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SOLAR SAIL STATION KEEPING OF HIGH-AMPLITUDE VERTICAL LYAPUNOV ORBITS IN SUN-EARTH SYSTEM

Abstract

The recent successful deployment of the sail performed by JAXA's IKAROS mission has finally validated the concept of solar sailing for spacecraft propulsion. A solar sail, by reflecting the photons from the Sun, offers the potential capability of delivering a continuous thrust without the need of any propellant mass, and therefore for a potentially unlimited amount of time.

This capability is extremely interesting for long interplanetary transfers, but also opens up the way to missions requiring the spacecraft to be in a displaced or artificial equilibrium point or in a non-Keplerian orbit. In both cases, a continuous acceleration is required to maintain the nominal orbit conditions.

Extensive work is found in the literature on a wide range of these orbits, and recently it was proposed the use of solar sails on large-amplitude eight-shaped vertical Lyapunov orbits at Lagrangian points L1 and L2 of the Sun-Earth system. While these orbits naturally bend towards the Earth for a range of amplitudes, it was shown that the use of a solar sail of modest lightness number displaces these orbits further towards the Earth, therefore making them a viable way to continuously cover the high-latitude regions and the poles of the Earth, for polar weather forecast, ice pack monitoring and ship routing. However, it was shown that these orbits are highly unstable, and therefore a robust and reliable control strategy is essential to exploit these orbits in real mission scenarios, where even small perturbations can potentially have extreme consequences.

In this work, we study the stability and controllability of a solar sail along these orbits. As for the well-known Halo orbits, the main instability is given by the unstable manifold. We will describe the natural dynamics around these families of periodic orbits and study how variations on the sail orientation and lightness number affect these dynamics. We will discuss the possibility of using this knowledge to derive station keeping strategies for a solar sail. In particular, we want to study if it is possible to find feasible sequences of changes on the sail orientation to maintain the trajectory of a solar sail close to a reference vertical orbit.