Precursor wave emission in relativistic ion-electron shocks

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Observations of active galactic nuclei and gamma ray bursts usually show broad nonthermal spectra, which are believed to originate from synchrotron radiation and inverse Compton scattering of relativistic electrons. Since the relativistic outflow from the central compact object is the common feature in AGNs and GRBs, relativistic shocks can be formed upon interaction between the jets and the interstellar medium. The relativistic shocks are assumed to play an important role for generating such nonthermal electrons.
Previous 1D PIC simulations showed that synchrotron maser instability (SMI) is the significant dissipation mechanism for relativistic magnetized shocks. SMI is driven by particles reflected off the shock-compressed magnetic field in the shock-transition region and emits electromagnetic waves of extraordinary mode (X-mode) both upstream and downstream (Hoshino & Arons 1991). Since the electromagnetic precursor waves have a non-negligible fraction of the upstream kinetic energy, the upstream flow is significantly perturbed by the precursor wave (Lyubarsky 2006). Hoshino (2008) demonstrated that the wave power is strong enough to induce wakefield in the upstream and that nonthermal electrons are generated by wakefield acceleration (WFA; Tajima & Dawson 1979; Chen et al. 2002) in 1D relativistic shocks propagating in magnetized ion–electron plasmas.
In multidimensional systems, it is well known that Weibel instability (WI) develops in the transition region of weakly magnetized shocks. Previous PIC simulation studies in multiple dimensions indeed showed that the shock transition is dominated by the WI at low magnetization. Since both WI and SMI are excited from the same free energy source in the same region and the growth rate of the WI is larger than that of the SMI at low magnetization, it was believed that the WI dominates over the SMI and the precursor wave emission could be shut off in multidimensional shocks.
Recently, by using 2D PIC simulations, we have shown that the SMI can coexist with the WI and that the precursor wave emission continues to persist to the Weibel-dominated regime (Iwamoto et al. 2017). We also showed that the wave power is sufficient enough to induce wakefield for a wide range of magnetization parameter. However, the WFA did not operate in our previous simulation in pair plasmas because the finite mass ration between positive and negative charges is essential for the WFA. To investigate the feasibility of the WFA in relativistic shocks, we carried out 2D simulations in ion-electron plasmas. We found that a clear suprathermal tail is not visible although the wakefield is indeed induced in the upstream. We discuss the acceleration mechanism in this presentation.

Keywords: acceleration of particles, collisionless shocks, cosmic rays

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