XXV SIGRAV Conference on General Relativity and Gravitation

Contribution ID: **37** Type: **not specified**

Tests of theories of gravitation in their weak-field and slow-motion limit with laser-tracked satellites

Friday, September 8, 2023 9:00 AM (1 hour)

The geodynamic satellites LAGEOS (NASA, 1976), LAGEOS II (ASI/NASA, 1992) and LARES (ASI, 2012) were taken as test masses and their motions were carefully studied and compared with that of a time-like geodesic of General Relativity (GR). This 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 GR. In this limit, 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 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, 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, 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, and it is related with intrinsic gravitomagnetism.
The precise and accurate measurement of these two precessions has not only allowed to verify the predictions of the GR but also to place significant constraints on the predictions of some alternative theories of gravitation. These theories may be both metric and non-metric in their consequences. A very interesting aspect in the verification of the gravitational interaction is represented by the possible existence of new long-range interactions. This kind of effect in gravitation has some importance since it cannot be interpreted within the standard Parametrized Post-Newtonian (PPN) formalism currently used in the WFSM limit of GR. Indeed, deviations of the gravitational potential from the Newtonian law would lead to new weak interactions between macroscopic objects that are predicted by several theories of gravity. For these theories, a Yukawa-like parameterization seems general at the lowest order of the interaction and in the non-relativistic limit, independently of the nature of the new field that contributes to mediate the gravitational interaction, that is, of a possible scalar, vector or tensor field.

As already underlined, the main goal is to verify the motion of each test mass along a geodesic of spacetime by means of a very precise determination of their orbits. In this regard, 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 the 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.

Some of these activities were carried out in a previous experiment called LARASE (LAser RAnged Satellite Experiment, 2013-2019), while others are currently performed in a new experiment called SaToR-G (Satellite Test of Relativistic Gravity), both funded by the National Scientific Committee 2 (CSN2) of the National Institute for Nuclear Physics (INFN).

The results achieved by the two experiments will be presented in the measurement of the main relativistic precessions in the orbits of the satellites together with the consequent limits obtained in several theories of gravitation alternative to GR. These constraints may concern metric theories of gravitation ⊠ such as scalar-tensor theories ⊠ and non-metric theories of gravitation ⊠ such as torsional theories. Finally, the prospects for ongoing and future measurements of the gravitational interaction in the field of the Earth with laser-ranged satellites will be presented.

Presenter: LUCCHESI, David (INFN Roma Tor Vergata; IAPS/INAF Tor Vergata)