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SOLAR SAIL EQUILIBRIUM POSITIONS AND TRANSFER TRAJECTORIES CLOSE TO A TROJAN ASTEROID

Abstract

Solar sails exploit the solar radiation pressure on a thin surface as their main propelling force. The idea of a solar sail was born in the early 20th century, and theoretical research about their dynamics has grown in the last two decades. In 2010 JAXA successfully deployed and tested a first prototype solar sail called IKAROS. JAXA is now studying a follow-up mission that uses a bigger sail to visit Jupiter and one or more asteroids in the trojan group. Both these spacecraft are “solar power sails”, having thin-film solar cells integrated in the sails and ion engines as an additional propulsion system.

The topic of this research is the study of equilibrium solutions and dynamics of a solar sail close to an asteroid. Scheeres and others have studied the dynamical environment in the proximity of an asteroid, and found stationary and periodic solutions for generic spacecraft. [Morrow, Scheeres and Lubin 2001] adapted these results to a perfectly reflecting solar sail and a generic asteroid in circular orbit around the sun. In this work we extend those results to a partially-absorbing/partially-reflecting sail and apply them to some specific cases of trojan asteroids with the parameters of JAXA’s foreseen mid-size solar power sail mission. Asteroids in circular sun-centered orbits and point-like bodies are assumed.

The locus of the equilibrium solutions theoretically extends up to the Hill radius of the asteroid, but feasible configurations are restricted to the proximity of the sun-asteroid line. Changing the reflectivity index of the solar sail, while keeping its size constant, alters the shape of the equilibrium locus which tends to a single point on the shadow side of the asteroid. However the presence of the shadow prohibits stationary positions too close to the sun-asteroid line. Basic stability analysis of the equilibrium solutions is performed and the modifications due to the use of ion engines and of asteroid orbits with non-zero eccentricity are investigated. Finally, we describe a range of impulsive and low-thrust transfer trajectories between different solar-sail-based equilibrium positions, ion-engine-based hovering positions and periodic orbits, found with optimal control methods.