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Collisionless shock in a relativistically hot and unmagnetized plasma

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Collisionless shocks in relativistically hot ($T \gg mc^2$) plasmas are investigated using the Particle-In-Cell (PIC) simulation. Shocks in space are collisionless shocks, which are mediated by wave-particle interactions rather than the Coulomb collisions. Considering the upstream temperature, shocks can be classified into two types: cold upstream ($T \ll mc^2$) and relativistically hot upstream ($T \gg mc^2$). Shocks in relativistically hot plasmas are thought to exist in the universe such as the internal shock model of gamma-ray bursts, the lobe of radio galaxies, and the downstream of a shock in a density inhomogeneous region because the downstream of a shock with relativistic velocity is relativistically hot. However, there are few kinetic simulation studies of such shocks, and we don't know how efficiently particles are accelerated, how strong magnetic fields are generated, or even whether a shock is formed as collisionless.
We elucidate the kinetic properties of shocks in unmagnetized electron-positron relativistically hot plasmas using the PIC simulation.

1. Shocks mediated by the Weibel instability are formed consistent with the Rankine-Hugoniot relation.
2. With appropriate standardization, kinetic properties such as the strengths and wavelengths of the magnetic fields and the energy spectrum are almost independent of the upstream temperature, even as the temperature becomes relativistically hotter and hotter.

Our simulation results can be understood by considering so-called the relativistic beaming effect. Our results can be applied to various high-energy astrophysical phenomena and the cosmic ray acceleration processes.

Collaboration(s)

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