ASTR/ATOC-5410: Fluid Instabilities, Waves, and Turbulence

Project description November 11, 2016, Axel Brandenburg

Project on alignment of structures in turbulence

Background

Numerical simulations have shown conclusively that $\boldsymbol{\omega}$ aligns itself with the *intermediate* eigenvector of the rate-of-strain matrix (Vincent & Meneguzzi, 1991). In MHD, on the other hand, it turns out that, the magnetic field vector aligns itself with the direction of *shear*, which is at 45° angles with the directions of *both* stretching and compression (Brandenburg et al., 1995). This project will focus mainly on hydrodynamic turbulence, but the application to MHD is a natural extension.

Project details

You will be provided with data of high-resolution simulations of decaying hydrodynamic and MHD turbulence.

1. Study the *local* alignment of vorticity $\boldsymbol{\omega}$ with the intermediate eigenvector of the rate-of-strain matrix, $\boldsymbol{e}_2$. How does it correlate with local increases of the dissipation rate, for example?
2. How big is the volume over which the alignment of $\boldsymbol{\omega}$ with $\boldsymbol{e}_2$ persists?
3. Are there locations where $\boldsymbol{\omega}$ aligns itself with $\boldsymbol{e}_1$ and $\boldsymbol{e}_3$?
4. Are there corresponding alignment properties in the magnetic field? How big are they? How does it depend on the magnetic Prandtl number, Pr_M? [You will have access to data with $\mathrm{Pr}_M = 0.01$, 1, and 100.]
5. Verify locally that $\boldsymbol{B}$ aligns itself with the direction of shear. Determine a corresponding characteristic vector from the velocity gradient matrix $u_{i,j}$.

References

Brandenburg, A., Nordlund, Å., Stein, R. F., & Torkelsson, U., "Dynamo generated turbulence and large scale magnetic fields in a Keplerian shear flow," *Astrophys. J.* **446**, 741-754 (1995).

Vincent, A. & Meneguzzi, M., "The spatial structure and statistical properties of homogeneous turbulence," *J. Fluid Mech.* **225**, 1-20 (1991).