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Numerical study on particle acceleration in multi-shock system

Masaru Nakanotani[1*], Tohru Hada[1], Shuichi Matsukiyo[1]

[1]ESST, Kyushu Univ

One of the plausible mechanisms producing cosmic rays is the first order Fermi acceleration in a collisionless shock wave. Most of the previous studies on this process are based on the assumption that charged particles interact with a single shock wave. However, a number of shock waves are ubiquitous in space. Two shocks frequently come close to or even collide with each other. For example, in the heliosphere, it is usual that an interplanetary shock collides with a terrestrial bow shock or the termination shock. In our research, we discuss particle acceleration processes in a system including two collisionless shock waves.

First, test particle simulations are performed to reproduce the particle acceleration process in a system including two motionless shocks. We find that power-law index of particle energy spectrum depends on particle energy, i.e., high energy particles show hard spectrum, while low energy particles denote soft one. We have extended the diffusion convection model to discuss the double shock system. The results are understood as follows: the high energy particles with a large diffusion coefficient are able to cross the two shocks within a typical scattering length scale and are efficiently accelerated as if they cross a single shock with a very large effective compression ratio. However, the low energy particles, associated with small diffusion coefficients, can cross only one shock within the same time scattering scale. The power-law index in the double shock system can be, then, harder than that of the strong shock limit (=2) in the single shock system.

Next, we investigate the process of particle acceleration when two collisionless shocks collide with each other by using one-dimensional full particle-in-cell (PIC) simulation. In the previous work [Cargill et al, 1986], they used a hybrid simulation and indicated that ions were efficiently accelerated when two supercritical shocks collided. However, electron dynamics are neglected in a hybrid simulation. Therefore, it cannot resolve the microstructures of the two colliding shocks. Here, we perform the PIC simulation to discuss detailed electromagnetic structures of the colliding shocks as well as the associated acceleration processes of ions and electrons.

Keywords: multi-shock waves, particle acceleration, numerical simulation