Two-fluid magnetic relaxation in RFPs and initial CT injection experiments at WiPAL

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Experimental measurements in the MST device and nonlinear simulations with extended MHD models show the importance of two-fluid effects in magnetic relaxation, a key mechanism in the self-organization of RFP plasmas. In standard RFP experiments with a steady applied loop voltage in MST, both parallel current density and parallel flow equilibrium profiles are observed to relax concurrently with large bursts of magnetic fluctuations during quasiperiodic sawtooth crashes. The magnetic relaxation is due to a dynamo-like EMF generated by the nonlinear interactions of multiple tearing modes. In two-fluid MHD, this is expressed via a mean-field generalized Ohm's law including the fluctuation-induced EMF terms called the MHD and Hall dynamos. A Hall-like term also appears as a Maxwell stress in the mean-field parallel momentum equation (where it is accompanied by a Reynolds stress term), coupling magnetic relaxation to flow relaxation. Although single-fluid MHD simulations (Reusch et al., PRL 2011) reproduce the qualitative dynamical behavior of the magnetic equilibrium and fluctuations and the durations of sawtooth periods, the predicted magnetic fluctuation amplitudes are about twice as large as in the experiment. Additional effects, such as the Hall term and ion gyroviscosity used in extended MHD simulations (King et al., POP 2012) with the NIMROD code, might resolve such discrepancies. In MST, recent probe measurements of the Hall EMF for $r/a>0.6$ show a complex radial profile, similar to the results of recent nonlinear simulations of extended MHD with NIMROD.

CT injection experiments have recently been started at the Wisconsin Plasma Astrophysics Laboratory (WiPAL) by D. Endrizzi, C. Forest, and coworkers. With support and loaned equipment from the CT injection team at Tri Alpha Energy, Inc. and Nihon University (see, for examples, I. Allfrey et al., T. Matsumoto et al., T. Roche et al., APS-DPP 2015), the WiPAL team has begun injecting CTs into the 3 m diameter MPDX spherical vacuum vessel with and without background plasmas and with and without applied background magnetic fields. Initial results and preliminary analyses of these tests are presented.