Study of temperature anisotropy in a turbulent multi-ion plasma: hybrid-Vlasov simulations

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The interstellar medium is a multi-component and weakly collisional system generally observed to be in a fully turbulent regime [1]. The system dynamics at short spatial scales appears to be dominated by kinetic effects that drive the interstellar gas far from the configuration of thermodynamic equilibrium [2, 3, 4]. We present a numerical analysis of a turbulent plasma composed of kinetic ions (protons and alpha particles) and fluid electrons in the typical conditions of the solar-wind environment, developed by using a low-noise hybrid Vlasov-Maxwell code [5, 6] in a five dimensional phase space configuration (two dimensions in physical space and three dimensions in velocity space) [7]. The ion dynamics at short spatial scales (shorter than the proton skin depth) display several interesting aspects, mainly consisting in the departure of the distribution functions from the typical Maxwellian configuration, which has been systematically quantified through the evalutation of the temperature anisotropy ratio (perpendicular to parallel temperature ratio) with respect to the local magnetic field. This temperature anisotropy appears to be a direct effect of the turbulent nature of the system dynamics. Moreover, the turbulent activity leads to the generation of coherent structures, such as vortices and current sheets. Conditioned ion temperature distributions suggest heating associated with coherent structures; the distribution of ion temperatures moves towards higher values with increasing PVI threshold for the upper inertial range in the turbulent spectra. This behavior is more evident for alpha particles than for protons. The physical phenomenology recovered in these numerical simulations reproduces very common features recovered in in situ measurements in the turbulent solar wind [8, 9, 10], suggesting that the multi-ion Vlasov model represents a valid approach to the understanding of the nature of complex kinetic effects in astrophysical plasmas.

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