Seminar

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Institute for Plasma Research

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Title: Power laws, Spectral Relation and Large-scale Magnetic Structure Formation in Helically Forced and Decaying 3D-MHD Turbulent Flows at various Magnetic Prandtl numbers

Speaker: Dr. Shiva Kumar Malapaka
IIIT-Bangalore

Date: 22nd September 2022 (Thursday)

Time: 03:30 PM

Venue: Seminar Hall, IPR

Abstract

Magnetic Prandtl number (Pr_M) characterizes the ratio of diffusivity of the velocity field to the diffusivity of magnetic field and in various astrophysical system can vary from ~ 10^{-7} in the planetary interiors to ~ 10^{14} in the interstellar medium. Thus if we wish to study the properties of the magnetic fields in these systems, it is necessary to perform MHD simulations with varying Pr_M. However, current day computations cannot achieve these ranges [1]. Usually, in numerical simulations one is able to obtain PrM of about 10^2 - 10^3 on the higher side and 10^{-2} – 10^{-3} on the lower side with very high-end machines [2]. Following this trend, we here present results of low and high PrM simulations with values of 0.1 and 10 on the lower and higher sides respectively. These 3D-MHD turbulent flow simulations at 512^3 resolution, on a periodic grid using a pseudo-spectral code with spherical de-aliasing are of three types (i) small scale helically forced turbulent flow simulations (ii) decaying turbulence simulations with initial condition in the intermediate-scales (we will call these pure decaying simulations) and (iii) three sets of simulations where initial condition of the flow was picked from the forced turbulent simulations of (i) and were allowed to decay without any further forcing. We also have data from our previous unity PrM simulations with exactly similar setup(s) at 1024^3 resolution. Thus in total we have in our hand a total of 15 sets of data.

The Energy Vs time and Energy dissipation Vs time plots in all the three pure decaying cases ie. $0.1 \leq Pr_M = 1 \leq 1$, show power law behaviour and we shall discuss about these power-laws. We also verify the individual spectral power laws and collective spectral relation obtained at $Pr_M = 1$ [3,4], in both low and high Pr_M turbulent flows for several physical quantities. These results will be discussed in the talk. We, next, look at large scale magnetic structure formation in all these cases, we observed that low Pr_M simulations need the largest amount of simulation time followed by unity Pr_M and high Pr_M. We find that the process of large-scale structure formation in decaying case is dependent on the amount of initial energy that was injected into the system. These simulations may be pointing towards a threshold initial energy necessary to form large- scale magnetic structures in a reasonable amount of time. From these simulations we try and identify the suitable conditions that can control large-scale magnetic structure formation which is an impediment in Fusion reactors.

Towards the end of the talk I wish to highlight our attempts to use Machine learning in identifying automatically vortices and their orientation in helically rotating turbulent flow data (resolution 128^3) and also our attempts at creating Persistence diagrams and calculation of Betti numbers (using Computational Topology) for the same data and understanding the results we obtain.

References: [1] Biskamp, D., 2003, Magnetohydrodynamic turbulence, Cambridge Univ. Press [2] Schekochihin, A. A., Iskakov, A. B., Cowley, S. C., McWilliams, J.C., Proctor, M.R. E., and Yousef, T.A., New J. Phys., 9, 300, 2007 [3] Muller, W.- C., Malapaka, S. K., and Busse, A., Phys. Rev. E, 85, 015302(R), 2012 [4] Muller, W.-C., and Malapaka, S. K., GApFD, 107, 93, 2013
