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Waves and linear stability of magnetoconvection in a rotating cylindrical annulus

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Magnetohydrodynamic waves in a rapidly rotating planetary core can cause the magnetic secular variation. To strengthen our understanding of the physical basis of such waves, we revisit the linear stability analyses of thermal convection in a quasi-geostrophic rotating cylindrical annulus with an applied toroidal magnetic field, and we extend the investigation of the oscillatory modes to a broader range of the parameters. Particular attention is paid to influence of thermal boundary conditions, either fixed temperature or heat-flux conditions.

While the non-dissipative approximation yields a slow wave propagating retrograde (westward), termed as a Magnetic-Coriolis/Magnetic-Coriolis-Archimedes (MC/MAC) Rossby wave, dissipative effects produce a variety of waves. When magnetic diffusion is much stronger than thermal diffusion, this can cause a very slow wave propagating prograde (eastward). Retrograde-travelling slow waves appear when magnetic diffusion is weaker. Emergence of the slow modes allows convection to occur at lower critical Rayleigh numbers than in the nonmagnetic case. When the magnetic diffusion is strong, the onset of the convection occurs with the prograde-propagating slow wave, whereas when it is weak, a slow MC mode conducts the critical convection.

Fixed heat-flux boundary conditions have profound effects on the marginal curves, which monotonically increase with the horizontal wavenumber, and lead to larger length scales at the onset of the convection, provided there is sufficient field strength that the Lorentz force is balanced with the Coriolis force. The effect, however, becomes less clear as the magnetic diffusion is weakened and various magnetohydrodynamic waves emerge.