Visualization of “iron snow” in ammonium chloride solutions

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Ganymede is the only moon in the solar system possessing a present-day magnetic field. According to the traditional theory explaining the mechanism of magnetic field generation on planetary bodies, Ganymede’s interior should be too cold to maintain the magnetic field. Although there are several studies attempt to explain the Ganymede’s magnetic field, there is no certified theory and this problem remains an open issue.

One of the plausible explanations, the iron snow regime, which is a new concept to explain Ganymede’s magnetic field, implies that dynamo action is sustained by motion of iron-crystals. In this, iron-crystals form at the core-mantle boundary and sink down to a depth where temperature and pressure are sufficient for remelting. This leads to a layer of iron rich fluid overlying a fluid with less iron content, which in turn leads to a compositional convection suppling the energy for a magnetic field generation via the dynamo-effect. Although numerical models show the feasibility of this concept, there are many open questions regarding the interplay of solidification and fluid dynamics for which experimental evidence is strongly required.

The aim of our study is to establish a model experiment for the iron snow regime and to generate a database for the mutual influence of solidification and convection in general. Experimental studies were conducted inside a transparent Hele-Shaw cell filled with ammonium chloride solution for visualization. Various flow regimes were studied by choosing different temperature boundary conditions. At sufficient supercooling (of the salt solution) equiaxed and columnar crystals nucleate, grow and get advected, whereby the individual phenomena strongly depend on the thermal convectional properties of the ambient fluid. Temperature visualization was realized using thermochromic liquid crystals. Equiaxed crystals, which model iron snow in our experiment, and columnar crystals were visualized by a LED-backlight, and tracked its advective motions. Quantified temperature and velocity fields were acquired from post-processing for consecutive visualized images. Numerous interesting phenomena, e.g., nucleation and growth of equiaxed crystals, fluid flows induced by crystal motion, compositional convection caused by concentration differences, stable density stratification at the cooling top of the fluid layer, were revealed. We will report our preliminary experimental results about them.

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