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Anelastic dynamo models of gas giants

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Evolution models of the gas giants suggest that Jupiter and Saturn interiors are separated into an outer non-conducting molecular envelope and an inner metallic region, where the dynamo takes place.

Typical numerical models for planetary dynamos rely mainly on the Boussinesq approximation, assuming that the background properties (temperature, density, ...) are constant with radius (Christensen & Aubert, 2006). While this approximation is suitable for liquid iron cores of terrestrial planets, it becomes more questionable in gas giants, where density increases by several orders of magnitude (Guillot, 1999). The anelastic approximation thus provides a more realistic framework to model the dynamics of Jupiter and Saturn as it allows to incorporate effects of the density stratification, while filtering out fast acoustic waves (Lantz & Fan, 1999). We also appropriately employ stress-free rather than rigid flow boundary conditions, typical for terrestrial dynamo models, which are known to promote a rich dynamical behavior, including hemispherical dynamos, or bistability phenomena (e.g. Simitev & Busse, 2009, Sasaki et al. 2011).

We present the results of a systematic parametric study on the effects of the background density stratification. While the previous Boussinesq results suggested that the dipolarity of the magnetic field may be a direct consequence of the relative influence of inertial effects (through the local Rossby number criterion developed by Christensen and Aubert (2006)), anelastic dynamos tend to produce a broader range of field geometries, showing two distinct dynamo branches: the first is characterised by dipole-dominated and magnetostrophic dynamos and weak zonal flows, while the second shows small-scale fields, is more geostrophic and zonal flows are significant. For some cases, multiple solutions can be found depending on the starting condition, reproducing a bistability (Simitev & Busse 2009). In conclusion, the combination of density stratification effects and the use of stress-free boundary conditions has a crucial influence on the geometry of the magnetic field, indicating that these effects are important to appropriately model the interior dynamics of gas giants.