

Tests of Fundamental Laws and Principles of Physics in Interstellar Flight

Roman Ya. Kezerashvili*

New York City College of Technology, City University of New York, Brooklyn, USA

Abstract

There are different ways for testing fundamental laws of physics: the use of specific scientific instruments on board a spacecraft, tracking the motion of a spacecraft, or a combination of these two approaches. Tracking an interplanetary or interstellar spacecraft is a significant technique for testing the laws of physics and exploring interplanetary or interstellar environments. Nevertheless, adding some instruments, such as an accelerometer on board, could provide orbit determination experts and physicists with further data of great interest: the values of the non-gravitational acceleration acting on the spacecraft, i.e. the deviation of the spacecraft from geodesic motion [1]. In particular, the analysis of spacecraft trajectories for missions where anomalies were already detected - or could be revealed in the future, may provide data related to unknown gravitational and non-gravitational effects.

General relativity can have a significant impact on the long-range escape trajectories of spacecraft and particularly on solar sails deployed near the Sun. The observation and study of the trajectories of a solar sail could potentially provide tests of various effects of general relativity [2]. The curvature of spacetime and frame dragging, in conjunction with solar radiation pressure, affects the trajectory of a spacecraft. Specifically, I'll present a study of Keplerian and non-Keplerian orbits near the Sun, as well as escape trajectories for a solar sail, for which general relativistic effects and the solar radiation pressure are considered simultaneously [3]. In contrast with the conventional solar mission, a solar sail allows for non-Keplerian orbits, for which the orbital plane lies above the sun. Our prediction shows that there is an analog of the Lense–Thirring effect for non-Keplerian orbits [2]. Also the solar radiation increases the amount of precession per orbit due to the Lense–Thirring effect for polar heliocentric orbits. A solar sail would also enhance the relative importance of effects associated with a possible net charge on the Sun, and during many rotations this effect may be measurable. The Poynting–Robertson [4] effect is considered for escape trajectories, heliocentric bound orbits and non-Keplerian bound orbits [5]. For escape trajectories, this drag force diminishes the cruising velocity, which has a cumulative effect on the escape distances. Since the Poynting–Robertson effect is due to the absorbed portion of the electromagnetic radiation, the degradation of the solar sail's material implies that this effect becomes enhanced during a mission.

One of the main interests is to interpret the inertial and gravitational forces entirely in terms of the geometry of space and time in conjunction with the electromagnetic radiation of the Sun. The possible gravitational influence of dark matter in the Solar system will be discussed.

Keywords: General relativity, Lense–Thirring effect, Keplerian, non-Keplerian orbits, Poynting–Robertson effect.

References:

- [1] J.D. Anderson, P.A. Laing, E.L. Lau, et al., Study of the anomalous acceleration of Pioneer 10 and 11, *Phys. Rev. D* **65**, 082004/ 1-50, 2002.
- [2] R. Ya. Kezerashvili and J. F. Vazquez-Poritz, Can solar sails be used to test fundamental physics? *Acta Astronautica* **83**, 54-64, 2013.
- [3] R. Ya. Kezerashvili and J. F. Vazquez-Poritz, Escape trajectories of solar sails and general relativity. *Phys. Lett. B* **681**, 387–390, 2009.
- [4] H.P. Robertson, Dynamical effects of radiation in the solar system, *Monthly Notices of the Royal Astronomical Society* **97**, 423–438, 1937.
- [5] R. Ya. Kezerashvili and J. F. Vazquez-Poritz, Drag force on solar sails due to absorption of solar radiation, *Adv. Space Res.* **48**, 1778–1784, 2011; *Acta Astronautica* **84**, 206-214, 2013.