Quantum satellites and tests of relativity

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Abstract

Satellite missions for secure quantum communications and ultra-precise time-keeping are now becoming reality. They also provide opportunities for new tests of fundamental physics. Ability to perform sensitive optical interferometry, s one of the key performance characteristic of such missions. It makes possible a new class of tests of the equivalence principle. Einstein equivalence principle (EEP) --- the foundation of general relativity and all other metric theories of gravity --- is comprised of three elements. Its final component is the local position invariance (LPI), and one of its aspects is demonstrated by measuring the gravitational red shift. Violation of the LPI is characterized by the parameter α that in all metric theories equals to 1. Usual searches for violation of LPI are focused on the matter sector, assuming that light travels in the usual way. We propose an interferometric test that deals exclusively with light. The main obstacle to its implementation is the first-order Doppler Effect that dominates the parameters of interest. Our design allows to eliminate this problem and potentially opens a way for all-optical tests that will put tighter bound on α-1. Universality of free fall --- the first component of the EEP is potentially challenged by spin-gravity effects. We describe the accepted and more controversial inertial and gravitational spin effects, proposals for their measurement via optical magnetometry (and weak measurements), and their potential effects on the performance of the satellite-based array of atomic clocks.