§13. Simulations of Shock Wave Acceleration of High Energy Particles Associated with Coronal Mass Ejections

Den, M. (NICT),
Ogawa, T. (Kitazato Univ.),
Yamashita, K. (Yamanashi Univ.)

We studied time evolution of an energy spectrum of a proton flux in the range of 47 – 4750 keV for the energetic particle event occurred on 314 DOY in 2000. It is believed that coronal mass ejection (CME) driven shock waves can produce energetic particles by diffusive shock acceleration. We modeled the process by the following two steps: a study of the shock propagation and a study of acceleration at the shock. The shock wave is realized by a three-dimensional hydrodynamic simulation with an Adaptive Mesh Refinement (AMR) scheme. The acceleration of particles is simulated by Stochastic Differential Equation (SDE) method.[1)] Figure 1 is a snap shot of the CME propagation on the x-y plane. The color contour is velocity, the sun is set on the center, and the earth is placed at the cross point. It shows that the shock wave is formed and passes through the earth orbit. Figure 2 presents time evolution of energetic particles observed by ACE satellite. It indicates that energetic particles were injected before shock wave passage, in other words, there existed pre-accelerated particles without a shock wave. In our simulation models, some assumptions are adopted for simplicity, and main one is constant diffusion coefficient. We will improve this in future. Here we modeled seed particle distribution as follows : Model A - particles of 0.05MeV are continuously input at the shock front, Model B – particles of which the spectrum is that just before the CME occurrence (see Fig. 2 right panel), Model C – 2% particles of Model B and 98% particles of 0.15MeV at the shock front at t=0.45day, where t=0 is the time when the CME occurred, Model D – similar to the Model C except the time of input of particles, not t=0.45day but t=0.15day. Figures 3 display simulated time evolution of energy spectrum for four models. It is seen that Model C may reproduce the observation qualitatively. Thus it is found that the spectrum depends on the seed particle model. As for compression ratio of the shock wave, we can evaluate that accurately because our code, adopting AMR and TVD scheme for flux part, can represent discontinuity with a minimum numerical viscosity. However we confirm that it is not so effective for acceleration of particles.

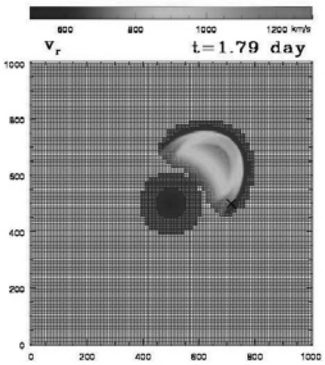
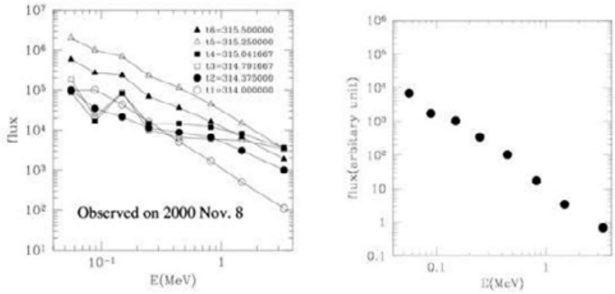


Fig. 1. A snap shot of the CME propagation on the x-y plane.



nts

Fig. 2. Time evolution of energy spectrum for observed energetic particles (left). Energy spectrum of ambient solar wind (right).

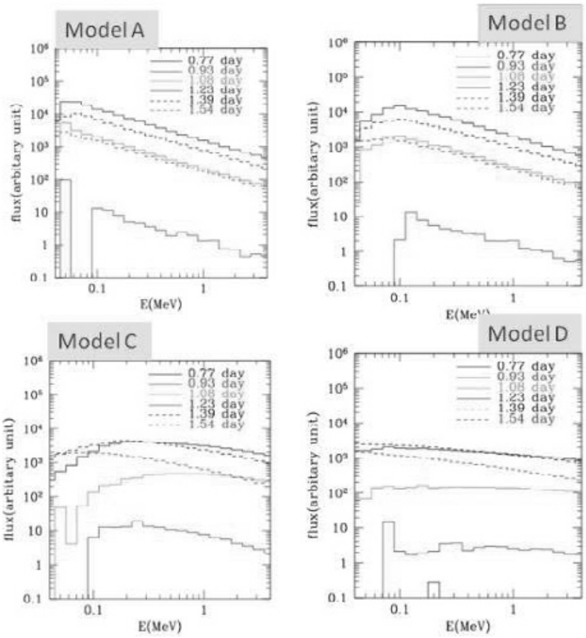


Fig. 3 Simulation results of time evolution of energetic particles for four seed particle models.

1) Yoshida, T. and Yanagita, S. : Prog. of Theor. Phys. **92** (1994) 1217.