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

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Acknowledgement
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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., accepted,* Phys. Plasmas].

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

   Ion meandering, larger diffusion region size, aspect ratio, and etc.

Here we address observable reconnection signatures in the downstream that are to be affected by the dynamic changes of reconnection.

Introduction: Dipolarization Front (DF)

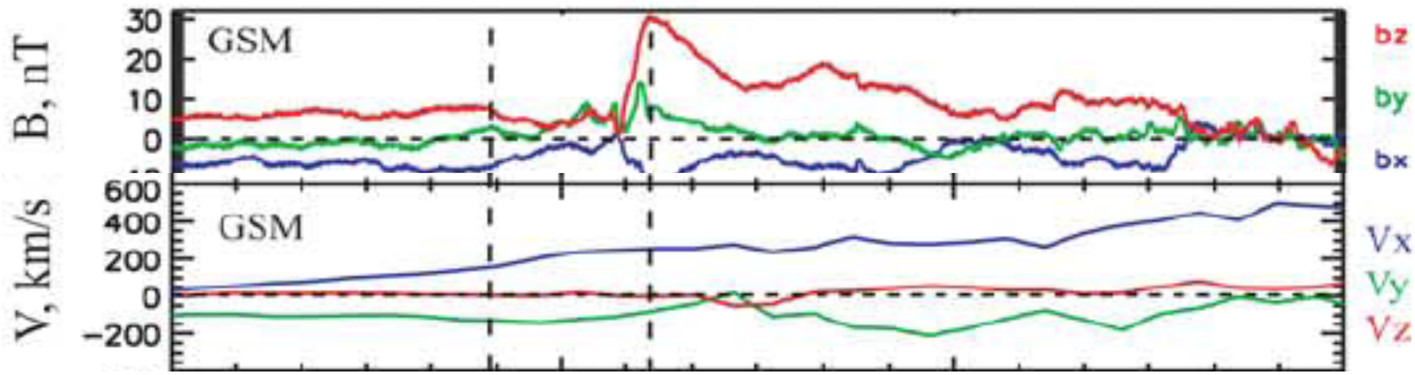
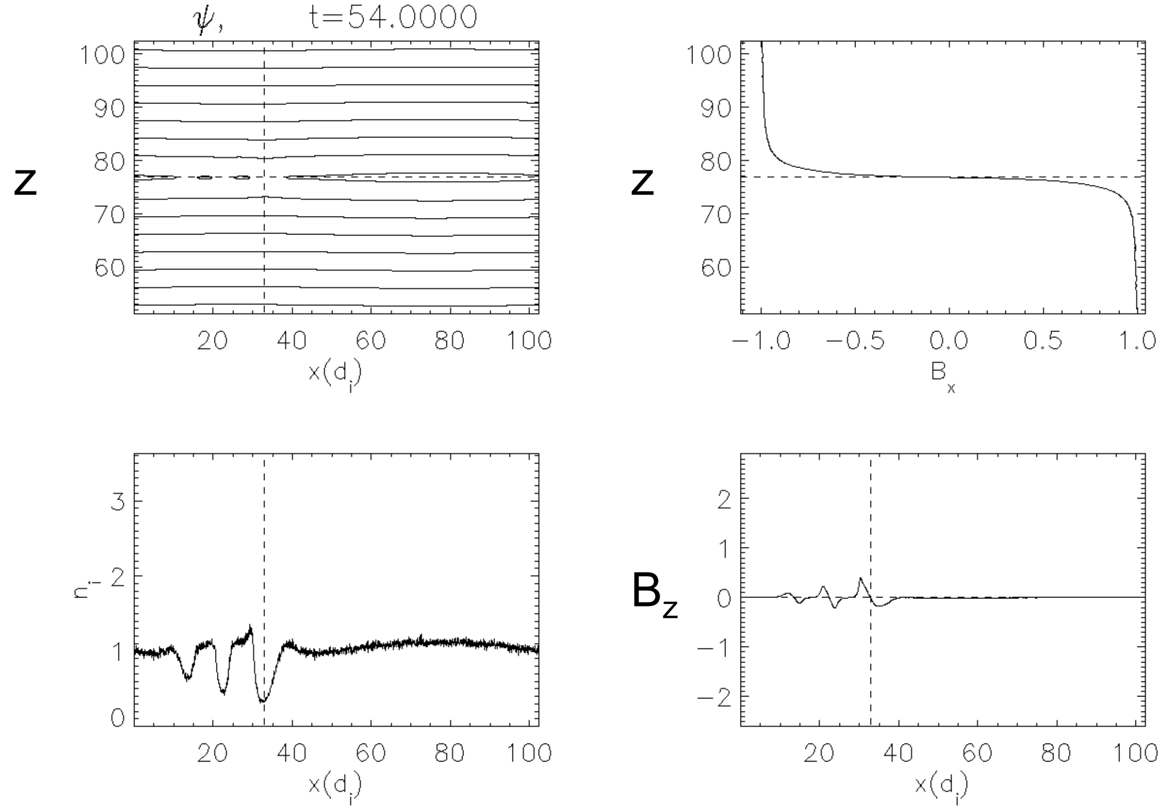


Figure from *Runov et al., 2009*.

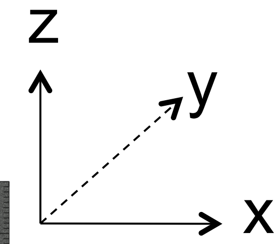
Also, observations of Ion acceleration [*Zhou et al., 2010, 2011*]

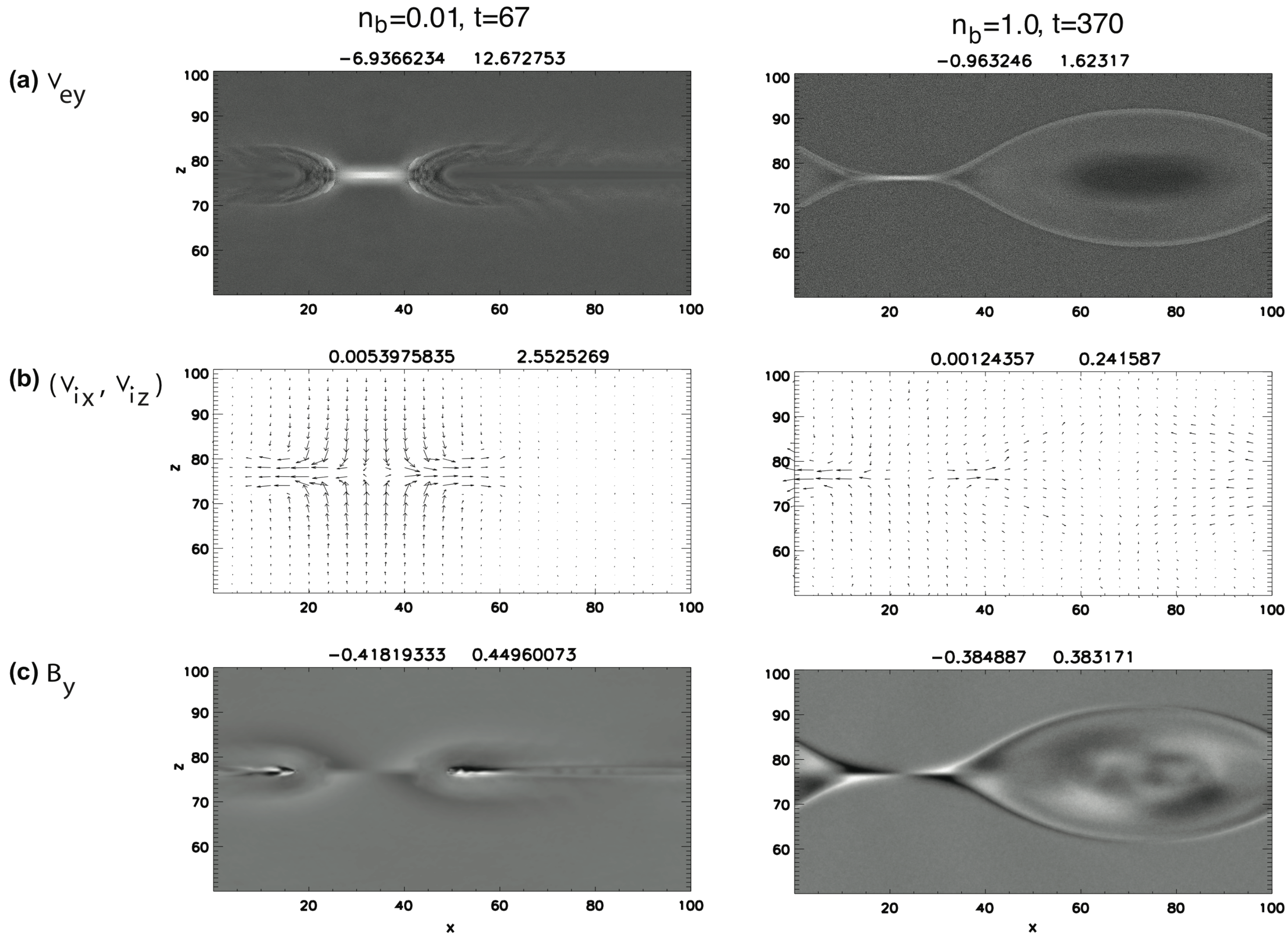
Introduction: Particle-in-Cell (PIC) simulations



Example: n_b=0.01

Result: overview

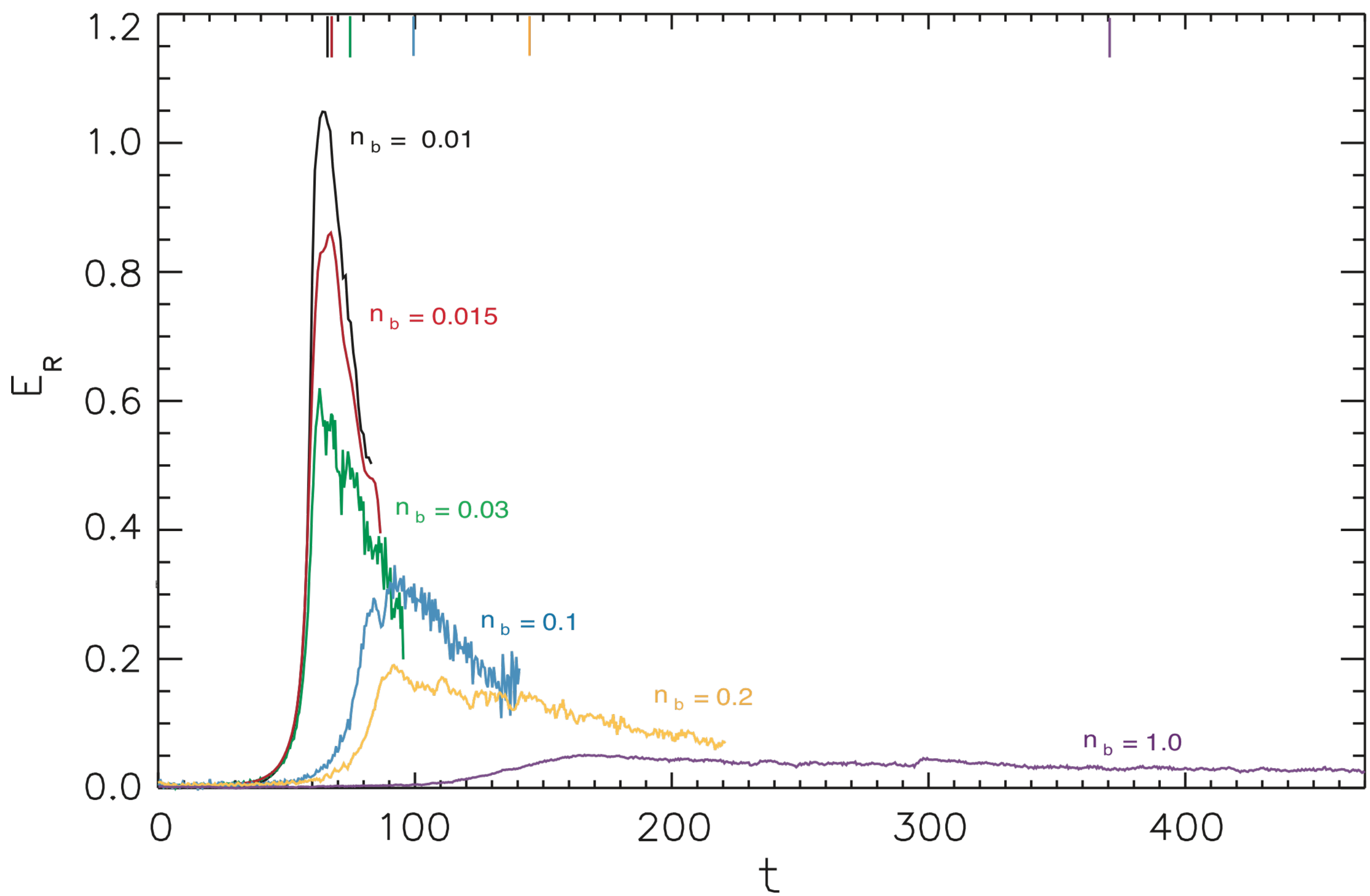




"Fishbone" instability (courtesy of William H. Matthaeus for coining the term)

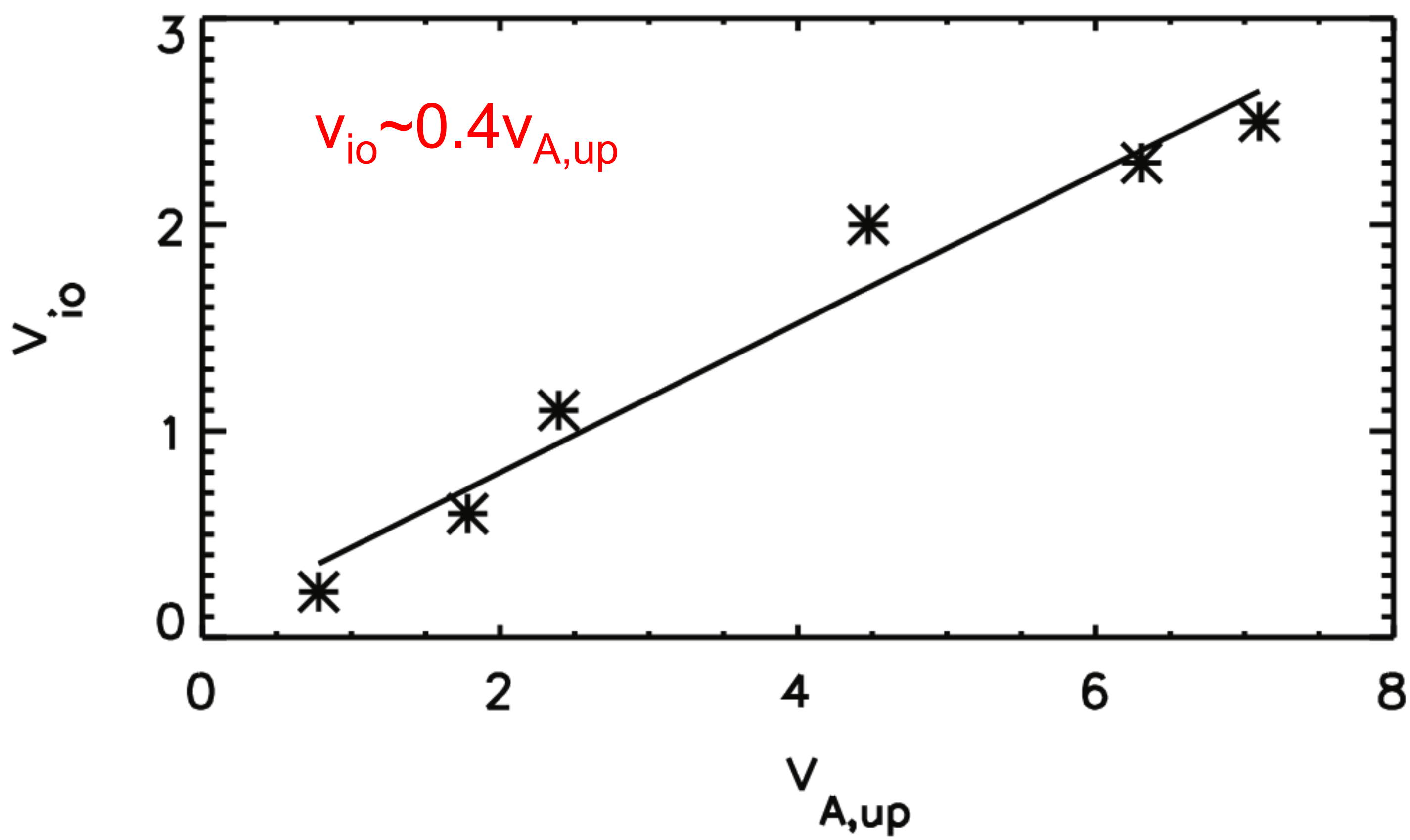
Wu et al., 2011, accepted, Phys. Plasmas

Result: reconnection rate vs. times at various densities



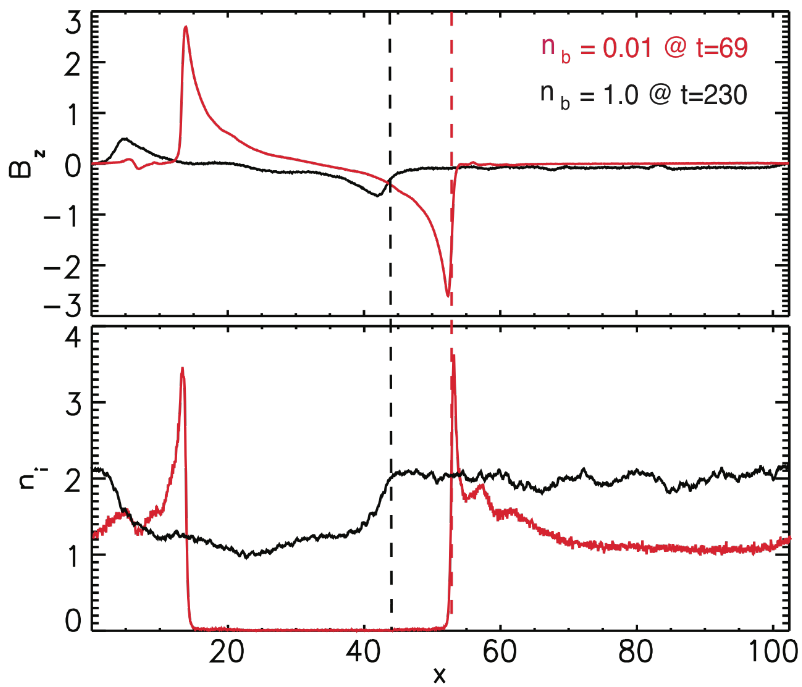
Wu et al., 2011, accepted, Phys. Plasmas

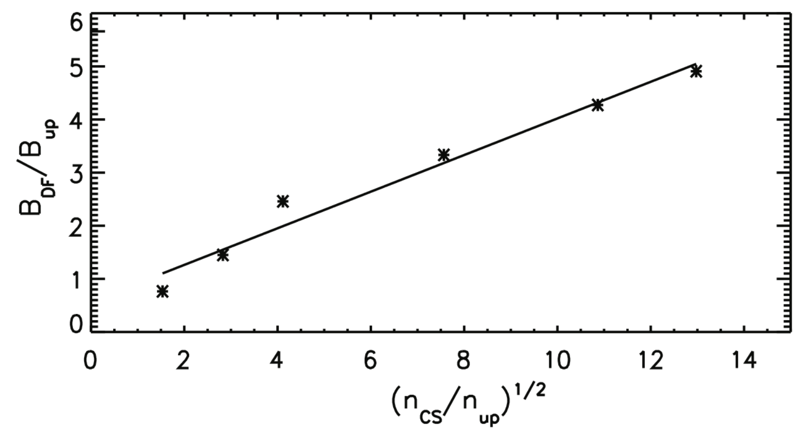
Result: Outflow



Wu et al., 2011, accepted, Phys. Plasmas

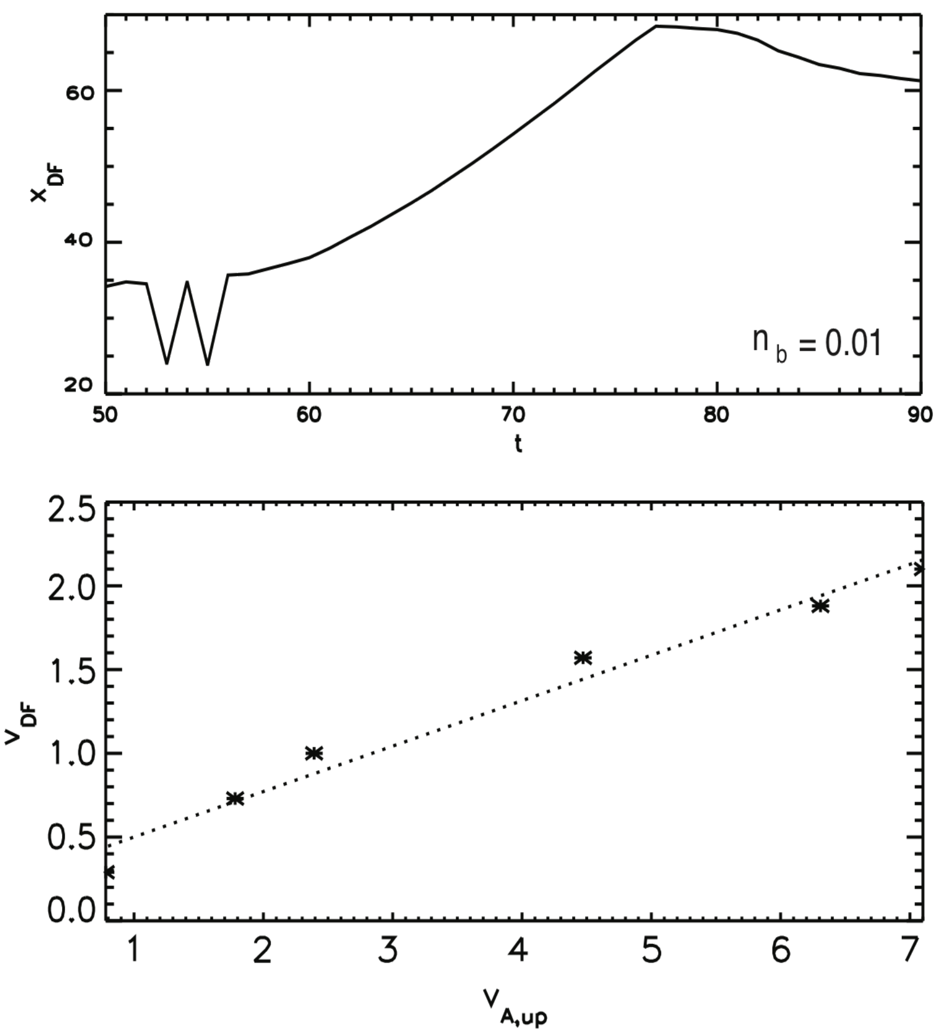
Dipolarization Front (DF) and Front





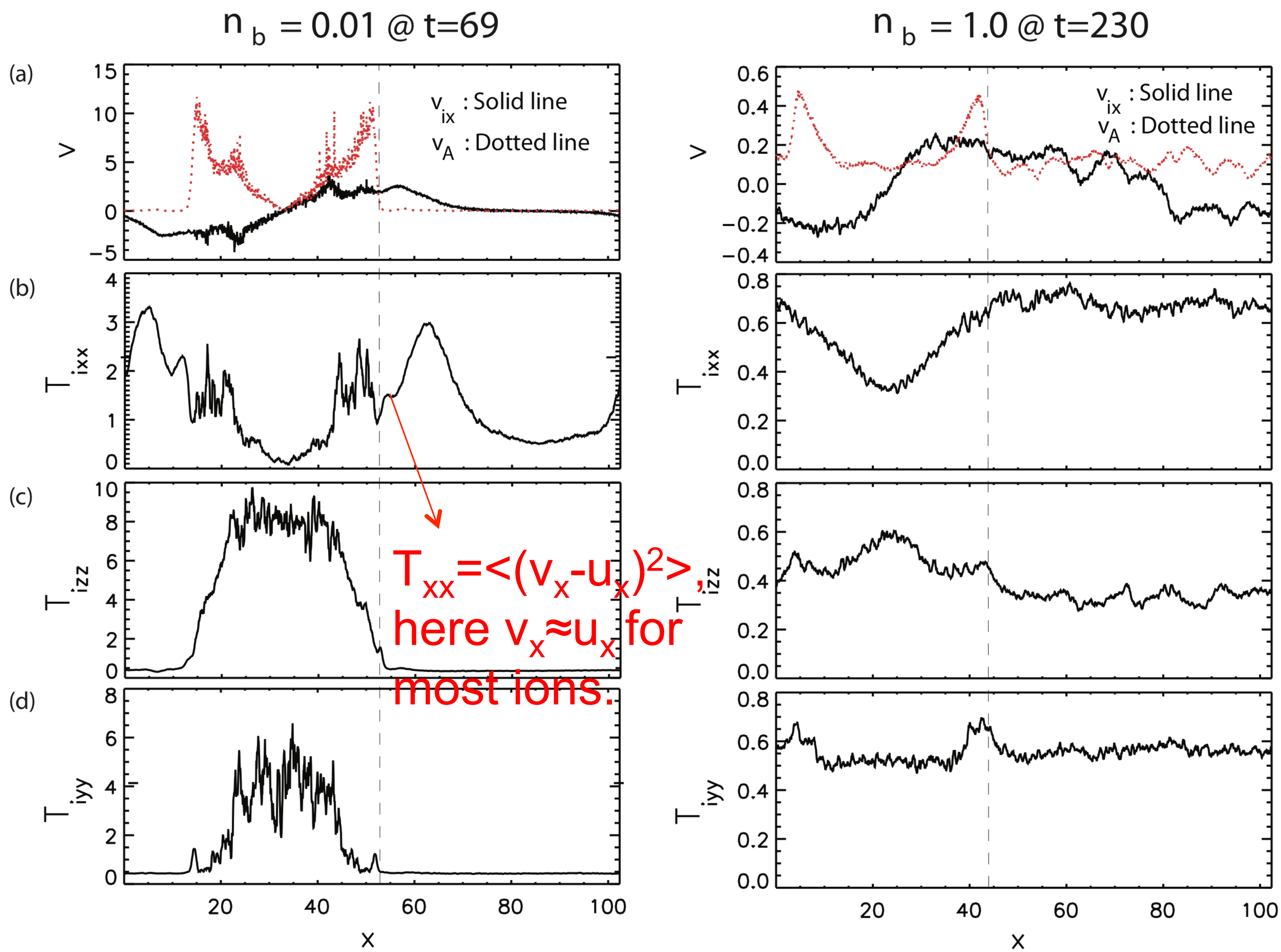
Wu et. al. (2011), to be submitted to GRL

Dipolarization Front (DF) Propagation vs. Inflow Quantification



Wu et. al. (2011), to be submitted to GRL

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



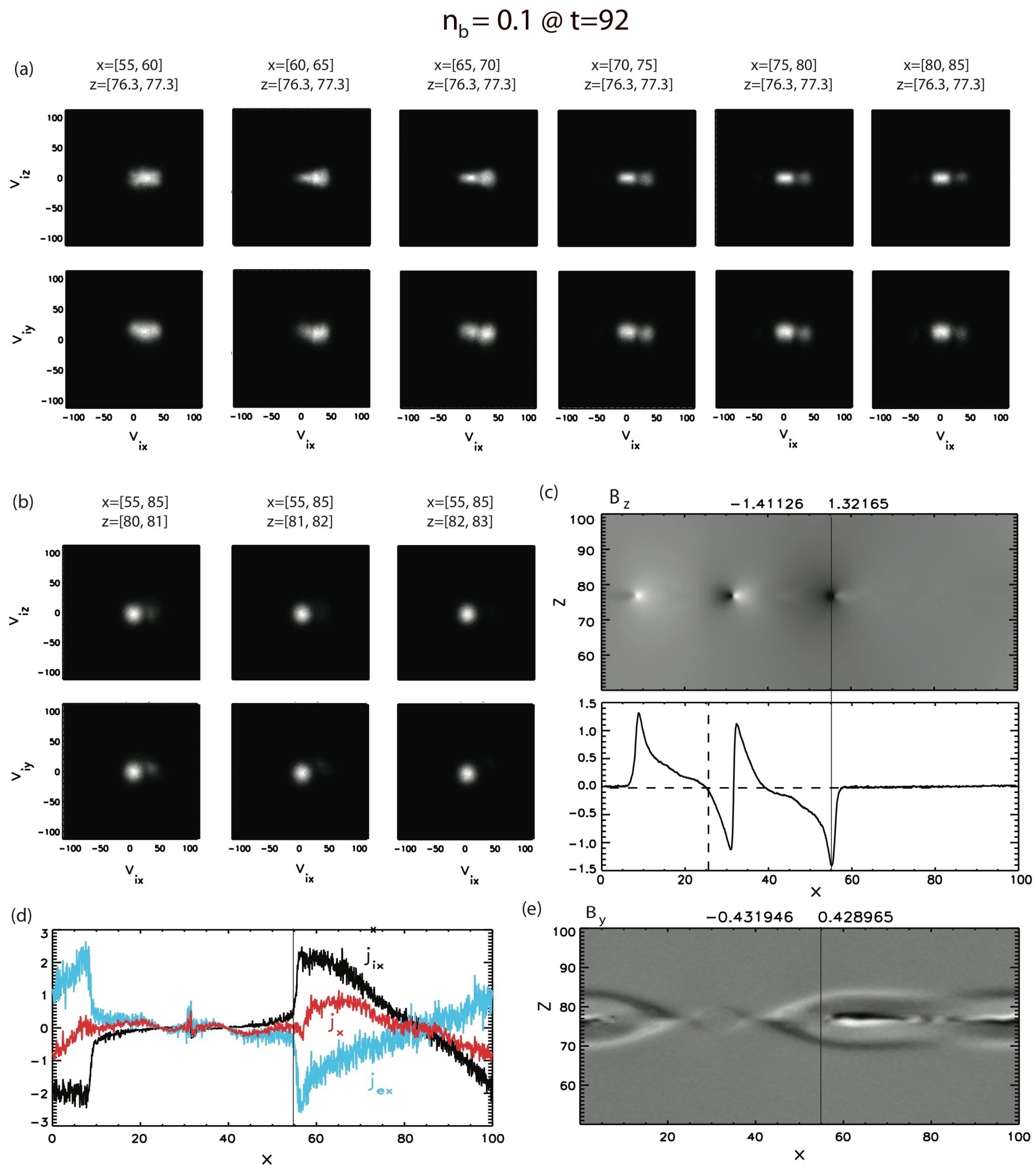
Wu et. al. (2011), to be submitted to GRL

Ion Reflection

Streaming acceleration: Very different from perpendicular shock ion reflection!

Localized to DF

Bipolar B field as consequence of Ion Streaming



Wu et. al. (2011), to be submitted to GRL

Summary: Effect of Inflow Density on Magnetic Reconnection

Downstream Dipolarization Front: as we lower inflow density

1. we quantify B_{DF} and v_{DF} scaling

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

Reconnection

We'll meet again
Don't know where
Don't know when

–Ross Parker

Particle-in-cell simulation

Code unit:

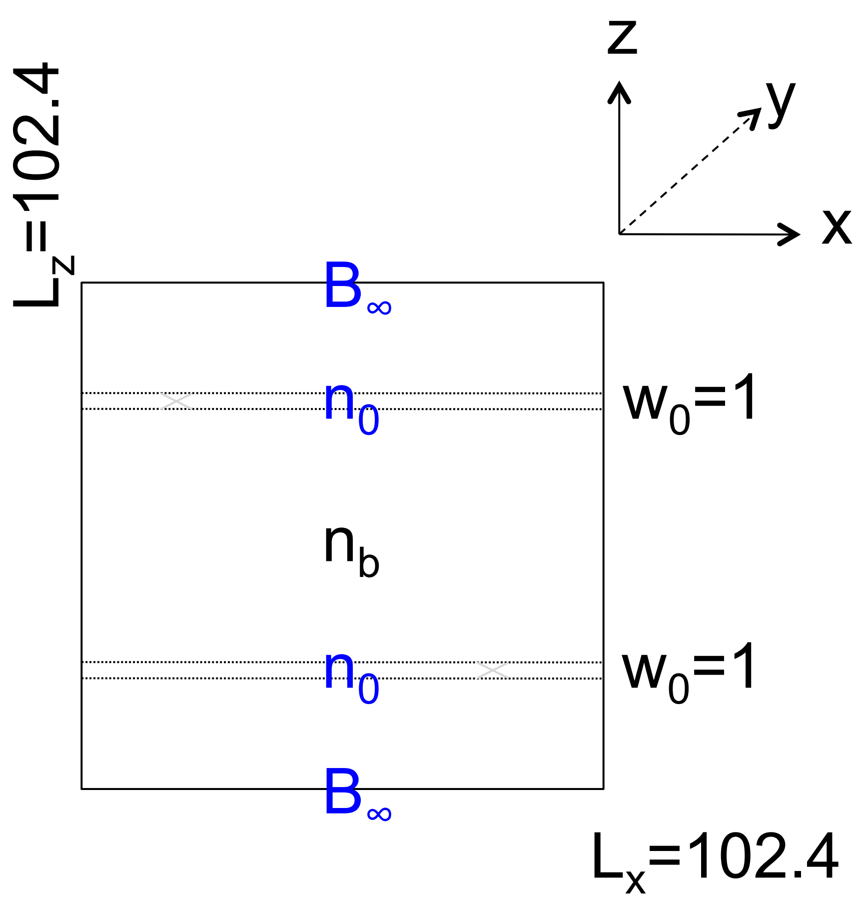
$$\frac{\partial \gamma \mathbf{v}_\alpha}{\partial t} = \frac{q_\alpha m_i}{m_\alpha}[\mathbf{E} + \mathbf{v}_\alpha \times \mathbf{B}]$$

$$\frac{\partial \mathbf{x}_\alpha}{\partial t} = \mathbf{v}_\alpha$$

$$\frac{\partial \mathbf{B}}{\partial t} = -\nabla \times \mathbf{E}$$

$$\frac{\partial \mathbf{E}}{\partial t} = \frac{c^2}{v_{A0}^2}(\nabla \times \mathbf{B} - \mathbf{J})$$

$$\nabla \cdot \mathbf{E} = \frac{c^2}{v_{A0}^2}(n_i - n_e)$$



Normalization:

B_∞, n_0, m_i, d_i, v_{A0},

E: $v_{A0}B_\infty/c$, T: $m_i v^2_{A0}$

Prescriptions: m_e=0.04, c=15

Harris-like current sheet