Measuring the Lense-Thirring precession of the orbits of laser-ranged satellites: state of the art and perspectives from the LARASE experiment

David M. Lucchesi on behalf of the LARASE collaboration.

MG15 - Session PT3 on Experimental Gravitation: invited talk

One hundred years ago, a collaboration between the astronomer and mathematician Josef Lense, and the physicist Hans Thirring, opened the experimental verification to one new, and very important, prediction of Einstein's novel theory of General Relativity: Gravitomagnetism. The problem was posed by Thirring in terms of the integration of the equations of motion of a test body into the field of a rotating mass by means of the perturbation theory, a branch of mathematical physics in which Lense was very expert. Their results were applied to the orbit of the planets and of their moons. Lense and Thirring pointed out that, in 1918, the new effects of Einstein's theory were too small to be measured accurately within the solar system [1].

Today, 100-yr after the original papers of Lense and Thirring, despite the improvements in the knowledge of the ephemerides of the orbits of planets and moons, the measurement of the Lense-Thirring effect, albeit noticeably improved, has not yet been achieved with sufficient accuracy in the solar system [2,3]. Conversely, more precise results have been obtained in the field of the Earth by means of measurements of the orbit of laser-ranged satellites [4-7]. However, for these measurements a refined and robust error budget, based on a reliable assessment of the systematic sources of error, it has not yet been fully achieved. In this context, we present the current results obtained by the LARASE experiment for the measurement of the Lense-Thirring precession on the combined orbits of the LAGEOS, LAGEOS II and LARES satellites.

The goals of the LAser RAnged Satellites Experiment (LARASE) are to provide precise and accurate measurements of the predictions of General Relativity in its weak-field and slow-motion limit. The test particles of LARASE are the above satellites, precisely tracked by means of the powerful Satellite Laser Ranging technique [8]. A peculiarity of LARASE is to develop new models to better manage the subtle effects that arise from the complex non-gravitational perturbations. After a description of the work performed to model the spin evolution of these satellites, and of the thermal effects due to the solar radiation pressure, we focus upon a recent precise and accurate measurement of the Lense-Thirring precession with the two LAGEOS and the LARES satellites. The details of the precise orbit determination of the satellites, the role of the unmodelled periodic effects and of the systematic errors related to the deviation from the spherical symmetry of the Earth's mass distribution will be discussed.

References

[1] Lense, J., Thirring, H. Über den Einfluss der Eigenrotation der Zentralkörper auf die Bewegung der Planeten und Monde nach der Einsteinschen Gravitationstheorie. Phys. Z., 19, 156, 1918.

[2] Iorio, L., Lichtenegger, H.I.M., Ruggiero, M.L., Corda, C., Phenomenology of the Lense-Thirring effect in the Solar System. Astrophysics and Space Science, Vol. 331, 2, 351–395, 2011

[3] Iorio, L., The Solar Lense-Thirring effect: perspectives for a future measurement. WSPC proceedings 2016. The Fourteenth Marcel Grossmann Meeting, 2017.

[4] Ciufolini, I., Pavlis, E.C., A confirmation of the general relativistic prediction of the Lense-Thirring effect, Nature 431, 958, 2004.

[5] Lucchesi, D.M., The Lense-Thirring effect measurement and LAGEOS satellites orbit analysis with the new gravity field model from the CHAMP mission. Adv. Space Res. 39(2), 324, 2007.

[6] Ciufolini, I., Paolozzi, A., Pavlis, E.C., Koenig, R., Ries, J., Gurzadyan, V., Matzner, R., Penrose, R., Sindoni, G., Paris, C., Khachatryan, H., Mirzoyan, S., A test of general relativity using the LARES and LAGEOS satellites and a GRACE Earth gravity model. Measurement of Earth's dragging of inertial frames, European Physical Journal C 76, 120, 2016.

[7] Lucchesi, D.M., Magnafico, C., Peron, R., Visco, M., Anselmo, L., Pardini, C., Bassan, M., Pucacco, G., Stanga, R., The LARASE research program. State of the art on Modelling and Measurements of General Relativity effects in the field of the Earth: a preliminary measurement of the Lense-Thirring effect. In 2017 IEEE International Workshop on Metrology for AeroSpace (MetroAeroSpace), pp. 131-145, 2017.

[8] Pearlman, M.R., Degnan, J.J. and Bosworth, J.M., The international laser ranging service. Adv. Space Res. 30, 135 (2002).