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# The impact of ice I rheology on interior models of Ganymede: The elastic vs. the visco-elastic case

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Many investigations on key processes of icy satellites are driven by the rheological behavior of planetary ices. Future missions to Jupiter's icy moons (e.g. JUICE / Europa clipper) aimed at constraining the thickness of the outer ice shell using radio science and/or laser altimetry will have to address this problem. We investigate for the case of Ganymede under which conditions the ice I viscosity could be constrained by measuring the phase-lag of the tidal response using laser altimetry.
In the absence of seismic data, interior structure models are constrained by the satellite's mean density and mean moment-of-inertia factor. One key observable to reduce the ambiguity of the corresponding structural models is the measurement of the dynamic response of the satellite's outer ice shells to tidal forces exerted by Jupiter and characterized by the body tide surface Love numbers h2 and k2. The Love number k2 measures the variation of the gravitational potential due to tidally induced internal redistribution of mass and can be inferred from radio science experiments. The Love number h2 is a measure for the tide-induced radial displacement of the satellite's surface. It is an advantage that Ganymede's surface displacement Love number h2 can be expected to be measured with a high accuracy using laser altimetry (Steinbrügge et al., 2014). However, the determination of the resulting ice thickness further depends on the possible existence of a liquid subsurface water ocean and on the tidally effective rheology of the outer ice shell (Moore and Schubert, 2003).
Here, we distinguish between an elastic, visco-elastic or even fluid behavior in the sense of the Maxwell model and alternative rheological models. In the case of Ganymede the fluid case would imply high ice temperatures which are at odds with thermal equilibrium models calculated by Spohn and Schubert (2003). However the visco-elastic case is still possible.
Laboratory measurements of ice I (e.g. Sotin et al., 1998) suggest that the rigidity can be constrained and the ambiguity left by the structural model can be recovered by the simultaneous determination of the linear combination 1+k2-h2 (Wahr et al., 2006). However, the less well known viscosity can play a major role when inferring the thickness of the outer ice shell. Limits for measurements by laser altimetry will be discussed.

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