Roles of microinstabilities in collisionless shocks

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Abstract

In a collisionless shock microinstabilities play important roles. They heat an incoming plasma to provide necessary dissipation in a transition region. They are sometimes able to directly produce non-thermal particles. Furthermore, they produce a scatterer of the non-thermal particles in the context of diffusive shock acceleration (DSA). We review the above mentioned roles of microinstabilities in some cases of quasi-perpendicular shocks from the viewpoint of full particle-in-cell simulation.

First, we focus on the instabilities generated in the so-called foot region, which is produced by the ions specularly reflected at the shock (ramp). The reflected ions become a beam in terms of the incoming plasma so that some microinstabilities get excited. Depending on the shock parameters a variety of instabilities are generated. Here, we introduce electron thermal Mach number, M_{te}, defined as the upstream flow velocity normalized to electron thermal velocity, which is proportional to Alfven Mach number divided by the square root of electron beta. When the Mach number is low, $M_{te} \lesssim 1$, as in the Earth's bow shock, electron cyclotron-drift instability, and modified two-stream instability are dominantly generated. These instabilities contribute to electron as well as ion heating. For higher Mach numbers, $M_{te} >> 1$, Buneman instability gets excited. The resultant large amplitude waves trap some electrons which are accelerated by the convection electric field to non-thermal energy while being trapped.

On the other hand, when $M_{te} < \cos\Theta_{Bn} (B_2/B_1)^{1/2}$, non-negligible amount of electrons are mirror reflected at a shock. The reflected electrons form a foreshock. In the foreshock resonant and non-resonant instabilities are generated. The latter is also called electron firehose instability and efficiently scatter the reflected electrons. The waves play crucial roles in injection of non-thermal electrons into DSA.