Three-dimensional structures of high-Mach-number shocks and associated electron accelerations

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Abstract

Astrophysical shock waves have been a candidate for the origin of cosmic-rays. In particular, X-ray emissions from supernova remnant shocks have provided great opportunities to examine how high-energy electrons are produced at collision-less shocks. Numerical simulations have revealed that electrons can be efficiently heated and accelerated via resonant interactions with plasma kinetic waves, such as the electron shock surfing acceleration mechanism in which electron-scale Buneman instability played key roles. Recently, Matsumoto et al. [2015] proposed a new acceleration mechanism by turbulent reconnection in the shock transition region through excitation of the ion-beam Weibel instability.

In order to deal with the two different acceleration mechanisms in a self-consistent system, we examined 3D PIC simulations of quasi-perpendicular, high-Mach-number shocks. With the help of the high computational capability of the K computer, we successfully followed a long time evolution in which the two different acceleration mechanisms coexist in the 3D shock structure. The Buneman instability was strongly excited ahead of the shock front in the same manner as have been found in 2D simulations. In the transition region, the ion-beam Weibel instability generated strong magnetic field turbulence in 3D space. The turbulence was much stronger than those found in 2D simulations. Plasma blobs found in the turbulent region indicated magnetic reconnection took place in 3D magnetic field structures. As a result, electron energy spectrum in the downstream region exhibited a high energy tail following a power-law distribution. In this talk, we present how such relativistic electrons are produced during traveling in the 3D shock structure.