B-I2 AAPPS-DPP2018

2nd Asia-Pacific Conference on Plasma Physics, 12-17,11.2018, Kanazawa, Japan

Kinetic turbulence in space and astrophysical plasmas: waves and/or structures?

D. Groselj[1], C. H. K. Chen[2], A. Mallet[3], N. F. Loureiro[4], R. Samtaney[5], K. Schneider[6], F. Jenko[1]

[1] Max Planck Institute for Plasma Physics, [2] School of Physics and Astronomy, Queen Mary University of London, [3] Space Science Center, University of New Hampshire, [4] Plasma Science and Fusion Center, Massachusetts Institute of Technology, [5] Mechanical Engineering, King Abdullah University of Science and Technology, [6] I2M-CNRS, Centre de Mathématiques et d'Informatique, Aix-Marseille University

e-mail (speaker): daniel.groselj@ipp.mpg.de

The topic of sub-ion scale turbulence in weakly collisional space and astrophysical plasmas has been at the forefront of plasma research in recent years. Identifying the key properties of the turbulent fluctuations and predicting the heating of ions and electrons at kinetic scales has proven difficult, due to the wide variety of kinetic processes that can take place at these scales. In view of this complexity, numerical simulations have emerged as an indispensable tool, alongside theoretical efforts and observations.

Here we present recent results from massively parallel, decaying and driven, fully kinetic simulations of plasma turbulence in three spatial dimensions [1, 2]. The simulation setup and plasma parameters are tailored to resemble the typical conditions observed at kinetic scales of the experimentally accessible solar wind. We carry out a set of detailed comparisons of our results against observations and theoretical predictions. For a plasma beta of order unity, we find that the sub-ion scale turbulence can be reasonably well described within the framework of kinetic Alfvén wave turbulence [3], even when the full range of three-dimensional kinetic physics is taken into account. In particular, the spectral field ratios are consistent with linear predictions for kinetic Alfvén waves and the local, scale-dependent anisotropy is found to be broadly consistent with the critical balance conjecture.

Alongside linear wavelike signatures we observe the formation of turbulent kinetic scale structures extending down to electron scales. These structures give rise to intermittent, non-Gaussian statistics of the electron density and magnetic fluctuations. To investigate the interplay between the wavelike features and the large-amplitude localized structures we introduce a set of novel diagnostic measures based on a wavelet scale decomposition (Fig. 1). More specifically, we introduce appropriate generalizations of the spectral field ratios to study the impact of the large-amplitude turbulent structures on the wavelike properties. The generalized ratios indicate that the turbulent structures themselves preserve linear signatures of kinetic Alfvén waves to order unity. This quantitative evidence, obtained from a first principles kinetic simulation and from solar wind spacecraft measurements, suggests that the wavelike properties and structure formation are not mutually exclusive but may instead work hand in hand. It also hints at the possibility that the sub-ion scale structures could be described within the framework of kinetic Alfvén wave turbulence as the nonlinearly evolving eddies of the wavelike turbulent cascade.

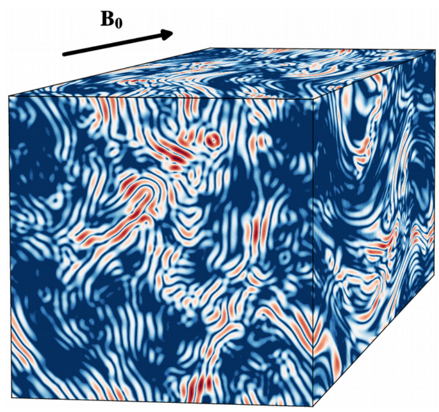

Figure 1: Wavelet decomposed sub-ion scale magnetic fluctuations in a forced 3D fully kinetic simulation.

References

[1] D. Groselj *et al., (2018), in preparation.*

[2] D. Groselj, A. Mallet, N. F. Loureiro, F. Jenko, Phys. Rev. Lett. **120**, 105101 (2018).

[3] G. G. Howes *et al.*, J. Geophys. Res. **113**, A05103 (2008); A. A. Schekochihin *et al.*, Astrophys. J. Suppl. Ser. **182**, 310 (2009); S. Boldyrev *et al.*, Astrophys. J. **777**, 41 (2013).