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Forced librations in longitude of the Galilean satellites

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Abstract

We investigate the dependence of rotation variations (or librations) of the Galilean satellites on the satellite's interior. Since the Galilean satellites are markedly aspherical due to rotation and static tides, Jupiter can exert a gravitational torque on them. In a circular orbit, the long axis of a satellite would always point towards Jupiter and the gravitational torque would be zero. However, the eccentric orbits of the Galilean satellites lead to misalignment of the long axis with the direction to Jupiter and a non-zero gravitational torque, which tends to modify the rotation of the satellites. Because the satellites' rotation axis is nearly perpendicular to their orbital plane, we only consider the longitudinal librations describing changes in the rotation angle in the equatorial plane.

Since the torque varies with the orbital phase, the main libration period is equal to the orbital period. In a first-order approximation (see, e.g., [1]), the main libration amplitude is usually calculated by assuming that the satellite reacts rigidly to the gravitational torque. The corresponding amplitudes, expressed as a shift at the surface of the orientation of the long axis with respect to that for the mean rotation rate, decrease with increasing distance from Jupiter from a few hundred meters for Io to about 10 m for Callisto ([1]). Internal liquid layers, such as a subsurface ocean, can lead to differential rotation of the solid and liquid layers and to differences of the libration of surface with respect to that for a rigid libration ([2]).

Here, we present a method to determine the influence of gravitational and pressure interactions between internal layers on the libration of the Galilean satellites. Besides entirely solid models, we consider interior strucure models for the satellites that can have a subsurface ocean and a liquid core. We quantify the sensitivity of the libration amplitude to the internal structure and assess expected improvements in the interior structure of the Galilean satellites from future libration observations with the joint NASA/ESA Europa Jupiter System Mission.

References

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