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Obtaining Io's internal state from in situ and remote observations

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Based on sound theoretical arguments, Io has long been suspected of harboring a magma ocean in its interior. The extremely high temperature of the lava erupting on Io's surface indeed hint at an extremely hot interior consistent with an internal magma ocean. However, the only direct evidence for a melt layer in Io's interior has been provided by Khurana et al. (2011), who used Jupiter's rotating magnetic field as an electromagnetic induction signal. They have shown that a strong dipolar field is present in Galileo magnetometer data, which is consistent with electromagnetic induction from large amounts of rock-melts in Io's interior. Modeling of this signature showed that the induction response from a completely solid mantle model is inadequate to explain the magnetometer observations. However, they found that a layer of asthenosphere $>$ 50 km in thickness with a rock melt fraction $\geq$ 20% is adequate to accurately model the observed magnetic field.

In this presentation, we first provide a progress report on our effort to marry the principles of thermodynamics with those of electromagnetism to further constrain the temperature profile inside Io. The constraints on the mineralogy, temperature and melt state of Io are being obtained from MELTS a modeling program that utilizes thermodynamic principles to calculate the chemical variations in the assemblages of minerals and melts as a function of pressure, temperature and oxygen fugacity. Electromagnetic induction response is calculated by solving the induction equation numerically for several different models of the interior and tested for their agreement with the Galileo magnetometer data.

Next, we explore how future in situ and remote observations could be used to characterize Io's interior using multi-frequency electromagnetic induction and auroral observations. We show that the lithospheric thickness can be obtained from induction response at the Jovian synodic period while information on the magma ocean thickness and its conductivity is provided by the signal at the orbital period of Io.

Finally, we investigate if observations of Io's UV aurora could be used to further constrain the electromagnetic induction signature observed by Galileo. We show that the equatorial spots seen on the sub-jovian and anti-jovian sides are excited by charge exchange between heavy ions and neutrals. In order for the induction magnetic field to influence the charge exchange process, the resulting magnetic pressure change would have to be large enough that the local velocity of the plasma changes considerably on the flanks of Io. We show that the induced field does not change the flow velocity appreciably and therefore cannot be deduced from auroral observations alone. It would also be necessary to account for the distribution of plumes on Io, as they strongly perturb the auroral signal (Geissler et al., JGR 106, 26137).