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EVIDENCES OF DIFFUSION RELATED TO THE CENTER MANIFOLD OF L3 OF THE SRTBP

Abstract

Diffusion of trajectories is crucial to mass transport processes in Astrodynamics. It is fundamental to know how likely it is for a particle to move from one region in the phase space to another and how long does it take. The investigation of these issues within the modeling provided by the Spatial Restricted Three-Body Problem (SRTBP) has concrete applications to the motion of small bodies in the Solar system, such as, comets, asteroids, dust, and space debris.

In this contribution we present evidences of diffusion of trajectories related to the center manifold of L_3, $W^C_{L_3}$, and introduce a methodology to quantify and to examine the diffusion process.

In the circular SRTBP, this center manifold is four-dimensional and contains vertical Lyapunov orbits, planar Lyapunov orbits, two-dimensional invariant tori, other periodic orbits associated to resonances, and small chaotic zones. In particular, $W^C_{L_3}$ is associated to a portion of the boundary of a practical stability domain detected near the triangular equilibria of the model. These stability regions contain trajectories which remain confined for very long time and, for small mass parameter, have sharp boundaries related to codimension-1 manifolds.

We compute the invariant structures inside $W^C_{L_3}$, in particular, we obtain a Fourier representation of invariant curves in a four dimensional space, corresponding to the Poincaré section of bidimensional invariant tori inside $W^C_{L_3}$. Then, we report the diffusion of trajectories with initial conditions very near these invariant curves for several values of Jacobi constant.

We introduce a methodology for diffusion analysis which provides statistics of the process and show that diffusion rate of trajectories is not constant in the phase space. The diffusion rate increases as trajectories go away from the vertical periodic orbit and then decreases when they approach the planar periodic orbit, wandering across the hyperbolic manifolds of distinct tori. Besides the analysis of large ensemble of trajectories, specific cases are also studied to illustrate the process. In some cases, stickiness to tridimensional tori is observed. Eventually, the trajectories escape due to approximation to the secondary. Finally, we show that the diffusion mechanism is associated to the existence of transition chains of heteroclinic connections and relate the rate of diffusion with the splitting of the stable and unstable hyperbolic manifolds of the two-dimensional invariant tori.

Our analysis corresponds to the investigation of the Saturn-Titan system, but our methodology can be extended to many other concrete applications in orbital dynamics in the Solar system.