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EFFECT OF A DRAG FORCE DUE TO ABSORPTION OF SOLAR RADIATION ON SOLAR SAIL ORBITAL DYNAMICS

Abstract

It is well known that the reflected, absorbed and emitted portions of the solar electromagnetic radiation can be used to propel a solar sail, due to the force from the electromagnetic pressure. What is less known is that the absorbed portion of the radiation induces a drag force on the solar sail, thereby diminishing its tangential speed relative to the sun [1]. This drag force is associated with the Poynting-Robertson effect, which was predicted by Poynting in 1904 for small spherical dust particles.

We consider the Poynting-Robertson effect, on various types of trajectories of solar sails. Since this effect occurs at order v/c, where v is the tangential speed relative to the sun, it can dominate over other special relativistic effects which occur at order v^2/c^2. For a solar sail directly facing the sun in a bound heliocentric orbit, the Poynting-Robertson effect decreases its orbital speed, thereby causing it to slowly spiral towards the sun. For escape trajectories, this diminishes the cruising velocity, which can have a cumulative effect on the heliocentric distance. We also consider this effect for non-Keplerian orbits in which the solar sail is tilted in the azimuthal direction. Due to the Poynting-Robertson effect, a non-Keplerian orbit of a solar sail exhibits oscillatory behavior in the polar direction. While in principle the drag force could be counter-balanced by an extremely small tilt of the solar sail in the polar direction, periodic adjustments are more feasible.

References

[1] R. Ya. Kezerashvili, J. F. Vazquez-Poritz, Advances in Space Research **46** (2010) 346–361.