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Universal Energy Cascade in Space and Astrophysical Plasma Turbulence

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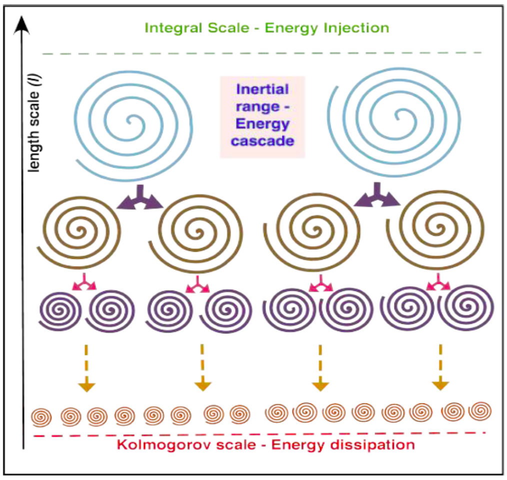
Turbulence plays a crucial role in explaining mixing, heating and acceleration of space and astrophysical plasmas. Despite highly complex and nonlinear behaviour, at large scales, space and astrophysical plasma turbulence can be satisfactorily modelled in the framework of Magnetohydrodynamic (MHD) turbulence where the corresponding plasma can be considered to be a single fluid. Similar to ordinary fluid turbulence, MHD turbulence also shows universal behaviour in terms of an energy cascade, which is characterized by a constant energy flux rate (ε) across the length scales far from both the macroscopic (integral scale) and microscopic dissipation scales. In Fourier space, this is represented by Kolmogorov's $k^{-5/3}$ power law for the energy power spectrum. However, in physical space, this universality can be expressed in terms of the "*exact relations*" connecting the two-point correlation functions or two-point increments with ε. Traditionally, both for incompressible hydrodynamic and MHD turbulence, such exact relations were derived by von Karman & Howarth (1938), Kolmogorov (1941), Yaglom & Monin (1959) and Politano & Pouquet (1998). For homogeneous and isotropic hydrodynamic (HD) turbulence, the derived exact relations predict a linear relation between the third-order velocity structure functions to the fluctuation length scales. In MHD turbulence, similar scaling relations can be obtained for the mixed third-order structure functions for the Elsasser variables. For compressible turbulence, this type of universality cannot be easily seen in terms of power law exponents. However, exact relations for compressible turbulence are obtained both for HD and MHD fluids [1, 2, 3, 4] using both isothermal and polytropic closures. The compressible exact relation for MHD turbulence helps in understanding the anomalous heating of the fast solar wind [5]. Unlike incompressible turbulence, the exact relations of compressible turbulence are much lengthy and consist of complicated terms which cannot give a very clear phenomenological idea. Later, an alternative formulation has already been proposed initially for incompressible HD and MHD turbulence [6] and then this formulation has been extended for compressible HD and MHD turbulence using isothermal closure [7].

Very recently, a more general exact relation has been derived for polytropic two-fluid plasma turbulence [8] which, on choosing suitable limits, can be reduced to the exact relations for HD, MHD and more complicated single fluid plasma turbulence. This presentation will discuss the universality in space plasma turbulence in terms of exact relations using both traditional and the aforesaid alternative formulation along with the advantages of the new formulation over the traditional one.



A schematic view of energy cascade

References:

[1] S. Galtier & S. Banerjee, Phys. Rev. Lett., 107, 134501 (2011)
[2] S. Banerjee & S. Galtier, Phys. Rev. E, 87, 013019 (2013)
[3] S. Banerjee & S. Galtier, J. Fluid Mech., 742, 230-242 (2014)
[4] S. Banerjee & A. G. Kritsuk, Phys. Rev. E, 96, 053116 (2017)
[5] S. Banerjee, L. Hadid, F. Sahraoui & S. Galtier, 829 (2), L29 (2016)
[6] S. Banerjee & S. Galtier, Journal of Phys. A, 50, 015501 (2017)
[7] S. Banerjee & A. Kritsuk, Phys. Rev. E, 97, 023107 (2018)
[8] S. Banerjee & N. Andres, Phys. Rev. E, 101, 043212 (2020)