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Dissipation in weakly-collisional turbulent plasmas

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Comprehending the mechanisms of heating and energy dissipation in the solar wind represents one of the long-standing problem for the space plasma community. Indeed, in-situ observations indicate that the cooling of the expanding solar wind is less efficient than expected for an adiabatic expanding gas. Hence, to keep the solar wind hot, a local source of heating must play a role in converting the energy into heat. Several collisionless mechanisms have been proposed to explain the energy dissipation [1]; however these processes, which do not take into account collisions, lacks the final part of the heating process description, related to the irreversible degradation of information.

In the solar wind collisions are considered far too weak to produce significant effects on plasma behavior. However, the presence of strong out-of-equilibrium phase space structures, whose signature has been highlighted by in-situ spacecraft measurements [2] and by means of kinetic numerical simulations [3], could enhance the inter-particle collisions and convert the non-equilibrium features into heat.

By focusing on a spatially homogeneous force-free weakly collisional plasma, here we show that fine velocity structures are dissipated by collisions in a time much shorter compared to global non-Maxwellian features – such as temperature anisotropies – thus indicating that plasma collisionality can locally increase due to the strong velocity space deformation of the particle velocity distribution function [4,5]. To estimate the effect of collisions in a general, turbulent scenario, a numerical campaign of hybrid Vlasov-Maxwell simulations has been performed. In the first part of the simulations, performed by neglecting collisions, we generated the typical kinetic turbulent plasma, which is characterized by the presence of coherent structures, such as vortices and current sheets, and by a strongly perturbed proton distribution function. Then, by turning on collisional effects, we analyzed the inter-play of collisions, which tend to restore the thermal equilibrium, and other collisionless, dynamical processes.

References

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