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Sala Grassano (Dipartimento di Fisica)

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"On chirality of Hall (partially two-fluid) and full two-fluid MHD turbulence"

Abstract

Symmetry breaking and restoration are key to fundamentals of turbulence (see, e.g., the monograph by Frisch [1] which starts with the introductory discussion of "turbulence and symmetry".) Chirality denotes the loss of parity symmetry, which appears to be a theme in multidisciplinaries of modern science [2], of course including turbulence. Recently Meyrand and Galtier [3] proposed the interesting Hall magnetohydrodynamics (MHD)[1] chirality signatured by their "magnetic polarization" defined by the multiplication of the normalized magnetic and cross helicities, while Zhu et al. [4] studied the one owing to pure helical modes (excitations with maximal helicity) universal to various (magneto)hydrodynamic models. These two chiralities refer to different physics but are related, which is here clarified and further explored for a better understanding of Hall MHD dynamics and relevant plasma turbulence in nature. In particolar Meyrand and Galtier's "magnetic polarization" is extended in full two-fluid MHD to be "electron/ion polarization" or "electric polarization", with the cross helicities defined with the electron and ion fluid velocities, to shed more lights, which in turn shows the uniqueness of Hall MHD and its limitation. We also show in detail that, as pointed out in Zhu et al. [4], Meyrand and Galtier's [3] argument based on linear waves can be generalized to the nonlinear regime by restricting to the unichiral (no necessarily homochiral[2]) subsystem.

References

[1] U. Frisch, Turbulence: The Legacy of Kolmogorov. Cambridge University Press (1995).
[2] L. D. Barron, Chirality, **24**, 879 (2012).
[3] R. Meyrand and S. Galtier, Phys. Rev. Lett., **109**, 194501 (2012).
[4] J.-Z. Zhu, W.-H. Yang and G.-Y. Zhu, J. Fluid. Mech., **739**, 479 (2014).

[1] Hall MHD, with a Hall term added to the classical (single-fluid) MHD, is in some sense already a (partially) two-fluid model, but unlike the fullly two-fluid model the electron mass is neglected; here we treat both these partially and fully two-fluid models.
[2] "Homochiral" means not only that each Fourier mode is unichiral but also that all modes are of the same chirality [see, e.g., L. Biferale et al. Phys. Rev. Lett., **108** 164501 (2012)].