Exploiting symmetries to explore the dynamics of ideal and dissipative MHD flows with wide scale separation

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Direct numerical simulations of turbulent magnetohydrodynamic (MHD) flows in three dimensions often require restrictively high resolution and thus computational resources. As an alternative to subgrid-scale models and adaptive mesh refinement, we compute flows with known symmetries using a code that implements these symmetries in such a way as to save computational time and memory. Both the velocity and magnetic fields are initialized with Taylor–Green-type symmetries, which are preserved by the dynamical equations. With computational savings of up to a factor of 32, we compute both ideal and dissipative flows to study their evolution in the absence of forcing. We follow the spontaneous formation and subsequent development of coherent structures, which we attempt to explain in light of energy spectra, complex-space singularities, current and vorticity maxima, and time scales. The particular symmetric flows we use are useful not only for their computational value but also for their versatility in exploring a wide variety of MHD flows, thereby helping to further our understanding of fundamental questions in MHD, such as those regarding spectral scaling laws and the possibility of singularity in the inviscid limit. The computational value of symmetric flows, however, cannot be overlooked, as they will allow petascale computers to explore Reynolds numbers far beyond what is presently attainable.