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Pathways to Dissipation in Weakly Collisional Plasmas

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The astrophysical plasma is frequently taken to be weakly collisional or collisionless. Therefore, an explicit form of viscous dissipation like in MHD turbulence cannot be easily defined. A mystery that pervades decades of studies without a consensus solution has been to identify the dissipation mechanism in weakly collisional or collisionless plasma by which heat is deposited in the solar corona.

Turbulence enters into space and astrophysical plasmas in many guises. The complexity and variability of the behavior of plasma turbulence is in large part due to the involvement of dynamics at many scales, ranging from macroscopic fluid to sub-electron scales. Observed turbulence in space and astrophysics is expected to involve cross-scale energy transfer and subsequent dissipation and heating.[1,2] Instead of identifying specific mechanisms, we discuss how plasma dynamics bridges multiple scales, what new ingredients are introduced in cross-scale transfer as models progress from fluid to kinetic, and identification of key steps in energy transfer.

Several surrogates, arising from the energy transfer process, are used to estimate energy dissipation rate in weakly collisional plasmas, including Politano-Pouquet law[3] that describes the scaling law of the mixed third-order moments of Elsasser fields increments, electromagnetic work on particles driving macroscopic and microscopic flows[4], and pressure-strain interaction producing internal energy[5,6]. This motivates an investigation in detail of the associations and differences that exist among these energy dissipation surrogates.[7] Figure 1 illustrates the formation of several types of coherent spatial structures in a well-resolved kinetic PIC simulation. These several types of coherent structures are found in nearby regions or even roughly co-located. Growing evidence is found from MHD, Particle in Cell, hybrid Vlasov-Maxwell simulations[8] and from Magnetospheric Multiscale Mission (MMS) observations[9].

References

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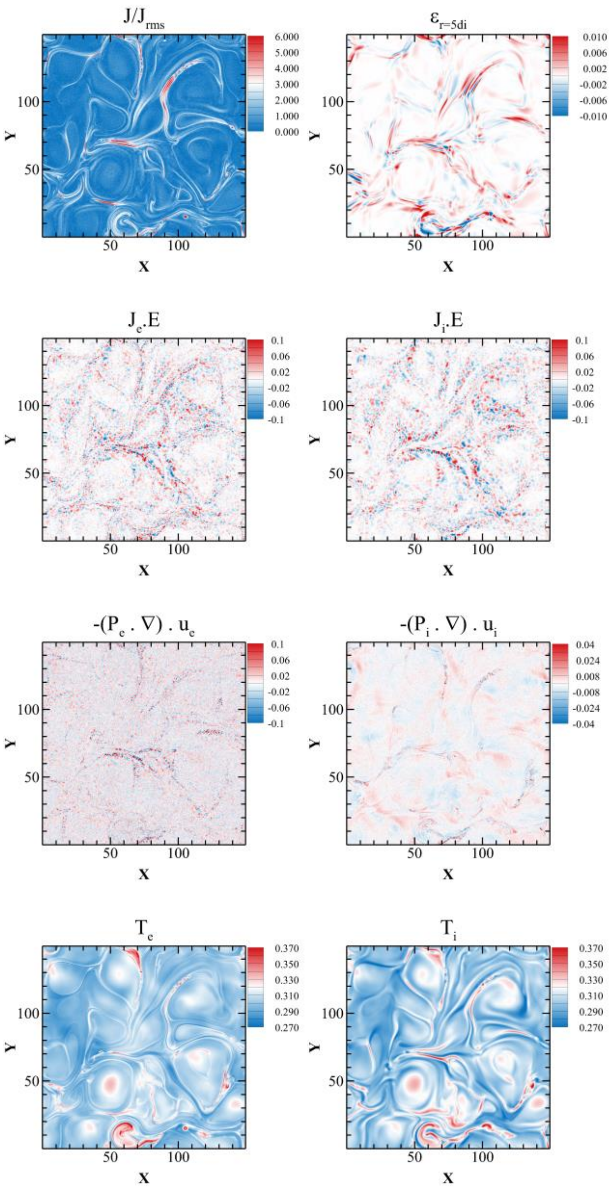
Figure 1. Contour maps of electric current density, different dissipation proxies, and electron and ion temperature, showing coherent structures and spatial coincidence.



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