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The key role of the Earth's gravitational field models in Fundamental Physics measurements with laser-ranged satellites

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During the last two decades significant improvements in the knowledge of the Earth's internal structure and of its time-dependent gravitational field have been reached thanks to dedicated space missions, such as CHAMP (Challenging Minisatellite Payload) and, especially, GRACE (Gravity Recovery and Climate Experiment) and GOCE (Gravity field and steady-state Ocean Circulation Explorer). In particular, the twin satellites of GRACE – with their inter-satellite Ka-band tracking plus their precise orbit determination (POD) via GPS and accelerometer measurements – and the gradiometric measurements of GOCE together with its GPS POD and accelerometer measurements have provided new insights not only in the physics of the solid Earth, but also in the movements of ice and water and, consequently, in oceanography and sea-level changes and, finally, gave fundamental contributions in climate research studies, geophysics and space geodesy. The great success of these missions in improving the knowledge of both the low- and medium-high degree and order of the Earth's gravitational field expansion in spherical harmonics clearly shows that the gravity variations can be very well determined and monitored from space. Therefore, the consequences of all these improvements are of fundamental importance in several fields of science and for civil applications.

Among the scientific applications, a very good knowledge of the Earth's gravitational field and of its time-dependency is very important to provide refined measurements of the gravitational interaction in its weak-field and slow-motion (WFSM) limit. This will help significantly to better test the predictions of Einstein's theory of general relativity (GR) and those of other theories of gravitation in this limit. Indeed, thanks to the cited improvements in the knowledge of the Earth's gravitational field, in addition to take into account the main even zonal harmonics of low degree (also considering their time evolution) – i.e. those that are responsible for a secular precession in the right ascension of the ascending node and on the argument of pericenter of an Earth-orbiting satellite – the time dependency of other harmonics (also of higher degrees) has to be considered in order to reach a 99% (or better) accuracy for some of these fundamental physics measurements.

In this talk, the results of the Laser Ranged Satellites Experiment (LARASE) will be shown regarding the modelling of the Earth's gravitational field for GR measurements in the WFSM limit of the theory. In this context, a main goal of LARASE is to improve the modelling of both the gravitational and non-gravitational perturbations on the LAGEOS, LAGEOS II and LARES satellites in such a way to further improve their POD to better extract, from their orbital residuals analyses, the expected tiny relativistic effects. On the basis of this modelling of the Earth's gravitational field, we will show our new results for a refined measurement of the Lense-Thirring precession on the combined orbits of the two LAGEOS satellites with that of LARES.