3rd Asia-Pacific Conference on Plasma Physics, 4-8,11.2019, Hefei, China

Intimate connection of turbulence and magnetic reconnection

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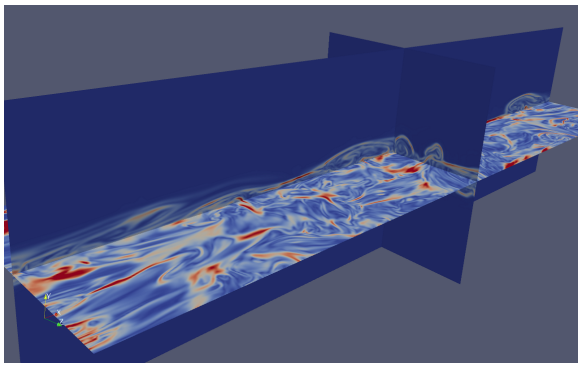
Magnetic reconnection is a long-standing problem with most attempts to solve it being focused on small scale plasma processes. At the same time, in most astrophysical settings the scales of reconnection are significantly larger than any relevant plasma scales. This scale disparity makes magnetic reconnection a really tough problem unless one accounts for the fact that astrophysical media is generically turbulent. I shall discuss magnetic reconnection at scales much larger than the typical plasma scales, i.e. at the scales that the MHD treatment of the process is appropriate. I shall show that MHD turbulence makes magnetic reconnection fast [1] and provide the comparison of the predictions of the turbulent reconnection theory with numerical simulations [2,3]. I shall demonstrate how the turbulent reconnection works both when turbulence is externally driven and is generated by the reconnection process itself [4]. The results for non-relativistic and relativistic reconnection will be presented [5]. I shall show that tearing is generically getting suppressed in the presence of turbulence, although this behavior is difficult to observe with PIC codes that usually do not have enough particles to reproduce fluid behavior in 3D. My message is that the MHD turbulent reconnection is the generic type of magnetic reconnection applicable to most of astrophysical situations that are characterized by large Reynolds numbers. I shall briefly discuss how the turbulent reconnection violates the famous Alfven theorem on magnetic flux freezing and what big implications the turbulent reconnection has for star formation, evolution of accretion disks, cosmic ray acceleration and gamma ray bursts.



An illustration of 3D MHD simulations by Kowal et al. (2019) of turbulent reconnection with turbulence generated by the reconnection outflow in a box with open boundary conditions.

References:
[1]. Lazarian, A., & Vishniac, E., 1999, Reconnection in Weakly Stochastic Field, ApJ, 517, pgs 700-718,
[2] Kowal et al. 2009, Numerical Tests of Fast Magnetic Reconnection in Weakly Stochastic Magnetic fields, ApJ, 700, 63-85,
[3] Eyink et al. 2013, Flux Freezing Breakdown in High Conductivity Magnetohydrodynamic Turbulence, Nature, 4750, 466-469,
[4] Kowal et al. 2017Statistics of Reconnection-driven Turbulence, ApJ, 838, 91,
[5] Takamoto et al. 2015, Turbulent Reconnection in Relativistic Plasmas and Effects of Compressibility, ApJ, 819, 96