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# Collisionless ion heating in space and astrophysical plasmas

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Many space and astrophysical plasmas, such as the solar wind, radiatively inefficient accretion flows onto black holes, and the intracluster medium of galaxy clusters (ICM), are hot and dilute, which makes them weakly collisional or even collisionless. We know from direct in-situ measurements (for the solar wind), radio and X-ray observations (for the ICM), and theoretical models alongside sub-mm observations (for the accretion flows) that these plasmas host a broadband spectrum of turbulent fluctuations. One of the outstanding problems in kinetic turbulence is how the energy, injected by large-scale processes, is dissipated at kinetic scales of the plasma, and how does this dissipation shape the distribution functions of particles.

In this talk, I will summarize recent developments in understanding the ion heating in space and astrophysical turbulence from first-principles kinetic simulations performed with a new hybrid-particle-in-cell code PEGASUS++ [1, 2].

In low- and moderate-beta plasmas, such as those in the solar wind and accretion-disk coronae, the dissipation occurs in the kinetic-Alfvén-wave range primarily through a combination of stochastic heating [3] and ion-cyclotron heating [4, 5]. The former process produces ion distribution functions with flat cores and is the dominant mechanism in low-beta regime (currently studied with the Parker Solar Probe in the solar wind). Our simulations of this regime reproduce the observed preferential perpendicular ion heating and the development of non-thermal beams in the ion distribution functions seen in the solar wind. In high-beta regime, deviations from thermodynamic equilibrium caused by the turbulent motions (or global expansion [6]) could make the plasma unstable to a number of kinetic microinstabilities (Figure 1). These instabilities introduce an effective collisionality into otherwise collisionless plasma and thereby impact the dynamics of turbulent fluctuations (similar behavior has been recently observed in the ICM turbulence [7]). Dissipation of turbulence in this regime occurs through a combination of Landau damping and anisotropic viscous heating [8], with the latter mechanism being more important and high values of beta (such as those in the accretion flows and the ICM).

## References

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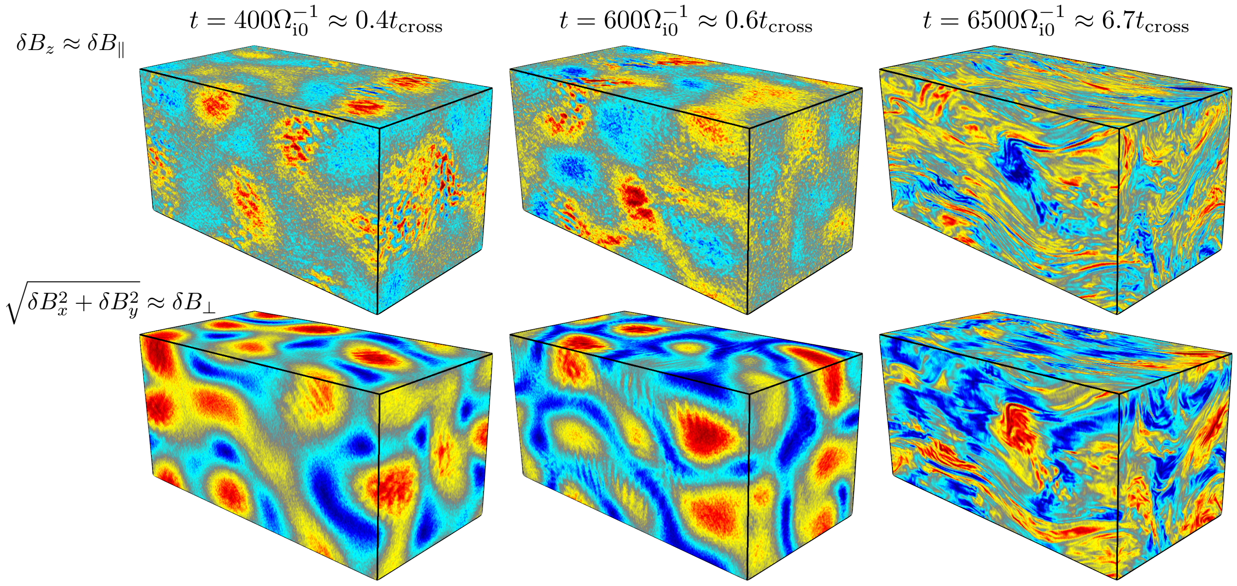

**Figure 1:** The time evolution of the magnetic field strength along the guide field (upper row), and perpendicular to the guide field (lower row) in kinetic simulation of high-beta turbulence [8]. Different snapshots show different stages of the simulation: the disruption of the fluctuations by the mirror instability (left), the ion-cyclotron instability (middle), and the steady-state of the simulation, where turbulence is mediated by the firehose instability (right).