A Relativistic Newtonian Mechanics Predicts with Precision the Results of Recent Neutrino-Velocity Experiments

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Abstract

The research on quasi-luminal neutrinos has sparked several experimental studies for testing the "speed of light limit" hypothesis. Until today, the overall evidence favors the "null" hypothesis, stating that there is no significant difference between the observed velocities of light and neutrinos. Despite numerous theoretical models proposed to explain the neutrinos behavior, no attempt has been undertaken to predict the experimentally produced $\frac{v-c}{c}$ results. This paper presents a simple novel extension of Newton's mechanics to the domain of relativistic velocities. For a typical neutrino-velocity experiment, the proposed model is utilized to derive a general expression for $\frac{v-c}{c}$. Comparison of the model's prediction with results of six neutrino-velocity experiments, conducted by five collaborations, reveals that the model predicts ***all*** the reported results with striking accuracy. Because in the proposed model, the direction of the neutrino flight matters, the model's impressive success in accounting for all the tested data, indicates a *complete collapse* of the Lorentz symmetry principle in stringent tests involving quasi-luminal particles, moving in two opposite directions. This conclusion is support by previous studies on the linear Sagnac effect, indicating that the travel-time difference between two counter-propagating light beams, relative to a uniformly moving fiber, is identical one detected in radial motion.

Keywords: Neutrino velocity, OPERA, MINOS, ICARUS, LVD, Borexino, Linear Sagnac effect.

1. Introduction

In 2011 the OPERA collaboration at CERN announced that neutrinos have travelled faster than light [1]. The reported anticipation time was 60.7 ±6.9 (stat.)± 7.4 (sys.) ns and the relative neutrino velocity was $\frac{v-c}{c}$ = (5.1 ±2.9) $\times 10^{-5}$. The excitement that swept physicists and laymen concerning the possibility that a new era is "knocking on physics doors", waned a few months later, after OPERA reported the discovery of hardware malfunctions in the GPS system, which resulted in a critical measurement error. After accounting for the error, the anticipation time was only (2.7 ± 3.1 $(\text{stat.}) + {}^{+3.8}_{-2.8}$ (sys.)) $\times 10^{-6}$, with corresponding $\frac{v-c}{c}$ = 2.67 x 10^{-6} [2]. Since then, the "null" result has been replicated by OPERA and by several collaborations, including ICARUS, LVD and Borexino [3-6]. The only "faster than light" result, which I am aware of, was reported in 2007 by MINOS collaboration [7], who reported an early anticipation time of 126 ± 32 (stat.) ± 64 (sys.) ns (C.L. = 68%), with corresponding $\frac{v-c}{c}$ = 5.1±2.9 (stat.+sys.)$\times 10^{-5}$. However, the high statistical and system errors, reported by MINOS, impede the validity of the above quoted result.

Notably, despite the vast body of theoretical research on the topic [e.g., 8-15], no attempt has been undertaken to produce a point prediction of the $\frac{v-c}{c}$ results reported by OPERA, and by other collaborations, who replicated the "null" result.

In the present paper I demonstrate that a simple relativistic extension of Newtonian mechanics, predicts with precision, the results reported by OPERA, MINOS, ICARUS, LVD and Borexino collaborations. The following section gives a brief account of the proposed model. Section 3 details the derivation of the model's $\frac{v-c}{c}$ term, for a typical neutrino velocity experiment, and contrasts the theoretical prediction with the findings of six neutrino velocity experiments. Section 4 summarizes and concludes.

2. **A Newtonian Relativistic Model**

The proposed model is a relativistic extension to Newtonian mechanics, termed Newtonian relativity. The model posits that at sufficiently low (non-relativistic) velocities, the laws of physics, in all internal frames, reduce to the classical laws of Galileo-Newton mechanics. To derive the term for the relativistic time, consider two observers who synchronize their watches just before one of them starts to move in +*x* direction with constant velocity *v*. Assume that a certain event started exactly at the time of departure ($t = t' = 0$). Suppose the event ended when the moving frame was at distance $x = d$ (in the rest frame of the "staying" observer). If the "moving" observer sends a signal to indicate the termination of the event, the signal will arrive at the "staying" observer after time dilation of $\Delta t = \frac{d}{c}$, where c is the velocity of the wave signal relative to "staying" observer. Thus we can write:

$$t = t' + \Delta t = t' + \frac{d}{c} \qquad \text{...... (1)}$$

But $d = v\,t$, where v is the velocity of the "moving" frame relative to the "stationary" frame. Substitution the value of d in Eq. 1 yields:

$$t = t' + \frac{v\,t}{c} = t' + \beta t \qquad \text{...... (2)}$$

Where $\beta = \frac{v}{c}$.

Or:

$$\frac{t}{t'} = \frac{1}{1-\beta} \qquad \text{...... (3)}$$

Note that eq. (3) is similar to the Doppler formula, except that the Doppler Effect describes frequency shifts of waves propagating from a departing or approaching wave source, whereas the result above describes the time "shifts" of moving bodies. For two frames that depart from each other $\beta > 0$, and thus $\frac{1}{1-\beta}$ is larger than one, implying a *time dilation* (comparable to redshift), whereas for two frames which approach each other, $\beta < 0$, and thus $\frac{1}{1-\beta}$ is smaller than one, implying a *time contraction* (comparable to blue-shift).

3. Prediction of $\frac{v-c}{c}$ for a typical neutrino-velocity experiment.

In a typical neutrino-velocity experiment, neutrinos travel a distance $d \approx 730$ km in matter, with one of the highest relativistic γ factors ever artificially produced, allowing the emergence of significant relativistic effects. A typical neutrino velocity experiment includes *three* frames: The neutrino frame F, the source frame F', and the detector frame F''. F is *departing* from F' with velocity v and *approaching* F'' with velocity $-v$. F' and F'' are at rest relative to each other. Using Eq. 3 we can write:

$$\Delta t_S = \frac{\Delta t}{1-\frac{v}{c}} \qquad \text{...... (4)}$$

And

$$\Delta t_D = \frac{\Delta t}{1-\frac{-v}{c}} = \frac{\Delta t}{1+\frac{v}{c}} \qquad \text{...... (5)}$$

Where , v is the neutrino velocity, c is the velocity of light. Δt, Δt_S, and Δt_D are the times, as measured in frames F (neutrino rest-frame), F' (source), and F'' (detector), respectively.

The neutrino time of flight tof_v (=, where d is the distance of travel), is equal to difference between the times as measured in the detector and the source, or:

$$tof_v = \frac{d}{v} = \frac{\Delta t}{1+\frac{v}{c}} - \frac{\Delta t}{1-\frac{v}{c}} = - \frac{2\frac{v}{c}}{1-(\frac{v}{c})^2} \qquad \text{…. (6)}$$

For an *early* neutrino arrival time, δt, with respect to the velocity of light, we can write:

$$\frac{d}{c} - \delta t = tof_v = - \frac{2\frac{v}{c}}{1-(\frac{v}{c})^2}\frac{d}{v} \qquad \text{….. (7)}$$

Solving for $\frac{v}{c}$ yields:

$$\frac{v}{c} = (\frac{2}{1-\frac{c\,\delta t}{d}} - 1)^{\frac{1}{2}} \qquad \text{…. (8)}$$

Or:

$$\frac{v-c}{c} = \sqrt[2]{\frac{2}{1-\frac{c\,\delta t}{d}} - 1} - 1 \qquad \text{…. (9)}$$

For the OPERA *corrected* result [2], d = 730.085 km and δt = (6.5 ± 7.4 (stat.) $\pm^{+9.2}_{-6.8}$ $(sys.)$) ns. Substituting in Eq. 10, we get:

$$\frac{v-c}{c} = (\frac{2}{1-\frac{299792.458 \, x \, 6.5 \, x \, 10^{-9}}{730.085}} - 1)^{\frac{1}{2}} - 1 \approx -2.67 \text{ x } 10^{-6} \qquad \text{…. (10)}$$

Which is almost identical to the reported result of $\frac{v-c}{c}$ $(Exp.)$ = (2.7 ± 3.1 $(stat.)$ $\pm^{+3.8}_{-2.8}$ (sys.))×10^{-6}. Applying Eq. 9 to five others experiments, conducted by MINOS, OPERA, ICARUS, LVD, and Borixeno collaborations, yields the results summarized in Table 1. As shown in the table, the mode yields precise predictions for ***all*** the tested experiments.

Table 1

Predictions of Complete Relativity (without the Lorentz Invariance)

Experiment	**Experimental** $\frac{v-c}{c}$	**Predicted** $\frac{v-c}{c}$
MINOS 2007 [7]	(5.1±2.9))(stat) $\times 10^{-5}$	5.14 10^{-5}
OPERA 2012 (corrected result) [2]	$(2.7 \pm 3.1\ (\text{stat.}) + ^{+3.8}_{-2.8}$ (sys.)) $\times 10^{-6}$	2.67 x 10^{-6}
OPERA 2013 [3]	(- $0.7 \pm 0.5\ (\text{stat.}) + ^{+2.5}_{-1.5}$ (sys.)) $\times 10^{-6}$	- 0.66 x 10^{-6}
ICARUS 2012 [4]	(0.4 ± 2.8(stat.) ± 9.8 (sys.)) $\times 10^{-7}$	0.41 x 10^{-7}
LVD [5]	(1.2 ± 2.5(stat.) ± 13.2 (sys.)) $\times 10^{-7}$	1.23 x 10^{-7}
Borexino [6]	(3.3 ± 2.9(stat.) ± 11.9 (sys.)) $\times 10^{-7}$	3.28 x 10^{-7}

4. Summary and concluding remarks

The present paper demonstrates that a simple, straightforward extension of Newton's mechanics, to the domain of relativistic velocities, is successful in producing strikingly accurate predictions of six experimental $\frac{v-c}{c}$ results, reported by five collaborations. Because in the proposed model, the direction of the neutrino flight matters, the model's impressive success in accounting for all the tested data, indicates a *complete collapse* of the Lorentz symmetry principle in stringent tests involving quasi-luminal particles, moving in two opposite directions. This conclusion is support by the findings of several studies on the linear Sagnac effect [e.g., 16-19], indicating that the travel-time difference between two counter-propagating light beams, relative to a uniformly moving fiber segment, is identical to the time difference detected for an equal segment length in a radial motion.

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