INFERRING IO'S INTERIOR FROM TIDAL MONITORING. M. Kervazo[1], G. Tobie[1], G. Choblet[1], C. Dumoulin[1] and M. Běhounková[2], [1]Laboratoire de Planétologie et Géodynamique,UMR-CNRS 6112, Université de Nantes, 44322 Nantes cedex 03, France., [2]Charles University, Faculty of Mathematics and Physics, Department of Geophysics, Prague, Czech Republic. (mathilde.kervazo@univ-nantes.fr).

Introduction: Io, the innermost of Jupiter's satellites, is the most volcanically active, and probably one of the most remarkable body in the outer Solar System [1]. The total power emitted from Io's surface is estimated to about 100 TW at present [2, 3], which is several orders of magnitude greater than can be explained by radiogenic heating alone: the spectacular heat flux is due to extreme and non-uniform tidal heating. Io's interior process manifests on the surface as extreme volcanic activity, providing some clues about the thermal state of its interior through the eruption properties and global distribution of volcanism [e.g. 4].

A variety of models have been proposed to determine the mechanism at the origin of the huge tidal dissipation in Io's interior [e.g. 5–8]. The presence of a partially molten layer in the upper mantle of Io is broadly consistent with these interior models prediction, as well as with magnetic induction measurements [9], although this interpretation has recently been questioned [10, 11]. However, while a high concentration of melts below the lithosphere is in line to explain the heat production and the heat released by volcanic activity, the degree of melting of this subsurface layer, going from moderately molten mantle to fully liquid subsurface ocean [6], is still largely debated.

The distribution of melt within Io is a key question driving the ongoing and future exploration of Io. This is the main mission goal of the 'Io Volcano Observer' (IVO) [12], one of the Discovery finalists currently under consideration by NASA, planning to test these interior models via a set of geophysical measurements. One way to characterize it is through the tides. The measurement of the tidal deformation (either via the potential Love numbers k_2 and h_2 or the phase lag) can provide information about the internal structure and/or viscoelastic properties of planetary bodies [e.g. 13]. Close flybys of Io are planned by JUNO [14] in its extended mission, allowing for a more precise determination of hotspot distribution and activity in polar regions, and will provide refined magnetic and gravity measurements, possibly permitting a first assessment of k_2 Love number. Moreover, prior to a dedicated mission to Io, such as the IVO mission, the JUpiter ICy moon Explorer (JUICE) mission [15] may also allow complement mapping of hotspot activity from distant flybys.

The total amount of heat produced by tidal friction and its distribution in the interior is intimately linked to the structure and thermal state of Io's interior, especially the distribution of temperature and melt fraction [7, 8]. Describing the mechanical response of partially molten rocks on a wide range of melt fraction is essential to correctly describe the tidal friction in Io, partial melt severely affecting viscoelastic properties of rocks. Understanding the retroaction between melt distribution and heat production is thus crucial to explain the heat budget of Io and to understand the tidally-induced volcanism on Io.

Method: In this context, the goal of the study is to calculate the tidal response of Io's interior [16] for various distribution of melt within the mantle, to discriminate them in future tidal monitoring. A coherent melt profile between the sublithospheric partially molten layer and the underlying mantle is considered following petrological and two-phase flow arguments [4, 17]. A rheological parameterization is developed in order to take into account the role of melt fraction on the elastic and viscous parameters of Io's partially molten interior. To account for the unknown composition and thermal state of Io's silicate mantle, we investigate a potential interior model with reference solid viscosities η_{ref} ranging from 10^{16} and 10^{20} Pa s. The results are analyzed in terms of tidal Love number k_2, taking into account a re-evaluation of the heat production by tidal friction in Io's partially molten interiors, by quantifying the role of melt fraction on both shear and bulk dissipation.

Results: Our calculations show that the amount of melt fraction within the 100-km thick asthenospheric partially molten layer could be discriminated from tidal k_2 measurements and heat flow patterns. Depending on the assumed value of viscosity at the melting point and extent of melting beneath the lithosphere, three groups of internal structure models able to reproduce Io's heat budget of 100 TW can be distinguished (Fig. 1) : (1) low viscosity mantle ($< 10^{17}$ Pa s) and moderately molten mantle and asthenosphere (<7%-<20% respectively) ; (2) high viscosity mantle ($> 10^{18}$ Pa s) with high melt content in the asthenosphere (>30%) ; (3) fully liquid magma ocean beneath a highly dissipative crust. Both mantle dissipation (1) and crust dissipation (2) models result in a comparable heat flow pattern, with maximal dissipation at the poles but can be distinguished by k_2 measurements. The asthenospheric dissipation (2) model has a k_2 Love number only slightly higher than the mantle dissipation

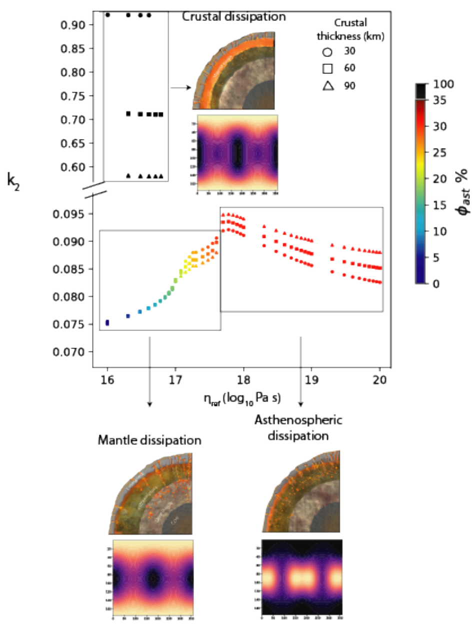

Figure 1: Tidal Love number k_2 as a function of the reference viscosity of the mantle. Colorscale refers the melt fraction in the top asthenospheric layer. Three internal structure models matching 100 TW are isolated, one of which is dominated by dissipation in a low viscosity mantle, another by dissipation within a molten asthenosphere and a third by crustal dissipation in the presence of a fully liquid magma ocean. Each of them is illustrated by internal structure sketches taken from [15] and by their respective tidal dissipation pattern integrated over Io's interior.

model, but results in a totally different heat flow pattern. Note that our computed dissipation included bulk dissipation in addition to shear dissipation, which further enhances dissipation in the equatorial region for the asthenospheric dissipation (2) model. For the two other dissipation model, bulk dissipation has a negligible effect.

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