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Ceres' Rotation Solution under the Gravitational Torque of the Sun

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The protoplanet Ceres is one of the targets of the ongoing NASA's DAWN mission, which is expected to provide crucial information on the history of the Solar System. An accurate determination of Ceres' shape is essential for the determination of its internal structure and, therefore, for understanding its evolution. An accuracy better than 0.5 km is demanded while the accuracy derived from actual observations limits to about 2 km. Even worse, some discrepancies are found when comparing the available shape measurements from different authors.

Available observations on the shape of Ceres show it as a rotationally symmetric, almost spherical, oblate spheroid. However, deviations from axisymmetry could happen to Ceres at the level of observational accuracy, and it is known that small deviations from axisymmetry may show non-negligible effects on the rotational dynamics of rigid bodies. Indeed, we check that a small departure from axisymmetry of few hundreds of meters in the length of the intermediate axis would have, by far, a larger effect on the rotation of Ceres than the small perturbation of its torque-free rotation produced by the coupling with its orbital dynamics about the Sun

When studying the rotational motion of Ceres, all these inconsistencies in the values of the physical parameters should be taken into account. Therefore, it seems desirable to have available a rotation solution for Ceres that may assume a small triaxiality and handles its physical parameters in a pure analytical way.

We study the perturbed rotation of a triaxial Ceres under the gravitational torque of the Sun. The problem is formulated in Andoyer variables, and the orbital motion of Ceres about the Sun is considered to be purely Keplerian. The resulting Hamiltonian is of three degrees of freedom and time dependent. The frequencies of the motion are obtained after the reduction of the Hamiltonian to a function of only momenta. This reduction is obtained by a chain of canonical transformations computed by the Lie series approach. In this way, the time and periodic terms are stepwise eliminated from the Hamiltonian up to a certain order. The reduction is carried out in a pure analytical way, although the ordering of the Hamiltonian is tailored to the actual values of Ceres.

The rotation theory is provided in an algorithmic way. The actual motion is recovered after propagating the secular terms and undoing the canonical transformations that allow to recover the periodic effects. Comparisons with numerical integrations show that the theory is accurate up to the first order in the ratio of the free rotation rate to the mean orbital motion. Thus, after six Ceres' orbital

periods, the rotation state is recovered within one tenth of arc seconds. Specifically, the analytical theory suffers from a secular trend that remains below few mas times orbital period for any angle, with periodic oscillations of the same order