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Magnetic Field Amplification Driven by a Relativistic Shock-Clump Interaction in Collisionless Plasma Systems

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Investigations of magnetic field amplification mechanisms at astrophysical shocks are important for understanding of acceleration mechanism of cosmic rays and radiation mechanisms in high-energy astrophysical phenomena. So far, magnetohydrodynamic (MHD) simulations and laboratory experiments have investigated magnetic field amplification in a non-relativistic or mildly relativistic shock propagating through inhomogeneous media. According to their studies, turbulence driven by the interaction between the shock and density fluctuation amplifies the ambient magnetic field in the post-shock region. The turbulent dynamo is thought to be a promising mechanism of magnetic field amplification. However, in collisionless systems, 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 collisionless 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 due to relativistic effects. 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 [Tomita et al. 2022].

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