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Electron Pre-acceleration Through Stochastic Shock Drift Acceleration at Intracluster Shocks

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Radio and X-ray observations of radio relics indicate acceleration of relativistic electrons at merger shocks in galaxy clusters. These large-scale shocks can also be sites of ultra-high-energy cosmic ray production. It is assumed that diffusive shock acceleration (DSA) produces synchrotron-radiating electrons but the process of electron pre-acceleration from thermal to supra-thermal energies is poorly known. Using large-scale fully-kinetic two-dimensional particle-in-cell (PIC) simulations of a quasi-perpendicular subluminal shock with low sonic Mach number ($M_s = 3$) and propagating in hot intracluster medium with plasma beta $\beta = 5$, we have recently demonstrated that the main electron pre-acceleration mechanism is stochastic shock-drift acceleration (SSDA). In this process electrons are confined at the shock by pitch-angle scattering off turbulence and gain energy while drifting along the motional electric field. We showed that multi-scale magnetic turbulence, including ion-scale shock rippling modes, is essential for electron energization. This turbulence is driven by effective ion and electron temperature anisotropies in the entire shock transition. Wide-energy non-thermal electron distributions are formed both upstream and downstream of the shock and the maximum energy of the electrons is sufficient for their injection into DSA. Here we report on our new PIC simulation studies of SSDA process in a range of plasma beta ($\beta = 3 - 30$) and subluminal shock obliquity angles. We show that SSDA persists in facilitating the electron injection in rippled shocks. We also present how the SSDA efficiency vary with intracluster medium and shock parameters.

Keywords

particle acceleration, galaxy clusters, shock waves, intracluster medium, plasma instabilities, PIC simulations

Collaboration

other Collaboration

Subcategory

Theoretical Results

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