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GENERAL RELATIVITY TESTS WITH THE TWO LARES MISSIONS AND THE PROPOSED LARES 3 LUNAR SATELLITE

Abstract

With the launch of LARES and LARES 2 satellites of the Italian Space Agency, by the maiden flights of VEGA on Feb. 13, 2012 and of VEGA C on July 13, 2022, our scientific team was able to measure the tiny effect of General Relativity (GR) known as "frame-dragging" with unprecedented accuracy. This effect, first derived from the equations of GR by the physicists Lense and Thirring in 1918, is due to the dragging of spacetime, exerted by the rotating mass of Earth, that in turn causes a shift of the nodes of the orbital planes of the two satellites. This tiny displacement, that for LARES is about 110 milliarcsecond/year or 4 m/year at 1450 km altitude and for LARES 2 about 31 milliarcsec/year or 2 m/year at 5900 km altitude, has been measured with the LARES mission with an accuracy at the level of a millliarcsec (i.e. 1 - 2% accuracy) and is confirmed by the current orbit analysis of the LARES 2 mission performed by the authors. Accumulation of more orbital data of LARES 2 will allow an improvement of one order of magnitude on the accuracy of the measurement. The LARES missions are not only for "frame-dragging" measurement but also to study the foundations of GR and theories of fundamental physics. Among the phenomena to be tested by the authors are the equivalence principle (EP), in its weak and very strong forms, which are at the basis of gravitational theories and of GR, besides its theoretical implications have fundamental applications in the simulation and the detection of the emission of gravitational waves and the nature of dark matter. In this paper the results obtained by the authors on the weak EP will

be reported showing that, although not comparable in accuracy with ground based tests and dedicated satellites, it provides its confirmation with previously untested materials and at significantly different ranges (for LARES and LARES 2). While a number of tests for the weak EP have been performed, the very strong EP (that basically states that the gravitational binding energy equally contributes to inertial and gravitational mass) was tested using Lunar Laser Ranging. To improve this last test the authors are studying and investigating a new laser-ranged satellite, LARES 3 to orbit the Moon. This paper reports the updated results of the LARES 2 mission and illustrates the preliminary concept of LARES 3 lunar mission.