The Elbert Range of Turbulent Rotating Magnetoconvection

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Rotating magnetoconvection is characterised by rich multimodal flow behaviours. Depending on the control parameters, a mix of boundary-attached, oscillatory, and geostrophic, magnetostrophic, and magnetic stationary modes constitutes the dynamic of the system[1]. Specifically, when thermal convection is subject to both a strong magnetic field and rapid rotation, two very distinct stationary modes can co-exist: a small-scale geostrophic and a large-scale magnetostrophic modes. This so-called Elbert range is geophysically the most relevant parameter regime (named after Donna DeEtte Elbert, who first discovered this unique property of rotating magnetoconvection[2]).

Here, we will present results from direct numerical simulations (DNS) of turbulent thermal rotating magnetoconvection inspired by the original liquid mercury experiments by Nakagawa[3]. Figure 1 shows our numerical counterparts. The DNS are conducted in a fluid with a Prandtl number of $Pr = 0.025$ contained in a wide cylinder with aspect ratio $\Gamma = 8$ and the rotation is kept fixed at an Ekman number of $Ek = 1.2 \times 10^{-4}$. We will discuss how the flow morphology, characteristic length scales and frequencies change with the magnetic field strength by varying the Chandrasekhar number in the range of $9.5 \times 10^1 \leq Ch \leq 5.0 \times 10^5$, corresponding to Elsasser numbers of $0.01 \leq \Lambda \leq 60$. We will focus on the Elbert range and explore if and how magnetostophic convection can create large length scales and thus provide favourable conditions for the dynamo generation in planetary cores.

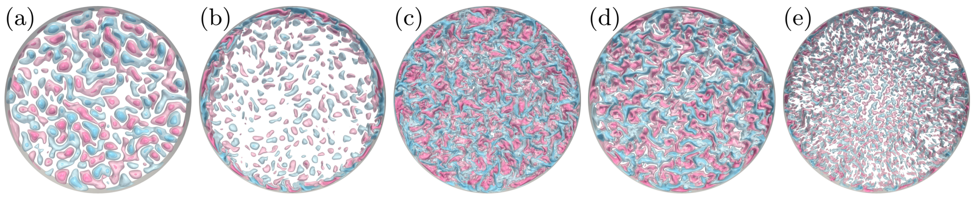

Figure 1: Flow fields visualised by the vertical velocity component in the five different regimes of rotating magnetoconvection: (a) geostrophic range (G), (b) geostrophic coexistence range (MG_1), (c) Elbert's magnetostrophic coexistence range (MG_2), (d) magnetically dominated magnetostrophic range (MG_3), (e) magnetic range (M). The rotation rate is kept constant at $Ek = 1.2 \times 10^{-4}$ and the magnetic field strength increases from left to right with $Ch = \{9.5 \times 10^1,\ 3.5 \times 10^3,\ 6.0 \times 10^3,\ 5.5 \times 10^4, 5.0 \times 10^5\}$, i.e. $\Lambda = \{0.01,\ 0.42,\ 0.72,\ 6.6,\ 60\}$.

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[1]Horn and Aurnou, *Proc. R. Soc. A* **478**, 2264 (2022)
[2]Chandrasekhar, *Hydrodynamic and hydromagnetic stability*, Clarendon (1961)
[3]Nakagawa, *Proc. R. Soc. A* **249**,1256 (1959)