EPSC Abstracts
Vol. 10, EPSC2015-659, 2015
European Planetary Science Congress 2015
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Longitudinal librations of Titan and Enceladus

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1 Abstract

The rotation rate of Titan, the largest satellite of Saturn, and of Enceladus, the most geologically active satellite of Saturn, is on average equal to their orbital mean motion. Here we discuss small deviations from the average rotation synchronous with their orbital motion. We examine different causes at various time scales and assess possible consequences and the potential of using librations as a probe of the interior structure of the satellites.

2 Discussion

As a result of the significant non-spherically symmetric mass distribution of the satellites (Iess et al. 2012, Iess et al. 2014), the 1:1 spin-orbit resonance of Titan and Enceladus is stable. Small variations in the rotation rate around the equilibrium state are, nevertheless, expected as a result of different torques acting on the satellites. For Titan, deviations from the synchronous state have been reported several times (Lorenz et al. 2008, Stiles et al 2008, Stiles et al. 2010, Meriggiola et al. 2012). The measurements of the rotation variations are based on determinations of the shift in position of Cassini SAR radar images taken during different flybys. The results, however, are inconclusive and the spin variations are smaller for the latest studies. For Enceladus, it has been suggested that librations may play a role in the temporal variation in the plume activity (Nimmo et al. 2014).

Theoretical estimates show that variations in the rotation rate can occur for several reasons (Van Hoolst et al. 2013, Jara-Orué and Vermeersen 2014). First, the rotation of the Saturnian satellites changes with a period equal to their orbital period as a result of the gravitational torque exerted by Saturn. Second, free librations with periods much longer than the orbital period might be excited. Third, deviations from a Keplerian orbit perturb the rotation at additional frequencies. Fourth, dynamic variations in the atmosphere of Titan induce changes in Titan's rotation with a main period equal to half the orbital period of Saturn.

The librations contain information on the interior of the satellite, and in particular can be used to constrain several properties of the ice shell of Titan (Van Hoolst et al. 2013). Here, we report on different theoretical aspects of the librations and compare theoretical predictions with observational results. We consider the influence of the rheology of the ice shell and take into account Cassini measurements of the external gravitational field and of the topography of Titan and Enceladus. We also evaluate the librations induced by Titan's hydrocarbon seas and use the most recent results of Titan's atmosphere dynamics.

Acknowledgements

This work was financially supported by the European Space Agency in collaboration with the Belgian Federal Science Policy Office.

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