Paper ID: 64391
student

IAF ASTRODYNAMICS SYMPOSIUM (C1)
Orbital Dynamics (2) (7)

Author: Mr. Naoki Hiraiwa
Kyushu University, Japan

Dr. Mai Bando
Kyushu University, Japan
Dr. Shinji Hokamoto
Kyushu University, Japan

ANALYSIS OF BALLISTIC ESCAPE BASED ON LOBE DYNAMICS

Abstract

In the trajectory design for deep space missions, it is important to leverage dynamical system theory for saving fuel consumption. Topputo et al. (2008) reported that ballistic escaping trajectories have a potential to yield a low energy interplanetary transfer, because a spacecraft can leave the Earth-Moon system at zero cost by the gravitational influence of the Sun, Earth, and Moon. Later, Mingotti et al. (2011) constructed Earth-Mars transfers that included a ballistic escaping trajectory from the Earth-Moon system. However, in the Sun-Earth-Moon restricted four-body problem, the dynamical structure of ballistic escape from the Earth-Moon vicinity is not investigated in detail. Therefore this paper aims to analyze the mechanism of ballistic escape in the planar bicircular restricted four-body problem (BCR4BP) based on lobe dynamics and to give insight into its application to the trajectory design.

In the Earth-Moon circular restricted three-body problem (CR3BP), the transition from a resonant orbit to another resonant orbit by passing through the Moon vicinity is called the resonance transition. When the gravity of the Sun is introduced and the system becomes the Sun-Earth-Moon BCR4BP, the resonance transition mechanism is broken outside the Moon's orbit. This break of the mechanism results in a spacecraft leaving the Earth-Moon vicinity. This is a ballistic escape, which serves as a low-energy transfer to heliocentric space. This paper analyzes the mechanism of ballistic escape to reveal the intrinsic nature of the planer BCR4BP contributing to ballistic escape. For this purpose, "lobe dynamics," which is used to study phase space transport in chaotic systems, is investigated in the planar BCR4BP. Lobe dynamics describes the evolution of states resulting from the intersection of stable and unstable manifolds of hyperbolic fixed points. However, lobe dynamics has not been analyzed in the BCR4BP framework so far. This paper applies lobe dynamics to the manifolds in the planar BCR4BP to observe the dynamical structure related to ballistic escape from the Earth-Moon system.

In the computation, we deal with resonant orbits in the Earth-Moon CR3BP and observe the resonance transition of these orbits. The same initial conditions are used to generate orbits in BCR4BP for the examination of ballistic escape. Periapsis Poincaré maps, whose surface of section lies in periapsis passages, are used to study the transport mechanism in the CR3BP and BCR4BP by 2-dimensional maps. Observing the lobe dynamics on periapsis Poincaré maps in the BCR4BP, we disclose the mechanism that distinguishes the resonance transition and ballistic escape.