Electromagnetic induction in icy moons of Jupiter - A review and its future perspective

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Internal oceans of icy moons of gas giants of our solar system are among recent hot topics in planetary sciences. Newly discovered evidence for hydrothermal vents in the liquid ocean of Enceladus (Hsu et al., 2015) is still fresh in our memory. Presence of the internal oceans is one of the necessary conditions for extra terrestrial life, although interaction of liquid water with the lithosphere of the icy moon in concern via, say, the hydrothermal activity, is also indispensable. It, therefore, worth revisiting the problem of internal oceans of Jupiter's Galilean satellites with icy surfaces at this time of coming successive Jovian probe missions such as Juno (Bagenal et al., 2014), JUICE (ESA, 2014) and so on.

The latter three of the four Galilean satellites, Io, Europa, Ganymede and Callisto, are covered with ice, while intense volcanic activity is ongoing on the Io’s surface due to the immense tidal force of Jupiter. Those volcanic ejecta become a dense source of plasmas of Io origin, which results in Io’s footprints of Jupiter’s auroras (e.g., Bonfond et al., 2013). It is noteworthy that the former three of the Galilean satellites have those footprints, while Callisto alone lacks in them implying a very thin plasma environment around that moon as it is the farthest to Jupiter without any significant source of plasmas from Callisto itself. This means that Callisto is least subject to the plasma effect in terms of electromagnetic induction.

Another feature of Callisto that is worth noting is its orbital state. While the former three revolutions are in the state of Laplace Orbital Resonance (Murray and Dermott, 1999), Callisto alone is out of it. This may cause a significant difference in tidal force which each moon feels. Tidal dissipation is one of the important factors (Chen et al., 2014) when we consider the heat source that maintains the internal oceans of the icy moons, if any.

In this study, we reanalyzed the vector magnetic field data at the time of Galileo Probe flybys around Callisto. Assuming a time-varying uniform external magnetic field (Khurana, 1997; Khurana and Schwarzl, 2005) with a direction almost parallel to the direction of Jupiter looking from Callisto, we calculated the induced dipole field generated by concentric spherical shells. As a result, a conductive shell with a similar conductivity of seawater on the Earth was found when the depth to it was constrained by an assumed phase diagram of water inside Callisto, which coincides with previous studies (Khurana et al., 1998; Zimmer et al., 2000).

However, if the internal structure of Callisto is significantly different from those of Europa and Ganymede in the sense that Callisto has experienced immature differentiation unlike rest of the two, Callisto may provide a better platform for extra terrestrial life by an increased chance for liquid water-lithosphere interaction. In this presentation, the obtained electrical structure will be further examined comparatively with that of Europa known to date. Comparison with that of Ganymede may be subject to another research because of the moon's peculiar intrinsic core field.

Keywords: Icy moons, Jupiter, Electromagnetic induction

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