Characterization of kinetic Alfvén turbulence in fully kinetic simulations

D. Grošelj[1], A. Mallet[2], S. S. Cerri[3], A. Bañón Navarro[1], C. Willmott[4], D. Told[1], N. F. Loureiro[4], F. Califano[5], R. Samtaney[6], F. Jenko[1]

[1] *Max-Planck-Institut für Plasmaphysik, Garching, Germany*

[2] *Space Science Center, University of New Hampshire, Durham, NH, USA*

[3] *Department of Astrophysical Sciences, Princeton University, Princeton, NJ, USA*

[4] *Plasma Science and Fusion Center, MIT, Cambridge, MA, USA*

[5] *Physics Department "E. Fermi", University of Pisa, Pisa, Italy*

[6] *King Abdullah University of Science and Technology, Thuwal, Saudi Arabia*

Several years of solar wind measurements have established the existence of a turbulent energy cascade beyond the inertial range, at scales below the ion gyroradius, where collisionless dissipation and dispersive wave physics come into play. The combined effort of observation, theory, and simulation led to much progress on the topic in recent years. However, a firm understanding of the kinetic range turbulence is still lacking.

Here we give an overview of recent results from fully kinetic simulations [1, 2], dedicated to the study of kinetic-scale plasma turbulence in the solar wind. To elucidate the nature of the turbulent cascade, we compare the fully kinetic results against reduced-kinetic simulations, and against phenomenological models. The results are found to be largely consistent with theoretical expectations for a kinetic Alfvén wave (KAW) cascade [3]. In particular, employing massively parallel, 3D simulations with the OSIRIS code [4], we find spectral properties consistent with linear predictions for KAWs and a scale-dependent anisotropy in broad agreement with so-called critical balance. Furthermore, for a plasma beta of order unity, the kinetic-scale spectra from 2D simulations are in excellent agreement with gyrokinetic results, where a KAW cascade is a natural consequence of the model assumptions. We discuss the implications of our results and touch upon the aspects presently outside the scope of the KAW turbulence phenomenology, such as intermittency and the coupling to linear modes other than KAWs.

References

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