Testing Lorentz symmetry with Microscope

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Abstract

Lorentz symmetry is a foundational assumption of both of our current best theories of physics: General Relativity and the Standard Model of particle physics. At the heart of Lorentz symmetry is the Principle of Relativity, which postulates that experimental results do not depend on the orientation of the laboratory (rotation invariance) or its velocity through space (boost invariance). A fundamental motivation for testing Lorentz symmetry is to participate in the search for new physics at the Planck scale [1], which can lead to suppressed deviations from known physics also at low energy scales.
A comprehensive framework for analyzing tests of Lorentz invariance is given by the Standard Model Extension (SME) [2,3]. Lorentz violating terms are constructed from the Standard Model and General Relativity fields along with coefficients for Lorentz violation that control the amount of Lorentz violation in the theory. Analysis of Lorentz invariance and of equivalence principle tests in the SME framework permits quantitative comparisons among experiments, and allows for more complex scenarios than e.g. a simple "yes-no" violation of the Weak Equivalence Principle.

The possibility of particle-species dependent coefficients for Lorentz violation in the gravitationally coupled matter sector of SME lead naturally to violations of the Weak Equivalence Principle, that vary at the characteristic frequencies associated with Lorentz violation: the frequencies (and their harmonics) with which the boost and orientation of the experiment change [4]. The model for the MICROSCOPE differential acceleration in the presence of SME coefficients for Lorentz violation has been calculated in detail. Thanks to the spinning mode in MICROSCOPE, new frequencies appear, which help to provide independent constraints on the coefficients involved.

The prospects for improved sensitivity to SME coefficients for Lorentz violation via an analysis of MICROSCOPE data are excellent. Based on existing constraints on coefficients [5] and the sensitivity estimates obtained for MICROSCOPE [4], the analysis could improve the sensitivities to certain combinations of coefficients by up to 3 orders of magnitude over

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existing published limits.

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