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TRANSPORT DYNAMICS OF CO-ORBITAL ASTEROIDS VIA INVARIANT MANIFOLDS FOR SPACE MISSION TRAJECTORIES

Abstract

This study highlights the transport dynamics of co-orbital asteroids with possible applications to space mission trajectories. There have been many studies on co-orbital asteroids and their transport among the Lagrange points, L3, L4, L5, and quasi-satellite orbits (QSO). In order to apply the unique features of such transport phenomena to space mission design, their dynamical mechanisms need to be fully understood. We focus on two natural transport phenomena: One is the transport between the vicinities of L4 and L5 called the “jumping Trojan” phenomenon, and the other is the transport between QSO and the L4 (or L5) region.

Our recent study (Oshima and Yanao, CMDA, 2015) revealed the dynamical mechanisms of the “jumping Trojan” phenomenon in terms of the invariant manifolds associated with the periodic orbits around L3, whose homoclinic tangles mediate the transport between the vicinities of L4 and L5 in the planar circular restricted three-body problem (CR3BP). Based on this mechanism, we design natural transfer trajectories between L4 and L5 without fuel consumption in the Earth-Moon system. The resulted trajectories exhibit many loops around L4 and L5, which may be useful for detecting interplanetary dusts around L4 and L5.

Since the transport between QSO and the L4 (or L5) region requires out-of-plane motions to avoid close encounters with the secondary body, we analyze the transport in the spatial CR3BP. In order to gain insights into the transport mechanism in the high-dimensional system, we use the method of Lagrangian coherent structures (LCSs) to reveal dynamical boundaries. We then found an asymmetric unstable periodic orbit (AUPO) enclosing both the secondary body and L4 (or L5) based on the LCSs. A set of invariant manifolds emanating from AUPO is captured into QSO, and the other is captured into the L4 (or L5) region. This result indicates that the transfer between QSO and the L4 (or L5) region is possible via the invariant manifolds emanating from AUPO. We also found that the instability of AUPO is weak, suggesting that AUPO is useful as a parking orbit for explorations around QSO and L4 (or L5).

In conclusion, we have designed natural transfer trajectories between L4 and L5 based on the “jumping Trojan” phenomenon, which may be useful for detecting interplanetary dusts in the Earth-Moon system. We have also shown that the transfer between QSO and the L4 (or L5) region is possible via AUPO, which could be a novel transport gateway.