Possible Evidence for Weak Violation of Special Relativity

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Possible relativity-violating effects, to be expected if the dynamic substratum (ether) interpretation of the observed Lorentz invariance, by Lorentz and Poincaré, should be true (instead of Einstein's kinematic interpretation), have been discussed by Atkins [1] and the author [2]. In the dynamic interpretation the Lorentz transformations result from the Lorentz-contraction, whereby the contraction is explained through the electromagnetic interaction of material objects with a substratum (ether). The time dilation follows there from the Lorentz-contraction, if all clocks behave like light clocks. A light clock consists of a rod with mirrors attached to both of its ends from which a light signal is reflected back and forth, and clocks consisting of solids held together by electromagnetic forces should behave like light clocks. Finally, if clocks are synchronized by reflected light signals, as it was done by Einstein in his formulation of the special theory of relativity, the Lorentz transformations can be derived solely from the contraction effect.

In Einstein's kinematic interpretation of special relativity, the Lorentz contraction is not a true physical effect suffered by a body, but rather results from a peculiar symmetry of space-time which finds its expression in the four-dimensional Minkowski space. In contrast, in the dynamic interpretation by Lorentz and Poincaré, the Lorentz contraction is a true physical deformation of a material body. However, a true contraction (or expansion), and likewise clock retardation (or acceleration) takes there only place through a change in the absolute velocity, requiring a change in state through a true acceleration. Contractions or time dilations which are observed through a change in the relative velocity by an accelerated motion of the observer are there explained as an illusion caused by a true Lorentz contraction (or expansion) of the observer. In this alternative interpretation, where special relativity is interpreted as an illusion caused by true physical deformations, the contraction must take a finite time. This therefore opens the possibility for the existence of nonadiabatic relativity-violating effects. However, because of the kinematic restrictions of special relativity, relativity-violating effects if they exist, can only be observed in a superposition of translational and rotational motion. Atkins has discussed the case where the Lorentz contraction takes place through compression waves. There the expected relativity-violating effects are very small. If instead the contraction takes place through bending waves, the case discussed by the author, a resonance can be reached and where the relativity-violating effect would become quite large.

Atkins suggests that there may be a relativity-violating effect for the rotating earth, assuming it moves with a finite velocity through a substratum. The result of his calculation, and for which he used the sidereal tide observed by Warburton and Goodkind with a superconducting gravimeter [3], does not agree with the plausible hypothesis that the presumed substratum is at rest relative to the cosmic microwave background radiation. This is in contrast to our calculation which shows a rough agreement in support of this hypothesis. According to Warburton and Goodkind, there is a sidereal tide with a maximum amplitude in a periodic variation of g, which is

$$|\Delta g/g|_{\max} \simeq 7 \times 10^{-11}. \tag{1}$$

The presumed relativity-violating effect is expressed through a change in lengths:

$$\delta l/l \simeq (v/c)^2 (\omega/\omega_E)^2 , \tag{2}$$

where $v/c \simeq 10^{-3}$, for a velocity of $v \simeq 300$ km/sec against the substratum. In (2) one would have to put $\omega = 2\pi/T$ ($T = 1$ day = 86 400 seconds) and $\omega_E \simeq 1.95 \times 10^{-3}\,\text{sec}^{-1}$, obtained from seismological data for the ${}_0S_2$ deformation [4]. $\delta l/l$ is related to the excentricity e of the deformed earth by

$$\delta l/l \simeq -e^2/2 , \tag{3}$$

and $\Delta g/g$ to e by [5]

$$\Delta g/g \simeq (e^2/30)(1 - 3\sin^2\theta) , \tag{4}$$

where θ is measured from the equator of the deformation spheroid. Because the microwave radiation intersects the earth axis under approximately 90°, and because the measurement was carried out at a geographical latitude of 34°, one has to put $\theta = 90° - 34° = 56°$. One therefore finds

$$|\Delta g/g|_{\max} \simeq (1/15)(v/c)^2 (\omega/\omega_E)^2 \simeq 9 \times 10^{-11} \tag{5}$$

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in rough agreement with the observed value (1). The phase of the observed sidereal tide is also in fair agreement with the microwave data. A better agreement can hardly be expected since the data from a superconducting gravimeter positioned at one fixed location can only provide two independent quantities, instead of the three needed to determine the vector of the substratum velocity.

Because of the fundamental importance of the question regarding the existence of nonadiabatic relativity-violating effects, other tests are highly desirable. Apart from experiments with bending waves, where a resonance could in principle be reached, atomic physic tests might be another possibility. An electron orbit with a nonzero angular momentum should also be subject to relativity-violating effects, whereby the Lorentz contraction of the electric field, holding the electron in its orbit, should go with the velocity of light. For hydrogen-like atoms with $Z = 1$, this could result in shift of the energy levels, of the order ($\alpha = 1/137$):

$$|\delta\varepsilon/\varepsilon| \simeq (v/c)^2 (\alpha/\pi)^2 \simeq 5 \times 10^{-12} . \quad (6)$$

It would show up as an energy difference under different orientations of the orbital axis of rotation relative to the direction of the substratum velocity. The effect would be of comparable smallness as the effects observed in experiments demonstrating parity-violation through the electroweak interaction (1 eV versus 300 GeV, that is small by the order 3×10^{-12}). Even though a predicted relativity-violating effect would not be parity-violating, it would act like a force which does not conserve angular momentum. This therefore raises the question if the discrepancies reported in these experiments could have their cause in a weak violation of special relativity.

For atoms with $Z > 1$ one could even reach a resonance at which relativity-violating effects would become very large, provided one could make $Z > 137\,\pi$, something which unfortunately is only possible with superheavy elements.

One of the most precise experiments quoted in support of special relativity has been done by Forston et al. [6]. It involves nuclear magnetic resonance, and its accuracy implies that a relativity-violating effect should be smaller than $\delta\varepsilon \simeq 2 \times 10^{-21}$ eV. The precession frequency in this experiment was of the order $\omega \simeq 10\,\text{sec}^{-1}$. The nuclear frequency is of the order $\omega_0 \simeq 0.1\, c/R$, where $R \simeq 10^{-12}$ cm is the nuclear radius. With these values the nonadiabatic, relativity-violating energy shift would be

$$|\delta\varepsilon/\varepsilon| \simeq (v/c)^2 (\omega/\omega_0)^2 \simeq 10^{-46} . \quad (7)$$

With $\varepsilon \sim 10^6$ eV, which is typical for a nucleus one finds $\delta\varepsilon \simeq 10^{-40}$ eV. The value is very much smaller than the lower limit of $\delta\varepsilon \simeq 2 \times 10^{-21}$ eV in the above quoted experiment. In spite of its great accuracy this experiment is therefore unsuitable to detect nonadiabatic relativity-violating effects.

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