Scientific context  Magnetic fields are important dynamically in a variety of situations in geophysics and astrophysics. Numerous observations are appearing, e.g. thanks to remote sensing and in particular to the CLUSTER ensemble of 4 satellites, allowing for an estimation of fields and of their derivatives in the Solar Wind close environment. In the magnetohydrodynamic (MHD) approximation valid for velocities small compared to the speed of light, the dynamical equations are quite close to the Navier-Stokes case for fluids (advection-diffusion), and thus MHD also represents a testing ground for ideas on turbulent flows in the incompressible case, in the presence of waves. Reaching high Reynolds numbers numerically is difficult and thus several approaches can be taken: direct numerical simulations (DNS), modeling, and DNS with symmetries, all of which are undertaken in the following.

The lack of universality in MHD  Using computations of three-dimensional MHD turbulence with a Taylor-Green flow whose time-independent symmetries are implemented numerically, and in the absence of either a forcing function or an imposed uniform magnetic field, we show that three different inertial ranges may emerge for three different flows, the selecting parameter being the ratio of Alfvén to nonlinear eddy turnover times, linked with the ratio of magnetic to kinetic energy as shown in Fig. 1. Equivalent computational grids range from $128^3$ to $2048^3$ points with a unit magnetic Prandtl number and Taylor Reynolds numbers up to 1000 or more at peak of dissipation (see (1) for the ideal non dissipative case). We also show that convergence in such results obtain for the highest Reynolds numbers reached in these runs (2). Our study is consistent with previous findings of a variety of energy spectra in MHD turbulence, studies performed in the presence of both a forcing term with a given correlation time and of a uniform and strong magnetic field in either boundary-driven reduced MHD or in MHD. In contrast to the previous studies, the ratio of characteristic time-scales can only be ascribed here to the intrinsic nonlinear dynamics of the flows under study. Further analysis of the data is in progress (3): why are these spectra different?

Furthermore, analyzing data at the peak of dissipation stemming from a series of decaying DNS up to a grid resolution of $1536^3$ points (world record) and up to a Taylor Reynolds number of $\sim 1200$, with initial velocity and magnetic fields helical and again in equipartition and with negligible correlation, we show that the dissipation in MHD seems to asymptote to a constant as the Reynolds number increases, thereby strengthening the possibility of fast reconnection events in the solar environment for very large Reynolds numbers. Furthermore, intermittency of MHD flows, as determined by the spectrum of anomalous exponents of structure functions of the fields, is stronger than for fluids, confirming earlier results; however, we also find that there is a measurable difference between the exponents of the velocity and those of the magnetic field, as observed recently in the solar wind (4); note that visualizations capabilities are enhanced by an extension of the VAPOR software (5). This massive run was performed thanks to a special allocation of computing resources in the framework of the ASD (Accelerated Scientific Discovery) at NCAR.

\footnote{1Also 0.75 FTE at the Department of Physics, University of Buenos Aires, Argentina}
Figure 1: Left: Total energy spectra compensated by $k^{5/3}$ for runs with enforced Taylor-Green (TG) symmetries on equivalent grids of $2048^3$ points, with Taylor Reynolds numbers of $\approx 1000$ or higher; spectra are averaged over one eddy turn-over time after the peak of dissipation; there is no forcing and no imposed uniform magnetic field. Arrows indicate magnetic Taylor scales. All runs have initially a TG flow for the velocity, a magnetic to kinetic energy ratio $R_E = 1$, less than 5% velocity-magnetic field correlation and zero magnetic helicity. Note the different spectra, compatible with Iroshnikov-Kraichnan (dots), Kolmogorov (dash) and weak turbulence (solid line). Center: Time evolution of $R_E$ for the same 3 flows. Right: Zoom on current structures at peak of dissipation (4).

**Clebsch variables in MHD** New generalized equations of motion for the Weber-Clebsch potentials that describe both the Navier-Stokes and MHD dynamics have been derived. Using DNS, the new formalism is used to detect magnetic reconnection in several two- and three-dimensional flows. Periods of intense activity in the magnetic dissipation are correlated with increasingly frequent resettings of the variables (6).

This work supports NCAR strategic priorities by performing and analyzing high resolution direct numerical simulations of turbulent flows in preparation for petascale and the Wyoming data center.

**References**


