Magnetic field generation in astrophysical fluids

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The origin of spatio-temporally organized magnetic fields in most astrophysical systems like the Sun, stars, galaxies, galaxy-clusters and accretion-disks remains a challenging open problem. The most popular paradigm is that of the turbulent dynamo, wherein turbulent motions of the underlying fluid convert kinetic energy to magnetic energy. Two types of turbulent dynamo, that can operate in the same system, are small-scale dynamo (SSD) and large-scale dynamo (LSD), depending on whether the growth of the fields is on scales smaller or larger than the turbulent outer scale, respectively.

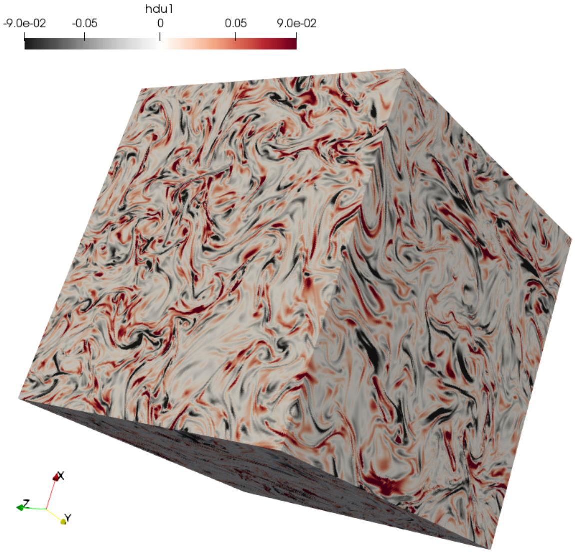

Figure 1 : Helically forced flow gives rise to the growth of small scale fields. The small-scale dynamo is the leading driver during the kinematic regime. Shown is the Bx component of the magnetic field during early stages of the turbulent dynamo action.

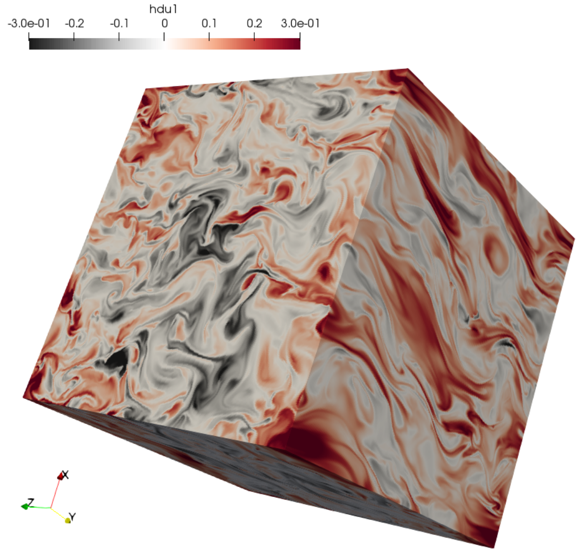

Figure 2 : Shown is the Bx component of the magnetic field during during the nonlinear regime of the turbulent dynamo action

I will introduce the paradigm of turbulent dynamos and highlight the major results obtained in this area. Further, I will present important kinematic models/frameworks for SSD and LSD, the Kazantsev theory [1] and mean field theory, respectively. A central issue has been the generation of organized magnetic fields on fast turbulent time-scales [2]. In particular, magnetic helicity conservation has been thought to be a barrier to achieving the desired fast growth. I will detail the issue and present recent studies of magnetic helicity evolution during the nonlinear dynamo action which throw new light upon the time-scale issue [3].

[1] P Bhat and K Subramanian (2014) "Fluctuation Dynamo at Finite Correlation Times and the Kazantsev Spectrum", ApJ Letters, 791, L34

[2] P Bhat, K Subramanian and A Brandenburg (2016), "Unified large-scale/small-scale dynamo in helical turbulence", MNRAS, 461, 1, 240-247

[3] P Bhat (2021), "Effect of anisotropic forcing on the saturation of the large-scale dynamo" (in preparation)