

The Incorrectness of Special Relativity and an Understanding of Time

Ronghua Cui¹

¹ School of Physics and Technology, Nantong University, Nantong, China

Correspondence: Ronghua Cui, School of Physics and Technology, Nantong University, Nantong 226019, Jiangsu, China. E-mail: ronghuacui@ntu.edu.cn

Received: October 11, 2023

Accepted: November 20, 2023

Online Published: February 7, 2024

doi:10.5539/apr.v16n1p40

URL: <https://doi.org/10.5539/apr.v16n1p40>

Abstract

This paper has analyzed the original paper of special relativity of Einstein carefully. It was found that the derivation process of the theory based on a fatal logic error of physics, which indicates that the theory of special relativity lacks a correct theoretical basis, combined with the analysis of its conclusions, inference and experimental verification, the conclusion is that special relativity is a wrong theory. With the incorrectness found in special relativity, the four-dimensional space-time derived from it then lost the foundation, so, the understanding of time almost only can go back to before the appearance of special relativity. Thus, based on previous concepts and experiments, this paper re-understood the nature of time.

Keywords: Einstein, special relativity, incorrectness, time

1. Introduction

In 1905, the paper "Zur Elektrodynamik bewegter Körper" - on the electrodynamics of moving bodies (OEMB) of Albert Einstein (Einstein 1905, Lorentz, Einstein et al. 1923), published in *Annalen der Physik*, means the birth of special relativity (SR). Einstein established a novel space-time system different from Newton's. In the following years, SR was accepted gradually by many people, and has influenced physics and many other fields of science profoundly over one hundred years (Franklin 1922, Miller 1933, Ives 1947, Hafele 1970, Ashby 2003, Lammerzahl 2006, Reinhardt, Saathoff et al. 2007, Wang, Zhao et al. 2014, Sanjuan, Abich et al. 2019, Duarte and Lima 2020, Woodruff 2020).

SR is based on two conjectures, the principle of relativity and the speed of light is constant. On the premise of the two conjectures, Einstein obtained the formulas of SR which include Lorentz transformation by mathematical derivation (Einstein 1905, Lorentz, Einstein et al. 1923). Since the appearance of the theory, the controversy over it has never stopped, both sides seem to have believable reasons. Really, parts of the conjectures or conclusions of SR show consistency with experiments. Michelson–Morley experiment is thought to be very important to SR, it has been repeated many times using the latest technology (Kennedy 1926, Muller, Herrmann et al. 2003, Mueller, Stanwix et al. 2007, Ahmed, Quine et al. 2012), which confirms the conjecture that the speed of light is constant in one interpretation; time dilation has been thought as a fascinating conclusion of SR, it was confirmed by many experiments (Saathoff, Karpuk et al. 2003, Gwinner 2005, Reinhardt, Saathoff et al. 2007, Botermann, Bing et al. 2014, Ozer 2020). But opponents also have their logic and facts. Bolstein has pointed out the mathematical logic failure of SR (Bolstein 2003); the null result of Michelson–Morley experiment can be interpreted with ether hypothesis (Miller 1925, Hunter 2009), some studies have shown that the speed of light is not constant and anisotropic (Gift 2009, Shao, Xiao et al. 2010, Gift 2012). As far as the evidences mentioned above are concerned, I think, it is difficult to confirm the right or wrong of SR. Even so, SR still has great influence on physics, philosophy and even people's mode of thinking. Therefore, it has necessity and extremely meaning for us to judge the correctness of SR.

In this paper, I have reviewed the original paper of SR, and I found that there has a fatal logic error of physics in the derivation process of the theory. Together with other analysis, this paper got the conclusion that SR is a wrong theory. In view of the incorrectness of SR, I summed up the possible reasons why a wrong SR can be widely accepted. And with the incorrectness found in SR, the four-dimensional space-time lacks the foundation, then, I have re-understood the nature of time.

2. Discussion

In the original paper of special relativity, firstly, Einstein proposed two conjectures (Einstein 1905, Lorentz,

Einstein et al. 1923): the principle of relativity and the principle of light speed constancy. The principle of relativity believes that “the same laws of electrodynamics and optics will be valid for all frames of reference for which the equations of mechanics hold good” (Lorentz, Einstein et al. 1923), the principle of light speed constancy means that “light is always propagated in empty space with a definite velocity c which is independent of the state of motion of the emitting body” (Lorentz, Einstein et al. 1923), Einstein raised them to the status of postulates. The above two conjectures cannot or are not easy to verify, and seems did not contradict the experiences or logic at that time. There is nothing wrong with making such conjectures in order to obtain advanced theories, but, the theoretical results obtained from the conjectures need to be strictly verified before they are fully accepted. As we know, there are many theories and experiments that do not support the conclusions of SR nowadays (Miller 1925, Bolstein 2003, Gift 2009, Hunter 2009, Shao, Xiao et al. 2010, Gift 2012).

Then, Einstein gave the definition of synchronism in stationary system in OEMB (Einstein 1905, Lorentz, Einstein et al. 1923). Einstein supposed that there is a clock at point A of space, there is another clock at point B in all respects resembling the one at point A, the straight distance between A and B is AB . Observer can determine time values of the events in the immediate proximity of the points. A ray of light start at “A time” t_A from A towards B, at “B time” t_B be reflected at B in the direction of A, and arrive at A again at “A time” t'_A . Einstein then established a concept of common time for A and B by definition that the “time” required by light to travel from A to B equals the “time” it requires to travel from B to A. In according with the definition, the two clocks synchronize if

$$t_B - t_A = t'_A - t_B \quad (1)$$

On the premise that the speed of light is constant, this does not violate common experience in stationary system. And the speed of light c is as follows:

$$c = \frac{2AB}{t'_A - t_A} \quad (2)$$

Subsequently, Einstein simulated a moving system with a rod (Einstein 1905, Lorentz, Einstein et al. 1923), the length of the rod in moving measured in stationary system is r_{AB} . The axis of the rod lying along the axis of X of the stationary system of coordinates, and that a uniform motion of parallel translation with speed v along the axis of X in the direction of increasing x is imparted to the rod. At the two ends A and B of the rod, clocks are placed which synchronize with the clocks of the stationary system. Let a ray of light depart from A at time t_A , let it be reflected at B at time t_B , and reach A again at time t'_A . Considering the principle of the constancy of the speed of light, he obtained that:

$$t_B - t_A = \frac{r_{AB}}{c - v} \quad (3)$$

and

$$t'_A - t_B = \frac{r_{AB}}{c + v} \quad (4)$$

Obviously

$$t_B - t_A \neq t'_A - t_B \quad (5)$$

So, Einstein believed that the two clocks in the moving system are not synchronous, we can see, the basis for the judgment in moving system is the definition of synchronism in stationary system. That is to say, he imperceptibly led in the content that the speed of light is constant in moving system too. But, when he calculates the time intervals $t_B - t_A$ and $t'_A - t_B$ of light travelling in moving system, the speed of moving system v is considered, the speed of light is not constant here, this is contradictory to the viewpoint of the constant speed of light in moving system just led in. Thus, I believe, at this point, the logic of physics of Einstein is confused and unclear. Also, there being no experiences support such judgment in moving system, and the judgment is not in line with common sense. I think this fatal logic error of physics may seriously destroy our trust in SR.

Thereafter, Einstein deduced the theory of SR in OEMB (Einstein 1905, Lorentz, Einstein et al. 1923). He has taken two systems of coordinate, a stationary system (K), a moving system (k). System k moves at constant speed v in the direction of the increasing x of system K . Coordinates x, y, z and time t are of system K , similarly, coordinates x', y, z and time τ are of system k , considering the movement of system k , he places

$$x' = x - vt \quad (6)$$

Then define τ as a function of x' , y , z and t . Let a ray of light emitted at time τ_0 along X -axis to x' from the origin of system k , and at time τ_1 be reflected to the origin of the coordinates, arriving there at time τ_2 . Then Einstein believed that

$$\frac{1}{2}(\tau_0 + \tau_2) = \tau_1 \quad (7)$$

It is right only if the speed of light is constant in moving system k , but, when inserting the arguments of the function τ , Einstein applied the principle of the constant speed of light in stationary system K , he expressed equation (7) as follows:

$$\frac{1}{2} \left[\tau(0,0,0,t) + \tau \left(0,0,0, t + \frac{x'}{c-v} + \frac{x'}{c+v} \right) \right] = \tau \left(x', 0,0, t + \frac{x'}{c-v} \right) \quad (8)$$

Here, the speed of light is took $c - v$ and $c + v$ in opposite direction in system k , this contradicts the constant speed of light in moving system. Thus, beginning with the logic error of physics, Einstein deduced the theory of SR. Therefore, we can see, SR hasn't a correct theoretical basis.

In Einstein's book "Relativity: The Special and General Theory" (Einstein 1924), when he elaborates the problem of simultaneity, he took a train travelling along embankment as model. On the train, there are two points A and B along the direction of movement, two light rays emitted from A and B respectively at the same time relative to embankment, both beams pass through the midpoint M^1 of A and B, the author considered that the observer sitting in the position M^1 will see the beams of light at different time. When judging which beam of light to see first, the author takes into account the movement of train obviously, however, in making the judgment of simultaneity, the movement of train is ignored. The physics thought of simultaneity in this book is consistent with OEMB indeed, and Einstein made the same mistake as in OEMB.

There are many other literatures relate to SR, As far as I know, the contents are generally the inheritance or interpretation of the idea of OEMB, and I have not find another theoretical derivations that support SR, I think the paper OEMB is the only theoretical derivation supporting literature of SR, and essentially, the other literatures have the same logic problem as OEMB.

SR is a theory about time and space. It has many conclusions and inferences. Many thought experiments are derived from these conclusions and inferences, peoples are familiar with the controversial paradoxes, the most representative of which are twin paradox and length contraction paradox (Pestic 2003, van Lintel and Gruber 2005), they are related to time and space respectively. As far as I know, neither twin paradox nor length contraction paradox have been satisfactorily explained, especially the twin paradox, Einstein himself gave different explanations in 1905 and 1918 respectively, but there lacks a convincing answer (Pestic 2003). Thus, it can be seen that SR has logic problems in both time and space related conclusions and inferences. Therefore, SR is not credible from the perspective of conclusions and inferences.

In terms of experiment, SR also was not confirmed satisfactorily. Some experiments deny the relevant content of SR directly (Gift 2009, Shao, Xiao et al. 2010, Gift 2012). The important experiment, Michelson-Morley experiment does not fully confirm the correctness of SR related content, its alternative explanation does not indicate that the speed of light in different reference systems is constant (Miller 1925, Hunter 2009). In addition, the famous around-the-world atomic clocks experiment, in order to ensure the consistency with SR, the authors falsified the experimental data (Hafele and Keating 1972, Lundberg 2020). This behavior violates the spirit of science, and would make people doubting other experiments which are said have confirmed SR. Of course, naturally, this would raise the doubts about the correctness of SR.

It can be seen from above that SR lacks a correct theoretical basis, and there are logic problems in its conclusions and inferences, also, some famous experiments failed to support SR, a famous experiment has falsified the data in order to support the conclusions of SR, and furthermore, some experiments deny the relevant content of SR directly. Therefore, I think, the related content, conclusions and inferences of SR are not credible, SR is unbelievable, it is a wrong theory.

A wrong theory, has many incredible conclusions and inferences, why can SR be accepted by many people? I think the reasons are as follows:

1). SR is based on the motion of light and the constant speed of light. However, the understanding of light is not enough (Ball 2006, Bi 2017, Henriksen, Angell et al. 2018); the speed of light is too fast, the measurement of it is not as easy as that of sound, therefore, the speed of light is constant or not in different systems is still under debate (Magueijo 2003, Munera, Hernandez-Deckers et al. 2007, Gift 2009, Shao, Xiao et al. 2010). So, people

cannot reject SR immediately for lack of conclusive evidences of its mistakes. Till now, light is thought as a kind of matter in physical world, it should not be special compared with others. When people have not fully understood the nature and the speed of light, we shouldn't rely too much on light and its properties, the construction of physical building cannot be based only on conjectures.

2). As we know, Lorentz transformation and time dilation existed before 1905 (Kittel 1974, Macrossan 1986), though they are different from the same terms of SR, for the contents that look like the same, to some extent, which paves the way for people to accept SR. In addition, many experiments confirm the conclusion of time dilation. Strictly, all these can only verify the existence of time dilation, but not enough to prove the correctness of SR. As far as I know, other inferences of SR confirmed strictly are rare. Instead, there are many controversial paradoxes.

3). The original paper of SR has comparatively complicated mathematical derivation. This could make people focus on mathematical process and ignore the logic of physics.

4). Some conclusions and inferences of SR are very fantastic. This coincides with the understanding and expectation of science of many people. In the case of not willing to doubt the correctness of SR, they selectively ignore or misinterpret the logic and experiments that proved the incorrectness of SR.

After SR was established, time and space were connected together, times in different reference frames can be transformed using relative velocity, Minkowski accordingly introduced a four-dimensional framework of space-time in 1908 (RAMOS 2001, Friedman 2007, Bertolami and Lobo 2009), so, time of SR is relate to space and independent of specific matter. Nowadays, the concept of time and space is almost dominant in physics. But, when we found SR is not credible, the four-dimensional space-time theory then lacks the foundation, thus, we have to go back to Newton's absolute space-time system, including his views of absolute space, absolute speed and etc. On this basis, we can redevelop the physics. We could re-understand time, the familiar but not very clear element of physics, based on the concepts before the appearance of SR and previous experiments.

What is time? People keep looking for the answers up to now (RAMOS 2001, Friedman 2007, Bertolami and Lobo 2009, Balasubramanian 2013, Polcaro 2013, Coumbe 2015, Sorli and Celan 2021). Time seems close to us, but also far away, unlike tangible objects that can be felt in a clear way, we couldn't have a direct contact with it. The cognition of time has not so many bases can be stated completely and clearly, which mostly roots in the subjective assumptions according to some phenomena, this is the reason why the understanding of time cannot breakthrough in a long time. Previous knowledge of time mainly comes from the accumulation from generation to generation.

In the history, there are a wide variety of concepts on time: In ancient age, the division and measurement of time indicate that time was thought as a self-existing and cyclical entity (Bertolami and Lobo 2009, Polcaro 2013); In Iron Age, people considered that the time is linear and flows from the past to the future (Polcaro 2013); Plato defined time being the moving image of eternity (Polcaro 2013); Aristotle viewed time as the measure of movement according to the "before" and "after" (Bertolami and Lobo 2009, Polcaro 2013); Galileo assumed that the existence of an objective reality has intrinsic properties which independent from the man who perceives it, time and motion are two of these properties (Polcaro 2013); Newton stated that time flows equably without relation to anything external, the absolute time concept of Newton substantially ruled physics till the appearance of SR (Bertolami and Lobo 2009, Polcaro 2013).

The above descriptions of time stem from production practice and the summary of wise men in history. They are reasonable, and also, they do not against the intuition of human being. Before we have any better choice, we should inherit and develop them. Refined the above opinions, we can obtain the following contents: time is linear and flows equably; time and movement are the intrinsic properties of objective reality; time is related to the movement. According to the latter content, we may infer that, no objective reality or no movement, there is no time.

Larmor put forward the concept of time dilation in 1897 (Kittel 1974, Macrossan 1986). In 20th century, there were many time dilation related experiments, Frisch *et al* measure the time dilation using μ -mesons, the results show that high speed mesons decay slowly than rest one, that is to say, the clocks of high speed objects run slow (Frisch and Smith 1963), negative pi-mesons have the similar results (Lederman, Booth et al. 1951). The famous around-the-world atomic clocks experiment, which let cesium beam clocks flown around the world on jet flights, though, to agree with SR, the authors falsified the data in the paper published in "science" (Hafele and Keating 1972, Lundberg 2020), but its original data still can indicate that the clock recorded different value of time at different speeds, just does not meet the transformation relationship of SR (Lundberg 2020). The times of the mentioned experiments are all associated with specific matter, so, the concept of time here is not exactly the

same as SR to some extent. Thus, qualitatively, these experiments also cannot fully prove the correctness of time dilation of SR.

According to the results of above experiments, we can obtain that time is related to the movement; the flow rate of time is related to the speed of the movement, the time of high speed objects run slowly. For μ -mesons and cesium beam clocks with different speeds have different lifetimes or recorded time values; cesium beam clocks moving together have the same recorded time values, we may think that, different μ -mesons or cesium beam clocks have its own time system, different speeds cause times flowing at different rates, when the speeds are equal, times flow at the same rate.

Combine the views of time in history and the analysis of time-related experiments, accompanied by suitable inference, I think that time in physics should as follows:

- 1). Time is linear and flows equably.
- 2). Time is related to the movement of object.

Time is the expression or record of the movement of object.

Different objects have different time systems. Objects with different movement, the times flow differently. Objects with similar motion states, the times flow at similar rates.

The movement of object with high speed, the time flows slowly.

Where there is no object or movement, there is no time.

Here, the object represents objective reality, regardless of the size, even if it's a quark or other smaller individual particles.

- 3). Time is always forward, it is irreversible, for the expressed or recorded movement of object have already existed.

The viewpoint of time refers and extends previous summaries and experimental results, it is not contradictory to the conclusion of time dilation verified by experiments, and can well in line with the experiments related. Unfortunately, this paper can't found the specific relationship between different time systems. I believe that, with the development of timing tools and space technology, the problem will be solved in future research.

Twin paradox is a thought experiment related to time dilation, which is a trouble to SR, the origin of the trouble is the absolute relativity of motion, because, under the absolute relative thinking, we can't know who should be relative to whom, this is the logic dilemma of the problem. However, in the opinion of time in this paper, different objects have different time systems, the twins in twin paradox have their own age record respectively, there is no logic dilemma about the age of the twins, the problem of twin paradox relate to SR is solved simply.

3. Conclusions

For about 100 years, whether SR is correct or not has been debated all the time, both sides of the argument lack a more convincing reason. SR should have been the target in the controversy, but in the process of debate, the understanding of SR was growing, it has been widely recognized and become the mainstream. Meanwhile, Einstein has been gradually mythologized, his hypotheses or inferences that have not been proved adequately or cannot be verified, such as the speed of light is constant and nothing moves faster than light, have been regarded as the truth and become an insurmountable red line in physics, this is not science, there is no rigor of science, this could affect the development of science seriously.

By analyzing the original paper of SR carefully, it was found that there has a fatal logic error of physics in Einstein's derivation of SR. In the preceding paragraph of original paper of SR, the speed of light is constant in different coordinate systems, the groundless viewpoint, was imperceptible introduced in the process of derivation, what's more, the viewpoint was used or not is casually, the context is contradictory. Combined with the analysis of the conclusions, inferences and experimental verification of SR, this paper got the conclusion that SR is a wrong theory. In order to clarify the problem further, I summarized the reasons why SR can be widely accepted. When we found SR is not right, the four-dimensional space-time based on SR is then meaningless. Thus, based on the concepts before the appearance of SR and previous experiments, the nature of time was re-understood. This paper believed that time expresses or records the movement of object, objects with different movement, their time systems are different, and time is forward and irreversible. The opinion of time in this paper can solve the problem of twin paradox simply. However, this paper only presents theoretical analysis, but I believe, with the progress of science and technology, there will be experiments support my conclusions. Furthermore, free from the constraint of SR, we can reinterpret the space and time, and enter a new world of physics.

Acknowledgments

No relevant content.

Authors' contributions

No relevant content: The only author, the corresponding author was responsible for all the contents of the paper.

Funding

No relevant content.

Competing interests

The author declares that he has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Informed consent

Obtained.

Ethics approval

The Publication Ethics Committee of the Canadian Center of Science and Education.

The journal and publisher adhere to the Core Practices established by the Committee on Publication Ethics (COPE).

Provenance and peer review

Not commissioned; externally double-blind peer reviewed.

Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Data sharing statement

No additional data are available.

Open access

This is an open-access article distributed under the terms and conditions of the Creative Commons Attribution license (<http://creativecommons.org/licenses/by/4.0/>).

Copyrights

Copyright for this article is retained by the author(s), with first publication rights granted to the journal.

References

- Ahmed, M. F., Quine, B. M., Sargoytchev, S., & Stauffer, A. D. (2012). A review of one-way and two-way experiments to test the isotropy of the speed of light. *Indian Journal of Physics*, 86(9), 835-848.
- Ashby, N. (2003). Relativity in the Global Positioning System. *Living reviews in relativity*, 6(1), 1-42.
- Balasubramanian, V. (2013). What We Don't Know About Time. *Foundations of Physics*, 43(1), 101-114.
- Ball, D. W. (2006). The baseline - Light: Particle or wave?. *Spectroscopy* 21(6), 30-33.
- Bertolami, O., & Lobo, F. S. N. (2009). Time and Causation. *Neuroquantology*, 7(1), 1-15.
- Bi, S. (2017). Discuss wave-particle duality of light. *Second International Conference on Photonics and Optical Engineering*, C. Zhang and A. Asundi. 10256, UNSP 1025650.
- Bolstein, A. (2003). The mathematical logic failure of Einstein's special relativity. *Kybernetes*, 32(7-8), 943.
- Botermann, B., Bing, D., Geppert, C., Gwinner, G., Haensch, T. W., Huber, G., ...Saathoff, G. (2014). Test of Time Dilation Using Stored Li+ Ions as Clocks at Relativistic Speed. *Physical Review Letters*, 113(12), 120405.
- Coumbe, D. N. (2015). Hypothesis on the nature of time. *Physical Review D*, 91(12), 124040.
- Duarte, S. E. S., & Lima, N. W. (2020). Special relativity from classical gedanken experiments involving electromagnetic forces: a contribution to relativity without light. *European Journal of Physics*, 41(4),

045602.

- Einstein, A. (1905). Zur Elektrodynamik bewegter Körper. *Annalen der Physik*, 17, 891-921.
- Einstein, A. (1924). *Relativity: The Special and General Theory*. Methuen & Co Ltd.
- Franklin, P. (1922). The Meaning of Rotation in the Special Theory of Relativity. *Proceedings of the National Academy of Sciences of the United States of America*, 8(9), 265-268.
- Friedman, M. (2007). Understanding space-time. *Studies in History and Philosophy of Modern Physics*, 38(1), 216-225.
- Frisch, D. H., & Smith, J. H. (1963). Measurement of the Relativistic Time Dilation Using μ -Mesons. *American Journal of Physics*, 31(5), 342-355.
- Gift, S. J. G. (2009). Light speed variation in stellar aberration. *Physics Essays*, 22(2), 83-85.
- Gift, S. J. G. (2012). A simple demonstration of one-way light speed anisotropy using Global Positioning System (GPS) technology. *Physics Essays* 25(3), 387-389.
- Gwinner, G. (2005). Experimental tests of time dilation in special relativity. *Modern Physics Letters A*, 20(11), 791-805.
- Hafele, J. C. (1970). Relativistic behaviour of moving terrestrial clocks. *Nature*, 227(5255), 270-271.
- Hafele, J. C., & Keating, R. E. (1972). Around-the-World Atomic Clocks: Observed Relativistic Time Gains. *Science*, 177(4044), 168-170.
- Henriksen, E. K., Angell, C., Vistnes, A. I., & Bungum, B. (2018). What Is Light?. *Science & Education*, 27(1-2), 81-111.
- Hunter, M. (2009). Huygens' principle and the Michelson-Morley experiment: Reconsidering the ether hypothesis. *Physics Essays*, 22(3), 318-324.
- Ives, H. E. (1947). Historical note on the rate of a moving atomic clock. *Journal of the Optical Society of America*, 37(10), 810-813.
- Kennedy, R. J. (1926). A Refinement of the Michelson-Morley Experiment. *Proceedings of the National Academy of Sciences of the United States of America*, 12(11), 621-629.
- Kittel, C. (1974). Larmor and the Prehistory of the Lorentz Transformations. *American Journal of Physics*, 42(9), 726-729.
- Lammerzahl, C. (2006). Relativity and technology. *Annalen Der Physik*, 15(1-2), 5-18.
- Lederman, L. M., Booth, E. T., Byfield, H., & Kessler, J. (1951). On the Lifetime of the Negative Pi-Meson. *Physical Review*, 83(3), 685-686.
- Lorentz, H. A., Einstein, A., Minkowski, H., & Weyl, H. (1923). *The Principle of Relativity*. New York, Dover Publications.
- Lundberg, R. (2020). Velocity and absurdity in modern physics. *Physics Essays*, 33(2), 118-139.
- Macrossan, M. N. (1986). A Note on Relativity before Einstein. *The British Journal for the Philosophy of Science*, 37(2), 232-234.
- Magueijo, J. (2003). New varying speed of light theories. *Reports on Progress in Physics*, 66(11), 2025-2068.
- Miller, D. C. (1925). ETHER-DRIFT EXPERIMENTS AT MOUNT WILSON. *Science* (New York, N.Y.) 61(1590), 617-621.
- Miller, D. C. (1933). THE ABSOLUTE MOTION OF THE SOLAR SYSTEM AND THE ORBITAL MOTION OF THE EARTH DETERMINED BY THE ETHER-DRIFT EXPERIMENT. *Science* (New York, N.Y.) 77(2007), 587-588.
- Mueller, H., Stanwix, P. L., Tobar, M. E., Ivanov, E., Wolf, P., Herrmann, S., ... Peters, A. (2007). Tests of relativity by complementary rotating Michelson-Morley experiments. *Physical Review Letters*, 99(5), 050401.
- Muller, H., Herrmann, S., Braxmaier, C., Schiller, S., & Peters, A. (2003). Modern Michelson-Morley experiment using cryogenic optical resonators. *Physical Review Letters*, 91(2), 020401.
- Munera, H. A., Hernandez-Deckers, D., Arenas, G., & Alfonso, E. (2007). Observation of a significant influence of earth's motion on the velocity of photons in our terrestrial laboratory - art. no. 66640K. *Nature of Light*:

- What Are Photons?*. C. Roychoudhuri, A. F. Kracklauer and K. Creath. 6664, 6640K.
- Ozer, M. (2020). Electrostatic time dilation and redshift. *Physics Letters B*, 802, 135212.
- Pesic, P. (2003). Einstein and the twin paradox. *European Journal of Physics*, 24(6), 585-590.
- Polcaro, V. F. (2013). The concept of time, from Palaeolithic to Newtonian physics. *Tm 2012 - the Time Machine Factory [Unspeakable, Speakable] on Time Travel in Turin*. M. Crosta, M. Gramegna and M. L. Ruggiero., 58, 03001.
- Ramos, A. L. L. (2001). CLASSICAL AND RELATIVISTIC TIME DILATION. *Reference Frames and Gravitomagnetism*, 333-338.
- Reinhardt, S., Saathoff, G., Buhr, H., Carlson, L. A., Wolf, A., Schwalm, D., ... Gwinner, G. (2007). Test of relativistic time dilation with fast optical atomic clocks at different velocities. *Nature Physics*, 3(12), 861-864.
- Saathoff, G., Karpuk, S., Eisenbarth, U., Huber, G., Krohn, S., Horta, R. M., ...Gwinner, G. (2003). Improved test of time dilation in special relativity. *Physical Review Letters*, 91(19), 190403.
- Sanjuan, J., Abich, K., Gohlke, M., Resch, A., Schuldt, T., Wegehaupt, T., ...Braxmaier, C. (2019). Long-term stable optical cavity for special relativity tests in space. *Optics Express*, 27(25), 36206-36220.
- Shao, L., Xiao, Z., & Ma, B.-Q. (2010). Lorentz violation from cosmological objects with very high energy photon emissions. *Astroparticle Physics*, 33(5-6), 312-315.
- Sorli, A. S., & Celan, S. (2021). Time as the result of the observer's measurement. *Physics Essays*, 34(4), 583-586.
- van Lintel, H., & Gruber, C. (2005). The rod and hole paradox re-examined. *European Journal of Physics*, 26(1), 19-23.
- Wang, Z., Zhao, L., Wang, S., Zhang, J., Wang, B., & Wang, L. (2014). COMPASS time synchronization and dissemination-Toward centimetre positioning accuracy. *Science China-Physics Mechanics & Astronomy*, 57(9), 1788-1804.
- Woodruff, R. A. (2020). On special relativistic effects via classical physics. *Journal of the Optical Society of America. A, Optics, image science, and vision*, 37(7), 1100-1104.