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TEST OF GENERAL RELATIVITY WITH GALILEO SATELLITES 5 AND 6

Abstract

On 22 August 2014, the GALILEO satellites Galileo-FOC FM1 and Galileo-FOC FM2 were injected into an incorrect orbit which has an eccentrictiy of about 0.16. Despite this launch anomaly, this incident turned out to offer the unique opportunity to carry out a test on the Equivalence Principle which builds up the foundation of Einsteins theory of General Relativity. Both satellites are equipped with highly accurate atomic clocks which allow measuring relativistic time phenomena as the Gravitational redshift. Depending on the position of the satellites on their eccentric trajectories within Earth's gravity field, the atomic clocks are expected to run more slowly or speed up in a periodic manner according to this relativistic effect. This experiment thus provides excellent conditions to improve on the results of the Gravity Probe A (GP-A) experiment governed in 1976. The recovery of the signature of this relativistic effect from the atomic clock signal requires resolving all systematic effects that are known to have an impact on the clocks' data. The omission or poor modeling of any systematic effect would lead to an uncertainty in the evaluation of the general relativistic redshift. It is shown, that precise modeling of non-gravitational disturbances like solar or thermal radiation pressure generated forces can significantly improve the quality of the clock data and thus reduce the uncertainty. In that respect, we present an a-priori finite element based radiation pressure model which incorporates realistic exterior geometry and thermo-optical properties of a GALILEO-FOC satellite. Finally, we analyze its performance by comparison to conventional radiation pressure models. As an independent measurement of the satellite orbit, Satellite Laser Ranging (SLR) normal point data are provided by the International Laser Ranging network ILRS. Especially for the two GALILEO satellites, there was a one-year dedicated SLR campaign since 1 May 2016 that helped to improve the calibration of precise satellite orbit data. We demonstrate how SLR residuals with respect to these precise orbit data can be used additionally to directly estimate the redshift uncertainty.