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Double Diffusive Convection in Jupiter as a result of H/He demixing

Nadine Nettelmann and Jonathan Fortney
UCSC, Santa Cruz, United States (nadinen@ucolick.org)

Demixing of hydrogen and helium with subsequent He rain has long been suggested to occur in giant planets once they have sufficiently cooled down during their evolution. Its occurrence in Jupiter is indicated by the observed atmospheric helium depletion.

He rain in a giant planet may cause a gradual increase of the helium abundance with depth and a super-adiabatic interior, in contrast to full homogeneity, or a sharp increase in form of a layer boundary as assumed for convenience in traditional adiabatic models. In the presence of a stabilizing compositional and a destabilizing temperature gradient, large-scale convection may be inhibited (Ledoux-stable) and replaced by layered double diffusive (LDD) or oscillatory double diffusive (ODD) convection with possible consequences for the internal dynamics and magnetic field generation.

We here present new Jupiter structure models due to assumed He sedimentation, along with the methods used to address this issue. In particular, we apply the ab initio H/He phase diagram of Lorenzen et al (2009, 2011), the transport properties of dense H/He according to French et al (2012), and the heat flux-temperature relations from hydrodynamics simulations (Mirouh et al 2012; Wood et al 2013).

In a first step, we find a He gradient in Jupiter between 1 and 3 Megabars. In a second step, we selfconsistently solve for the super-adiabaticity in the demixing region that is required to reproduce the observed heat flux, assuming that double diffusive convection does occur. However, a warmer-than-adiabatic interior also tends to shrink the first-step demixing region. Thus in a third step, we explore the interaction between the size of the demixing region and its compositional, temperature, and heat flux profiles.

Our work is meant to advance the current approach of planetary structure modeling by coupling the assumed structure to the physical background mechanisms that are responsible for the planet as we observe it today. Our models may help to understand dynamo operation in gas giants such as Jupiter and Saturn as opposed to the ice giants Uranus and Neptune.