Simultaneity and Synchronization and Einstein´s Relative Simultaneity

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Abstract

In this paper it is reconsidered the physical meaning of Einstein´s Relative Simultaneity, based on the results obtained previously in the context of the meaning of simultaneity and synchronization that has also been addressed in several other papers.
In the standard Special Relativity, usually, simultaneity and synchronization is considered with the Einstein one-way speed of light that has been introduced by Einstein in the 1905 article "by definition". In the standard interpretation the one-way speed of light is not considered since the Einstein speed of light is considered the speed of light. However, in our previous work we have shown that this is a terminological confusion. Now it is addressed Einstein´s Relative Simultaneity with a very simple concise formalism using two clocks in every point of a frame, frame that is moving in relation to the preferred frame, a synchronized clock, and a Lorentzian clock. We previously obtain an expression that shows an intrinsic desynchronization of Lorentzian clocks in every frame except in the preferred frame where the one-way speed of light is isotropic. Therefore, we designate the preferred frame by Einstein Frame (EF). Allegedly the conventionality of the one-way speed of light originate the conventionality of simultaneity. Therefore, we clarify the meaning of simultaneity and Einstein´s Relative Simultaneity concluding that Einstein´s Relative Simultaneity is not simultaneity except in EF. Simultaneity is not relative. However, we conclude that Einstein´s Simultaneity is relative since Lorentzian clocks are desynchronized except in EF.

Introduction

In previous works [1-16] a broad approach of Special Theory of Relativity (STR) has been formulated. The implications of this approach in the interpretation of Einstein´s Relative Simultaneity is now considered. In Special Relativity the problem of the physical meaning and the experimental determination of the one-way speed of light has been debated since the emergence of the theory when Maxwell discovered the wave equation in his equations of the Electromagnetic Field. The similitude of the value of the speed of propagation of the waves obtained theoretically with the experimental value early obtained by Römer, Bradley, Fizeau, Foucault, naturally convinced Maxwell that the speed of light must be related with the theoretically description he obtained. This is the origin of the idea of the independence of the speed of light of the speed of the source sometimes misinterpreted as implying that the speed of light is the same in every frame. For sure one of the postulates of STR based on experience and theoretical reasoning is that the speed of light is isotropic in vacuum independently of the speed of the source in one frame that we previously designate by Einstein Frame (EF) [6, 7]. Another postulate of special relativity based on the experiences of Michelson-Morley-Miller is that the two-way speed of light in every frame is the same in every direction in vacuum with the value

c obtained experimentally (although the experiment has been originally performed in air and does not give a null result, but it has been assumed initially that air does not interfere [17] (see Irvine experiment)). Therefore, the value of the one-way speed of light in EF is also *c*. From these postulates without invoking the constancy of the one-way speed of light Special Relativity has been constructed initially by FitzGerald, Larmor, Poincaré and Lorentz with a constructive theory based on experience interpreted with the assumption of a privileged frame where the one-way speed of light have the value *c* [9-13, 16, 18]. In our previous works based on these postulates we conciliate the analysis of Einstein based on a Principle theory [19] with the Lorentz-Poincaré approach [1-16]. Several works, some very recent, point out the importance of this discussion about the foundations of Relativity, Quantum Mechanics, Cosmology and Biophysics [1-95]. The articles "Special Relativity, The Preferred Frame and the Relativity Principle", "Simultaneity and Synchronization, The Preferred Frame and the Principle of Relativity" and "A Motion Paradox from Einstein's Relativity of Simultaneity" also address Einstein´s Relative Simultaneity conceptualization in the context of the intrinsic desynchronization of Lorentzian times $t_L^{'}$ [9, 11, 23-25, 35, 88, 89].

In section I we consider two rods designated by S and S´ [51, 52] moving relatively to each other longitudinally and we obtain the one-way speed of light and the Einstein speed of light, simultaneity, and Einstein´s simultaneity.

In Ia we consider the rod S´ with length l_1 moving with speed v_1 in relation to EF where is located rod S with proper length l_0. The rod S´ is moving longitudinally in the same direction defined by the rods. Since the rod S´ is Lorentz contracted (S is the EF) [2] we know l_1 when the extremities of the rods pass by each other simultaneously. This is the most primitive notion of simultaneity that Special relativity does not rule out [2-16, 18-29, 73]. Consequently, we can calculate the one-way speed of light in S´ confirming that it is not *c*. Of course Einstein one way speed of light is *c* by definition since the Lorentz clock at the extremity of the rod is desynchronized of the clock synchronized, the clock has been desynchronized conveniently with the condition that light arrives to the extremity of the rod where a clock is waiting marking l_1/c. Therefore, both values of the "speed of light" are true and must be observed if not the theory collapse. From the one-way speed of light and from Einstein´s speed of light we obtain the intrinsic desynchronization of Lorentzian clocks.

In Ib it is considered the emission of light from the extremities of the rods, A, B, A´ and B´ when A´ pass by A and B´ by B, simultaneously. However, the spherical waves of these emissions in frame S´ does not "fly by" an observer in the middle of A´B´ simultaneously. Einstein definition of simultaneity is introduced, and the standard conclusion is that Einstein´s simultaneity is relative. From the intrinsic desynchronization of the Lorentzian clocks the conclusion is unavoidable, Lorentzian clocks in two locations aren't synchronized except in EF.

I. Simultaneity and Einstein´s Relative Simultaneity by rods.

Ia. Intrinsic desynchronization of Lorentzian clocks.

Consider a rod S´ [51, 52] with proper length l_1 moving with speed v_1 in relation to EF where is located another bar S with proper length l_0 (Fig.1).

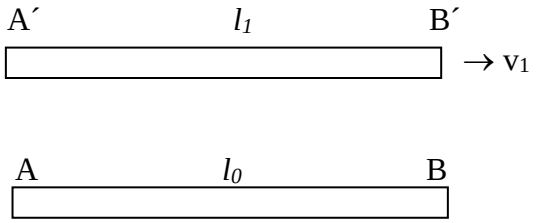

Fig. 1 Rod S´ is moving with speed v_1 in relation to rod S at rest in EF. The extremities of the rods coincide simultaneously and therefore, can synchronize clocks at A, A´, B and B´.

The rod S´ is moving with speed v_1. Since the bar S´ is Lorentz contracted (since S is at rest in the EF) we know l_1 in function of l_0 when the extremities of the rods pass by each other simultaneously, when A´ coincide with A and B´ with B as represented in the figure 1. This is the most primitive notion of simultaneity that Special Relativity does not ruled out. However standard interpretation induce to think that it is impossible to synchronize clocks because it is not possible to send a signal from A´ to B´ with infinite speed and since the one-way speed of light was not known in frame S´ Einstein postulate that the one-way speed of light is also *c* in S´ [3, 16, 19]. In this context this affirmation must be ruled out [4].

Indeed, we can calculate the one-way speed of light at S´.

We have

$$l_1 = \frac{l_0}{\sqrt{1-\frac{v_1^2}{c^2}}} \quad (1)$$

From the origin of S´ (A´) it is emitted a ray of light in the direction of the extremity B´ of S´ when A´ pass by A. This ray of light moves in the EF with speed *c*. Therefore, we can calculate the coordinate *x* where the ray of light intercepts the extremity B´

$$x = l_0 + v_1 t \quad (2)$$

$$x = ct \quad (3)$$

$$t = \frac{l_0}{c - v_1} \quad (4)$$

Since S´ is moving with speed v_1 in relation to EF we have the Larmor time dilation [11, 13, 16, 18]

$$t' = t\sqrt{\left(1 - \frac{{v_1}^2}{c^2}\right)} \quad (5)$$

From (4) and (5)

$$t' = \frac{l_0}{c - v_1}\sqrt{\left(1 - \frac{{v_1}^2}{c^2}\right)} \qquad (6)$$

Therefore, we obtain the one-way speed of light in S´

$$c_+ = \frac{l_0}{\sqrt{\left(1 - \frac{v_1^2}{c^2}\right)}} \times \frac{c - v_1}{l_0} \times \frac{1}{\sqrt{\left(1 - \frac{v_1^2}{c^2}\right)}} \qquad (7)$$

$$c_+ = \frac{c - v_1}{1 - \frac{v_1^2}{c^2}} = \frac{c}{1 + \frac{v_1}{c}} \qquad (8)$$

As expected, the one-way speed of light is not *c*. Only in a first order approximation is *c* and we obtain the Galileo approximation $c - v_1$ for a second order approximation.

Consider now Einstein's one-way speed of light. By definition Einstein has defined "Einstein synchronization" by a clock at *x´* (the generic coordinate of B´) marking *x´/c* and awaiting the arrival of the ray of light emitted at $(x' = 0, t_L' = 0)$ to initiate. This time is the Lorentzian time t_L' and of course $x'/t_L' = c$, it cannot be otherwise [2-4]. Since $t' = x'/c_+' = (x'/c)\,(1 + v_1/c)$ we have $t_L' = t' - (v_1/c^2)\,x'$. Since the clocks marking *t´* are synchronized the clocks marking t_L' are desynchronized. Note that the one-way speed of light that preserve the value *c* for the two way of light is the harmonic mean of c_+' and c_-' [30] given by

$$c_\pm' = \frac{c}{1 \pm \alpha\frac{v_1}{c}} \qquad (9)$$

with $\alpha \in [0, 1]$.

Therefore, we obtain (10) the intrinsic desynchronization of Lorentzian clocks [2-13]

$$t_L' = t' - \frac{v_1}{c^2}x' \qquad (10)$$

that also permit the resolution of the Twin Paradox (see III. Time dilation equation-like between frames S´´ and S´ and IV. The ageing of the twin´s conundrum at p. (5-7) [92] and [9, 11, 23-25, 35, 88, 89, 92, 93]).

Ib. **Simultaneity and Einstein´s Relative Simultaneity**

Lorentz was right, t_L' is the local time and SR can be formulated with the synchronized time [11]. Clearly this analysis address the problem of conventionalism [64] since the simultaneous passing of the extremities of the rods by each other is not a convention.

Indeed, we can consider the four clocks (fig.1) initiating marking zero when A´ pass by A and B´ by B. Therefore the events coincidence of the extremities of the rods are

simultaneous. From these events from extremity A and from extremity B we can send light to the coordinate x correspondent to the middle of AB ($l_0/2$) where we can consider an observer that receive the two rays of light simultaneously since rod AB is located at EF and the speed of light is isotropic.

(About Einstein´s relative simultaneity, YouTube has the animation from MyEarbot, Simultaneity-Einstein and the Theory of Relativity**.**

https://www.youtube.com/watch?v=wteiuxyqtoM

Another animation is "Discovering the Relativity of Simultaneity"

"How dis Einstein take the "Step" ? "

https://sites.pitt.edu/~jdnorton/Goodies/rel_of_sim/index.html).)

Since the one-way speed of light is c (S is the EF) the two rays of light are emitted simultaneously from points A and B (t=0 at A and t=0 at B when light is emitted). The emission of light is simultaneous. However, when we consider the emissions from A´ and B´ we have the problem that light emitted to the middle of A´B´ does not arrive at the observer located at the middle simultaneously since the observer is moving in the direction of B. Indeed, light emitted by A´ (or B´) coalesce with light emitted by A (or B). We have the same spherical wave in frame S, the preferred frame. This is the presupposition of special relativity that the speed of light at S is independent of the speed of the source. Therefore, we have the standard statement that if light has the same speed c at the frame S´, then the emission of light at A´ and B´ are not simultaneous (the observer first receives the emission from B´ and after the emission from A´). But we know that $t´=0$ at A´ and $t´=0$ at B´ for the emissions and therefore with clocks synchronized ($t´$) the events are simultaneously. The reason of this apparent discrepancy is the intrinsic desynchronization of Lorentzian clocks ($t_L^{´}$) that equation (10), $t_L^{´}=t´-(v_1/c^2)\,x´$, reveal, and standard interpretation is not aware and cannot be aware [35]. Einstein defined simultaneity of events by the arrival of light simultaneously to the middle of the segment that unite the events. Einstein are considering Lorentzian clocks. And for these clocks since $t´=0$ the Lorentz clocks does not mark the same number $t_L^{´}$ since $x´$ is different (the coordinates $x´$ of A´ and B´ are different and therefore the values of $t_L^{´}$ are different). Of course, this Einstein simultaneity is a different concept and must be designated by Einstein´s simultaneity. If not, we have a paralogism. A word with several meanings. In this case opposite meanings. Einstein definition only in one frame is simultaneity. For other frames Einstein definition is Einstein´s simultaneity. It is not simultaneity [23-25].

References

1. de Abreu, R. Estabelecimento da transformação de Lorentz recorrendo a um conceito de velocidade limite Gazeta de Física, vol. 21, Fasc. 3 (1998) https://www.spf.pt/magazines/GFIS/398/1153

2. de Abreu, R. Reinterpretation of Lorentz Transformation and resolution of Special Relativity's paradoxes http://arxiv.org/abs/physics/0203025 ; EPS-12 Trends in Physics, Abstracts p. 270, Budapest (2002). http://vixra.org/abs/1505.0065

3. de Abreu, R. Deduction of Lorentz Transformation from the existence of absolute rest. Deduction of the speed of light in any frame of reference https://arxiv.org/abs/physics/0210023

4. de Abreu, R. The physical meaning of simultaneity and synchronization in Special Relativity https://arxiv.org/abs/physics/0212020

5. Homem, G. Physics in a synchronized space-time. Master's thesis, Instituto Superior Técnico, Universidade Técnica de Lisboa, 2003

6. de Abreu, R. The Relativity Principle and the Indetermination of Special Relativity Ciência & Tecnologia dos Materiais, vol. 14, nº 1, p. 74 (2004) https://vixra.org/abs/2301.0139

7. de Abreu, R. and Guerra, V. Relativity – Einstein's Lost Frame (Extra]muros[, Lisboa, 2005), 1st ed. http://web.tecnico.ulisboa.pt/vguerra/papers/relshort.pdf

8. Guerra, V. and de Abreu, R. Special Relativity in Absolute Space: from a contradiction in terms to an obviousness https://arxiv.org/abs/physics/0603258

9. Guerra, V. and de Abreu, R. On the Consistency between the Assumption of a Special System of Reference and Special Relativity Foundations of Physics, Vol. 36, No. 12, December (2006) DOI:10.1007/s10701-006-9085-5

10. Guerra, V. and de Abreu, R. The conceptualization of time and the constancy of the speed of light, Eur. J. Phys. 26, 6 (2005) European Journal of Physics, Volume 26, Number 6

11. de Abreu, R. and Guerra, V. The Principle of Relativity and the Indeterminacy of Special Relativity, Eur. J. Phys. 29, 1 (2007) https://iopscience.iop.org/article/10.1088/0143-0807/29/1/004

12. de Abreu, R. and Guerra, V. Special Relativity as a Simple Geometry Problem Eur. J. Phys. 30, 2 (2009) https://iopscience.iop.org/article/10.1088/0143-0807/30/2/001

13. de Abreu, R. Guerra, V. Speakable and Unspeakable in Special Relativity: Time Readings and Clock Rhythms EJTP Vol. 12 Issue 34, p183 (2015) http://www.ejtp.com/articles/ejtpv12i34p183.pdf

14. de Abreu, R. Guerra, V. Speakable and Unspeakable in Special Relativity: the Ageing of the Twins in the Paradox http://vixra.org/abs/1804.0320

15. de Abreu, R. Guerra, V. The Resolution of the Twin Paradox in a One-Way Trip http://vixra.org/abs/1805.0126

16. de Abreu, R. On the Experimental Determination of the One-Way Speed of Light https://vixra.org/abs/1808.0646

17. Consoli, M. Pluchino, A. THE CLASSICAL MICHELSON-MORLEY EXPERIMENTS: A NEW SOLUTION TO AN OLD PROBLEM Atti della Accademia Peloritana dei Pericolanti Vol. 96, No. S1, A2 (2018) http://dx.doi.org/10.1478/AAPP.96S1A2

18. Kittel, C. Larmor and the Prehistory of the Lorentz Transformations Am. J. Phys. 42, 726 (1974) https://doi.org/10.1119/1.1987825

19. Einstein, A. Ann. Phys. 17, 132 (1905): "On the Electrodynamics of Moving Bodies", "Einstein´s Miraculous Year, Five Papers That Changed the Face of Physics" Edited and Introduced by John Stachel, Princeton University Press (1998)

20. Andersen, F. Experience and Theory: A Defense of the Kantian A priori and Kepler's Philosophy of Science in Light of Modern Space-Time Physics, PhD Thesis, NMBU (2017) https://nmbu.brage.unit.no/nmbu-xmlui/handle/11250/2500054

21. Myrstad, J. A. https://philpapers.org/rec/MYRWRP Borderology: Cross-disciplinary Insights from the Border Zone, p. 93, Springer (2019) DOI: 10.1007/978-3-319-99392-8_8

22. Consoli, M. Pluchino, Michelson-Morley Experiments: An Enigma For Physics And The History Of Science, World Scientific (2019) https://www.worldscientific.com/worldscibooks/10.1142/11209

23. Haug, E. The Return of Absolute Simultaneity and Its Relationship to Einstein's Relativity of Simultaneity http://vixra.org/abs/1605.0057

24. Haug, E. A Motion Paradox from Einstein's Relativity of Simultaneity http://vixra.org/abs/1711.0408

25. de Abreu, R. Comment on "A Motion Paradox from Einstein´s Relativity of Simultaneity" http://vixra.org/abs/1810.0452

26. Geloni, G. Kocharyan, V. Saldin, E. Misconception Regarding Conventional Coupling of Fields and Particles in XFEL Codes https://arxiv.org/abs/1601.07738

27. Geloni, G. Kocharyan, V. Saldin, E. https://arxiv.org/abs/1610.04139

28. Geloni, G. Kocharyan, V. Saldin, E. https://arxiv.org/abs/1704.01843

29. de Abreu, R. Guerra, V. Comment on "Misconceptions Regarding Conventional Coupling of Fields and Particles in XFEL Codes" http://vixra.org/abs/1906.0312

30. Mansouri, R. and Sexl, R. A test theory of special relativity: I. Simultaneity and clock synchronization Gen. Relat. Gravit. 8, 497 (1977) https://doi.org/10.1007/BF00762634

31. Zbigniew Oziewicz, Ternary relative velocity; astonishing conflict of the Lorentz group with relativity, Vladimir Gladyshev, Editor, Physical Interpretations of Relativity Theory, Moscow 2007, pages 292-303, ISBN 978-5-7038-3178-6 https://arxiv.org/abs/1104.0682

32. Gianfranco Spavieri *et al* 2018 Thought experiment discriminating special relativity from preferred frame theories *J. Phys. Commun.* **2** 085009

33. Spavieri, G. Testing Einstein's second postulate with an experiment of the Sagnac type PAIJ vol.1, Issue 1 (2017) DOI: 10.15406/paij.2017.01.00003

34. Consoli, M. Pluchino, A. Cosmic Microwave Background and the issue of a fundamental preferred frame Eur. Phys. J. Plus 133:295 (2018) https://doi.org/10.1140/epjp/i2018-12136-5

35. Burde, G. Special Relativity, The Preferred Frame and the Relativity Principle, Journal of Modern Physics, vol. 9, Nº 8 (2018) https://doi.org/10.4236/jmp.2018.98100

36. Ricou, M. On the speed of light Physics Essays, Vol. 30, 461-468 (2017)

37. de Abreu, R. Guerra, V. Comment on "On the speed of light" (2019) http://vixra.org/abs/1906.0310

38. Wutke, A. https://www.researchgate.net/publication/326672264_Absolute_Simultaneity_and_Rest_Consistent_with_Special_Relativity_Science_or_Philosophy

39. Bricmont, J. History of Quantum Mechanics or the Comedy of Errors https://arxiv.org/pdf/1703.00294.pdf

40. Grady, M. Two time solution to quantum measurement paradoxes https://arxiv.org/abs/1708.04275

41. Mamone-Capria, M. On the Incompatibility of Special Relativity and Quantum Mechanics Journal for Foundations and Applications of Physics, vol.5, Nº 2, 163 (2018)

42. Gianfranco Spavieri *et al* 2018 Reply to Comment on 'Thought Experiment discriminating special relativity from preferred frame theories' *J. Phys. Commun.* **2** 118002

43. Chandru Iyer, Comment on 'Thought experiment discriminating special relativity from. preferred frame theories' 2018 *J. Phys. Commun.* **2** 118001

44. Potvin, G. Ether Interpretation of General Relativity, RESEARCHERS.ONE (2018) https://www.researchers.one/article/2018-12-7

45. Grøn, Ø. The twin paradox in the theory of relativity Eur. J. Phys. 27, 885 (2006). European Journal of Physics, Volume 27, Number 4

46. Iyer, C. Harmonic mean, the Gamma factor and Speed of Light https://arxiv.org/abs/0811.0785

47. Iyer, C. Comment on 'The principle of relativity and the indeterminancy of special relativity' Eur. J. Phys. 29, 4 (2008) https://iopscience.iop.org/article/10.1088/0143-0807/29/4/L01

48. Iyer, C. Prabhu, G. A constructive formulation of the one-way speed of light Am. J. Phys. 78 (2) (2010) https://doi.org/10.1119/1.3266969

49. Iyer, C. Prabhu, G. Time Dilation and the Equivalence of Inertial Frames https://arxiv.org/abs/0710.1594

50. Moller, C. New experimental tests of the special principle of relativity Proc. of The Royal Soc. A vol. 270, Issue 1342 (1960) https://doi.org/10.1098/rspa.1962.0220

51. Schwartz, H. A New Method of Clock Synchronization without Light Signals Am. J. Phys. 39, 1269 (1971) https://doi.org/10.1119/1.1976621

52. Sears, F. W. Simultaneity without Synchronized Clocks Am. J. Phys. 37, 668 (1969) https://doi.org/10.1119/1.1975747

53. Ramanakrishnan, A. Journal of Math. Anal. and App. 249, 243 (2000)

54. Bricmont, J. https://arxiv.org/pdf/1703.00294.pdf

55. Giovanelli, M. https://www.researchgate.net/publication/338680431_Lorentz_Contraction_vs_Einstein_Contraction_Reichenbach_and_the_Philosophical_Reception_of_Miller's_Ether-Drift_Experiments

56. Mamone-Capria, M. On the Incompatibility of Special Relativity and Quantum Mechanics Journal for Foundations and Applications of Physics, vol.5, Nº 2, 163 (2018) https://arxiv.org/abs/1704.02587

57. Spavieri, G. Gillies, G. T. Haug, E. G., Sanchez, A. (2019): Light propagation and local speed in the linear Sagnac effect, Journal of Modern Optics, http://doi: 10.1080/09500340.2019.1695005

58. Unnikrishnan, C. The Theories of Relativity and Bergson's Philosophy of Duration and Simultaneity During and After Einstein's 1922 Visit to Paris. *Preprints* **2020**, 2020010273 http://doi: 10.20944/preprints202001.0273.v1

59. Spavieri, G. Guerra, V. de Abreu, R. Gillies, G. T Ether drift experiments and electromagnetic momentum Eur. Phys. J. D. 47, 457 (2008) https://link.springer.com/article/10.1140/epjd/e2008-00062-x

60. Spavieri, G. Rodriguez, M. Sanchez, A. Testing Absolute vs Relative Simultaneity with the Spin-orbit Interaction and the Sagnac Effect Applied Physics Research Vol. 11, No. 4 (2019) https://doi.org/10.5539/apr.v11n4p59

61. Spavieri, G. and Haug, E. G. Why the Sagnac effect favors absolute over relative simultaneity Physics Essays**,** Vol. 32, 331-337 (2019) https://doi.org/10.4006/0836-1398-32.3.331

62. Spavieri, G. Gillies, G. T. Haug, E. G. The Sagnac effect and the role of simultaneity in relativity theory Journal of Modern Optics, vol. 68, Issue 4 (2021) https://doi.org/10.1080/09500340.2021.1887384

63. Salmon, W., 1977. "The Philosophical Significance of the One-Way Speed of Light," *Noûs*, 11: 253–292 https://doi.org/10.2307/2214765

64. Conventionality of Simultaneity
https://plato.stanford.edu/entries/spacetime-convensimul/

65. Perez, I. On the experimental determination of the one-way speed of light
https://arxiv.org/abs/1102.4837

66. Guerra, V. de Abreu, R. Comment on: "From classical ether-drift experiments: the narrow window for a preferred frame" [Phys. Lett. A 333 (2004) 355] Phys. Lett. A 361, Issue 6 (2007) http://web.tecnico.ulisboa.pt/vguerra/papers/PhysLettA.pdf

67. Lewis, G. F. Barnes, L. A. The One-Way Speed of Light and the Milne Universe Publication of the Astronomical Society of Australia, vol. 38, (2021)
https://arxiv.org/abs/2012.12037

68. Buenker, R. The Relativistic Velocity Transformation and the Principle of Absolute Simultaneity J Astrophys Aerospace Technol (2015) DOI: 10.4172/2329-6542.1000125

69. Netchitailo, V. S. New Cosmology – Third Revolution in Physics
https://vixra.org/abs/2012.0222

70. Pagano, A., Pagano, E.V. A note on Lorentz transformations and simultaneity in classical physics and special relativity EPJ H 44, 321-330 (2019)
https://doi.org/10.1140/epjh/e2019-90058-4

71. Greaves, E. D., Michel Rodrigues, A., Ruiz-Camacho, J. A one-way speed of light experiment Am. J. Phys. 77, 894 (2009) https://doi.org/10.1119/1.3160665

72. de Abreu, Guerra, V. Comment on "A one-way speed of light experiment" (2009)
https://www.researchgate.net/publication/45886873

73. Leaf, B. Philosophy of Science, The Clock Paradox in the Special Theory of Relativity vol. 22, Number 1 (1955) https://doi.org/10.1086/287387

74. Spavieri, G. Quintero, J. Unnikrishnan, C. Gillies, G. Can the one-way speed of light be used for detection of violations of the relativity principle? Phys. Lett. A 376(s 6-7):795-797 (2012) DOI: 10.1016/j.physleta.2012.01.010

75. SCOTT BLAIR, G. Relativity and Indeterminacy. *Nature* **170,** 582 (1952). https://doi.org/10.1038/170582a0

76. Hines, C. Relativity and Indeterminacy. *Nature* **170,** 582 (1952). https://doi.org/10.1038/170582a0

77. Mayantz, L. The enigma of probability in physics https://inis.iaea.org/search/search.aspx?orig_q=RN:18074404

78. Mayantz, L Beyond the quantum paradox, Taylor & Francis (1994)

79. Medvedev, S. Yu. Superluminal Velocities in the Synchronized Space-Time Progress in Physics, vol. 10, 151 (2014) http://www.ptep-online.com/2014/P04.PDF

80. Del Santo, F. Gisin, N. The relativity of indeterminacy http://philsci-archive.pitt.edu/id/eprint/18601 (2021)

81. Fleming, A. Matveev, V. Matvejev , O. https://www.researchgate.net/publication/264851293_Self-field_Theory_and_General_Physical_Uncertainty_Relations

82. Hill, J. Cox, B. Proc. Einstein's special relativity beyond the speed of light Royal Soc. A (2012) https://doi.org/10.1098/rspa.2012.0340

83. Leubner, C. Aufinger, K. Krumm, P. Elementary relativity with 'everyday' clock synchronization Eur. J. Phys. 13, 170 (1992) https://iopscience.iop.org/article/10.1088/0143-0807/13/4/004/meta

84. Drągowski, M., Włodarczyk, M. The Doppler Effect and the Anisotropy of the Speed of Light. *Found Phys* **50,** 429–440 (2020). https://doi.org/10.1007/s10701-020-00337-5

85. Ronald Anderson, S.J., Stedman, G.E. Distance and the conventionality of simultaneity in special relativity. *Found Phys Lett* **5,** 199–220 (1992). https://doi.org/10.1007/BF00692800

86. Thyssen, P. Conventionality and Reality. *Found Phys* **49**, 1336–1354 (2019). https://doi.org/10.1007/s10701-019-00294-8

87. Luigi Maxmilian Caligiuri, Alfonso Nastro https://www.researchgate.net/publication/270105253_About_the_conventionality_of_simultaneity_and_Synchronization

88. de Abreu, R. Simultaneity and Synchronization by Rods as a Simple Geometry Problem https://vixra.org/abs/2103.0196

89. de Abreu, R. Simultaneity and Synchronization, The Preferred Frame and The Principle of Relativity https://vixra.org/abs/2204.0060

90. de Abreu, R. Comment on “Criticism of the Twin Paradox” by Luís Dias Ferreira https://vixra.org/abs/2107.0077

91. de Abreu, R. Comment on “Has the Twin Paradox Really Been Resolved” https://vixra.org/abs/2209.0045

92. de Abreu, R. Proper Times, Time Dilation, Lorentz-FitzGerald Contraction and Distance, Time Ageing, Time Dilation-like and the Twin Paradox Conundrum https://vixra.org/abs/2301.0029

93. de Abreu, R. The Time Dilation Conundrum and the Ageing of the Twins https://vixra.org/abs/2301.0086

94. de Abreu, R. The Relativity Principle and the Indetermination of Special Relativity https://vixra.org/abs/2301.0139

95. Ricou, M. On the speed of light https://www.researchgate.net/publication/312303056_On_the_speed_of_light