Beam-plasma interaction in strongly inhomogeneous solar wind plasmas: Hamiltonian description and numerical modelling

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Observations performed in the solar wind by different satellites show that electron beams accelerated in the low corona during solar flares can propagate up to distances around 1 AU, that Langmuir waves' packets can be clumped into spikes with peak amplitudes three orders of magnitude above the mean and that the average level of density fluctuations in the solar wind plasmas can reach several percents.

A Hamiltonian model is built describing the properties of Langmuir waves propagating in a plasma with random density fluctuations by the Zakharov's equations and the beam by means of particles moving selfconsistently in the fields of the waves. This modeling can be considered as an intermediate approach between the full Vlasov treatment and the Particle-In-Cell description. It consists notably in splitting the particle distribution into two populations : (i) the bulk particles, forming the background plasma, which cannot interact resonantly with the waves and whose motion does not require a kinetic description, and (ii) the resonant beam particles which experience strong energy exchanges with the waves and whose dynamics is described using the kinetic approach. This modeling allows one to reduce the number of macroparticles used in the simulations, giving the possibility to study the microscopic beam dynamics and the Langmuir turbulence over long time periods.

Numerical simulations, performed using parameters relevant to solar type III conditions at 1 AU, show that when the average level of density fluctuations is sufficiently low, the beam relaxation and the wave excitation processes are similar to those in a homogeneous plasma and can be described by the quasilinear equations of the weak turbulence theory. On the contrary, when the average level of density fluctuations overcomes some threshold depending on the ratio of the thermal velocity to the beam drift velocity, the plasma inhomogeneities crucially influence on the characteristics of the Langmuir turbulence and the beam-plasma interaction.

References

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