ISSN: 2639-0108

Research Article

Advances in Theoretical & Computational Physics

Violation on the Constancy of Light Speed in the Presence of Redshift

Taekjin Kim*

OMRSCAN 1, Gyeongdaero 5 gil, Daegu, South Korea

*Corresponding Author
Taekjin Kim, OMRSCAN 1, Gyeongdaero 5 gil, Daegu, South Korea.

Submitted: 2023, Oct 15; **Accepted:** 2023, Nov 23; **Published:** 2023, Nov 28

Citation: Kim, T. (2023). Violation on the Constancy of Light Speed in the Presence of Redshift. *Adv Theo Comp Phy, 6*(4), 252-254.

Abstract

This study provides an in-depth analysis focusing on the violation of speed-of-light invariance in the presence of a redshift. The concept of speed-of-light invariance was introduced because of the changes in space and time between stationary and moving frames of reference. According to this principle, one would not expect to observe any redshifts. However, a redshift exists empirically, thereby presenting a logical inconsistency between the two. The findings of this study can provide new directions for theoretical and experimental physical research

1. Introduction

Newtonian mechanics and electromagnetism are two major components of classical physics. Although Newtonian mechanics are symmetrical with respect to Galilean transformations [1], electromagnetism does not exhibit this symmetry under Galilean transformations [2, 3]. When applying Galilean transformations to Maxwell's equations, the assumption that the physical laws are identical in all inertial frames is violated, failing to account for various electromagnetic phenomena. In 1895, Hendrik Lorentz published a theory describing electromagnetic phenomena in moving frames [4]. He introduced a new concept of "local time" to calculate the transformation of frames, which was later named as the "Lorentz transformation" by Poincar´e in 1905 [5]. In the same year, Einstein proposed a relativistic electromagnetism that employed Lorentz transformations while formulating electromagnetism for moving objects. He proposed the principle of the constancy of the speed of light [6].

Even after the advent of the theory of relativity, papers have been consistently published suggesting that the speed of light may vary, including articles authored by Einstein [7]. The varying speed of light (VSL) theory can address various cosmological, quantum gravitational, experimental, and observational issues. According to VSL theories, the speed of light may vary depending on factors such as time, space, and frequency [8].

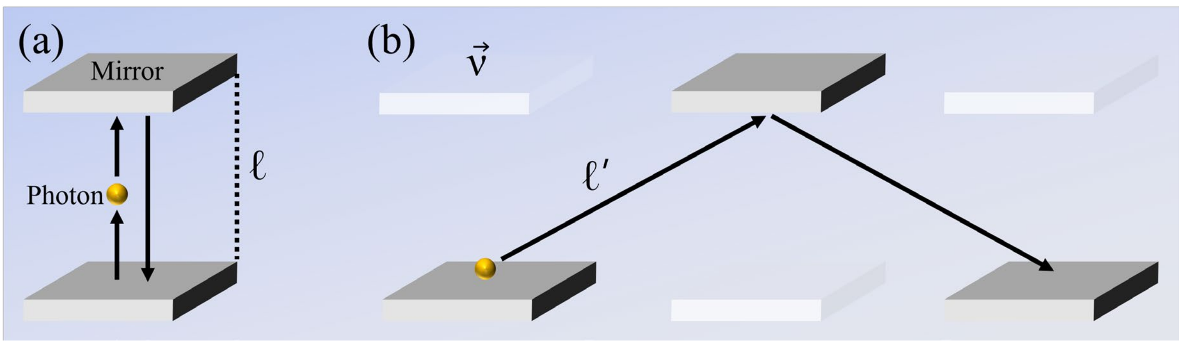

Figure 1: (a) Stationary light clock. Photon propagates with velocity c between two mirrors with distance ℓ and (b) light clock moves with velocity v. Light path is elongated from ℓ to ℓ′.

The fine-structure constant α is a dimensionless constant that characterizes the strength of the electromagnetic force and is defined as follows:

$$\alpha = \frac{e^2}{4\pi\epsilon_0\hbar c} \tag{1}$$

where e is the elementary charge, ϵ_0 is the vacuum permittivity, $\hbar$ is the reduced Planck constant, and c is the speed of light in vacuum. However, the fine structure constant has been observed to vary depending on the location in the universe [9-13]. Therefore, what we have considered as constants may actually be variables subject to changes in space and time. Research has also suggested that Planck's constant has different values in the early universe [14, 15]. The permittivity of space varies depending on the model of the universe [16, 17]. Consequently, the VSL theories, which postulate that the speed of light may change depending on variables such as space, time, and frequency [18], require rigorous reconsideration.

2. Speed of Light in the Light Clock

Figure 1(a) shows a light–clock structure in which light oscillates vertically between two mirrors situated at either end. This specific design entails precise alignment of the two mirrors, allowing light to traverse between them in a strictly vertical path. Assuming that an observer is situated within the same inertial frame as this light clock, the following scenario can be observed: light is seen to move internally within the clock, making a perfectly vertical round trip from the bottom to top mirror. The trajectory followed by the light has optical characteristics and is referred to as the 'light path.' If the length of this light clock is denoted by ℓ, then

$$\ell = ct_0 \tag{2}$$

where t_0 represents the time interval for light to travel to a segment within the clock.

Consider a situation in which the light clock is moving at a constant velocity v [Figure 1(b)]. In this case, the observer is not within the same inertial frame as the original light clock but an external stationary observer (O'). From the viewpoint of this stationary observer (O'), the situation becomes more complex. The light path, which originally moves vertically from bottom to top, now appears to have a zigzag shape when considering the forward motion of the light clock . This zigzag path is a result of the combined effects of the motion of the light clock and speed of light. When focusing specifically on one linear segment of this transformed light path, this segment represents the interval during which the light moves between the mirrors. This interval has significant implications when considering both the overall motion of the light clock and the optical characteristics of the light. From the perspective of the stationary observer (O'), this linear path is related to the forward direction of the moving light clock; thus, its shape differed from the original vertical light path. In this context, the path length ℓ' is defined as follows:

$$\ell' = \sqrt{(vt_0)^2 + (ct_0)^2} \tag{3}$$

First, in the scenario in which the light clock is in motion, the length of the light path as observed by a stationary observer, denoted ℓ', is longer compared to the original light path length ct_0 ($(vt_0)^2 > 0$). This elongation signifies that the distance that light must travel increases owing to its zigzag transformation.

From the standpoint of the stationary observer (O'), because the light path has lengthened, the time interval t' (where $t_0 < t'$) required for the light to traverse one segment must also increase to maintain a constant speed.

$$c = \frac{\ell'}{t'} \tag{4}$$

The principle of the constancy of the speed of light posits that the speed of light remains invariant across all inertial frames of reference.

$$c = \frac{\ell}{t_0}, c' = \frac{\ell'}{t'} \tag{5}$$

According to this principle, if $c = c'$, then

$$\frac{\ell}{t_0} = \frac{\ell'}{t'} \tag{6}$$

In this scenario, an observer (O'), which is stationary with respect to a moving light source, observes a transformed path length ℓ' instead of the original path length ℓ of the light. Based on the theory of special relativity, time t_0 experienced by the moving light source and time t' experienced by the stationary observer are different. Both observers perceive the speed of light to be identical: $c = c'$.

Here, if the entire path ℓ of the light from the source is perceived by the observer as ℓ' with a constant speed c due to the principle of the constancy of the speed of light, then the observer cannot discern any change in the wavelength determined by ℓ'.

Therefore, if the speed of light is invariant, any alterations in time and space should also render the wavelengths—and, by extension, the frequencies—of light constant when observed.

3. Violation with redshift

Based on the principle of the constancy of the speed of light, the optical path length of light should appear identical in both moving and stationary light clocks, which entail no changes in the wavelength or frequency of light. This principle serves as a foundational assumption in physics and provides fundamental insight into the properties and interactions of light. According to this assumption, phenomena, such as a redshift or an increase in wavelength, should not be observable by an external observer.

However, in reality, redshift, which indicates the elongation of the wavelength, is empirically observed. This is explicitly contradictory to the initial assumption, and signifies that the wavelength of light elongates, which is a unique physical phenomenon that occurs in moving objects.

Thus, it can be concluded that the principle of the constancy of the speed of light is insufficient for describing the actual universe. This significant discovery raises fundamental questions about one of the core principles in physics.

4. Conclusion

The principle of the constancy of the speed of light is a cornerstone of the theory of special relativity, which posits that the speed of light is invariant in any inertial frame of reference. When describing the optical path of a light clock based on this principle, the wavelength of light should be preserved, which is consistent with the principle. In other words, if the speed of light is constant, then it logically follows that the corresponding wavelength should also be constant. However, phenomena such as redshifts exist, indicating that the wavelength of light is not necessarily constant and can vary.

This discrepancy can be interpreted as evidence that the Lorentz invariance and theory of special relativity do not perfectly describe the actual spatiotemporal structure of the universe. Thus, based on this perspective, the principle of the constancy of the speed of light may have limitations depending on the physical circumstances. Therefore, it may be necessary to treat the speed of light, which was previously considered a constant, as a variable that can change depending on the physical situation. This suggests that the principle of the constancy of the speed of light may not fully explain the diverse physical scenarios in the actual universe, thus supporting the claim that the speed of light should be treated as a variable contingent on physical conditions.

References

1. Avetissian, A. K. (2009). Planck's constant variation as a cosmological evolution test for the early universe. Gravitation and Cosmology, 15, 10-12.
2. Einstein, A. (1905). On the electrodynamics of moving bodies. Annalen der physik, 17(10), 891-921.
3. Einstein, A. (1911). On the Influence of Gravitation on the Propagation of Light. Annalen der Physik, 35(898-908), 906.
4. Ellis, J., Farakos, K., Mavromatos, N. E., Mitsou, V. A., & Nanopoulos, D. V. (2000). A search in gamma-ray burst data for nonconstancy of the velocity of light. The Astrophysical Journal, 535(1), 139.
5. Fiordilino, E. (2021). Quest for time variation of Planck constant-A new time standard and parametric chaos. The European Physical Journal Plus, 136(1), 54.
6. Heras, J. A. (2010). The Galilean limits of Maxwell's equations. American Journal of Physics, 78(10), 1048-1055.
7. King, J. A., Webb, J. K., Murphy, M. T., Flambaum, V. V., Carswell, R. F., Bainbridge, M. B., ... & Koch, F. E. (2012). Spatial variation in the fine-structure constant–new results from VLT/UVES. Monthly Notices of the Royal Astronomical Society, 422(4), 3370-3414.
8. L´evy-Leblond, J. M. (1971). In: Galilei group and Galilean invariance. Elsevier, 221-299.
9. Lorentz, H. A. (1895). Attempt of a Theory of Electrical and Optical Phenomena in Moving Bodies; Versuch einer Theorie der Electrischen und Optischen Erscheinungen in Bewegten Körpern. Versuch einer Theorie der Electrischen und Optischen Erscheinungen in Bewegten Körpern. EJ Brill.
10. Magueijo, J. (2003). New varying speed of light theories. Reports on Progress in Physics, 66(11), 2025.
11. Peik, E., Lipphardt, B., Schnatz, H., Schneider, T., Tamm, C., & Karshenboim, S. G. (2005, May). New limit on the present temporal variation of the fine structure constant. In AIP Conference Proceedings (Vol. 770, No. 1, pp. 103-111). American Institute of Physics.
12. Poincaré, H. (2012). The value of science: essential writings of Henri Poincaré. Modern library.
13. Prestage, J. D., Tjoelker, R. L., & Maleki, L. (1995). Atomic clocks and variations of the fine structure constant. Physical review letters, 74(18), 3511.
14. Rousseaux, G. (2013). Forty years of Galilean electromagnetism (1973–2013). The European Physical Journal Plus, 128, 1-14.
15. Sumner, W. Q. (1994). On the variation of vacuum permittivity in Friedmann universes. The Astrophysical Journal, vol. 429, no. 2, pt. 1, p. 491-498, 429, 491-498.
16. Sumner, W. Q. (1994). On the variation of vacuum permittivity in Friedmann universes. The Astrophysical Journal, vol. 429, no. 2, pt. 1, p. 491-498, 429, 491-498.
17. Webb, J. K., King, J. A., Murphy, M. T., Flambaum, V. V., Carswell, R. F., & Bainbridge, M. B. (2011). Indications of a spatial variation of the fine structure constant. Physical Review Letters, 107(19), 191101.
18. Webb, J. K., Flambaum, V. V., Churchill, C. W., Drinkwater, M. J., & Barrow, J. D. (1999). Search for time variation of the fine structure constant. Physical review letters, 82(5), 884.