STR Test Theories

Dr. Adrian Sfarti

A STR test theory is a generalization of the Lorentz transforms using additional parameters. One can then analyze experiments using the test theory instead of STR and fit the parameters of the test theory to the experimental results. If the fitted parameter values differ significantly from the values corresponding to STR, then the experiment is inconsistent with STR. But more normally, such fits can show how well a given experiment confirms or disagrees with STR and what is its experimental accuracy. This gives a general and tractable method of analysis which can be common to multiple experiments.

Different test theories differ in their assumptions about the form of the Lorentz transforms. There are at present three test theories of STR[1,2,3]

Robertson showed that one can unambiguously deduce the Lorentz transform of STR to an accuracy of ~0.1% from the following three necessary and sufficient experiments: Michelson and Morley, Kennedy and Thorndike, Ives and Stilwell.

Zhang[4] discusses the interrelationships and presents a unified test theory encompassing the other three, with a better and more interpretable parameterization. His discussion implies that there will be no more test theories of STR that are not reducible to one of the first three. He named this theory RMS. Zhang also showed that modern experiments determine the Lorentz transforms coefficients to within a few parts per million.

These test theories can also be used to examine potential alternate theories to STR - such alternate theories predict particular values of the parameters of the test theory, which can easily be compared to values determined by experiments analyzed with the test theory. The existing experiments put rather strong experimental constraints on any alternative theory. In particular, Zhang showed that these experimental limits essentially require that any theory based upon the existence of an ether be experimentally indistinguishable from STR and have an ether frame which is unobservable (the only alternative is for a theory to "live in the error bars" of the experiments, which is quite difficult given the high accuracies achieved by many of these experiments).

RMS starts by admitting by reduction to absurd that there is a preferential inertial frame Σ in which the light propagates isotropically with the speed c_0. All other frames in motion with respect to Σ are considered non-preferential. Let S be such a frame. If at t=0 a beam of light is emitted in Σ and if S moves with the speed v with respect to Σ and if v makes the angle θ with respect to the direction of the light beam then RMS assumes that S measures for light the speed c, where :

$$c(\theta,v)=c_0(1+A\frac{v^2}{{c_0}^2}\sin^2\theta+B\frac{v^2}{{c_0}^2})$$

Parameter A is a measure of light speed isotropy and is generally measured through a Michelson-Morley class of experiments. These experiments verify light speed isotropy. Parameter A has been tested by [5,6,7,8,9,10,11] to be less than $3*10^{-15}$

Parameter B is a measure of light speed invariance relative to the speed of the emitter/receiver and it is generally measured through Kennedy-Thorndike experiments. These experiments verify light speed invariance with the movement of the emitter/observer. Parameter B has been tested by [12.13.14] to be less than $2*10^{-13}$. STR predicts A=B=0 and the experimental asymptotical limits for both A and B under STR are indeed zero.

Non STR theories have non zero values for A and B. An example of such theory is the emissive theory[15]. Any supporter of such theories needs to reconcile the theoretical values predicted for A and B with the experimental values. In other words, any proponent of a theory competing with STR must pass the RMS test.

References

[1] Robertson,Rev. of Mod. Phys. **21**, p378 (1949).

[2] Edwards, Am. J. Phys. **31** (1963), p482

[3] Mansouri and Sexl, Gen. Rel. Grav. **8** (1977), p497, p515, p809.

[4] Zhang, Special Relativity and its Experimental Foundations.

[5] H. Müller, S. Herrmann, C. Braxmaier, S. Schiller, and A. Peters, *"Modern Michelson-Morley experiment using cryogenic optical resonators"*, Phys. Rev. Lett. **91**, 020401 (2003).

[6] H. Müller, S. Herrmann, C. Braxmaier, S. Schiller, and A.Peters: *"Theory and technology for a modern Michelson-Morley Test of Special Relativity"*, invited paper in preparation for Appl. Phys. B (2003).

[7] H. Müller, S. Herrmann, T. Schuldt, M. Scholz, E. Kovalchuk, and A. Peters, *"Offset compensation by amplitude modulated sidebands in optical frequency standards"*, Opt. Lett. in press.

[8] H. Müller, C. Braxmaier, S. Herrmann, O. Pradl, C. Lämmerzahl, J. Mlynek, S. Schiller, and A. Peters: *"Testing the foundations of relativity using cryogenic optical resonators"*, Int. J. Mod. Phys. D, **11**, 1101-1108 (2002).

[9] H. Müller, C. Braxmaier, S. Herrmann, A. Peters, and C. Lämmerzahl: *"Electromagnetic cavities and Lorentz invariance violation"*, hep-ph/0212289, Phys. Rev. D **67**, 056006 (2003).

[10] A. Brillet and J.L. Hall, *"Improved Laser Test of the Isotropy of Space"*, Phys. Rev. Lett. **42**, 549 (1979).

[11] J.A. Lipa et al., *"New Limit on Signals of Lorentz Violation in Electrodynamics"*, Phys. Rev. Lett. **90** 060403 (2003).

[12] C. Braxmaier, H. Müller, O. Pradl, J. Mlynek, A. Peters, S. Schiller, *"Test of Relativity using a cryogenic optical resonator"*, Phys. Rev. Lett. **88**, 010401 (2002).

[13] D. Hils and J.L. Hall, *"Improved Kennedy-Thorndike Experiment to Test Special Relativity"*, Phys. Rev. Lett **64**, 1697 (1990).

[14] P. Wolf et al., *"Test of relativity using a microwave resonator"*, Phys. Rev. Lett. **90** 060402 (2003)

[15] Principles of Emission Theory . A.A.Cyrenika , APEIRON vol7, January-April 2000 , http://redshift.vif.com/JournalFiles/Pre2001/V07NO1PDF/V07N1CYR.pdf