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Electron Acceleration in the Earth's Magnetotail Using Multi-Scale Simulations

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Magnetic reconnection in magnetized plasma represents a change in the topology of magnetic fields and is associated with a concomitant energization of charged particles that results from a conversion of magnetic energy into particle energy.

Using data from the THEMIS and Cluster missions together with global and test particle simulations, we demonstrate that during a substorm on February 15, 2008 electrons are energized in two distinct regions: A low-energy population (up to a few keV) appears to arise in the diffusion region where particles are demagnetized and the magnetic topology changes. In addition a high-energy component that is energized by betatron acceleration arises within dipolarization fronts as they sweep toward the inner magnetosphere far from the diffusion region. This study concluded that particle energization is not associated solely with the conversion of magnetic to kinetic energy but, at least in the magnetosphere, also arises in conjunction with macroscopic flows. In a second substorm study, on March 11, 2008 we found that the test particle results compared favorably with observations only when we added a high-energy tail to the distribution function near the reconnection site. This implies that acceleration near the X-line was substantial and needs to be included. THEMIS and Cluster observations indicate that plasma waves are associated with the dipolarization fronts [1]. The test particle calculations are not self-consistent and do not include plasma waves. Therefore, to fully understand the processes that lead to electron acceleration throughout the near-Earth tail, we need to utilize a self-consistent kinetic approach that includes waves and electron acceleration near the neutral line along with large-scale dynamics.

We present results from a model which couples the large scale magnetospheric processes and kinetic processes by developing a simulation approach in which a global MHD simulation is coupled with a particle in cell simulation. In this approach we couple the UCLA global MHD code [2] with the iPIC3D implicit particle in cell code [3]. We use a two dimensional version of iPIC3D to investigate the multi-scale nature of the electron energization during the February 15, 2008 substorm. In this multi-scale simulation the electric and magnetic fields show the quadrupolar signature of Hall-MHD which is absent in the resistive MHD simulation. Moreover the electrons move much faster than the ions especially at the separatrices and the inflow boundary. We note that during this event, just like in the case of the MHD, dipolarization fronts are formed mainly earthward of the neutral line. Finally, we find that electrons are energized near both the x-line and dipolarization fronts, but the energization is greater at the latter location.

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