Internal dissipation and evolution of tidally heated moons around giant planets

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Tidal heating is a major driver of the thermal and orbital evolution of the Galilean satellites, where it dominates the internal energy budget and strongly couples interior dynamics to orbital forcing. Observations from Voyager program, Galileo mission and Juno mission, as well as upcoming constraints from JUICE mission and Europa Clipper, provide a unique opportunity to test models of their internal structure, differentiation, and thermo-orbital evolution.

Within the Galilean system, tidal dissipation is unevenly distributed between bodies and internal layers. Io, where dissipation is largely concentrated in a partially molten silicate mantle, acts as the primary energy sink of the Laplace resonance and plays a central role in controlling its long-term evolution. In contrast, in icy satellites such as Europa and Ganymede, dissipation may be partitioned between the silicate interior, subsurface ocean, and overlying ice shell, reflecting their differentiated structure and the presence of a global hydrosphere.

The efficiency and localization of tidal dissipation are therefore intimately linked to the internal structure inherited from formation and differentiation processes, including core formation, silicate mantle evolution, and the development of internal oceans. A key control is the rheological evolution of silicate mantles, in particular the onset and evolution of partial melting. By modifying the viscoelastic response of planetary materials, melt can strongly enhance tidal dissipation and redistribute tidal dissipation between the deep interior and outer layers.

These processes introduce non-linear feedbacks between temperature, rheology, internal structure, and tidal forcing, potentially leading to transient regimes of enhanced dissipation, variability in heat flux distribution, and long-term evolution of both the internal state and orbital configuration. In this review, I will discuss recent advances in modelling the coupled evolution of tidal dissipation, thermal state, and interior structure, and how these processes can be constrained by current and future observations (e.g., gravity, magnetic induction, surface activity, and heat flux). Broader perspectives toward tidally heated rocky exoplanets will also be addressed.