Recent measurements and extended MHD simulations expose the importance of two-fluid physics in the relaxation and self-organization of the current and momentum profiles in RFP plasmas. A hallmark of relaxation is the inductive electric field is not balanced by resistive dissipation, prompting the study of fluctuation-induced emfs in the generalized Ohms law, \( E_{\text{ind}} - n_{\text{eff}} = -\left(\nabla \times \vec{B}\right) + \frac{q}{c} \frac{n_{\text{eff}}}{\rho} \), the two terms on the right known as the MHD and Hall dynamos, respectively. The Hall emf is measured in the outer half of the MST plasma minor radius using an armored deep-insertion probe. The emf matches previous measurements in the edge, \( E_{\text{ind}} - n_{\text{eff}} > 0 \), but in the new region examined \( E_{\text{ind}} - n_{\text{eff}} \sim 0.8 \), it is much larger than \( E_{\text{ind}} - n_{\text{eff}} \), implying the MHD dynamo must also be large and oppositely directed. Recent nonlinear simulations that include two-fluid effects using the extended-MHD NIMROD code show complex radial structure for the emf terms, but the size of the measured Hall emf is much larger than predicted by the simulations. In the two-fluid model, the Hall dynamo couples to the parallel momentum as the mean-field Maxwell stress. The simulations predict relaxation of the parallel flow profiles that is also qualitatively consistent with measurements in MST plasmas.

**Abstract**

**Equilibrium Measurements**

We can calculate the current from the measured magnetic field by using a cylindrical approximation in Ampere's law, \( \mu \nabla \times \vec{B} = \nabla \times \left( \nabla \times \vec{B} \right) \). The current in MST is typically antiparallel although it can be run in a parallel current configuration. Using Faraday's law we can calculate the equilibrium electric field. Values are averaged over a 0.1 ms window during a relaxation event.

**Ohm's Law**

Mean field two fluid resistive Ohm's law is given by

\[
\left( \nabla \times \left( \rho \nabla \phi \right) - \left( \nabla \times \left( \nabla \phi \right) \right) \right) = \frac{1}{\rho} \left( \nabla \times \left( \nabla \phi \right) \right)\nabla.
\]

where we have already taken the parallel component. Concentrating on the Hall term, we can expand it using Ampere’s law yielding

\[
\mu_0 \left( \nabla \times \vec{B} \right) = \left( \frac{\mu_0}{\rho} + \frac{\mu_0}{\rho \times \nabla B_0} \right) \left( \left( b_b \right) \delta_0 + \frac{q}{c} \left( b_b \right) \delta_0 \right)
\]

Calculating this term only requires knowledge of the radial dependence of the three components of the magnetic field, something that magnetic probes on MST can measure. Other terms in Ohm’s law can be directly measured or inferred using other methods. Below are previous measurements from Kuritsyn et al. Phys. Plasmas 16, 055903 (2009)

**Simulation Comparison**

To the right we have a NIMROD simulation with parameters similar to the studied MST discharges, averaged in time over the peak of the event. Shaded locations denote areas not covered by probe measurements. A few points of interest:

- EMF amplitudes are comparable to those measured in experiment
- Hall and MHD show complex structure, similar to what is seen in experiment

We see that our estimated profile of Ohm's law agrees qualitatively with simulation. Locations of the peaks of the emf do differ, possibly to the simulation using a flat pressure profile, altering the nonlinear coupling of the tearing modes known to be important in experiment.

**Future Work**

- Use additional diagnostics to measure MHD dynamo in mid-radius region
- Incorporate realistic edge profile in simulation models to better portray edge physics