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A SURVEY OF HETEROCLINIC CONNECTIONS IN THE EARTH-MOON SYSTEM

Abstract

Throughout the past decade, significant international interest in exploring cislunar space has been generated. Dealing with the additional complexity of operating in this chaotic environment is rewarded with the ability to exploit dynamical structures unique to it. Particularly advantageous structures in the Earth-Moon (EM) system are heteroclinic connections. Heteroclinic connections refer to a special phenomena wherein a single trajectory belongs to the unstable manifold of one orbit and the stable manifold of another. When this occurs, a spacecraft is able to nominally transfer between orbits without expending propellant. While connections between periodic orbits in the spatial circular restricted three-body problem (CR3BP) are relatively uncommon, these connections exist generically between quasi-periodic orbits (QPOs). The objective of the current work is to perform an exhaustive study of heteroclinic connections between QPOs around the first and second libration points in the EM system, providing both topological and mission-relevant analysis of these zero-cost transfers.

At a given energy level in the CR3BP, heteroclinic connections between QPOs exist in two-parameter families. Previous studies have focused on computing these families in the closely related Hill three-body problem which provides a representation of the Sun-Earth system. We have utilized our recently developed numerical procedures to compute these families in the EM representation of the CR3BP. Connection families in the EM system will vary substantially from those studied in the Sun-Earth system. In particular, we see by analyzing zero-velocity curves that orbits around L_1 and L_2 cannot connect until we consider energies where the halo orbit bifurcation occurs around L_1. This bifurcation significantly alters the underlying structure of the connection family between the libration points. Our paper will provide analysis on the topology existing within this new class of connection family.

The forthcoming paper will also focus on mission-relevant properties of these connections. One property of particular interest is the minimum number of revolutions required to perform a zero-cost transfer from L_1 to L_2 at a given energy level. The more revolutions around the moon a spacecraft is required to make along a heteroclinic connection, the longer the transfer time is likely to be. Knowing the minimum number of revolutions at each energy level can help inform the mission design process. We will also investigate properties such as the perilune of connections and the change in in-plane and out-of-plane amplitude that can be provided from a given connection.