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Dissipation of tidal energy in synchronously rotating satellites and super-Earths

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Most natural satellites and close-in rocky exoplanets are locked in synchronous rotation and subject to tidal forces exerted by their primaries. It is generally believed that the triaxial ellipsoidal shape of their surfaces was acquired in a tidal environment early after formation, when the deep interiors were sufficiently hot and deformable and overlain by thin lithospheres. The nonspherical part of the corresponding low-degree gravity fields is also predominated by spin and tidal contributions, which are related to the radial mass distribution. In addition, time-varying surface distortion and gravity variation due to tiny radial and librational tides may occur along slightly non-circular orbits, thereby causing the dissipation of tidal energy by internal friction. This has important consequences for the orbital evolution and present thermal state of planetary satellites and close-in exoplanets. Here, we examine the possible role of tidal dissipation in regards to internal heat transfer, partial melting, core composition and state (solid vs. liquid), and implications for magnetic field generation.

Tidal heating is a viable heat source other than radiogenic heating by decay of long-lived radioactive isotopes of U, Th, and K, and provides an explanation for the past or even present geologic activity of a number of satellites in the outer solar system. Active volcanism, anomalous intrinsic luminosity, and high-temperature lava flow deposits at Io's surface and indirect evidence for the existence of a liquid subsurface water ocean below Europa's outer ice shell emphasize the importance of tidal heating in the Jovian system, essentially maintained by gravitational interaction due to the resonant orbits of Io, Europa, and Ganymede (Laplace resonance). Tidal heating above a liquid water reservoir confined to beneath the south-polar region would help explain Enceladus' south pole hot spot and associated circular topographic depression. If close-in exoplanets with rocky bulk composition, such as CoRoT-7b and Kepler 10-b, were in a resonant and sufficiently eccentric orbits, tidal heating would substantially affect their present thermal states. It is suggested that a substantial part of the lowermost mantle of massive rocky exoplanets is in a sluggish convective regime, primarily due to pressure effects on viscosity, resulting in higher deep-interior temperatures than previously reported from parameterized convection models.