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Particle-in-Cell Simulations of Synchrotron Maser Emission and Associated Particle Acceleration in Relativistic Shocks

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Relativistic shocks are ubiquitous in the universe, in which synchrotron maser instability produces intense electromagnetic precursor waves. Recent one-dimensional Particle-in-Cell (PIC) simulations show that longitudinal electrostatic waves, which are called wakefields, are induced in the wake of the large-amplitude electromagnetic waves and that nonthermal particles are generated during the nonlinear collapse of the wakefields (Lyubarsky 2006; Hoshino 2008). This particle acceleration may explain the origin of ultra-high-energy cosmic rays (Chen et al. 2002).

Although the synchrotron maser instability in the context of relativistic shocks are important for the cosmic ray acceleration, it has so far been discussed solely with one-dimensional PIC simulations (e.g., Langdon et al. 1988) and it is not well known whether the same mechanism can operate in more realistic multidimensional systems. However, our high-resolution two-dimensional PIC simulations (Iwamoto et al. 2017, 2018) showed that the wave emission continues with substantial amplitude for the first time. We confirmed that the large-amplitude electromagnetic precursor waves continue to persist and that the wakefields are indeed excited by the intense electromagnetic waves (Iwamoto et al. 2019). The wakefields collapse during the nonlinear process of the parametric decay instability in the near-upstream region, where both ions and electrons are accelerated by the motional electric field in the upstream and produce clear nonthermal tails in the particle energy spectra measured in the upstream rest frame. In this talk, we discuss this particle acceleration and wave-plasma interaction for more details.

Keywords

particle acceleration; plasma instabilities; shock waves

Collaboration

other Collaboration

Subcategory

Theoretical Results

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