Linking orbits and interiors: towards a coupled thermal-orbital model for the Galilean satellites

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Jupiter's three innermost Galilean moons Io, Europa, and Ganymede are locked in the Laplace mean-motion resonance, which both sustains tidal heating in their interiors and governs the long-term stability of the system. Subsurface oceans have been identified beneath the icy crusts of Europa and Ganymede, and suspected on Callisto, making these moons some of the best candidates for habitability in the Solar System. This, in turns, makes the long-term thermal-orbital history of the system a central question for assessing and understanding this habitability potential, and a key scientific driver of the upcoming JUICE and Europa Clipper missions.

However, the long-term history of the system is still largely unresolved. Surface geology across the moons records orbital reconfigurations (Greenberg, 2010) that likely involved periods of enhanced tidal heating due to eccentricity growth. Such eccentricity variations would be accompanied with ice shell thinning, ocean expansion, and possibly partial mantle melting (Běhounková et al., 2021). The frequency and intensity of such episodes are intrinsically tied to the resonance evolution, which remains poorly constrained beyond present-day astrometric measurements (Lainey et al., 2009).

The orbital and thermal evolutions of the systems have so far largely been studied in isolation, and truly coupled models are limited (Showman et al., 1997; Hussmann and Spohn, 2004; Bland et al., 2009). We aim to address this gap by linking an N-body integrator to interior models, allowing tidal parameters to follow the evolution of the moons' orbits and interiors. We focus on the last few hundred million years of the system's history, targeting possible periods of increased eccentricity, to place constraints on past tidal heating episodes and map plausible evolution scenarios for the Galilean system.

References

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