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Tidal Evolution in the Saturnian Satellite System

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We discuss the significance of tidal interaction between the satellites and Saturn for the orbital history of the satellites. Such an interaction is closely connected to the interior structure of the bodies. The high abundance of water ice in the satellites of the outer solar system can be inferred from their mean densities and from their surface spectra. It is also consistent with theories of the formation of these bodies, suggesting the condensation of volatile components in the outer regions of the solar system. For the largest satellites the formation of liquid water layers is possible if small amounts of ammonia are present within these bodies, and if the bodies are differentiated into a rock core and a water ice layer. This may also be valid for some of the smaller satellites early in their evolution when radiogenic heating rates in the rocky component were much larger. Orbital evolution (variations in eccentricity and semi-major axis and the synchronization of rotation periods) is a consequence of the dissipation of tidal energy within a satellite and its primary. Tidal deformation amplitudes and internal dissipation rates are mainly dependent on the rheological properties and structure of the satellite interior. If an ocean is present, the ice layer decouples from the deep interior and will be deformed more effectively by the periodic tidal forcing. However, depending on the satellite's thermal state an increase in the rate of deformation is not necessarily accompanied by higher internal dissipation rates. The interior becomes less dissipative in the presence of volatile components such as ammonia due to the significant melting point reduction thereby decreasing the internal temperature of the entire water-ice liquid shell. In this case, the satellite will move outward at a comparatively rapid rate due to the tidal torques exerted by the primary. On the contrary, high dissipation rates within the satellite will lead to a slower increase in semi-major axis, partly balancing the effect of the primary. We report interior structure models of the satellites and the resulting Love-numbers which are measures for the tidal deformation of a satellite. We calculate the effect on the orbital evolution in terms of changes of eccentricity and semi-major axis for different interior structure models. We compare models with and without internal liquid layers for those satellites where both states are possible. In the case of Titan, we will discuss the consequences for the 4:3 resonance with Hyperion, which could serve as a test for the validity of the tidal evolution model.