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WHICH ARE BETTER: RETROGRADE OR PROGRADE ORBITS FROM THE PERSPECTIVE OF PLANETARY MISSION DESIGN

Abstract

Discovered by Henon (1969), there exist three periodic orbit families around the secondary body in Hill's problem and circular restricted three-body problem: distant retrograde orbits (*f* family), prograde orbits and its bifurcation orbits (*g* and *g*' family). Due to the strong stability, the *f* family members are employed as science orbits in many planetary missions including MMX of JAXA, Artemis 1 of NASA, and Chang'e 5 of China. However, there have been few studies on the *g* and *g*' families or their possible utilization to planetary exploration. All of the *g* and *g*' families are partially beneath the Phobos body, thus they are not able to construct a whole science orbit (Liang et al. 2022). Nevertheless, in the Earth-Moon system, a large number of stable prograde orbits exist with the altitude of ∼5 km to ∼50000 km above the lunar surface. In terms of stability, they play an equivalent role with retrograde ones. Moreover, the prograde orbits have considerable advantage in fuel consumption for they accord with the Earth's spinning direction. It suggests to the authors that it is more than necessary to thoroughly discuss the advantage of retrograde orbits and prograde orbits from the perspective of planetary mission, especially focusing on the lunar mission.

First, the global map of planar and spatial prograde orbits is refined by continuation and bifurcation approach in the space of (mass ratio μ, stability, and Jacobi energy), where μ ranges from 10^{-8} (Mars-Phobos) to 10^{-1} (Pluto-Charon case). The planetary systems owing feasible prograde orbits are then picked out by planetary radius r. Next, in the Earth-Moon system, we focus on the following scenarios: Earth-Moon transportation, polar region observation of the Moon, NRHO rendezvous, relay communication, and deep space transfer. The associate engineering requirements are parameterized by fuel consumption, time of flight, coverage rate, maximum/minimum altitude, and launch/rendezvous window, eclipse length, orbit decay rate, etc. Using the budget tree analysis (Larson and Wertz, 1992), the primary elements including availability, cost, and timing are budged in the aforementioned space mission design for each feasible retrograde and prograde orbits, as their engineering advantages.

Furthermore, targeting at lunar science station, a type of three-dimensional eight-shaped orbits are produced from the prograde *g* family. We show that they are as remarkably effective as Molniya satellite for polar region observation and communication by their sub-satellite point trace.