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Verification of the gravitational interaction in the field of the Earth with the LARASE and SaToR-G experiments

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The previous experiment LARASE (LAser RAnged Satellite Experiment, 2013-2019) and the current experiment SaToR-G (Satellite Test of Relativistic Gravity, 2020-2024) – both funded by the National Scientific Committee 2 (CSN2) of the National Institute for Nuclear Physics (INFN) – have so far allowed to obtain a series of significant results in the study of the gravitational interaction in the so-called weak-field and slow-motion (WFSM) limit of General Relativity (GR) in its linearized form.
In the WFSM limit of the theory, Einstein's equations reduce to a form quite similar to those of electromagnetism, with a gravitoelectric field produced by masses, analogous to the electric field produced by charges, and a gravitomagnetic field produced by mass currents, analogous to the magnetic field produced by electric currents.
These two fields are at the origin of two non-classical precessions of the orbit of an artificial satellite. The first precession is due to the mass of the Earth, and it is known as Schwarzschild's or Einstein's precession of the orbit. This is a spin-independent secular precession. The second precession is due to the angular momentum (or spin) of the Earth, and it is known as the Einstein-Thirring-Lense secular precession of the orbit. The latter is a spin-orbit effect, also known as frame-dragging, as Einstein called it. This precession is related with intrinsic gravitomagnetism.
The LARASE and SaToR-G experiments focused on measuring these precessions using the geodetic satellites LAGEOS (NASA, 1976), LAGEOS II (ASI/NASA, 1990) and LARES (ASI, 2012) as test masses. These are passive satellites equipped with corner cube retroreflectors tracked by means of the powerful Satellite Laser Ranging technique. The main goal was to verify the motion of each test mass along a geodesic of spacetime by means of a very precise determination of their orbits. The challenge is represented by a reliable modeling of the main gravitational and non-gravitational perturbations (NGPs) acting on the considered satellites.
Indeed, both types of perturbations can have a negative impact in relativistic measurements. Mismodeling of gravitational perturbations, especially of the even zonal harmonic coefficients, can completely mask the tiny relativistic precessions due to GR because of their much larger classical precession of the orbit. Conversely, NGPs are very complicated to model and have a periodic impact in the orbital elements, with very long period perturbations superimposed on the relativistic precessions making their measurement extremely complicated.
The results achieved by the two experiments will be presented in the measurement of the main relativistic precessions in the orbits of the three satellites together with the consequent limits obtainable from these measurements for several theories of gravitation alternative to GR. These constraints may concern both metric theories of gravitation, such as scalar-tensor theories, and non-metric theories of gravitation, such as torsional theories. Finally, the prospects for future measurements of the gravitational interaction in the Earth field with laser-ranged satellites will be presented.

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