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Particle populations and energy fluxes in non-thermal plasmas

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Energy is transferred in space plasmas by fields (via the Poynting flux) and by particles (via bulk, enthalpy and heat flux). An energy equation can be written separately (or combined) for each energy channel: electromagnetic, bulk and thermal energy. The energy fluxes than contribute to the balance of each of the energies via divergences of the fluxes mentioned above. This description relies on the moments of the distribution function. The energy flux is the third order moment of the distribution function (density is the zeroth, momentum the first and the pressure tensor the second). We will show in PIC simulation (using ECsim [1,2]) that for different non-thermal heliospheric conditions this description can be misleading. We show that when the plasma is not thermalized and is composed of multiple populations (e.g interpenetrating beams) described by non-Maxwellian distributions, the description via energy fluxes is misleading and gives the false interpretation of beam interactions as a form of energy flux. This is especially the case for different turbulent conditions, such as those observed in the proximity of a shock or near a reconnection site. We will consider especially the role of suprathermal particles and of their angular dependence using, as an example, conditions observed by the MMS mission in the solar wind (MMS has spent part of its time in the solar wind. Even though this was not a main mission-focus) and in the Earth's magnetosphere.

[1] Lapenta, G. (2017). Exactly energy conserving semi-implicit particle in cell formulation. Journal of Computational Physics, 334, 349-366.

[2] Lapenta, G., Gonzalez-Herrero, D., Boella, E. (2017). Multiple-scale kinetic simulations with the energy conserving semi-implicit particle in cell method. Journal of Plasma Physics, 83(2).