**Shock Acceleration with Focused Transport Equation**

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The focused transport equation (FTE) includes all the necessary physics for modeling the shock acceleration of energetic particles with a unified description of first-order Fermi acceleration, shock drift acceleration, and shock surfing acceleration. What’s most important is that the FTE can avoid the limitation of small pitch angle anisotropy inherent in the cosmic ray transport equation. This makes the focused transport theory as an extension of diffusive shock acceleration (DSA). It can be used to investigate the dynamics of low-energy thermal particles or pickup ions near the shock, and it allows calculation of the injection efficiency problem, something that is not easy to solve using other popular shock acceleration theories.

In recent years, the FTE–based theory has been proved to be an efficient tool for reproducing the observational features of the lower energy Termination Shock Particles (TSPs) by Voyagers (*e.g.* le Roux et al. 2007; Florinski 2009). We have investigated the energy spectrum of pickup ions accelerated at shocks of various obliquities with FTE by using a stochastic approach model. Here we focus our discussion on how the focused transport acceleration using FTE is transformed to diffusive shock acceleration. The shock acceleration leads to two-component energy spectra. The low-energy component of the spectrum is made of particles that interact with shock one to a few times. For a parallel shock, the high energy component of the spectrum of power law with the spectral index being the same as the prediction of DSA theory, starts just a few times injection speed. For an oblique or quasi-perpendicular shock, the high-energy component of the spectrum exhibits a double power-law distribution: a harder power-law spectrum followed by another power-law spectrum with a slope the same as the spectral index of DSA. It can be concluded that the shock acceleration will eventually go into the DSA regime at higher energies even if the particle anisotropy is not small. The intensity of the energy spectrum given by the FTE, in the high-energy range where particles get efficient acceleration in the DSA regime, is different from that given by the standard DSA theory for the same injection source. Our simulation is able to qualitatively explain the production of multiple power-law energy spectra of TSPs observed by Voyagers.

Here I would like to present another test particle simulation of injection and acceleration of low-energy particles by parallel shocks with the focused transport model. In the simulation, we found that the particles with speed of a portion of to a few times the shock speed can indeed be directly injected and accelerated into the diffusive shock acceleration process by parallel shocks. Starting from a few times shock speed, the accelerated energy spectrum is a power-law spectrum with spectrum index same as the solution of standard DSA theory although the particles are highly anisotropic in the upstream. The injection efficiency that measures the relative acceleration rate of source particles accelerated to high energy varies with the shock strength. It becomes larger for a stronger shock. And it evidently increases with the injection speed of source particles for a given stable shock. In addition, if the injection speed is above a few times the shock speed, the power-law spectrum is well consistent with the prediction of standard DSA theory.