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Magnetic field amplification by turbulent dynamo in relativistic collisionless shocks

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Cosmic rays are thought to be efficiently produced in collisionless shocks in high-energy astrophysical sources, where cosmic rays are diffusively scattered by magnetic fluctuations. The magnetic field near the shock decides the maximum energy of cosmic rays accelerated in the sources and emission mechanisms by the accelerated particles. However, magnetic field strength and structure around the shock are not understood yet.
Recent magnetohydrodynamics (MHD) simulations of shocks propagating into inhomogeneous media show that the ambient magnetic field is amplified by turbulent dynamo in the downstream region. According to these simulations, the turbulent dynamo always works as long as the magnetic energy is smaller than the kinetic energy of the downstream turbulence. However, the shocks formed in astrophysical phenomena are often driven by collisionless plasma, where non-thermal particles are generated, so that it is unknown whether the MHD approximation is applied to the downstream flow. For shocks in gamma-ray bursts, the size of density fluctuations has to be about ten times the gyroradius of the thermal protons to amplify the magnetic field by the downstream turbulence. We perform particle-in-cell simulations of relativistic collisionless shocks propagating into a pair plasma with a density clump whose size is ten times the gyroradius of downstream thermal plasmas. We found that the magnetic field amplification does not work if the amplitude of the upstream density fluctuation is below a critical value.

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Gamma rays

Summary

In order to investigate whether the MHD approximation is satisfied in the downstream region of collisionless shocks, we perform particle-in-cell simulations of relativistic collisionless shocks propagating into an inhomogeneous magnetized plasma. As a result, the magnetic field amplification by turbulent dynamo does not work if the amplitude of the upstream density fluctuation is below a critical value.

Primary author: Dr TOMITA, sara (Tohoku University)

Co-author: Dr OHIRA, Yutaka (The University of Tokyo)

Presenter: Dr TOMITA, sara (Tohoku University)

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