Inferring proximity to the reconnection site via structural changes to the magnetopause caused by asymmetric reconnection.

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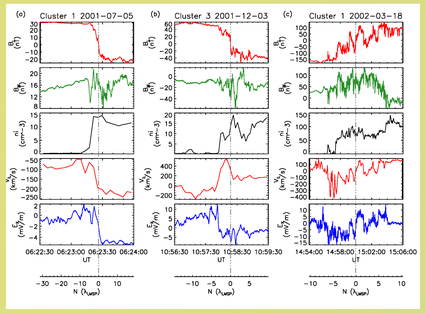
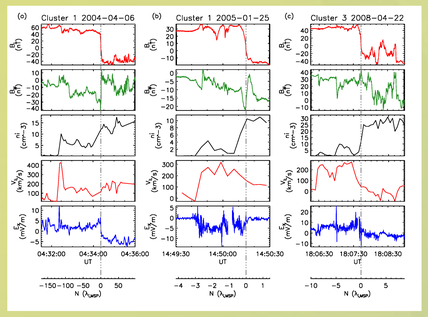
Motivation

- Quantities, such as the electron frame dissipation measure [Zenitani, et. al, 2011], agyrotropy [Scudder and Daughton, 2008], nongyrotropy [Aunai, et. al, 2013], and others [Pritchett and Mozer, 2009] used to identify dissipation and diffusion regions do not uniquely identify the X-line when asymmetries are present.
- Magnetic reconnection causes structural and topological changes to the magnetopause.
- Asymmetries between the magnetosheath and magnetosphere contribute to these structural changes.
- Case studies of the changes asymmetries imbue on the reconnection region should reveal universal characteristics of asymmetric reconnection, if they exist.
- Observations of asymmetric reconnection by Cluster motivate simulation and laboratory experiments studies that reveal a correlation between transition offsets across the magnetopause and proximity to the X-line

Case Studies: Cluster



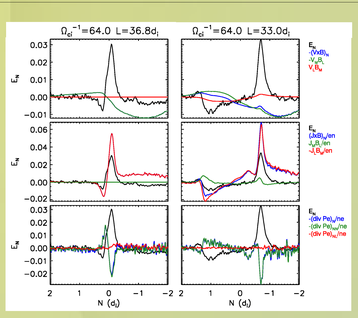


- Asymmetries modify:
  - Reconnecting magnetic field (B_L)
  - Hall magnetic field (B_M)
  - Ion density (n_i) gradient
  - Ion outflow jet (V_{iL}),
  - Normal electric field (E_N)
- $E_X = E_N$ within 33 ± 14 degrees

- B_L reversal can occur over 1-10 $\lambda_{i,MSP}$
- B_M can have unipolar or bipolar profiles
- The density gradient can occur with B_L=0 or removed by up to 125 $\lambda_{i,MSP}$
- DC E_X reversal occurs from B_L=0 to either side of the density gradient
- V_{iL} can be observed between B_L=0 and density gradient or earthward of the density gradient

Contributions to E_N in 2D Simulations

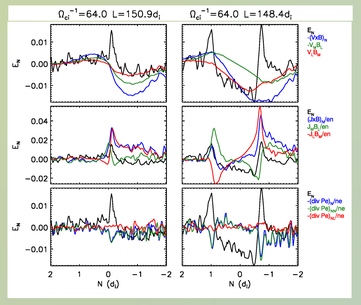
Bg = 0



X-line
- Malakit, et. al [2013] discusses Larmor electric field due to finite Larmor radius effect.
- We claim that the ion current sheet causes E_C.
- For B_g = 1, E_H points sunward on both sides of the current sheet.
- Pressure gradients are comparable to E_H

Downstream
- Current sheet broadens, and so does E_C.
- Mozer, et. al [2008] shows E_H modified to a unipolar structure.
- Flow along separatrices maintains asymmetric, bipolar E_H.
- Pressure gradients opposes E_H.

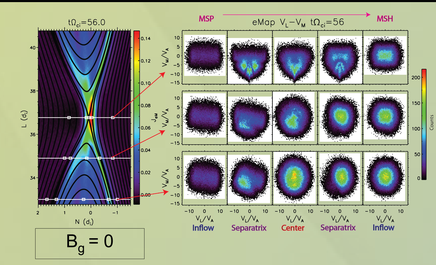
B_g = 1



X-line
- Guide field and E_C create v_{ExB} drift upstream
- V_{ExB} interacts with B_g to enhance E_C.
- Tilt of separatrices causes electron flow along M

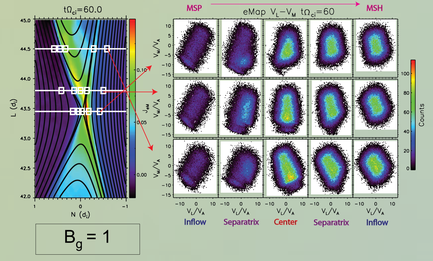
Downstream
- Ion outflow crosses X-line and offsets E_C reversal
- E_H points sunward at MSH separatrix and is no longer asymmetrically bipolar.

An Independent Check: Distribution Functions



B_g = 0

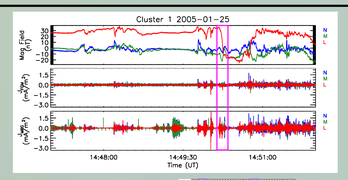
- Inflow distributions are elongated along the reconnecting field.
- Separatrix distributions are a mix of inflow and accelerated electrons.
- X-line is identified by a unique delta-shaped distribution.
- In the central exhaust several populations are visible.

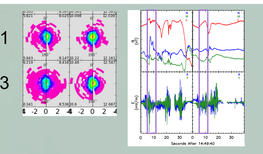


B_g = 1

- Inflow distributions are elongated along both B_x and B_y.
- In the magnetosphere, a second population is visible
- Separatrix distributions again are a mix if inflow and accelerated particles.
- X-line is not uniquely identified by a particular shape.
- The exhaust distributions show electrons accelerated along y.

Cluster

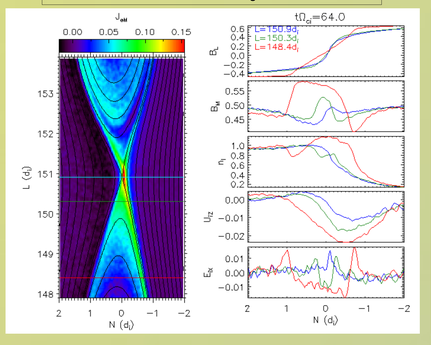




In close proximity to the X-line, Cluster observes:
- Enhanced currents (combined product)
- Triangular shaped distributions.

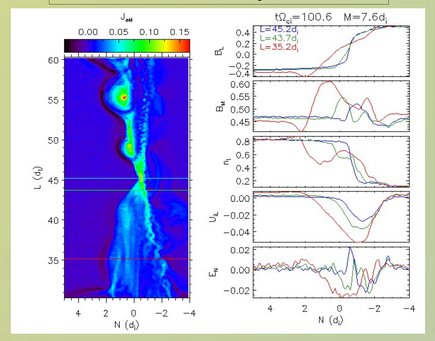
Simulations and Experiment

2D PIC with B_g = 1



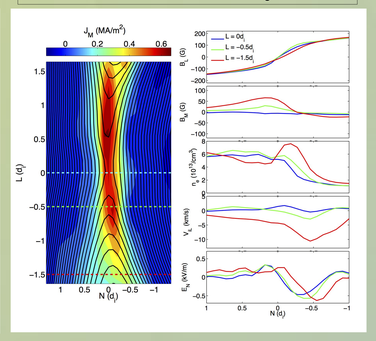
Near the X-line
- B_L, n, and E_X transition simultaneously
- Simultaneous transitions occur only within 5d_e of the X-line
- Ion outflow is earthward of the density gradient

3D PIC with B_g = 1



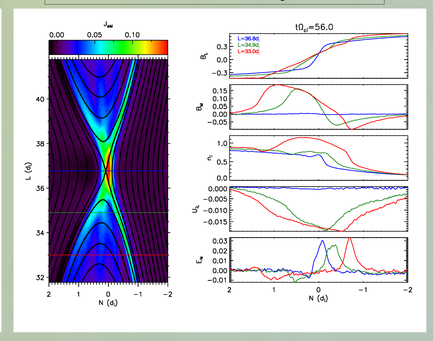
Downstream
- n develops a dip along the magnetosheath separatrix
- Closer to the X-line, where the dip is approximately equal to the distance between separatrices, a plateau is observed.
- Ion outflow crosses the separatrix into the exhaust
- DC electric field reversal is offset from B_L = 0

MRX Experiment with B_g = 0



B_g = 0
- Near the X-line, transitions are still simultaneous with the B_L reversal

2D Simulation with B_g = 0



Differences between B_g = 0 and B_g = 1
- Density dip is present at the X-line
- No ion outflow earthward of the X-line
- Electric field maintains an (asymmetric) bipolar structure that crosses zero in the vicinity of B_L=0.

Conclusions

- Transitions in B_L, n, and E_N across the magnetopause are correlated to proximity to the X-line.
- Only within 5 de of the X-line to transitions occur together. This is true for both strong and weak guide-field cases.
- Downstream, transitions separate from one another.
- For B_g = 1:
  - Ion outflow is observed upstream from the X-line.
  - DC electric field reversal depends on location of outflow jet.
  - At the X-line, density transitions directly from high to low.
- Electron distributions uniquely identify the EDR – serve as independent check.
- Cluster event in close proximity to the X-line exhibits:
  - Triangular electron distributions.
  - Enhanced currents in combined FGM & SCM data product.

References

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