The Search for an Inverse Cascade in Rotating Compositional Convection

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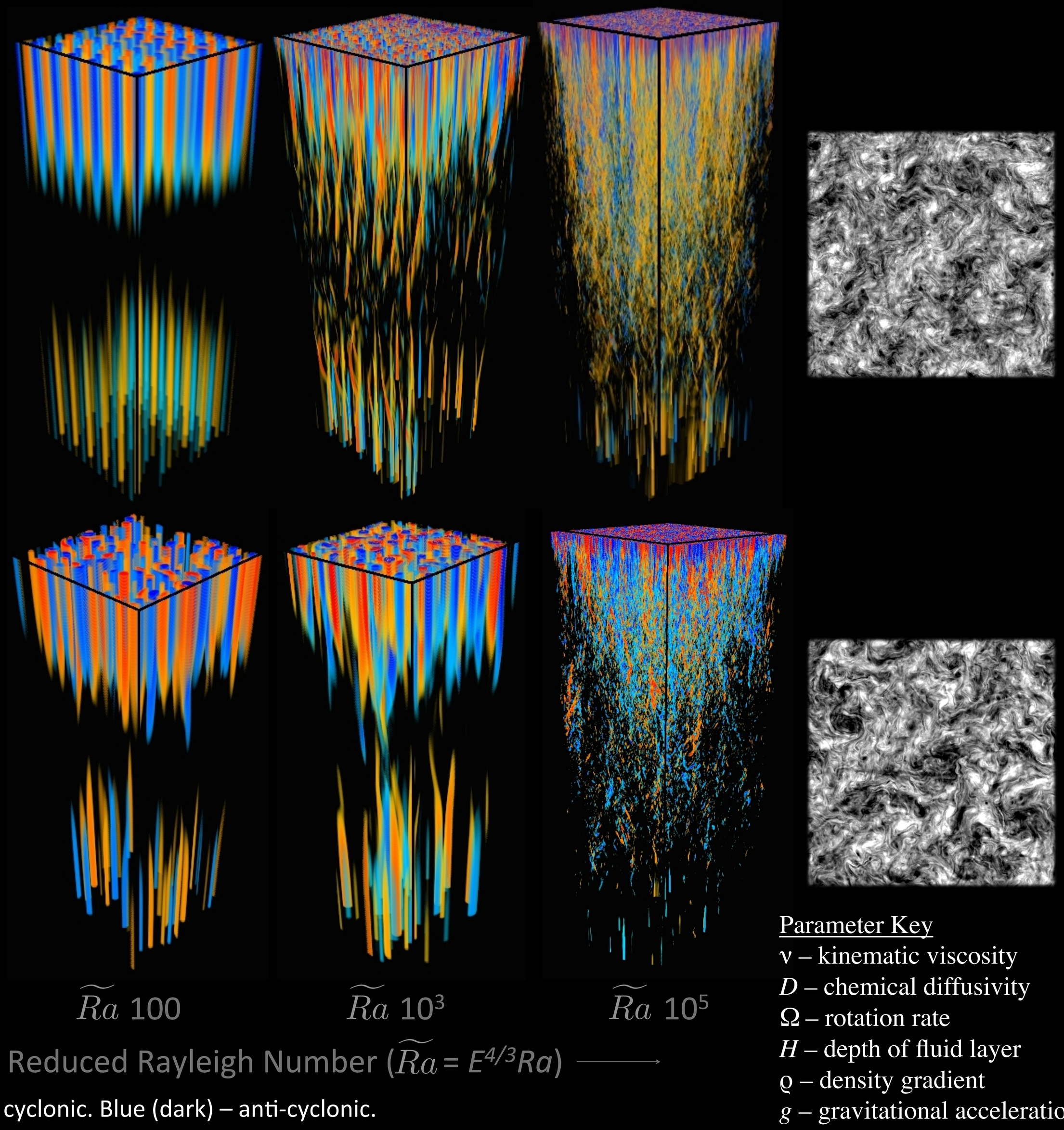
Buoyancy-driven turbulence of liquid metal is the primary driving-force of planetary magnetic fields. Compositional convection is characterized by density heterogeneities inducing a buoyant force in the metallic fluids that compose a planet's interior. For rotating compositional convection, the dependent parameters are the Schmidt number ($Sc = \nu/D$), the Rayleigh number ($Ra = g\varrho H^4/D\nu$), and the Ekman number ($E = \nu/2\Omega H^2$). Asymptotically reducing the governing equations in the limit $E \to 0$, we are able to perform direct numerical simulations of highly turbulent regimes. It is known that fluids with a small Schmidt number exhibit an inverse cascade during turbulence, but an inverse cascade has never been observed for Schmidt numbers greater than one. Below, we visualize vortical columns for varying Schmidt and Rayleigh numbers. An inverse cascade would appear as large light and dark structures in the vertically averaged vorticity (last column).



Red (light) – cyclonic. Blue (dark) – anti-cyclonic.

Parameter Key

ν – kinematic viscosity
D – chemical diffusivity
Ω – rotation rate
H – depth of fluid layer
ϱ – density gradient
g – gravitational acceleration