Modelling thermal evolution of molten and tidally-heated Io-Like planetary mantles

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Internal heating in rocky bodies shape their interior and surface characteristics as well as their evolution. Among internal heat sources, tidal dissipation is a key one. The most striking evidence in the Solar System is the case of Io, archetype of tidally-heated world hosting extreme volcanism. There may be abundant Io-like worlds around other stars or their giant planets, and Io is the best Solar System analog for understanding these exoplanets and exomoons.

Io’s internal dynamics is complex due to the large and tidally-produced heat flux, leading to widespread melting in the interior. For Io-like bodies, the dissipation and heat transport models have thus to incorporate interactions between solid and liquid phases. This requires the investigation of mechanisms on short temporal (years to days) and small spatial (of the order of km) scales. Io’s mantle is commonly modelled either as a solid convective mantle, adapting models of terrestrial planets, or as a fluid magma ocean, adapting models of fluid water oceans of icy moons. However, neither of these two classifications likely accurately describes Io’s partially fluid, partially solid interior.

In that context, we model Io's interior thermal evolution following the work of Sanchis et al (2022, EPSC), who developed a magma ocean modelling, using the CHIC convective code (e.g. Noack et al. 2013, Infocomp). In that framework, the effective local properties whenever melt is present or generated is modelled following an approach developed by Golabek et al. (2011, Icarus). In addition, we take into account heat generated by tidal dissipation accounting for the effect of melt presence on the viscous and elastic parameters of the mantle. Tidal dissipation is computed for shear and bulk contribution following Kervazo et al. (2021), bulk dissipation being important when a large amount of melt is present in planetary mantles.

Our study provides valuable insights into the role of a large amount of melt in the thermal evolution of rocky planets and moons, and our modeling approach is applicable to other rocky planets with hot interiors, including the Trappist-1 planets and various known rocky exoplanets. This facilitates future investigations into the interiors of these bodies and expands our understanding of the formation and evolution of rocky planets and moons.