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Key characteristics of the Fe-snow regime in Ganymede's core

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In view of the fact that Ganymede shows signs of an internally produced magnetic field [1] the study about its origin became a scientific challenge. For small planetary bodies such as Ganymede the iron snow regime, i.e. the top-down solidification of iron, has been suggested to play an important role in the core cooling history [2,3]. In that regime, iron crystals form first at the core-mantle boundary (CMB) due to shallow or negative slopes of the melting temperature [2,3]. The solid iron particles are heavier than the surrounding Fe-FeS fluid, settle to deeper core regions, where the core temperature is higher than the melting temperature, and remelt again. As a consequence, a stable chemical gradient in the Fe-FeS fluid arises within the precipitation zone – we speculate this style of convection via sedimentation to be small scale, therefore it lacks an important criterion necessary for dynamo action [4]. Below this zone, the process of remelting forms a dense Fe-rich fluid on top of a lighter Fe-FeS fluid, which creates a gravitationally unstable situation. We propose that this could be the starting point for large scale compositional convection within the deeper core regions of Ganymede and the driving mechanism for a potential dynamo. However, as soon as the precipitation zone is present within the entire core and an inner core forms this compostional convection would stop. Thus, dynamo action would be restricted to the time period of growing the precipitation zone across the entire core.

With a 1D thermo-chemical evolution model, we investigate the key characteristics of the iron snow regime within Ganymede's core: the compositional density gradient evolving across the precipitation zone and the time period necessary to grow this zone across the entire core. To investigate the influence of the core temperature profile on these parameters we apply both an adiabatic and conductive temperature profile. In case of the conductive temperature profile we also include the latent heat of crystallization and melting. We further vary the initial sulfur concentration of the core, the core heat flux and the thermal conductivity. For all models, the compositional density gradient varies between 0.3 g/m4 and 0.7 g/m4 corresponding to a stable density variation across the entire core of 210 kg/m3 and 590 kg/m3, respectively. We find that all tested scenarios would require strong superadiabatic cooling for thermal bouyant motions to overcome the stable compositional density gradient inconsistent with thermal evolution models [2,3]. The investigated time periods to grow the precipitation zone across the entire core can differ from 220 to 1120 Myr. Comparing our findings to the results of [2], we find larger time spans to grow the precipiation zone across the entire core. Our model results and the present-day dynamo of Ganymede thus suggest that the iron snow regime should have started late in its thermal history and that Ganymede has no present-day inner solid core.

References

1. Kivelson, M., K. Khurana, C. Russell, R. Walker, J. Warnecke, F. Coroniti, C. Polanskey, D. Southwood, and G. Schubert (1996), Nature, 384(6609), 537–541.
2. Hauck II, S., J. Aurnou, and A. Dombard (2006), JGR, 111(E9), E09,008.
3. Williams, Q. (2009), EPSL, 284(3), 564–569.
4. Christensen, U. and J. Wicht (2007), Treatise of Geophysics vol 8: core dynamics, Ed. G. Schubert, Elsevier, pp. 245-282.