2nd URSI AT-RASC, Gran Canaria, 28 May – 1 June 2018

Ion Trapping and Acceleration at Dipolarization Fronts: High-Resolution MHD/Test-Particle Simulations

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Much of plasma heating and transport from the magnetotail into the inner magnetosphere occurs in the form of mesoscale discrete injections associated with sharp dipolarizations of magnetic field (dipolarization fronts). In this study we investigate the mechanisms of ion acceleration at dipolarization fronts in a high-resolution global magnetospheric MHD model (LFM). We use large-scale three-dimensional test-particle simulations (CHIMP) to address the following science questions: 1) what are the characteristic scales of dipolarization regions that can stably trap ions? 2) what role does the trapping play in ion transport and acceleration? 3) how does it depend on particle energy and distance from Earth? 4) to what extent ion acceleration is adiabatic? High-resolution LFM was run using idealized solar wind conditions with fixed nominal values of density and velocity and a southward IMF component of -5 nT. To simulate ion interaction with dipolarization fronts, a large ensemble of test particles distributed in energy, pitch-angle, and gyrophase was initialized inside one of the LFM dipolarization channels in the magnetotail. Full Lorentz ion trajectories were then computed over the course of the front inward propagation from the distance of 17 to 6 Earth radii. A large fraction of ions with different initial energies stayed in phase with the front over the entire distance. The effect of magnetic trapping at different energies was elucidated with a correlation of the ion guiding center and the ExB drift velocities. The role of trapping in ion energization was quantified by comparing the partial pressure of ions that exhibit trapping to the pressure of all trapped ions.