LINKING CONVECTIVE BOUNDARY LAYERS AND MAGNETIC FIELD MORPHOLOGIES

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The magnetic fields of planets and stars are generated by the motions of electrically conducting fluids within them. These fluid motions are likely driven by convection, and that convection is subject to the effect of the bodies' rotation. Under the strong influence of rotation, convective flow is organized by the Coriolis force into quasi-two-dimensional, axially aligned structures. This organization is thought to account for the many magnetic fields (such as Earth's) that are distinguished by strong, axisymmetric dipole components. Numerical models of rapidly rotating, convectively driven dynamos typically reflect the robustness of this dipolar field morphology. Some planets and models, however, generate more complex non-dipolar magnetic fields. A mechanism behind the transition between these two distinct forms has not yet been identified.

I present an investigation of the influence of rotation on convection and magnetic field generation via a suite of coupled laboratory and numerical experiments over a broad parameter range ($5 \times 10^{-7} \leq E \leq \infty$; $10^5 < Ra \leq 3 \times 10^{10}$; $0.1 \leq Pr \leq 30$; $0 \leq Pm \leq 20$), including both hydrodynamic, plane layer convection as well as dynamo simulations in spherical shells. The magnetic field morphology transitions are linked to convective regime transitions controlled by boundary layer dynamics. As the thermal boundary layer becomes thinner than the Ekman layer, the rotational influence on convection is lost, and the ensuing chaotic flow can generate more disorganized, multipolar magnetic fields. Heat transfer scaling laws permit predictions of which regime a given planet, star or model should occupy based on the heat flux (Rayleigh Number), and rotation period (Ekman Number). We predict, for example, that convection in Earth's core occurs near this regime transition, which may help explain observed polarity reversals in the geomagnetic field.

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