Precursor Waves in Relativistic Shocks

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The origin of high energy cosmic rays has been a long-standing problem in astrophysics. Many particle acceleration mechanisms such as Fermi shock acceleration in relativistic jets and magnetic reconnection in pulsar/magnetor magnetosphere have been proposed so far, however, there is no plausible model to explain such energetic particles. Recently Chen et al. (2002) proposed the particle acceleration by the ponderomotive force of a large amplitude Alfvén wave as a model of ultra-high energy cosmic rays, based on the wakefield acceleration process (Tajima and Dowson 1979). Since then the mechanism attracts interests in astrophysical field. In relativistic shocks, the generation of large-amplitude precursor electromagnetic waves is discussed by synchrotron maser instability (Hoshino and Arons 1991). Lyubarsky (2006) suggested the precursor waves excited in the relativistic shock front induces the electrostatic field, and argued that it may be responsible to the particle acceleration. Hoshino (2008) extended the previous studies and demonstrated the efficient particle acceleration by the incoherent wakefields induced by the large-amplitude precursor electromagnetic waves in the upstream region of a relativistic shock wave by using one-dimensional Particle-In-Cell (PIC) simulation.

However, the efficiency of the particle acceleration by the wakefield mechanism is sensitive to the nature of the precursor electromagnetic waves, because the ponderomotive force is known to strongly depend on the wave amplitude and the wave coherence. In this study, we argue the precursor waves in relativistic shocks by using the two-dimensional PIC simulation. Since relativistic shocks are mainly controlled by “sigma parameter” which is the ratio of the Poynting flux and plasma flow energies, the amplitude of the precursor wave depends on sigma parameter. For instance, in our simulations, the amplitude of the precursor wave gets smaller and the wave coherency of the precursor wave gets lower as sigma parameter decreases, and the amplitude dependence on sigma parameter in two-dimensional simulations is different from that in one-dimensional simulations. Furthermore, the previous one-dimensional simulations could not investigate the wave coherency of the precursor wave. We must take account of the wave coherency when considering the wakefield acceleration because the wave coherency of the precursor wave, which is required for the ponderomotive force, is essential to the wakefield acceleration. In this presentation, we compare two-dimensional simulations to one-dimensional simulations and report our results.

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