Particle-in-Cell simulation of Magnetotail Dipolarization Fronts and Associated Ion Reflection

Pin (Penny) Wu

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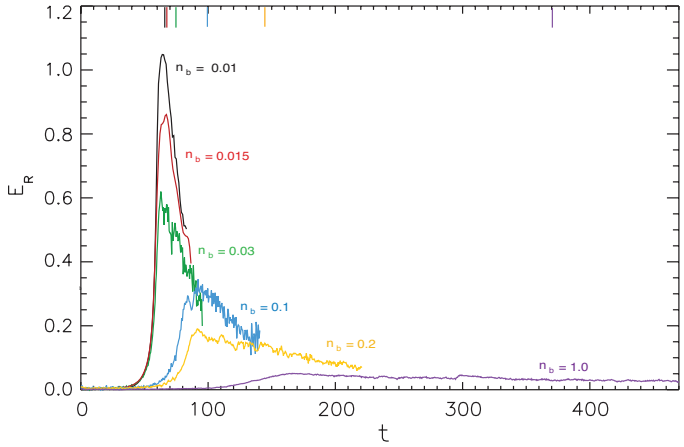
Motivation: Upstream inflow density matters

Magnetotail lobe density is highly variable: [0.007-0.092] cm^{-3} with the most probable value 0.047 cm^{-3} [*Svenes et al., 2008*].

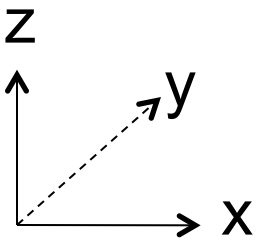
Such lobe density (n_b) variation modifies reconnection diffusion region physical processes and reconnection rate drastically [Wu et al., Phys. Plasmas, 2011]:

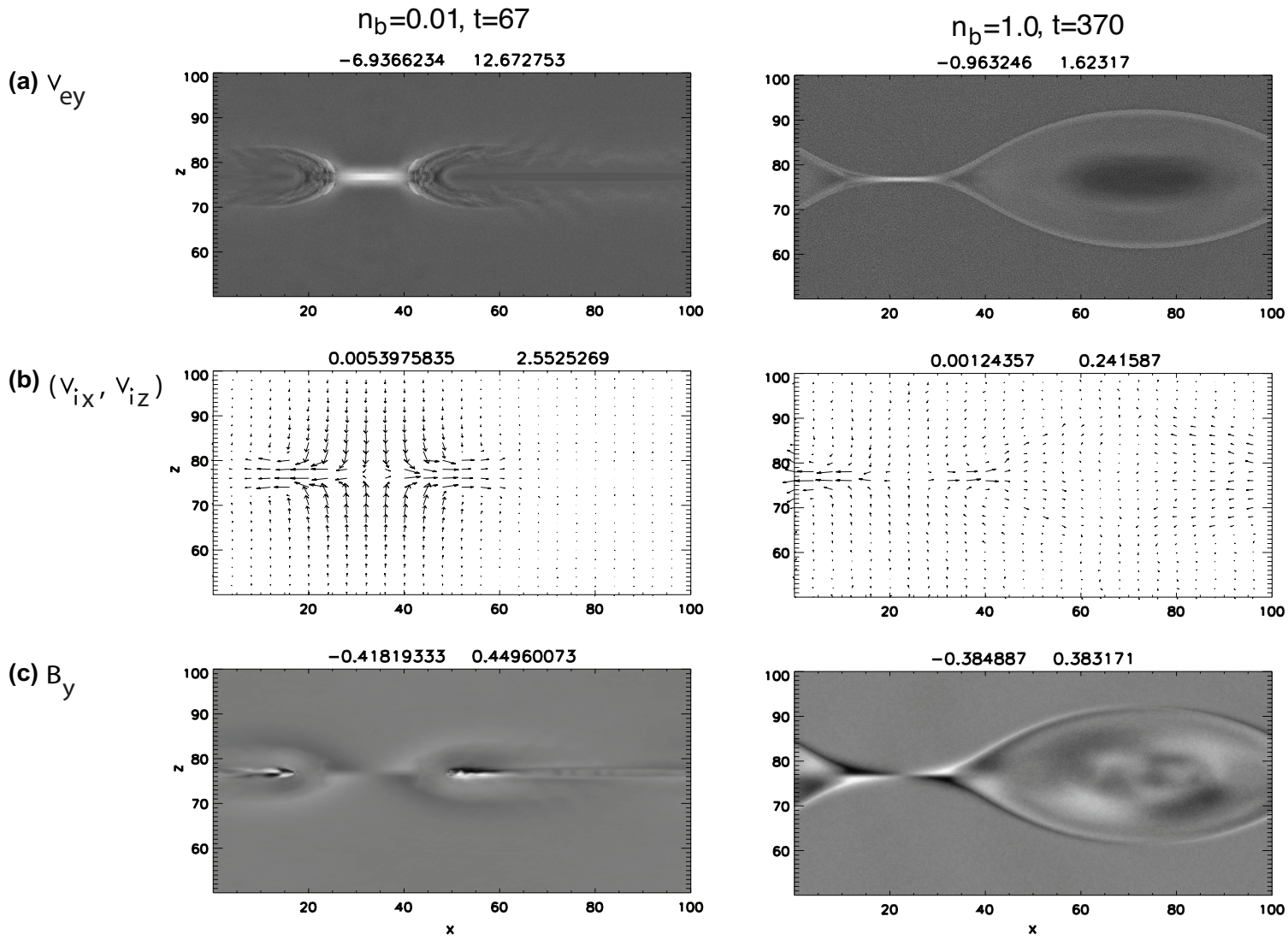
1. Violent and fast reconnection at small n_b
2. Faster outflow at n_b : $v_{out} \sim 0.4 v_{A,up}$



Wu et al., 2011, Phys. Plasmas

Result: overview

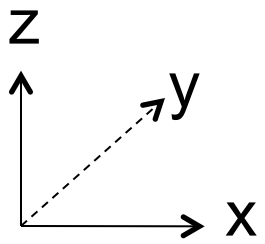


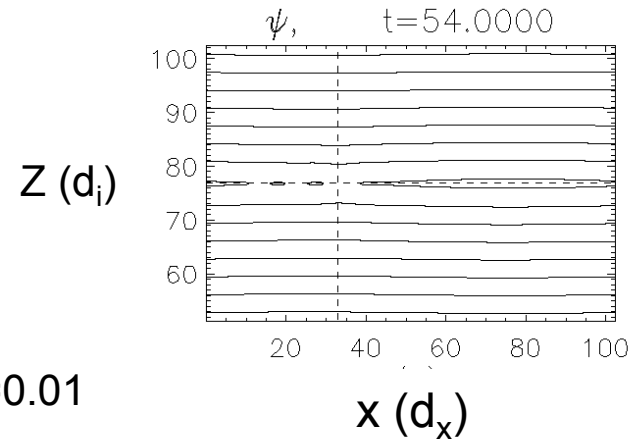


Fishbone-shaped instability (courtesy of William H. Matthaeus for coining the term)

Wu et al., 2011, Phys. Plasmas

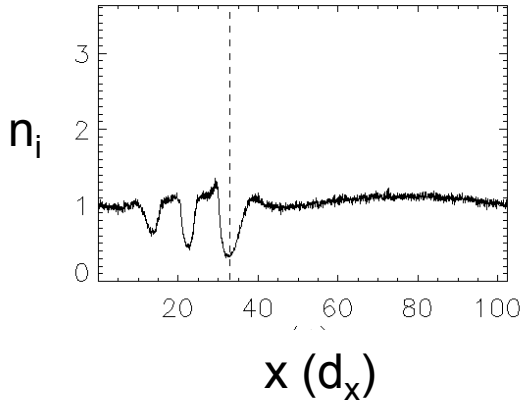
Today address downstream dipolarization front

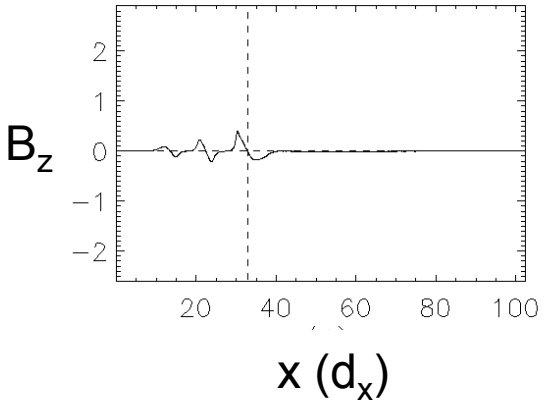




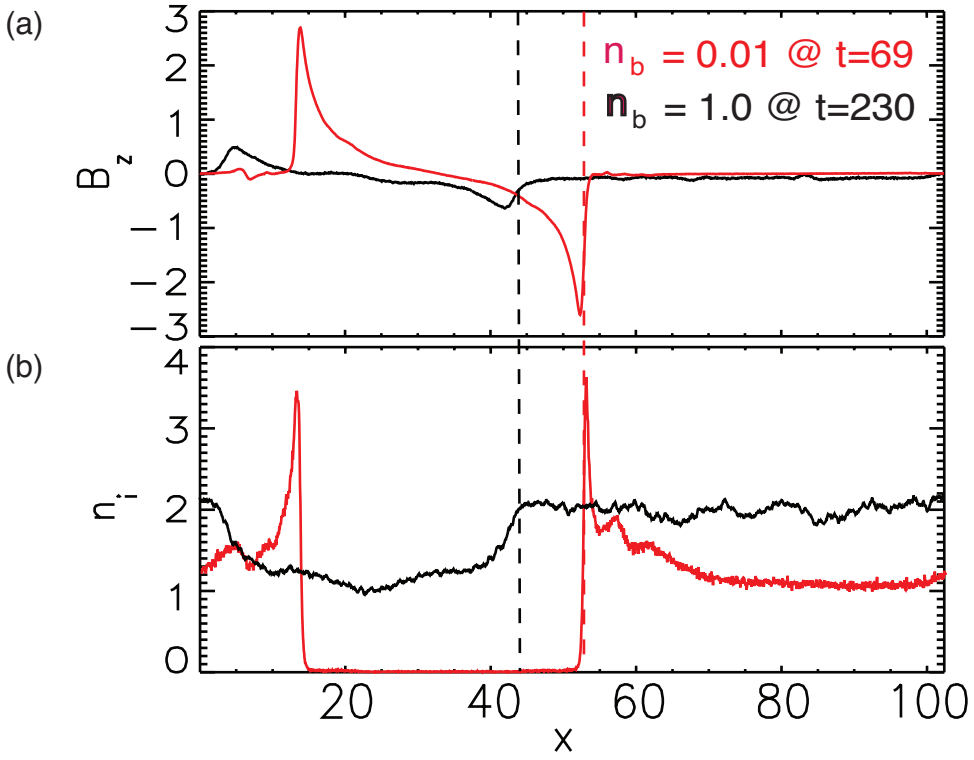
Example: n_b=0.01

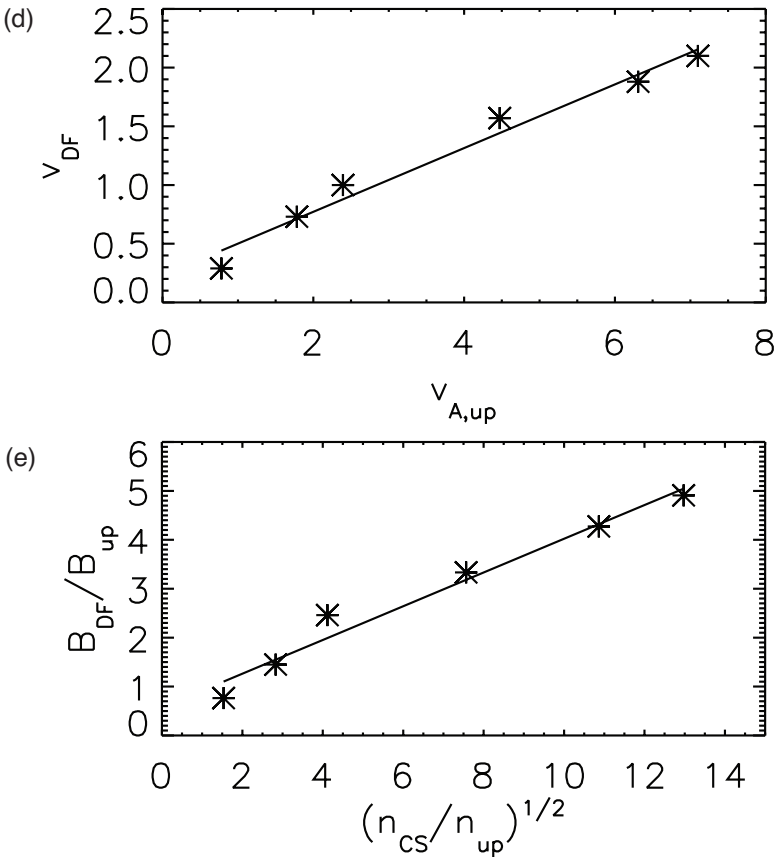
Cut along symmetric line at y=76.8





Dipolarization Front (DF) Scaling and Density rise in front of the DF



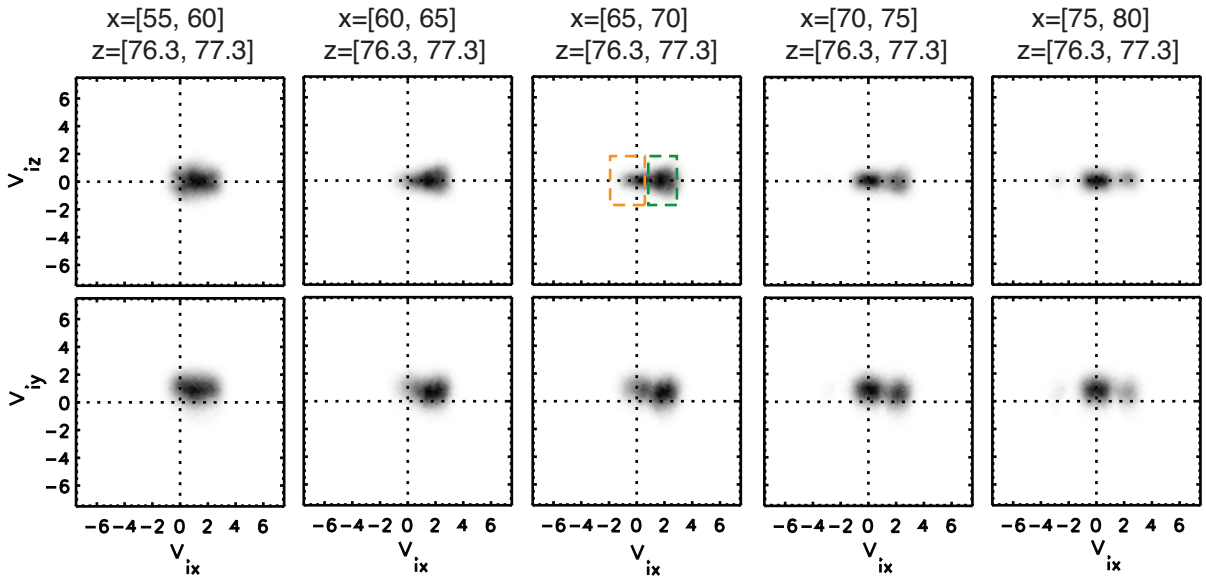


Wu and Shay, 2012, GRL

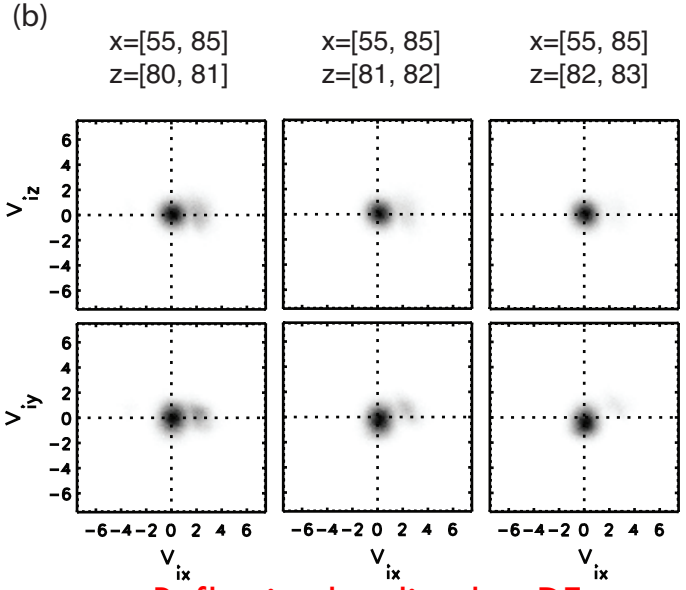
Ion Reflection

$n_b = 0.1$ @ t=93

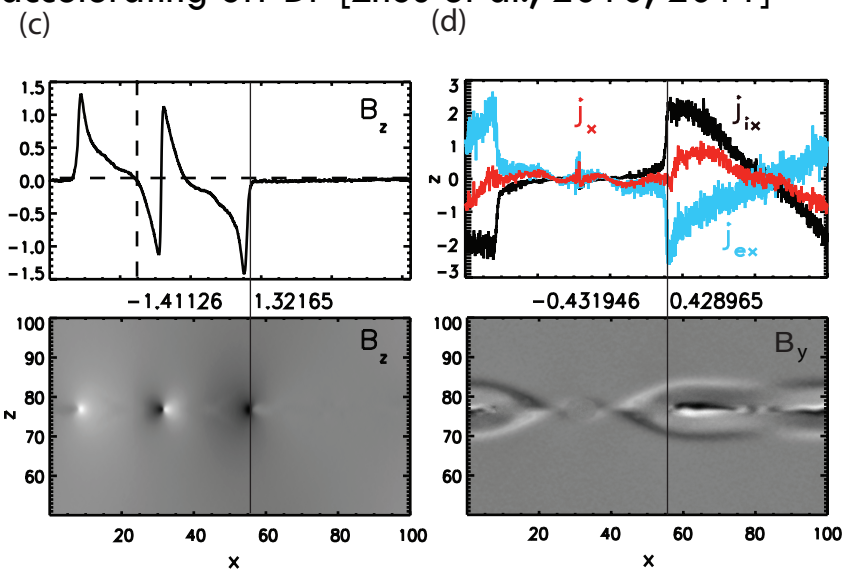
Streaming acceleration: Very different from perpendicular shock ion reflection [e.g., Wu et al., 2009]



consistent with the observation of ion accelerating off DF [Zhou et al., 2010, 2011]



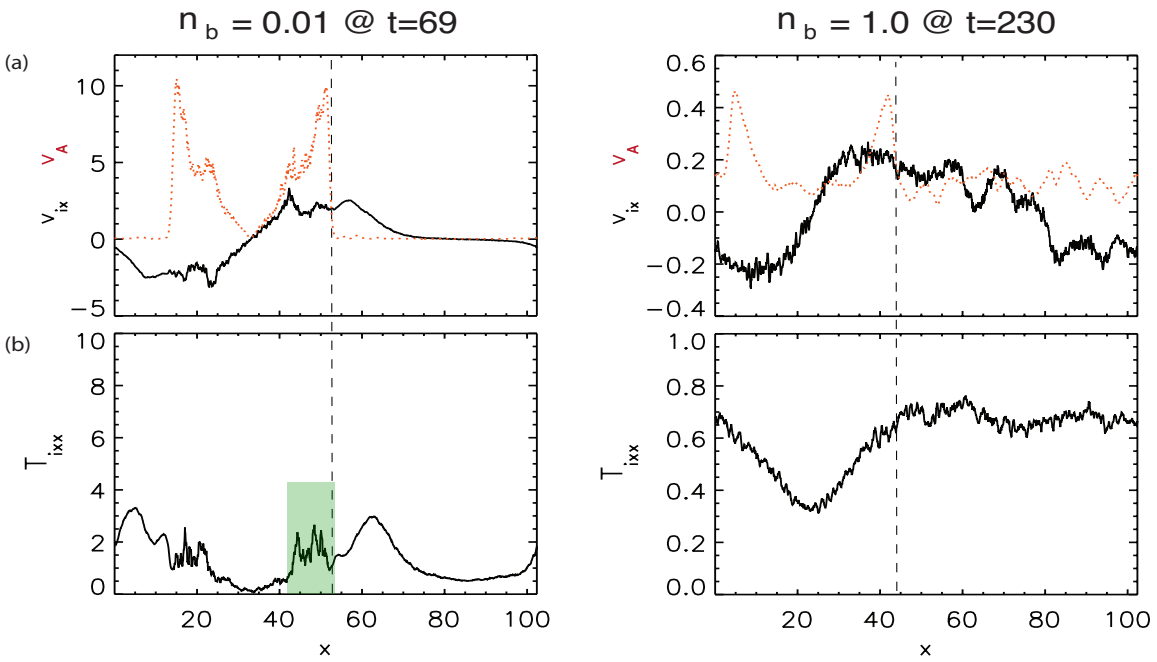
Reflection localized to DF



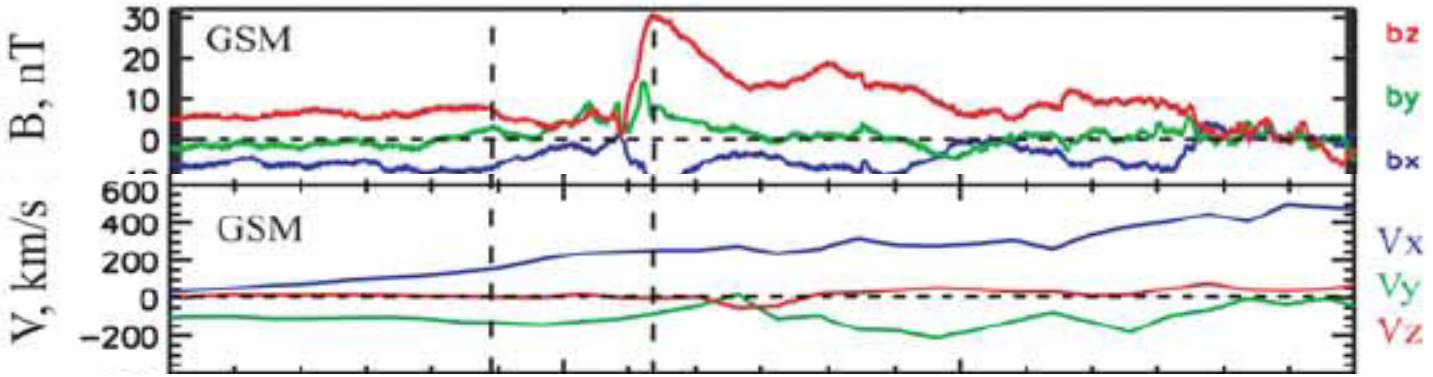
Bipolar B field

Wu and Shay (2012), GRL

Dipolarization Front (DF) Flow and Temperature (two extreme density cases)



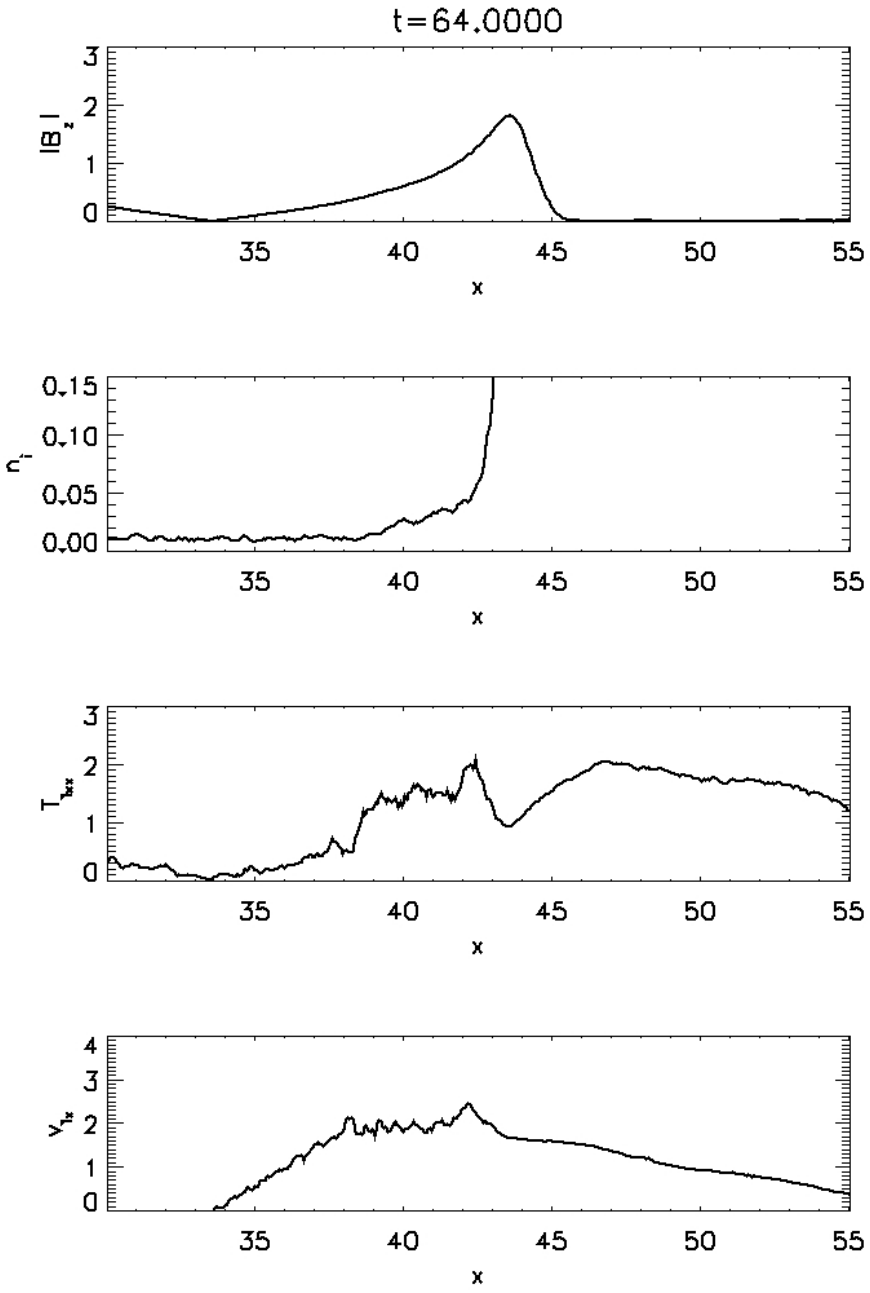
Wu and Shay (2012), GRL



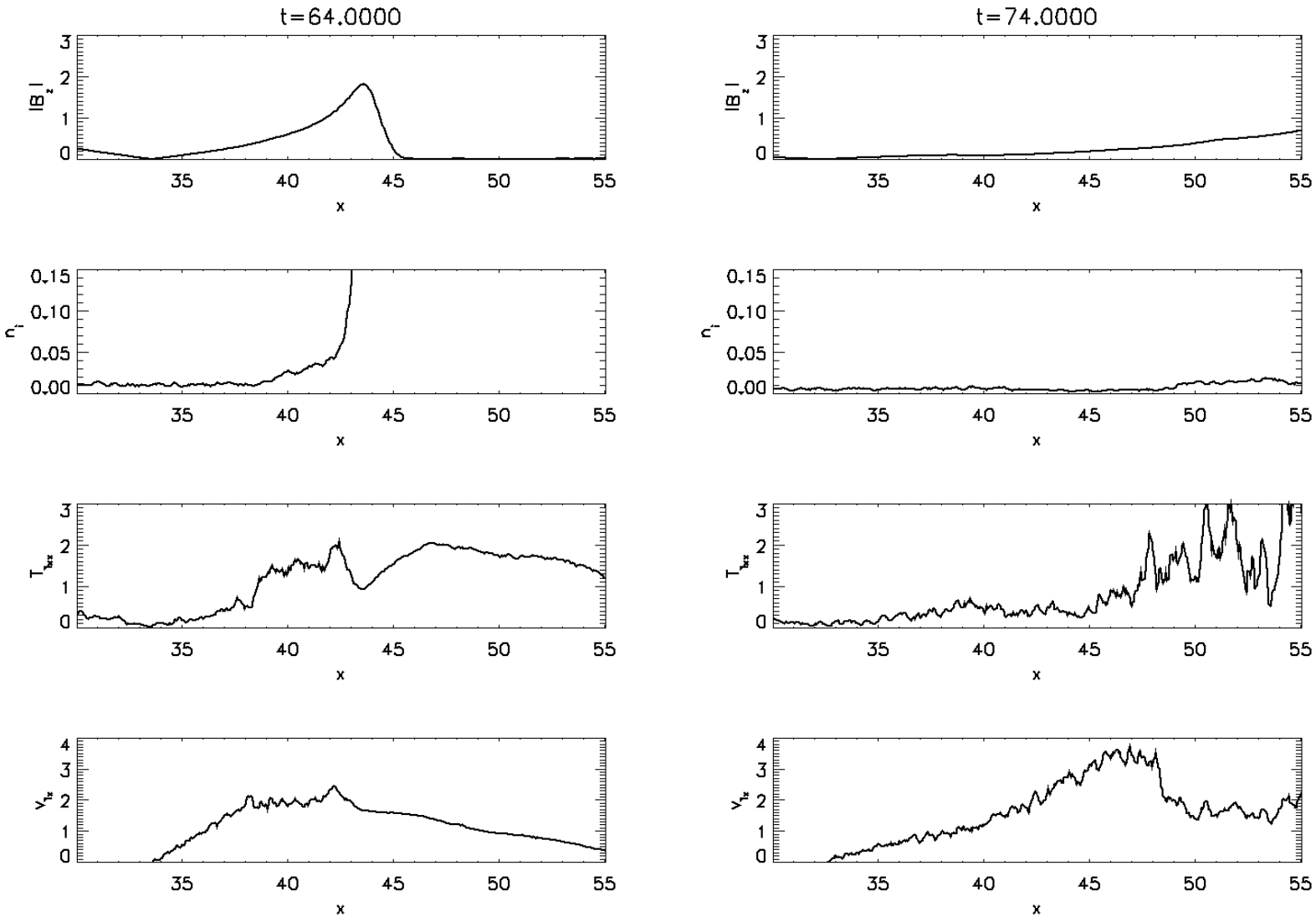
Themis observation by *Runov et al., 2009*.

Steepening and compression heating behind the DF

Work in progress



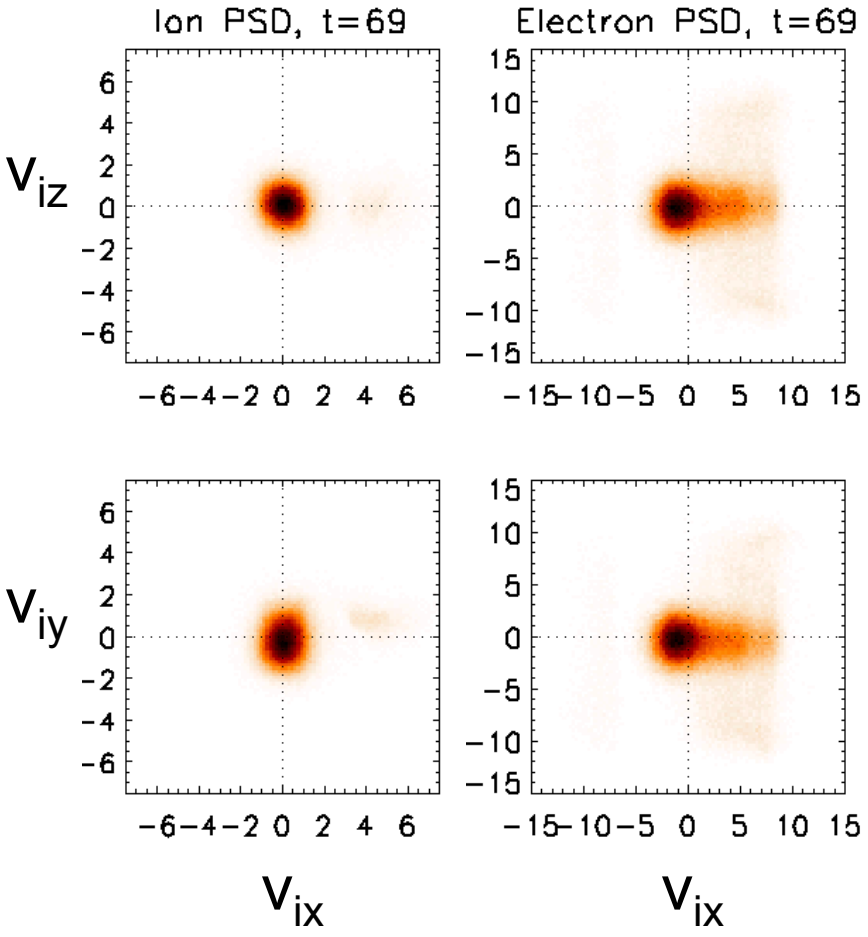
Steepening and compression heating behind the DF

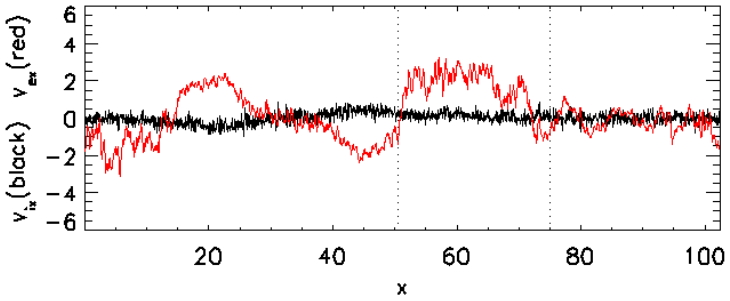


Work in progress

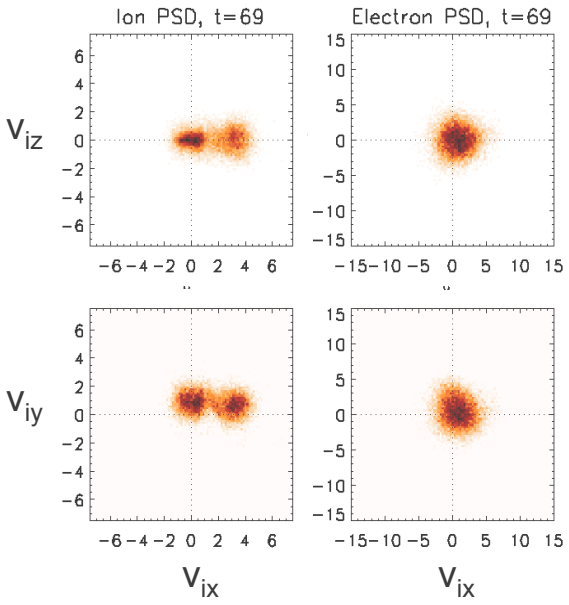
Electrons streaming off the symmetric line

n_b=0.01 case, off the symmetric line X at y=[80,84]





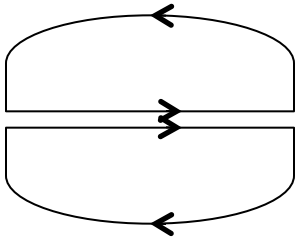
Along X at y=[76.3, 77.3]



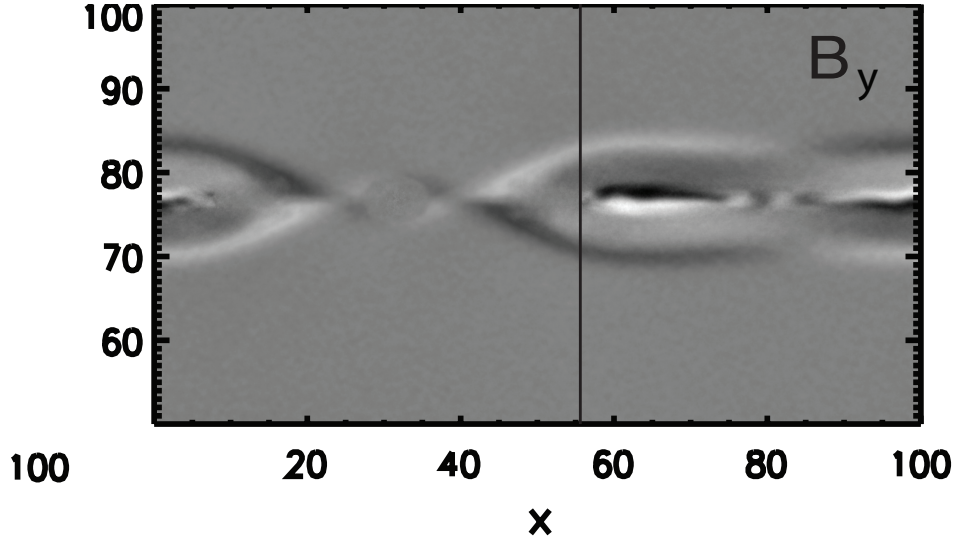
Work in progress

Current Loops lead to bipolar magnetic field straddling the symmetric line in front of the DF

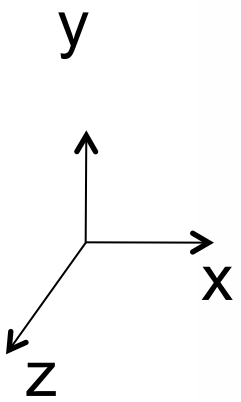
Electron current off the symmetric line



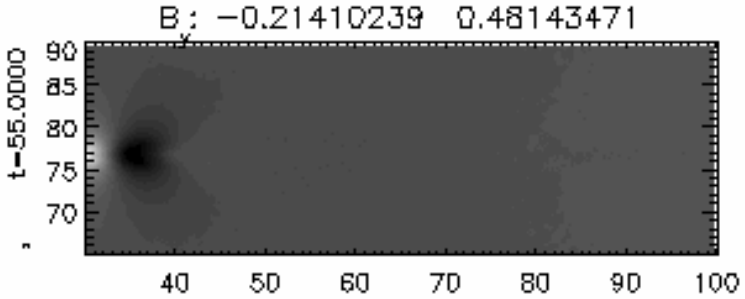
Ion current along the symmetric line

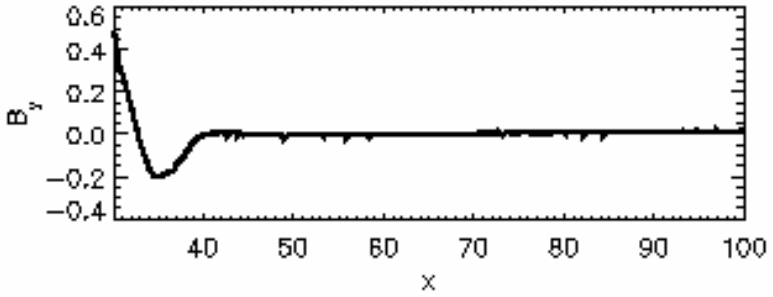


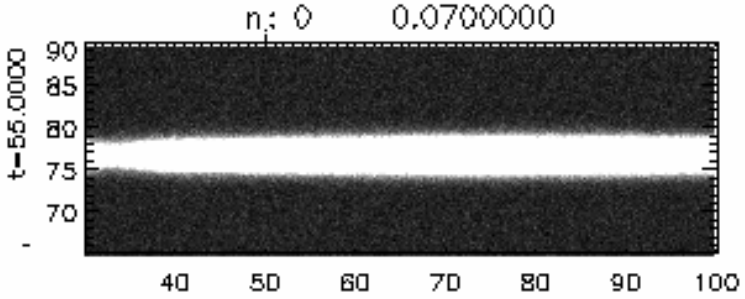
Work in progress, collaborator: S. Peter Gary

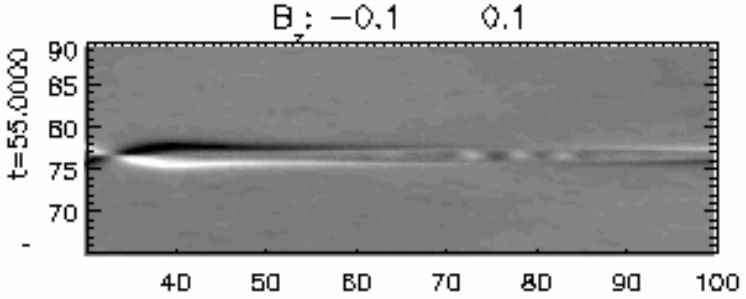


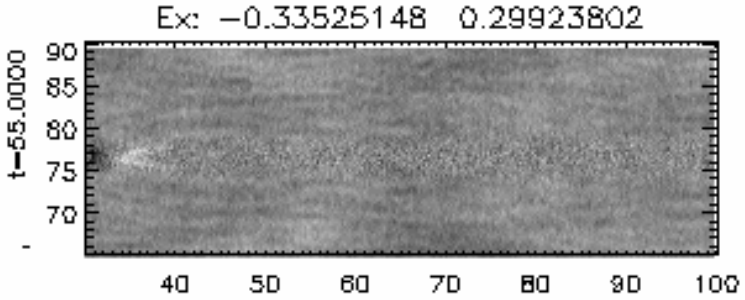
Fishbone-shaped instability

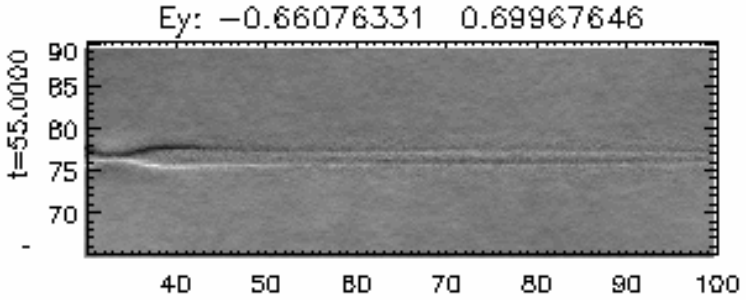


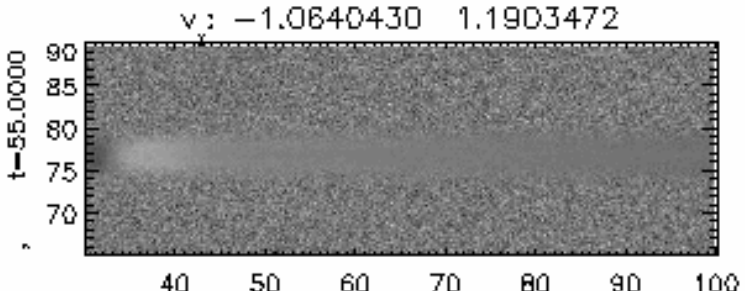


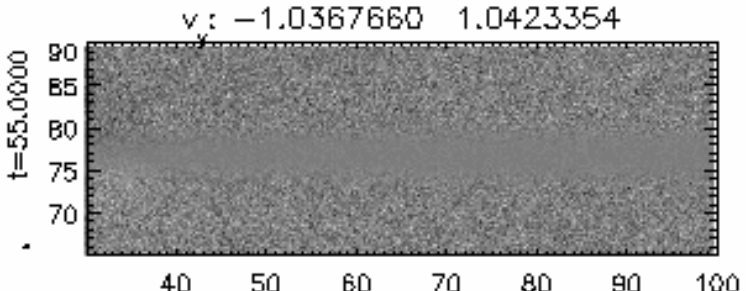




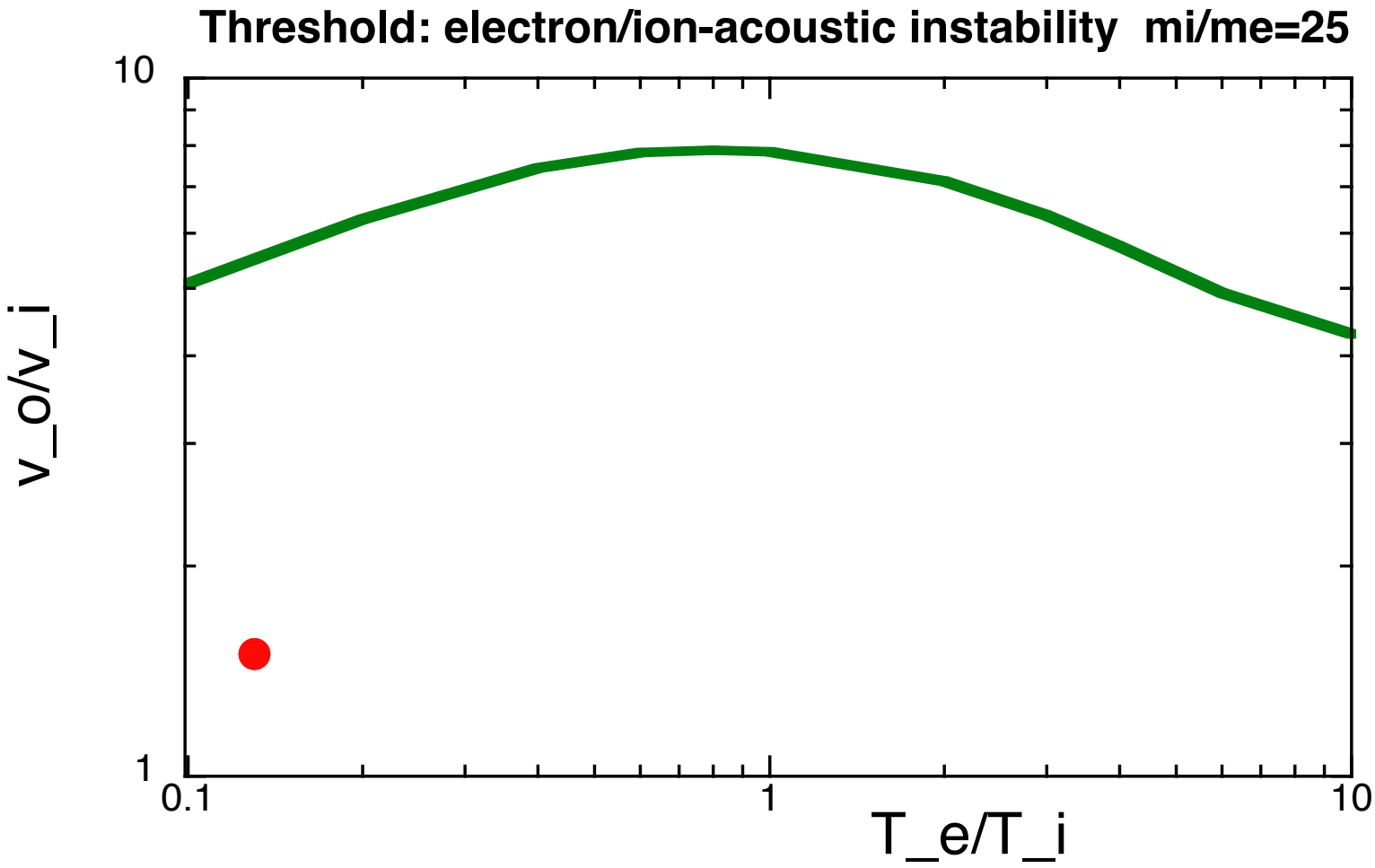








Rule out electron/ion-acoustic instability
Collarborator: S. Peter Gary



v_o: relative drift between ion and electron
v_i: ion thermal velocity

Summary: Particle-in-Cell simulation of Magnetotail Dipolarization Fronts and Associated Ion Reflection: Inflow density matters!

Downstream Dipolarization Front: as we lower inflow density n_b

1. We find both B_{DF} and v_{DF} increase and scales with $1/\sqrt{n_b}$ [Wu and Shay, GRL, 2012].

2. We study Ion reflection in the self-consistent PIC simulation and find
   - Super-Alfvenic streaming along the symmetric line in front of the DF,
   - Preferential heating in X,
   - Bipolar magnetic field,
   - Ion reflection as localized and transient as the DF.

   [Wu and Shay, GRL, 2012]

3. Work in progress
   - Steepening structure behind the DF associate with additional ion heating
   - Electron dynamics off the symmetric line in front of the DF,
   - Fishbone-shaped instability.

SHINE 2012 Session 16. The Turbulent Solar Wind and Dissipation
Date and time: Wednesday June 27 morning-noon, Thursday June 28 morning-noon
Pin (Penny) Wu, Mike Shay, Chuck Smith

This session aims to improve the plasma physics knowledge, the modeling endeavors, and observational interpretations of the turbulent solar wind energy cascade, energy dissipation, and related plasma heating. The session will cover the proposed topic in relation to coherent structures in the solar wind such as reconnection, current sheets, shocks, discontinuities, and co-rotation interaction regions (CIRs), as well as to MHD and kinetic waves and instabilities. The session will attract physicists studying the solar wind from various perspectives and applying various tools; and will address critical issues such as whether the identification of characteristics of "wave modes" (whistler, kinetic Alfven wave, and etc.) is sufficient to describe the physics. The aim is to bring together senior researchers for converging toward an integrated understanding of the turbulent solar wind, and to provide a "big picture" for young researchers such as graduate students and postdocs. The aim matches SHINE's spirit of a research discussion orientated workshop that focuses on unsettled, provocative, and controversial issues. The aim also assists SHINE's educational goal for young researchers.

Invited speakers
Marco Velli (JPL) : Review of current sheets in the solar wind
Stuart Bale (University of California, Berkeley), Observational interpretation of the solar wind turbulence
Sergio Servidio (University of Calabria), Reconnection in a turbulent environmentHoma Karimabadi (University of California, San Diego):
Sheer driven reconnection and turbulence

To submit your abstract (deadline **May 31**): http://shinecon.org/shine2012/AbstractSub2012.html

Contact: penny@udel.edu