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Production of non-thermal electrons at nonrelativistic perpendicular shocks of young supernova remnants

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Abstract content

The injection problem is a key and still unresolved issue of diffusive shock acceleration theory. Electron injection mechanisms at high Mach-number nonrelativistic perpendicular shocks are under consideration here for parameters that are applicable to young SNR shocks. Using high-resolution large-scale two-dimensional fully kinetic particle-in-cell (PIC) simulations we explore the production of high-energy electrons in the shock transition. Tracing individual particles we in detail analyze the physics of the formation of non-thermal electron population. Ion reflection off the shock leads to the formation of magnetic filaments in the shock ramp, resulting from Weibel-type instabilities, and electrostatic Buneman modes in the shock foot. Electrons are accelerated via shock surfing acceleration (SSA) in the Buneman-instability region and undergo further scattering in the Weibel-instability region via a second-order Fermi-like process. The combination of these two processes leads to the formation of a non-thermal electron population, but their individual impact strongly depends on the Alfvenic Mach number and reduced ion-to-electron mass ratio. We discuss the resulting electron spectra and the relevance of our results to the physics of systems with real ion-to-electron mass ratio and fully three-dimensional systems.

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