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Internal translational motions of three–layer icy moons

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Abstract

Some interior models of the outer bodies of the solar system make feasible the existence of a subsurface ocean beneath their surface (see, for example, [2]). A simple description of this internal structure considers a spherical body differentiated into three homogeneous layers: an external ice–I layer, a subsurface ammonia–water ocean, and a rocky inner core. From a dynamical point of view this structure exhibits an interesting feature: it allows a relative translational motion of its solid constituents around the barycenter of the body, that is to say, internal translational motions.

We present a mathematical model that describes the internal translational motions of a three-layer isolated celestial body ([1]). This is achieved with the concourse of the methods of analytical mechanics, under the hypothesis that the solid constituents are rigid, and that the subsurface ocean is an ideal fluid, its motion being irrotational. Linearizing the equations of motion, we found that the solid layers perform translational oscillations of different amplitudes with the same period. The expression of this period depends on the physical characteristic of each layer. We have determined it analytically, showing that it is a function of the densities and masses of the ocean and the rocky inner core, and the mass of the icy body.

These results are applied to some possible internal models developed in [2] for Europa, Titania, Oberon, and Triton, as well as Pluto, Eris, Sedna, and 2004 DW. It turns out that the situation for these bodies is quite different from the cases of three-layer models of the Earth and Mercury, our formulation giving a proper explanation of the source of these differences.

Another remarkable aspect is that the period of the translational oscillation is significatively sensible to the thickness of the external layer. Namely, for diverse three–layer structures of the same body, differing in the thickness of the ice–I layer, the associated periods present a relative variation of at least 10%. In the case of different models for Titania and Oberon that relative variation is larger, reaching a percentage change about 37% and 30%. It entails an absolute difference of the order of three and two hours, respectively. This suggests that the free period of the internal oscillations might play a role in constraining the internal structure of three–layer icy moons.

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References

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