Using LLR Data for Testing Various Versions of the Equivalence Principle

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Abstract

From 1969 on, Lunar Laser Ranging (LLR) data are collected by various observatories and analyzed by different analysis groups. In the past years, observations with bigger telescopes (APOLLO) and at infrared frequencies (OCA) have been carried out, which resulted in a better spread of precise LLR data over the lunar orbit and the reflectors on the Moon. In Germany, the software package LUNAR has been developed to study the Earth-Moon system and to determine a multitude of related model parameters. Research covered physical libration and orbit of the Moon, coordinates of observatories and retro-reflectors, Earth orientation parameters, lunar interior and, with special modifications, tests of Einstein's theory of relativity such as a possible violation of the equivalence principle or a temporal variation of the gravitational constant. Based on 53 years of LLR data, we present recent results for various facets of the equivalence principle as a central cornerstone of Einstein's theory of General Relativity. We address three cases:
i) Equivalence of inertial and gravitational mass in the gravitational field of the Sun;

ii) Equivalence of inertial and gravitational mass with respect to assumed dark matter in the center of the galaxy;

iii) Equivalence of active and passive gravitational mass of the Moon.
In addition, we will present new results for further relativistic parameters as constrained by LLR. All LLR results confirm the validity of Einstein's relativity theory with high accuracy.

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