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Observation of a DC Voltage Induced by a Steady Magnetic Field: A Possible Electromagnetic Breakdown of Lorentz Invariance?

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Abstract

A recently proposed electromagnetic test of the breakdown of local Lorentz invariance, based on the detection of a nonzero force between a circular stationary current and a charge (both at rest in the Earth frame), has provided positive evidence for such an effect. We analyze in detail the experimental results obtained, together with their implications. Possible theoretical interpretations are briefly discussed. It is shown that the corresponding values found for the parameters of Lorentz invariance violation are consistent with the existing upper limits.

Key words: special relativity, local Lorentz invariance, electrodynamics, parameters of violation of LLI

1. INTRODUCTION

It is a long-debated problem whether local Lorentz invariance (LLI) preserves its validity at any length or energy scale (far enough from the Planck scale, when quantum fluctuations are expected to come into play). Doubts on the reliability of a Lorentz-invariant description of physical phenomena at subnuclear distances were put forward, in the mid-sixties, even in standard (and renowned) textbooks.(1) Early theoretical speculations on a possible breakdown of LLI, and its experimental consequences, are due, e.g., to Bjorken,(2) Blokhintsev,(3) Redei,(4) and Phillips.(5)

In the next years, the issue was faced from a different (more basic) point of view, namely by questioning the very foundations and formalism of special relativity (SR). For instance, in the early seventies it was pointed out by Recami and one of the present authors (R.M.)(6) that (i) a correct use of the relativity principle requires specifying the class of physical phenomena to which it applies; (ii) *a priori*, for each different class of phenomena considered, a different *formal* (and therefore *mathematical*) formulation of SR is expected to hold (in particular, the *usual* SR is expected to be strictly valid only for processes ruled by electromagnetic interaction); (iii) *different* invariant speeds correspond, in general, to the different formulations of SR.(6)

Among the most serious attempts at a generalization of the SR mathematical formalism (i.e., the structure of Minkowski space), more or less based on the above critical analysis, let us quote the anisotropic theory of Bogoslovsky(7) (based on a Finslerian metric(8)), and the "isotopic" SR.(9) Moreover, a (constant) non-Minkowskian metric was introduced on a phenomenological basis, for weak interactions, by Nielsen and Picek.(10)

Recently, some authors(11) developed a perturbative framework to deal with the observable implications of tiny departures from LLI, and carried out a thorough analysis of possible Lorentz-violating mechanisms within the framework of the standard model. It has also been proposed that such small departures from LLI can affect particle kinematics in such a way as to remove the cosmological Greisen– Zatsepin–Kuz'min (GZK) cutoff.(12),1 The problem of violation of LLI and PCT by Chern–Simons terms was also considered.(13) Both approaches put stringent limits on such effects.

From the experimental side, the main tests of LLI can be roughly divided into three groups:(14)

(a) Michelson–Morley (MM) type experiments, aimed at testing the isotropy of the round-trip speed of light;
(b) tests of the isotropy of the one-way speed of light (based on atomic spectroscopy and atomic timekeeping);
(c) Hughes–Drever (HD) type experiments, testing the isotropy of nuclear energy levels.

All such experiments put stringent upper limits on the degree of violation of LLI.

Recently, we proposed a generalization of SR based on a "deformation" of space-time, assumed to be endowed with a metric whose coefficients depend on the energy of the process considered.(15–17) Such a formalism (*deformed special relativity* (DSR)) applies in principle to *all* four interactions (electromagnetic, weak, strong, and gravitational)2—at least as far as their nonlocal, nonpotential part is concerned—and provides a metric representation of them (at least for the process and in the energy range considered).(16,17,18–21) DSR predicts, among other things, different maximal causal (i.e., maximum attainable) speeds for different interactions and/or different systems, in agreement with the analysis of Ref. 6 and the results of Ref. 11. Moreover, it was shown that such a formalism is actually a five-dimensional one, in the