Contribution ID: **55** Type: **Oral**

Electron injection in merger shocks of galaxy clusters

Tuesday 3 December 2019 14:30 (20 minutes)

Radio and X-ray observations of so-called radio relics indicate electron acceleration at merger shocks in galaxy clusters. These large-scale shocks are also candidate sites for ultra-high-energy cosmic ray production. Merger shocks have low Mach numbers and propagate in high beta plasmas, $\beta \gg 1$. Particle acceleration and in particular electron injection mechanisms are poorly understood in such conditions. Here we report results of our large-scale 2D particle-in-cell simulations of cluster shocks that allow the development of multi-scale turbulence in the shock transition, including ion-scale shock rippling modes. We show that the presence of turbulence in multi scales is critical for efficient electron pre-acceleration. The main injection process is stochastic Shock Drift Acceleration, in which electrons are confined in the shock region by pitch-angle scattering off magnetic turbulence and gain energy from motional electric field. Wide-energy non-thermal electron distributions are formed both upstream and downstream of the shock. We demonstrate that the downstream electron spectrum has a power-law form with index $p = 2.4$, in agreement with observations. Pre-acceleration to very high energies occurs that should lead to electron injection to Diffusive Shock Acceleration processes in the presence of long-wave MHD upstream turbulence.

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Session Classification: Parallel

Track Classification: Cosmic rays