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Magnetic Rossby waves in the Earth's core

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Magnetohydrodynamic waves in rapidly rotating planetary cores can produce several secular variations of the planetary magnetic field. Some axisymmetric modes, including the torsional Alfven waves, are thought to be responsible for certain observed features of the Earth's core dynamics and the geomagnetic variation. It is, on the other hand, possible for other waves to lead to the nonaxisymmetric variations. A potential candidate is the magnetic Rossby wave, which migrates in the azimuthal direction along the internal toroidal field. This can be related to the westward drift of the geomagnetic field, which has been observed in the Atlantic hemisphere for the past hundred years. Though the drift has commonly been believed to reflect advection due to large-scale lateral flows beneath the top of the core, propagation of the waves excited within the core may also account for it. This was originally proposed by Hide (1966), who showed that a slow mode of magnetic Rossby waves, sometimes called a slow MC-Rossby mode, could propagate westward on timescales of hundreds years.

To investigate whether this mode can be relevant in the Earth's core, we extend Hide's linear theory to quasi-geostrophic cylinders and explore nonlinear dynamo simulations in rotating spherical shells. By performing tempo-spatial spectral analyses, we identify slow MC-Rossby waves that propagate at the correct speed, given by the Alfven and Rossby speeds, with respect to the mean zonal flow. The result indicates that this mode could be excited in the planetary fluid core and that the wave propagation may indeed play a role in the magnetic drift. Taking geomagnetic drift speeds, the theory suggests the internal toroidal field of about 10 mT at the mid core radius. This could give a framework for inferring the physical properties in the fluid core, in terms of nonaxisymmetric waves.