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ANALYTICAL PERTURBATIVE THEORIES OF MOTION IN HIGHLY INHOMOGENEOUS GRAVITATIONAL FIELDS

Abstract

The motion of bodies subject to inhomogeneous gravitational fields is a classical subject of research in the context of celestial mechanics. In recent years this type of research has become important to future planned missions of spacecraft to the moon and other solar system bodies, in addition to asteroid detection missions. The analysis of spacecraft motion about these bodies is particularly challenging as they typically feature shapes and density distributions more irregular than those of planets. Such irregularities break symmetries and require more complicated analytical expressions for their description, increasing the complexity involved in such studies.

Numerical methods are today widely used to study the trajectories of objects orbiting specific irregular bodies. These methods can be highly computational and require a complete re-design for each different body. Analytical methods, by contrast, have the potential to rapidly generate suitable reference motions for general bodies with inhomogeneous gravitational fields. Furthermore, analytical methods can provide a full dynamical picture of the motion around irregular bodies that can be used to search and study particular classes of orbits useful. However highly inhomogeneous bodies require symbolic computations involving extensive algebraic manipulations, which cannot be carried out "by hand". Therefore analytical methods are usually limited to the oblateness and ellipticity terms describing the gravitational potential of the body, moreover truncation of the analytic transformations has only be considered to the first order.

This paper presents a general perturbative theory of motion, which considers the terms of the gravitational potential up to an arbitrary order to construct a precise Hamiltonian formulation of the problem. The general, analytical, computer assisted, method here described is based on the application of Deprit's method for the relegation on variables in the Whittaker polar-nodal coordinates and a Delaunay normalisation to arbitrary order to reduce the complexity of the problem (i.e. the number of degrees of freedom). This allows a more accurate description of the dynamics of the system which can be applied to every celestial body and which, in particular, can be exploited for finding initial conditions to yield frozen orbits. These orbits can then be used as reference trajectories in missions that require close inspection of asteroids. To this end an application to derive frozen orbits for Eros 433 is provided which could be of key interest for observational missions around this asteroid.