§15. Three-dimensional Simulations of Explosive Phenomena on the Solar Surface

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We studied influences of solar wind structure on coronal mass ejection (CME), one of macroscopic plasma phenomena, by using 3D hydro-dynamical simulations of an ambient solar wind and a CME and shock diffusion acceleration process of energetic particles associated with CMEs.

For the former theme, our purpose is to reproduce CME occurring on July 20, 2004. We assume that slow wind region is formed on magnetic neutral line obtained from source surface data provided by WSO and we simulated ambient solar wind structure. The right figure of Fig. 1 shows a hierarchical mesh structure and solar wind velocity distribution (color on the mesh) on the horizontal plane. The sun is centered and the unit is the solar radius. The left one of Fig. 1 is snap shot of density distribution of CME propagation on that structured ambient solar wind.

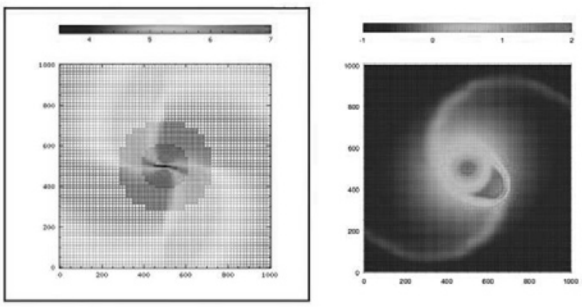

Fig. 1 Left: A hierarchical mesh structure with velocity contour. Right: Color contour of density distribution.

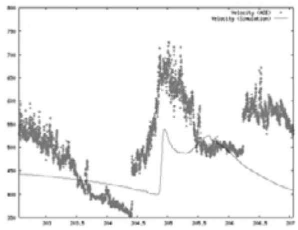

Fig. 2 Velocity profile at the L1 point. Our simulation result (thin line) and observation data (red line).

Figure 2 represents the velocity profiles of our simulation result and that observed by the ACE satellite. The horizontal axis is day of year. Simulated shock wave arrived later than the observed one though the timing of the peak is in good agreement. The difference may be partly due to the ambient solar wind model and more detail analysis is needed.

For the latter theme, 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 255 DOY in 1999. It is believed that 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 hydrodynamic simulation with an Adaptive Mesh Refinement (AMR) scheme. The acceleration of particles is simulated by Stochastic Differential Equation (SDE) method. Figure 3 is time evolution of radial component of solar wind velocity, which shows shock wave formation and propagation. Figures 4 display time evolution of the energy spectrum of the energetic particles accelerated by the shock wave. It is found that the spectrum depends on the seed particle model.

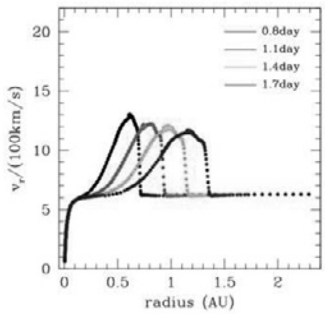

Fig. 3 The profile of radial component of velocity at 0.6 day, 1.1 day, 1.4 day and 1.7 day after CME occurred. The horizontal axis is the distance from the sun, and unit is AU.

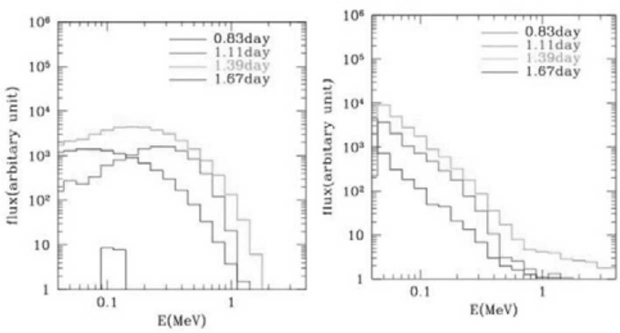

Fig. 4 Time evolution of an energy spectrum. Time indicates that after CME occurred. The energy spectrum of seed particles is different between left and right model. Pre-accelerated particles are assumed in the left model.