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EXPLORATION OF NEAR RECTILINEAR HALO ORBITS AND THEIR TRANSFER TRAJECTORIES IN THE JUPITER-EUROPA SYSTEM

Abstract

The icy moons of Jupiter have attracted widespread attention due to the potential existence of liquid ocean beneath the ice shell. For this reason, several missions have been developed, including the Europa Clipper Mission led by NASA and the Jupiter Icy Moons Explorer (JUICE) led by ESA, to explore the icy moons of the Jovian system. From the perspective of scientific return, moons orbiters, especially those working on low-altitude, high-inclination orbits, are excellent choices since they can provide prolonged and systematic measurements. However, due to the strong gravitational perturbation of Jupiter, low-altitude, high-inclination orbits around icy moons could be dynamically unstable. This is more obvious for Europa. In addition, low-altitude orbits locate deeply in the gravity well of the central body, resulting in high fuel cost for capture.

Near rectilinear halo orbits (NRHOs) are members of halo orbits associated with libration points L1 and L2. Previous research shows that NRHOs have favorable stability properties, small closest distances to the secondary and high inclinations. Besides, NRHOs are less restricted by the gravity of the secondary and thus have higher energy compared with low-altitude orbits, enabling lower fuel cost for insertion. Based on the above-mentioned desirable characteristics, NRHOs can be used as science orbits in Europa exploration missions. A pair of symmetric northern and southern NRHOs could provide low-altitude and full-coverage measurements for Europa.

This paper investigates the NRHOs in the Jupiter-Europa system for purposes of their exploitation in icy moons exploration. To our best knowledge, this is the first time to attempt to explore NRHOs in the Jovian system. First, the circular restricted three body problem (CRTBP) is established to serve as the dynamical model. Then, the L1 and L2 Halo families of orbits are calculated by using the multiple shooting strategy and continuation method. Bifurcation analysis is presented to determine the bounds of NRHOs. Properties of NRHOs including geometry, stability and orbital resonance are thoroughly examined and discussed. Finally, in order to assess the availability of the pairing NRHOs scheme, transfers between symmetric northern and southern NRHOs are investigated. The distribution of transfer time and delta-V cost of the transfer trajectories are analyzed. Our results indicate that the Jupiter-Europa NRHOs have enormous potential to be further utilized, and icy moons missions supported by NRHOs are worthy of great expectations.