Complex dynamics of the Tayler instability-driven dynamo in stably stratified astrophysical flows

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Résumé

In astrophysical stably stratified objects such as accretion disks and stellar radiative zones, turbulence triggered subcritically by MHD instabilities can drive dynamo action, i.e., amplify and sustain large-scale magnetic fields. Dynamo action driven by the kink instability of strong azimuthal magnetic fields, the so-called Tayler instability, is a promising mechanism to explain angular momentum transport in radiative zones and the formation of magnetars (highly magnetised neutron stars). While this dynamo has been observed very recently in direct numerical simulations, it remains poorly understood. I will present new simulations of stably stratified spherical Couette flows showing for the first time that the Tayler instability-driven dynamo can generate very complex dynamics with spontaneous transitions between different states: stationary axisymmetric, non-axisymmetric hemispherical, and reversing magnetic fields. We observe that the dynamics is strongly correlated with the equatorial symmetry breaking of the flow. Focusing on a fiducial dynamo simulation, we propose a simple interpretation of its dynamics, which consists in the coupling of two large-scale magnetic modes with two opposite equatorial symmetries by the flow symmetry breaking. While this interpretation captures the simplest observed dynamics, the nonlinear interaction between a higher number of magnetic modes is certainly required to describe some of the more complex regimes. In addition to questioning previous modelling of the Tayler instability-driven dynamo, our study fosters new investigations uncovering the complex dynamical landscape and bifurcations that underlie this dynamo to better understand how it is excited in astrophysical systems.

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