Solitary magnetic Rossby waves in spherical shells

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Finite-amplitude hydromagnetic Rossby waves in the magnetostrophic regime are studied. We consider the slow mode, which travels in the opposite direction to the hydrodynamic or fast mode, in the presence of a toroidal magnetic field and zonal flow by means of quasi-geostrophic models for thick spherical shells. The weakly-nonlinear, long waves are solved asymptotically using a reductive perturbation method. The problem at the first order is found to obey a fourth-order ODE, which resembles the Orr-Sommerfeld equation and is nonsingular when the wave speed approaches the mean flow. Investigating its neutral, nonsingular eigensolutions for different basic states, we find the evolution is described by the Korteweg-de Vries equation. This implies the nonlinear slow wave forms solitons, giving rise to a coherent eddy such as a single anticyclone filling up the cavity. We speculate its link to asymmetric gyres seen in Earth's fluid core and in spherical dynamo DNS.

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