{g_{01}}{g_{00}} \pm \frac{1}{g_{00}} \sqrt{g_{01}^2 - g_{00} g_{11}} \right] dx^{(1)}, \tag{2}$$

where the subscripts $+,-$ refer to propagation in the positive and negative direction, respectively. We assume the convention $g_{00} > 0$, and also note that $g_{01}^2 > g_{00} g_{11}$ must hold.

Next, we define a frame with global simultaneity such that the light received at an absorber A at time T_A was emitted at the same time, $T_A - T_0$, from every emitter in the universe, independent of the distance between the absorber and the emitter. Similarly, for purposes of symmetry we postulate that the time for light to propagate in the opposite direction is constant. In other words, we postulate:

$$\begin{aligned} \int_0^L \left[-\frac{g_{01}}{g_{00}} + \frac{1}{g_{00}} \sqrt{g_{01}^2 - g_{00} g_{11}} \right] dx^{(1)} &= T_0 \\ \int_L^0 \left[-\frac{g_{01}}{g_{00}} - \frac{1}{g_{00}} \sqrt{g_{01}^2 - g_{00} g_{11}} \right] dx^{(1)} &= T_1, \end{aligned} \tag{3}$$

where T_0 and T_1 are constants for any coordinate distance L between the absorber and the emitter. We demand that relationship (3) holds for all absorbers, independent of reference frame.

In special relativity, the one-way speed of light is assumed to be equal to the two-way speed of light. Therefore, the equations that transform between reference frames preserve the relationship: $\frac{dx^{(1)}}{dx^{(0)}} = 1$. Our proposed theory requires a velocity of light that depends on the separation distance between emitter and absorber. Accordingly, to transform between reference frames, we would require preserving $\frac{dx_+^{(1)}}{dx^{(0)}} = \frac{L}{T_0}$ and $\frac{dx_-^{(1)}}{dx^{(0)}} = \frac{L}{T_1}$, which for a single emitter-absorber pair is trivially equivalent to a Lorentz transformation coupled with a synchronization transformation that depends on the emitter-absorber separation distance. For multiple emitters, the transformation equations can become much more complicated and can become functions of space and time, which is outside of the purview of this investigation.

Assuming a static space-time, Equations (3) are equivalent to the following:

$$\begin{aligned} -\frac{g_{01}}{g_{00}} + \frac{1}{g_{00}}\sqrt{g_{01}^2 - g_{00}g_{11}} &= \frac{cT_0}{L} \\ -\frac{g_{01}}{g_{00}} - \frac{1}{g_{00}}\sqrt{g_{01}^2 - g_{00}g_{11}} &= -\frac{cT_1}{L}, \end{aligned} \tag{4}$$

which yield the following for the two metric terms relative to g_{00}:

$$\begin{aligned} \frac{g_{11}}{g_{00}} &= -\left(\frac{c}{L}\right)^2 T_0 T_1 \\ \frac{g_{01}}{g_{00}} &= \frac{1}{2}\frac{c}{L}\left(T_1 - T_0\right). \end{aligned} \tag{5}$$

We note that condition $g_{01}^2 > g_{00}g_{11}$ leads to $T_0 + T_1 > 0$. If $T_0 = T_1$ then the absorber and emitter will define the same global simultaneity frame. However, if $T_0 \neq T_1$ then the absorber and emitter will have different perceptions of time.

Physical measurements can place an additional constraint on the metric terms since the equations must be consistent with the measured two-way speed of light. In other words:

$$\frac{2\ell}{c} = \sqrt{g_{00}}\left(T_0 + T_1\right) \tag{6}$$

where

$$\ell = \int_0^L d\ell \tag{7}$$

with

$$d\ell = \sqrt{-g_{11} + \frac{g_{01}^2}{g_{00}}}\; dx^{(1)}. \tag{8}$$

Therefore

$$g_{00} = \left(\frac{2\ell}{c}\right)^2 \frac{1}{\left(T_0 + T_1\right)^2}. \tag{9}$$

Knowledge of the physical separation and the sum $T_0 + T_1$ yield the metric component g_{00}.

We now consider the phase, ϕ, of a plane wave in space-time:

$$\frac{\phi}{2\pi} = g_{\mu\nu} k^\mu x^\nu, \tag{10}$$

where $k^0 = \frac{\nu}{c}$ and $k^1 = -\frac{1}{\lambda^0}$ are the frequency and inverse wavelength of the wave in the absence of the non-diagonal metric term. The frequency and wavelength of the wave are given by:

$$\begin{aligned} \frac{\nu}{c} &= g_{00} k^0 + g_{01} k^1 \\ \frac{1}{\lambda} &= g_{01} k^0 + g_{11} k^1. \end{aligned} \tag{11}$$

We consider the limit $\frac{g_{01}}{g_{00}} \ll 1$. This yields:

$$\frac{\Delta\lambda}{\lambda_0} \backsimeq \frac{g_{01}}{g_{11}} + \left(\frac{g_{01}}{g_{11}}\right)^2, \tag{12}$$

where $\Delta\lambda = \lambda - \lambda_0$. We rewrite the above equation as:

$$\frac{\Delta\lambda}{\lambda_0} \backsimeq \frac{H_0 L}{c} + \left(\frac{H_0 L}{c}\right)^2 \tag{13}$$

with

$$H_0 = \frac{1}{2}\left(\frac{1}{T_1} - \frac{1}{T_0}\right), \tag{14}$$

where H_0 can be identified with the Hubble constant, indicating $T_0 > T_1$. We see that the proposed model predicts cosmological redshifts in a static universe consistent with observation if $T_0 \neq T_1$. This model predicts both the observed linear relationship attributed to cosmological expansion as well as the non-linear relationship currently attributed to late-time cosmological 'acceleration'. In addition, the proposed model predicts frequency shifts according to:

$$\frac{\Delta\nu}{\nu_0} = \frac{1}{2}\frac{c}{L}\left(T_1 - T_0\right). \tag{15}$$

3 Conclusion

In summary, we seek to address the conflict between relativity and presentism by introducing a new synchronization scheme that depends on the distance between emitter and absorber. Our primary departure from the conventional viewpoint is the postulate of a fixed duration of coordinate time between the emission and absorption of light that is independent of the separation distance and independent of the motion of the absorber relative to the emitter. This leads to a one-way speed of light that is a function of the distance between the emitter and the absorber.

We have seen that if an asymmetry in the absorber-emitter relationship exists, then the proposed model accounts for cosmological redshifts consistent with wavelength shifts measured from light propagating on astrophysical scales. This eliminates the need to propose ad hoc mechanisms, such as cosmological expansion and dark energy, to account for the observed functional relationship between redshift and distance. We note that the predicted shift in wavelength will prevent the saturation of a finite-waveband observer that could result from an infinite number of sources positioned throughout the universe in that same band. In closing, we observe that the proposed model suggests a teleological interpretation of light such that the one-way speed of light is fixed based on the emitter-absorber relationship. While somewhat surprising from a classical viewpoint, such an interpretation is consistent with the strange behavior of light and particles in the quantum domain.

References

[1] A. Einstein. On the electrodynamics of moving bodies. *Annalen der Physik*, 17, 1905.

[2] A. Einstein. *The Meaning of Relativity.* Princeton University Press, Princeton, New Jersey, 1945.