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Author: Dr. Maisa Terra
Instituto Tecnológico de Aeronáutica (ITA), Brazil

Dr. Sheila Assis
Brazil

ESCAPE DYNAMICS IN THE SOLAR SYSTEM: APPLICATIONS TO SMALL BODIES MISSION WITH THE RTBP

Abstract

Transport of trajectories in the phase space of many-body models is a fundamental process both for the dynamical evolution of natural systems, specially small bodies such as comets, asteroids, moons, and planetary rings, and for modern space mission design. For example, escape basins with fractal boundaries are related to the unpredictability of collision with the Earth of NEO which suffer gravitational effects of distinct planets in the Solar system, and also to applications in space debris mitigation.

In this paper we investigate the processes of escape of trajectories in the planar circular restricted three-body problem with scattering region around the small primary, considering several values of the mass parameter corresponding to different subsystems of the Solar System. Our goal is to examine the properties of the escape basins and the fractal properties of their boundaries in systems with practical interest in Astrodynamics. The primaries considered in this analysis are: Sun, Earth, Jupiter, Europa, Io, Neptune, Callisto, Saturn, Titan, Moon, Pluto, and Charon. We look at the escape processes through the neck around the collinear points L_1 and L_2, and also at the leaking produced by collisions with the surface of the small primary.

The relevant parameters for this investigation are the mass parameter and the scaled mean radius of the smaller primary. For each pair of parameters, different transport channels are available as a function of the Jacobi constant. So, four distinct escape regimes are analyzed. Besides the calculation of exit basins and of the spatial distribution of escape time, a qualitative dynamical investigation through Poincaré sections is performed in order to elucidate the escape process. Additionally, the spatial distribution of escape time values is investigated and associated with the fractality of the boundaries.

Our analyses identify the biparametric dependence of safe domains of the phase space which allow transfers to specific regions of interest, avoiding the effect of final state uncertainty with initial condition variations, that is, far from fractal basin boundaries.

Finally, these properties are related to modern mission design strategies that employ the natural dynamics of many-body systems to design low-energy transfer orbits from the vicinity of a primary body to another region. In particular, for the Earth-Moon system, we analyze how these low-energy transfer possibilities can be applied for space debris mitigation, using the natural transport channels of the RTBP to drive away small particles to safe regions with specific dynamical properties in the phase space.