相対論的衝撃波における航跡場加速

岩本 昌倫 [1]; 天野 孝伸 [1]; 星野 真弘 [1]; 松本 洋介 [2]
[1] 東大・理; [2] 千葉大理

Wakefield acceleration in two-dimensional relativistic shocks

Masanori Iwamoto[1]; Takanobu Amano[1]; Masahiro Hoshino[1]; Yosuke Matsumoto[2]
[1] University of Tokyo; [2] Chiba University

The origin of high energy cosmic rays has not been fully understood, and the acceleration mechanism is still controversial. Recently Chen et al. (2002) proposed the particle acceleration by the large-amplitude Alfven waves at gamma-ray bursts as a model of the generation of ultra-high energy cosmic rays, based on the wakefield acceleration (WFA) mechanism which was initially proposed by Tajima and Dowson (1979) in the context of laser-plasma interactions in the laboratory. The WFA in laboratory is induced by an intense laser pulse (or transverse electromagnetic waves) propagating in a plasma. The mechanism may also operate in relativistic shocks in nature because it is known that large-amplitude electromagnetic precursor waves are excited by synchrotron maser instability (SMI) driven by the particles reflected off the shock-compressed magnetic field in relativistic shocks (Hoshino and Arons, 1991). In fact, Hoshino (2008) demonstrated the generation of the non-thermal electrons by the wakefield induced by the ponderomotive force of the electromagnetic precursor waves in relativistic magnetized shocks by means of 1D PIC simulation.

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 the wakefield is indeed induced in the upstream. In this presentation, we discuss the acceleration mechanism.