DPP05-2005-000619

Abstract for an Invited Paper
for the DPP05 Meeting of
the American Physical Society

Two-fluid effects on 3D reconnection in the SSX experiment with comparisons to space data

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We report on several new experimental results from spheromak merging studies at the Swarthmore Spheromak Experiment (SSX) with relevance to three dimensional reconnection in laboratory and space plasmas. First, we discuss a measurement of non-ideal terms of the generalized Ohm's law at a reconnection site of a weakly collisional laboratory plasma (recently reported in GRL, Cothran, et al). Time resolved vector magnetic field measurements on a 3D lattice ($\mathbf{B}(\mathbf{r},t)$) enables evaluation of the various terms. Results show that the Hall term dominates everywhere ($\mathbf{J}\times\mathbf{B}$); resistive and electron inertia terms are small. The suggestion is that electron pressure supports the reconnection electric field at the neutral point. Second, we discuss experimental measurement of the in-plane Lorentz force and out-of- plane magnetic field associated with the Hall electric field near the reconnection zone. Both show a quadrupolar structure at the ion inertial scale. Earlier work at SSX has shown that formation of three- dimensional structure at the ion inertial scale is temporally and spatially correlated with the observation of superthermal, super-Alfvénic ions ions accelerated along the X-line normal to the local 2D plane of reconnection. Anomalous resistivity, while not ruled out, is not required to account for the results. Third, we report on recent velocity and temperature measurements of impurity ions using ion doppler spectroscopy (IDS). Bi-directional outflow at nearly the Alfvén speed is clearly observed. Each of these will be related to and compared with similar measurements in a solar or space context.