

Experimental Test Theories for STR: Part 1

The Ives-Stilwell Experiment

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Abstract

Alternative explanations to STR exist and continue to be produced. In order for such theories to be accepted they need to coincide with experimental data. While it is easy to explain the Michelson Morley or the Sagnac experiments, it is much more difficult and sometimes impossible to produce data coincident with the experiments in other cases. One of such cases is the well-known Ives-Stilwell experiment. For decades anti STR people have rallied around this experiment because of the (incorrect) belief that it disproves STR.

1. Experimental Verification

Let $\gamma = [1 - v^2/c^2]^{-1/2}$. The general form of the longitudinal Doppler effect, where the emitter path makes an angle θ with the line of sight is:

$$T_a = \gamma T_0 (1 - \beta \cos \theta) < \gamma T_0 \text{ for the approaching wavelength (blue shift)} \quad (5)$$

$$T_r = \gamma T_0 (1 + \beta \cos \theta) > \gamma T_0 \text{ for the receding wavelength (red shift)} \quad (6)$$

Ives and Stilwell were trying to measure the transverse Doppler red shift T_t that is superimposed over the longitudinal effect. They came up with a very clever scheme of separating the very small transverse effect from the much larger longitudinal effect.

Let δT_r be the total red shift of the receding wave and let δT_a be the total blue shift of the approaching wave. Then:

$$\delta T_r = (T_r - \gamma T_0) + T_t = \beta \gamma T_0 \cos \theta + T_t \quad (7)$$

$$\delta T_a = (\gamma T_0 - T_a) - T_t = \beta \gamma T_0 \cos \theta - T_t \quad (8)$$

Ives and Stilwell could measure on a spectrograph the quantities δT_r and δT_a . From (7) and (8) they obtained :

$$T_t = 1/2(\delta T_r - \delta T_a) \quad (9)$$

$$\text{By taking the sum : } \delta T_r + \delta T_a = 2\beta \gamma T_0 \cos \theta \quad (10)$$

Ives and Stilwell calculated the speed v of the ions from:

$$\beta\gamma=(\delta T_r + \delta T_a)/(2T_0\cos\theta) \quad (11)$$

Arranging for θ to be very close to zero they obtained:

$$\frac{v/c}{\sqrt{1-v^2/c^2}} = \frac{\delta T_a + \delta T_r}{2T_0} \quad (12)$$

2. Observations

- Ives and Stilwell did their measurements at an angle θ very close to zero. There is no mention of any measurements at 90 degree angles (actually they did everything to avoid such an inconvenient angle).

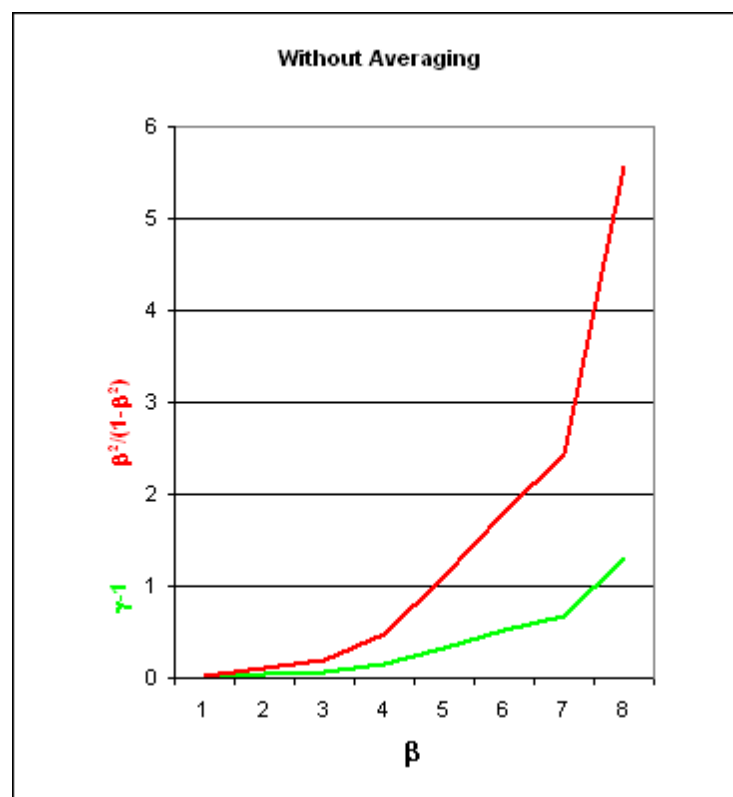
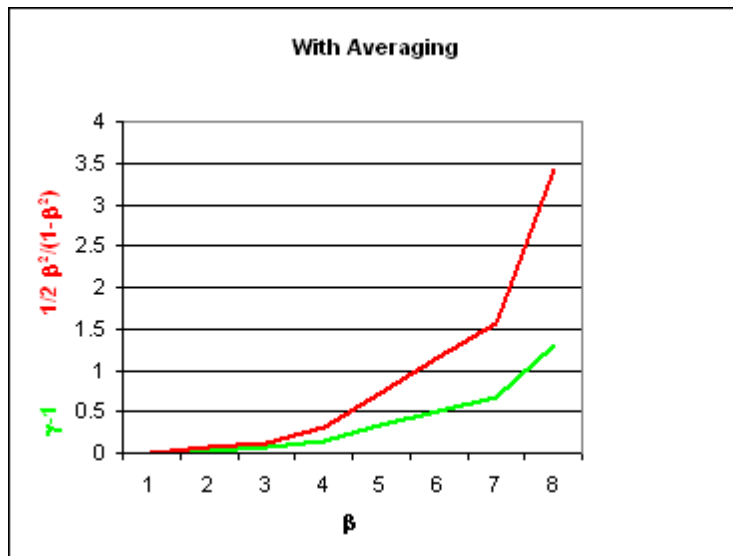
- It should be noted that other theories, like the "emission theory" predict¹ totally different expressions from (3) for the Doppler shift and as such they disagree with the results of the Ives and Stilwell experiment. By contrast, STR has been verified to agree within 10^{-9} with the modern time dilation experiments^{2,3}. At very high values of v the emission theory based explanations start failing very badly as seen in the two seen graphs below:

With "averaging"

$\beta=v/c$	$\gamma=1/\sqrt{1-\beta^2}$	$\gamma-1$	$1/2 \beta^2/(1-\beta^2)$	Error(%)
0.1	1.005037815	0.005037815	0.005050505	0.251890763
0.25	1.032795559	0.032795559	0.033333333	1.639777949
0.3333	1.060646914	0.060646914	0.062485939	3.032345722
0.5	1.154700538	0.154700538	0.166666667	7.735026919
0.66	1.33108717	0.33108717	0.385896527	16.55435851
0.75	1.511857892	0.511857892	0.642857143	25.5928946
0.8	1.666666667	0.666666667	0.888888889	33.33333333
0.9	2.294157339	1.294157339	2.131578947	64.70786694

Without "averaging"

$\beta=v/c$	$\gamma=1/\sqrt{1-\beta^2}$	$\gamma-1$	$\beta^2/(1-\beta^2)$	Error(%)
0.1	1.005037815	0.005037815	0.01010101	100.5037815
0.25	1.032795559	0.032795559	0.066666667	103.2795559
0.3333	1.060646914	0.060646914	0.124971877	106.0646914
0.5	1.154700538	0.154700538	0.333333333	115.4700538
0.66	1.33108717	0.33108717	0.771793055	133.108717
0.75	1.511857892	0.511857892	1.285714286	151.1857892
0.8	1.666666667	0.666666667	1.777777778	166.6666667
0.9	2.294157339	1.294157339	4.263157895	229.4157339



3. Conclusions

While STR predictions coincide with the experimental data, neither the Newtonian nor the “emission” theories agree with the Ives-Stilwell results.

4. References

1. Principles of Emission Theory . A.A.Cyrenika , APEIRON vol7, January-April 2000 , <http://redshift.vif.com/JournalFiles/Pre2001/V07NO1PDF/V07N1CYR.pdf>
2. New Methods for Testing Lorentz Violations in Electrodynamics, <http://arxiv.org/ftp/hep-ph/papers/0408/0408006.pdf>
3. [G. Saathoff *et al.*, Phys. Rev. Lett. **91**, 190403 \(2003\)](#)