Flow Dynamics and Diamagnetic Drift in Asymmetric Guide Field Reconnection

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Motivation

Magnetic reconnection is a widely-studied phenomena in which the magnetic field changes topologies, and where the flux lines reconnect with one another to reduce the energy stored in the field lines.

Reconnection with a density asymmetry across the current sheet has been studied more frequently in recent years, and is universal at the dayside magnetopause. A guide field is at times present in this configuration, but is not usually greater than the reconnecting field.

Strong guide fields and asymmetries, however, are ubiquitous in tokamaks and other fusion-based plasmas, especially during sawtooth oscillations. The reconnection in these plasmas may be explained further by studying the reconnection qualities of these plasmas. Specifically, this case of guide field asymmetric reconnection is relatively understudied compared to its abundance in space and its relevance to fusion.

Introduction: Magnetic Reconnection

Magnetic reconnection is a violation Ideal MHD conditions: $\vec{E}+\vec{V}\times\vec{B}=0$, and as such, the field lines are frozen into the fluid. Any change in magnetic topology therefore must occur through magnetic reconnection in collisionless, magnetized plasmas.

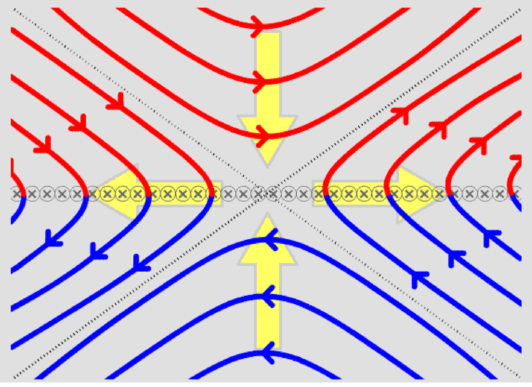
Reconnection is associated with the presence of current sheets, which form parallel to the outflow, and out of plane.

Reconnection converts magnetic energy into kinetic energy through magnetic field annihilation

- Occurs in a geometry which has a magnetic null or strong shear

In recent years, asymmetric reconnection (the plasma parameters of the inflow plasmas are largely different) in the presence of a guide field (out- of plane field perpendicular to reconnection) has received increased attention due to its abundance and dissimilarity to more studied plasmas.

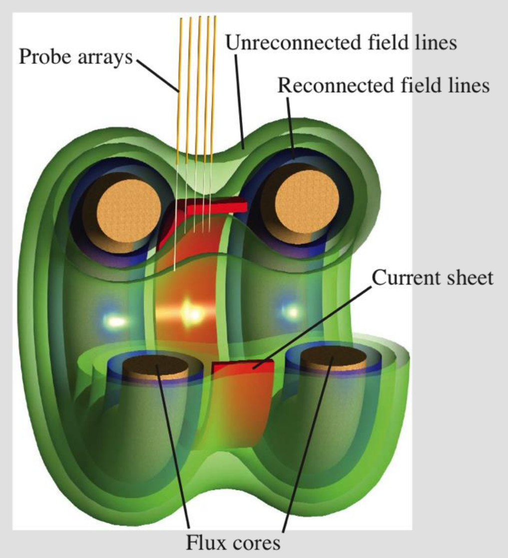
Inflows: arrows point to center
Outflows: away from center

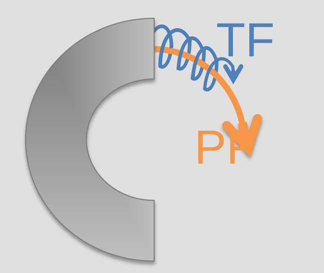


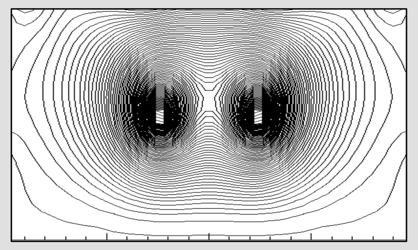
Introduction: MRX (Magnetic Reconnection Experiment)

How does MRX create reconnection events?

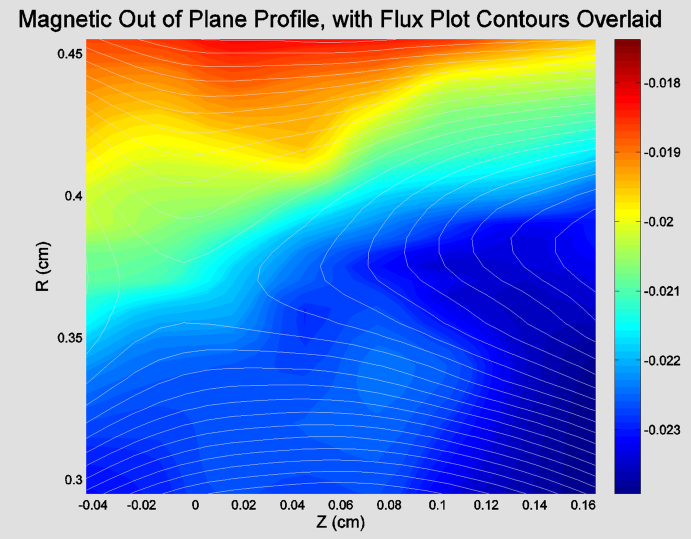
- First, a gas is injected into the vacuum chamber.
- Currents through the flux cores create strong electric and magnetic fields to ionize plasma
- A current sheet spontaneously develops in the plasma, and driven reconnection begins
- Probes measure the magnetic field, temperature, and density.

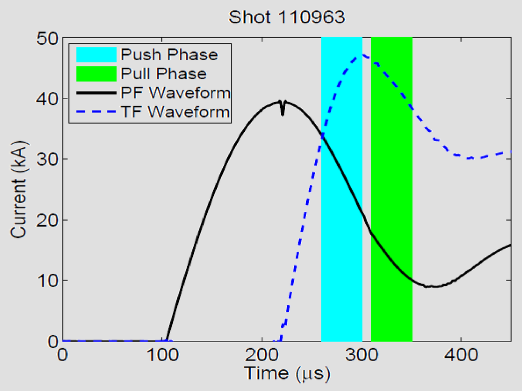






- The Toroidal Field produces an electric field
  - Creates Plasma
  - Drives a toroidal magnetic field (bad)
- The Poloidal Field creates the magnetic field lines seen above, which are the driving force of reconnection.





Diamagnetic Drift

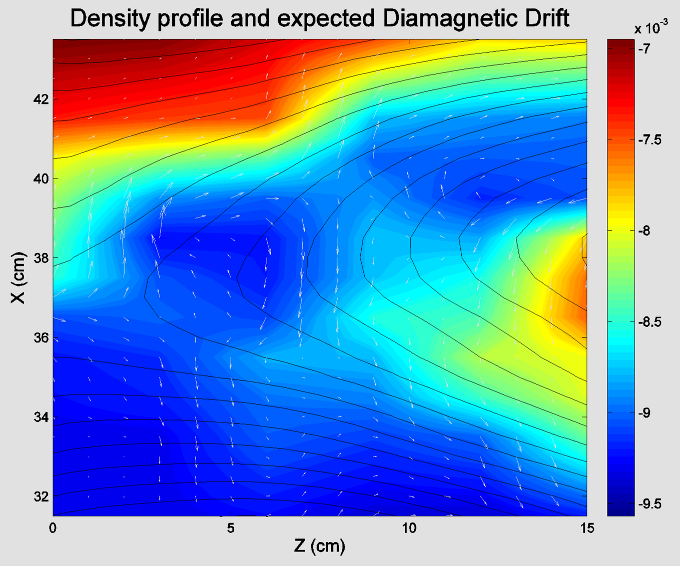
Theory

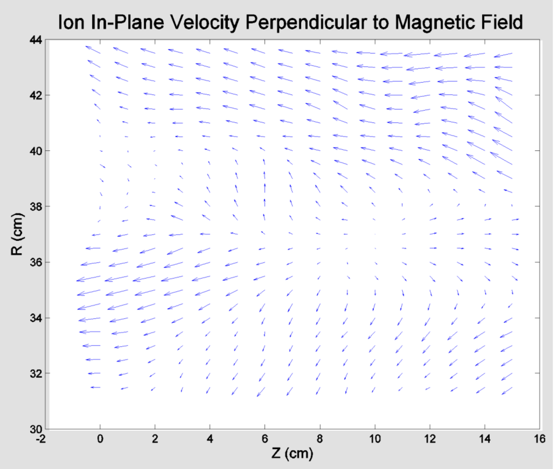
Diamagnetic Drift, in short, is the process by which the X line of a reconnecting plasma drifts because of pressure gradients.
According to Swisdak et al., 2002, $v_{drift} = \frac{-\nabla p \times B}{qnB^2}$
Where v_{drift} refers to the drift velocity of the x line.

- Outflow velocity of ions and electrons becomes:
  - $V = V_{out} \pm V_{drift}$
- Larger drift velocity implies less flux reconnected
- Larger Guide Field leads to lower drift rate
  - In theory, low drift rate, high flux reconnected should be observed

Experiment

Using the formula above for diamagnetic drift, we take the gradient of the pressure field and assume constant temperature to obtain the following expected diamagnetic drift profile:





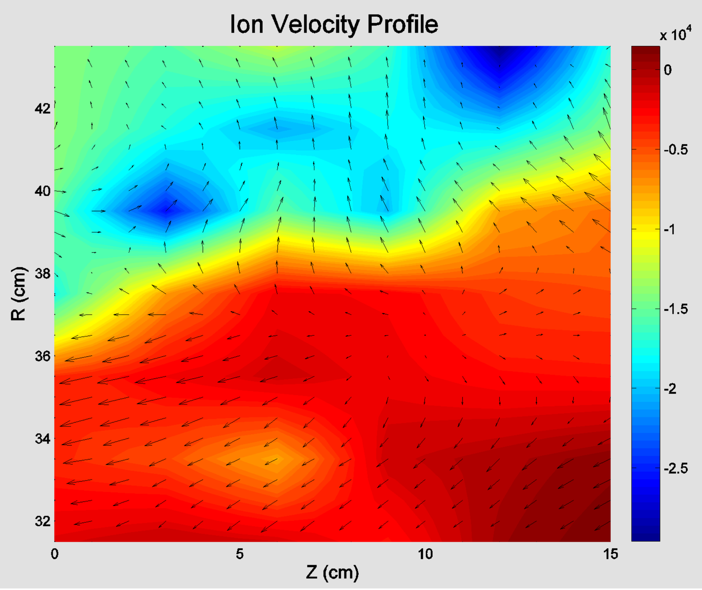
The perpendicular velocity to the magnetic field lines is a drift, and the $V_{\perp}$ profile macroscopically doesn't resemble the diamagnetic drift profile.

- Possible Mach probe measurement error because of high out of plane velocities
- Possible understudied reconnection geometry

Ion Flows

The flow of ions in this plasma is unexpected, as it directly contradicts not only all basic models of reconnection, but common sense as well.

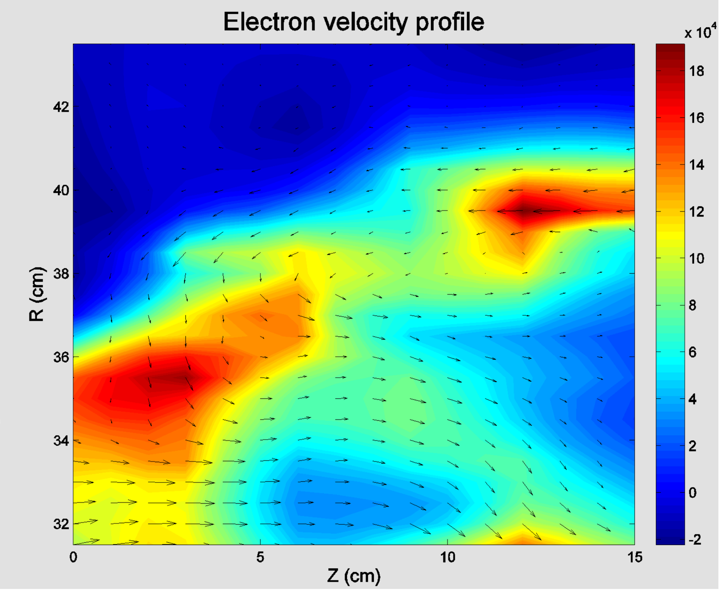
- Sources and sinks of flow, which violates the assumption of a globally 2D reconnection plane
- Inflows and outflows are switched



Electron Flows

The electron flow profile is much more similar to the expected profile:

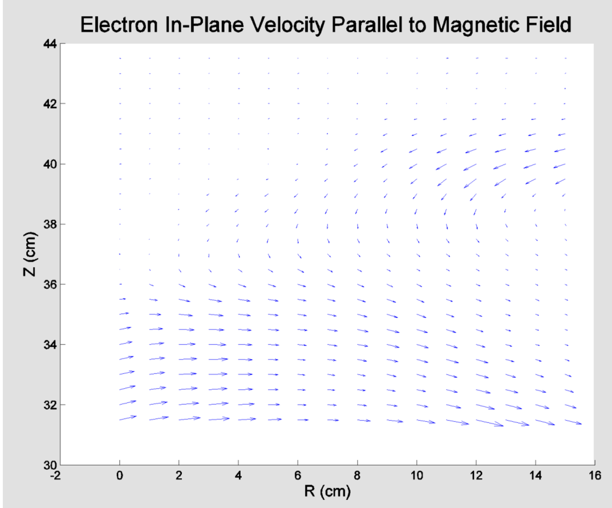
- High out of plane velocities along separatrices and near the x-point
- Distinct inflows and outflows
- Electrons flow over separatrices during reconnection into the outflow.

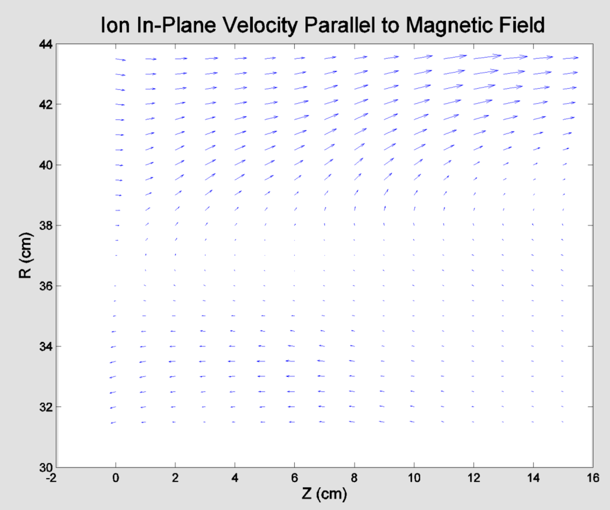


Parallel Currents

Interesting currents spontaneously develop parallel to the reconnecting field lines in this plasma. These parallel flows have a large out of plane component, due to the guide field.

- Structure of these parallel flows is intriguing
  - Primarily inflow parallel currents
  - Inflow mostly magnetized, so it obeys ideal MHD, which doesn't allow parallel currents.





Conclusions and Future Work

The Mach probe data is unexpected, but the probes functioned as expected both before and after these shots.

- Probe design is not compatible with this plasma?
  - High out of plane velocity might be impacting the measurement of flow
  - New Mach probes will be tested in future experiments, and IDSP (ion dynamic spectroscopy probes) will be used to verify the resulting data.
- Possibly the probes work, but this magnetic geometry is simply not well understood.
  - Low density regions of this plasma, temperature and ion flow data is most noisy.
  - More data will be taken in the future to verify the effects
- Global effects interference
  - Exceptionally hard to model and truly account for, because of scale size differences.

Acknowledgements

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