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Rapidly rotating MHD dynamos in a full sphere

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Despite their relevance for many geo- and astrophysical objects, such as the early Earth's core and its magnetic field, MHD dynamos in a full sphere geometry are rarely reported in the scientific literature, in particular when compared to the abundance of spherical shell studies. This is partly due to the additional difficulty of an adequate numerical treatment of the singularity that arises at the centre of a full sphere. Using a fully spectral simulation framework where the choice of radial basis functions (the so-called Jones-Worland polynomials) guarantees smoothness in the entire domain and allows us to compute dynamos in a full sphere geometry.

In the absence of an inner core, we rely on internally heated convection together with fixed flux boundary conditions to drive fluid motion within the sphere (see figure 1a). We demonstrate that such a setting is indeed capable of creating a variety of different dynamo solutions. This includes strong- and weak-field solutions, where either magnetic or kinetic energy is dominating, but also dynamos that vacillate between the two states. We map out the existence of these solutions in the parameter-space of Ekman, Rayleigh and magnetic Prandtl number (an example of such a diagram at a single Ekman number is given in figure 1b) and discuss their dependence on the initial conditions.

We further discuss the velocity fields within the sphere, in particular the differences (and similarities) with rotating convection and dynamos in spherical shell geometries. Finally, we have a detailed look at the morphology of the created magnetic fields and their temporal evolution, including the observation of polarity reversals of the dipolar component of the magnetic field.

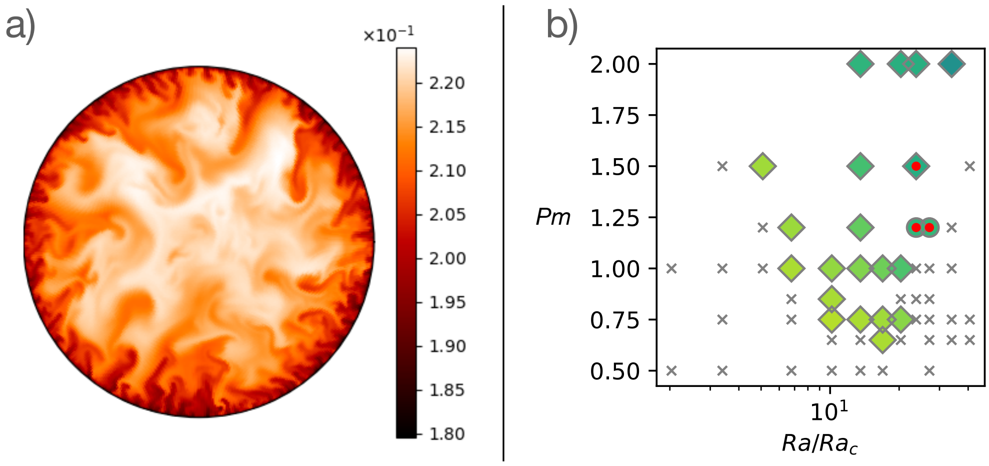

Figure 1: a) Convection in a rapidly rotating full sphere is driven by internal heating and fixed flux boundary condition. We display the total temperature field. b) Example of a regime diagram for dynamos in a full sphere. Diamonds, circles and crosses represent strong field, weak field and failed dynamos, respectively. Red dots denote dynamos vacillating between the two states. Colour coding represent a measure for the degree of dipolarity of the magnetic field (dark colours less dipolar than light colours).

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