Confirming the Frame-Dragging Effect with Satellite Laser Ranging

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Abstract

The theory of General Relativity predicts several non-Newtonian effects that have been observed by experiment, but one that has proven to be challenging to directly confirm is the so-called 'frame dragging' effect. One manifestation of this effect is the Lense-Thirring precession of a satellite's orbital plane due to the Earth's rotation. While the signal is large enough to be easily observed with satellite laser ranging, the Lense-Thirring measurement uncertainty is limited by the knowledge of the even zonal harmonics of the Earth's gravity field that also produce Newtonian secular orbit precessions. In the late 1980's, it was proposed to launch the LAGEOS-3 satellite matching LAGEOS-1, except that the orbit inclination would be exactly supplementary to LAGEOS-1. This would have allowed the cancellation of the equal but opposite orbit precession due to the Earth's gravity field to reveal the Lense-Thirring precession. However, this satellite was never launched, and the orbit selected for LAGEOS-2 was not sufficiently close to the proposed LAGEOS-3 orbit specifications to support an accurate Lense-Thirring experiment with the available gravity models. However, this problem has been largely overcome with the dramatically improved models resulting from the joint NASA-DLR Gravity Recovery and Climate Experiment (GRACE) mission. Using laser ranging to LAGEOS-1 and LAGEOS-2, we demonstrate, with an error analysis based on several now-available GRACE gravity models, that the General Relativity prediction of the Lense-Thirring precession can be confirmed with an uncertainty better than 15%, in good agreement with previously published results. In addition, with extensive modeling improvements in the various models, including the terrestrial reference frame and solid earth and ocean tides, we show that a credible experiment can be conducted with just four years of SLR overlapping the GRACE mission.