

Transition from large- to small-scale dynamo in boxes of large aspect-ratio

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Magnetic fields on the Sun exist on a vast range of spatial and temporal scales that coexist in the physical processes. They can be categorised as large-scale and small-scale fields. The Sun's large-scale magnetic field exhibits coherence in space and time on much larger scales than the turbulent convection that ultimately powers the dynamo. Moffatt (1978) and Krause (1980) introduced the framework of mean-field theory to describe the origin and self-sustainment of a large-scale magnetic field in astrophysical objects. The theory outlines how small-scale turbulent motions produce a coherent global field through the interaction with small-scale magnetic fields in the limit of high magnetic diffusivity.

We investigate the spatial scale selection for coherent structures of magnetic fields due to the dynamo action in the presence of a velocity field that has a single spatial scale (classic ABC flow) and a two-scale velocity field with a long modulation. Mean-field theory predicts long wavelength modes at the onset of dynamo action, whereas small scales are more energetic at larger R_m . The transition from large- to small-scale dynamo is of interest. We test this idea numerically by considering a cuboid that is extended in one direction and includes multiple copies of the periodic cell of the flow, to examine whether the magnetic field can grow on scales longer than that of the flow as the magnetic Reynolds number is increased.

By using spectral filtering we demonstrate that the scales responsible for dynamo action are consistent with those predicted by the asymptotic theory in the range it is expected to apply to. The simulations showed that the critical R_m is related to the longest scales in a box. The transition from large scales to small scales at different R_m for the two flows, so the mean-field approximation is valid for a varying range of magnetic diffusivities yet still limited to the low R_m regime.
