Magnetic Field Amplification Driven by Relativistic Shock-Clump Interaction

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Understanding magnetic field amplification in astrophysical shocks is important for understanding of acceleration mechanism of cosmic rays and radiation mechanisms of high-energy photons in high-energy astrophysical phenomena [1,2]. So far, magnetohydrodynamic (MHD) simulations [3,4] and laboratory experiments [5] have investigated magnetic field amplification in a non-relativistic or mildly relativistic shock propagating through inhomogeneous media. According to their studies, turbulence is driven by the interaction between the shock and density fluctuation in the shock downstream region and amplifies the ambient magnetic field. The turbulent dynamo is thought to be a promising mechanism of magnetic field amplification.

Shock waves formed in high-energy astrophysical phenomena are generally collisionless system. In the collisinless system, the shocked density fluctuations could easily decay due to particle diffusion because the coulomb mean-free path is much longer than the system size. We investigate - for the first time- the relativistic magnetized shock-clump interaction by means of particle-in-cell (PIC) simulations. We also perform relativistic MHD simulations for the same condition and compared the results between PIC and MHD. In both the PIC and MHD simulations, the shocked clump rapidly decelerates. We can derive the deceleration of the shocked clump in an analytic formula. Moreover, in the PIC simulation, particles in the shocked clump escape along the magnetic field line. As a result, the vorticity in the PIC simulations is lower than that in the MHD simulations. Owing to the particle escape and the rapid deceleration, we found that the turbulent dynamo by the shock-clump interaction is not efficient for relativistic collisionless shocks [6].

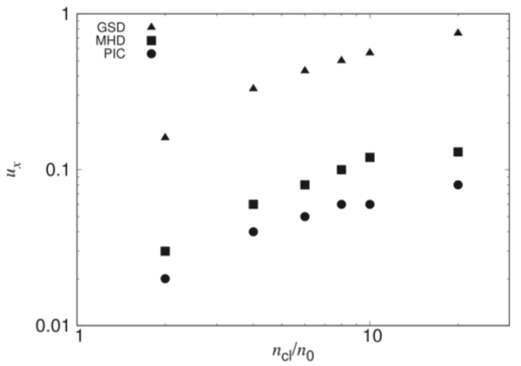

Fig.1 The x component of four velocity of the shocked clump at t=2t_{esc}, as a function of the density of the clump. t_{esc} is the escape time along the magnetic field line.

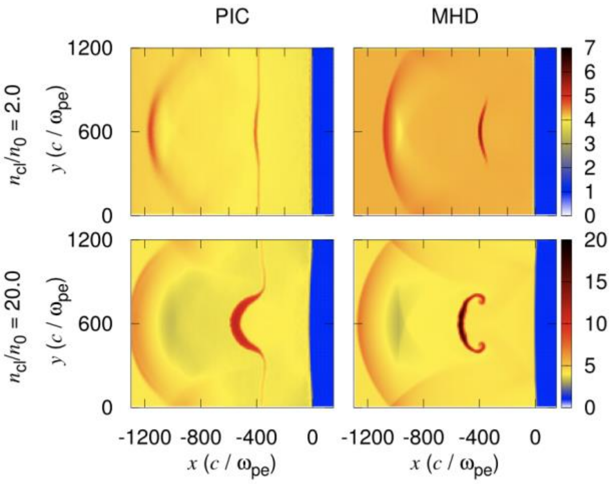

Fig.2 Density distribution in the downstream region at t=2t_{esc}, for the density of the clump, n_{cl}/n_0=2 (top row) and n_{cl}/n_0=20 (bottom row). The left and right columns show the results for the PIC and MHD simulations, respectively.

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