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Fine velocity structures collisional dissipation in plasmas

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In a weakly collisional plasma, such as the solar wind, collisions are usually considered far too weak to produce any significant effect on the plasma dynamics [1]. However, the estimation of collisionality is often based on the restrictive assumption that the particle velocity distribution function (VDF) shape is close to Maxwellian [2]. On the other hand, *in situ* spacecraft measurements in the solar wind [3], as well as kinetic numerical experiments [4], indicate that marked non-Maxwellian features develop in the three-dimensional VDFs, (temperature anisotropies, generation of particle beams, ring-like modulations etc.) as a result of the kinetic turbulent cascade of energy towards short spatial scales. Therefore, since collisional effects are proportional to the velocity gradients of the VDF, the collisionless hypothesis may fail locally in velocity space.

Here, the existence of several characteristic times during the collisional relaxation of fine velocity structures is investigated by means of Eulerian numerical simulations of a spatially homogeneous force-free weakly collisional plasma. The effect of smoothing out velocity gradients on the evolution of global quantities, such as temperature and entropy, is discussed, suggesting that plasma collisionality can increase locally due to the velocity space deformation of the particle velocity distribution.

In particular, by means of Eulerian simulations of collisional relaxation of a spatially homogeneous force-free plasma, in which collisions among particles of the same species are modeled through the complete Landau operator, we show that the system entropy growth occurs over several time scales, inversely proportional to the steepness of the velocity gradients in the VDF. We report clear evidences that fine velocity structures are dissipated by collisions in a time much shorter than global non-Maxwellian features, like, for example, temperature anisotropies. Moreover we indicate that, if small-scale structures in the VDF are artificially smoothed out by fitting the VDF with some analytical model as, for example, the bi-Maxwellian one, the physics related to small scale structures (entropy growth, existence of many characteristic times) is definitively lost.

These results support the idea that high-resolution measurements of the particle velocity distributions are crucial for an accurate description of weakly collisional systems, such as the solar wind, in order to answer relevant scientific questions, related, for example, to particle heating and energization. Future space missions, planned to increase both energy and angular resolution for the measurements of the particle VDFs, will provide insights for understanding these processes.

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