

Particle acceleration in high Mach number quasi-parallel shocks

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We study particle acceleration process of electrons and protons in high Mach number ($M_A \sim 30$) quasi-parallel collisionless shocks by particle-in-cell (PIC) simulation. We found that a fraction of protons which consist of the plasma are injected into acceleration mechanisms and efficiently accelerated around the shock. The energy spectrum of the accelerated protons becomes power-law like distribution. A part of electrons are also accelerated around the shock although they are roughly two orders of magnitude fewer than the accelerated protons. For both protons and electrons, the acceleration processes are often not diffusive and their time-scales are even shorter than the respective gyration times. We also found that protons reflected at the shock generate circularly polarized Alfvén waves with very large amplitude in the upstream region of the shock and that, because of the strong perpendicular magnetic field of these waves, the structure of the collisionless shock itself is in fact similar to that of quasi-perpendicular shocks.

Keywords: particle acceleration, plasma, collisionless shocks