Characterizing Electrons in Secondary and Primary Magnetic Islands During Magnetic Reconnection

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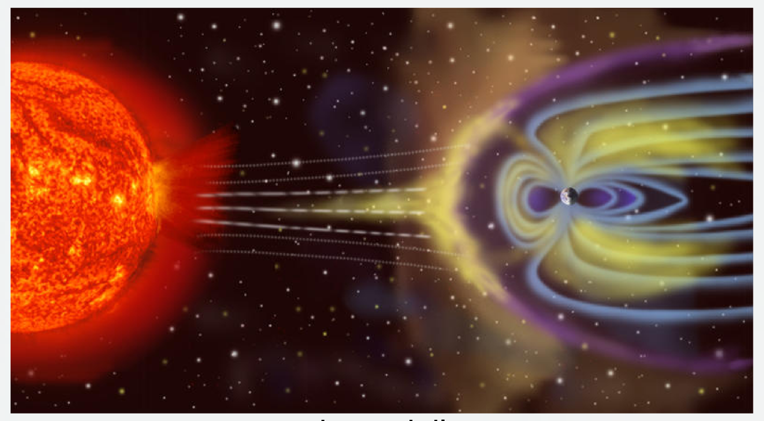

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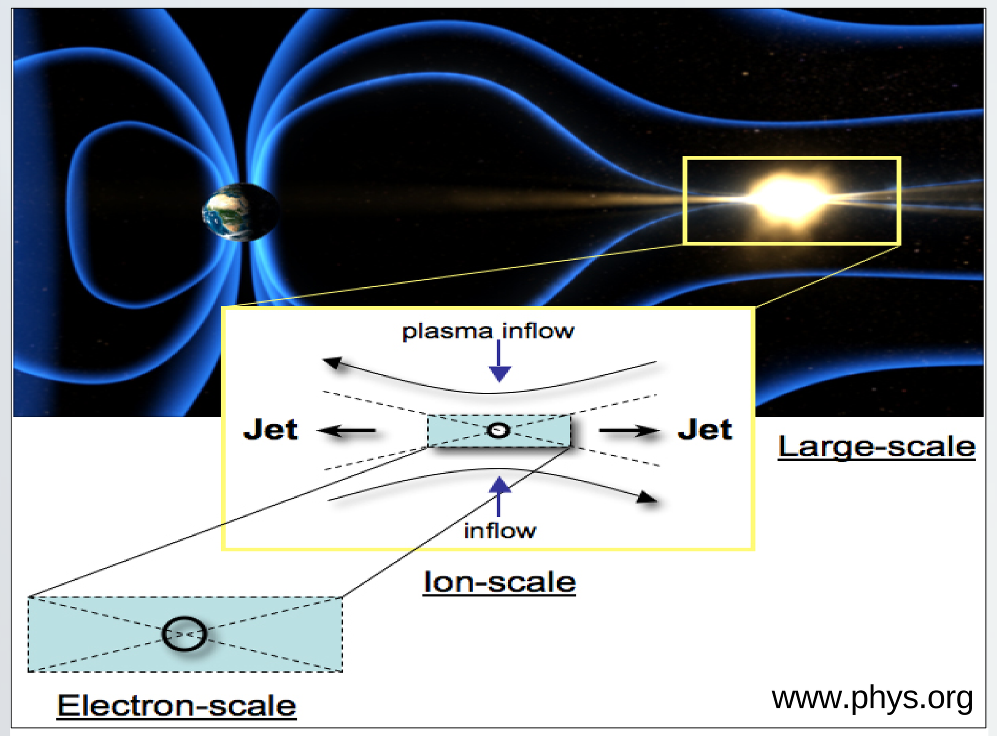
INTRODUCTION

What is magnetic reconnection?

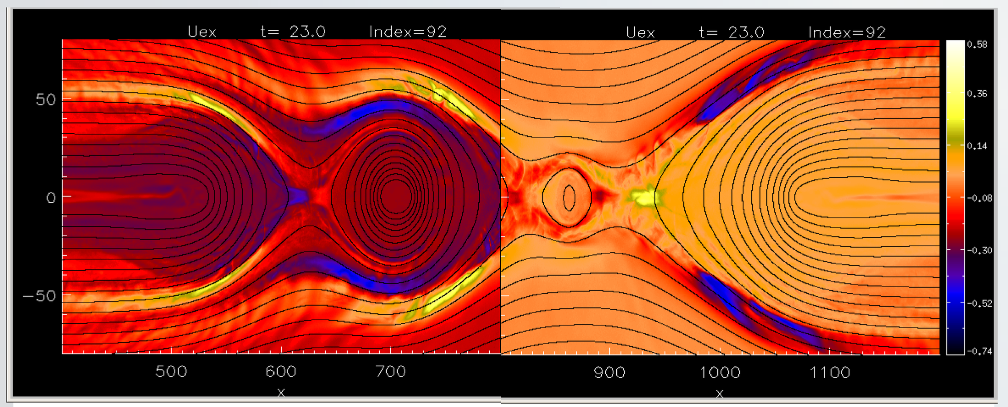
- Fundamental energy conversion process [1]: stored magnetic energy ► plasma kinetic energy and heat.
- Active field of research, as scientists work to discover the underlying physics of energy released in reconnection.



Magnetic explosion triggered by reconnection

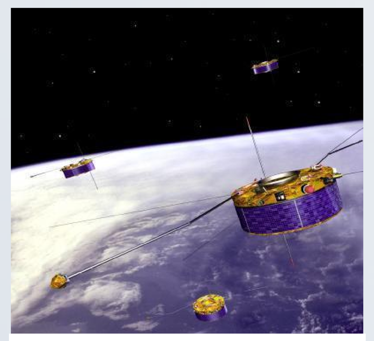
What are magnetic islands?

- Closed loops in the magnetic field within a plasma.



Simulated primary and secondary magnetic islands

- Crucial to understand magnetic island formation to learn how energy is dissipated in reconnection events [2].
- Established link between the production of energetic electrons and magnetic islands observed by Cluster spacecraft [2].



Cluster spacecraft

Particle-in-Cell (PIC) Simulations:

- Newton's 2nd Law and Maxwell's Equations to solve for each particle [4], [5]:

E – electric field
B – magnetic field
J – current density
v – particle velocity

$$m\frac{d\mathbf{v}}{dt} = \mathbf{F} \qquad \frac{d\mathbf{x}}{dt} = \mathbf{v}$$
$$\mathbf{F} = q\mathbf{E} + q(\mathbf{v}\times\mathbf{B})$$
$$\frac{\partial \mathbf{E}}{\partial t} = c(\nabla\times\mathbf{B}) - 4\pi\mathbf{J}$$
$$\frac{\partial \mathbf{B}}{\partial t} = -c(\nabla\times\mathbf{E})$$

Newton's 2nd Law, Maxwell's Equations

- Simulation used in this study:
  - open boundary conditions
  - collisionless reconnection
  - no guide field
  - $m_i/m_e = 400$
  - number of particles: ~1.5 x 10^9

RESEARCH STUDY

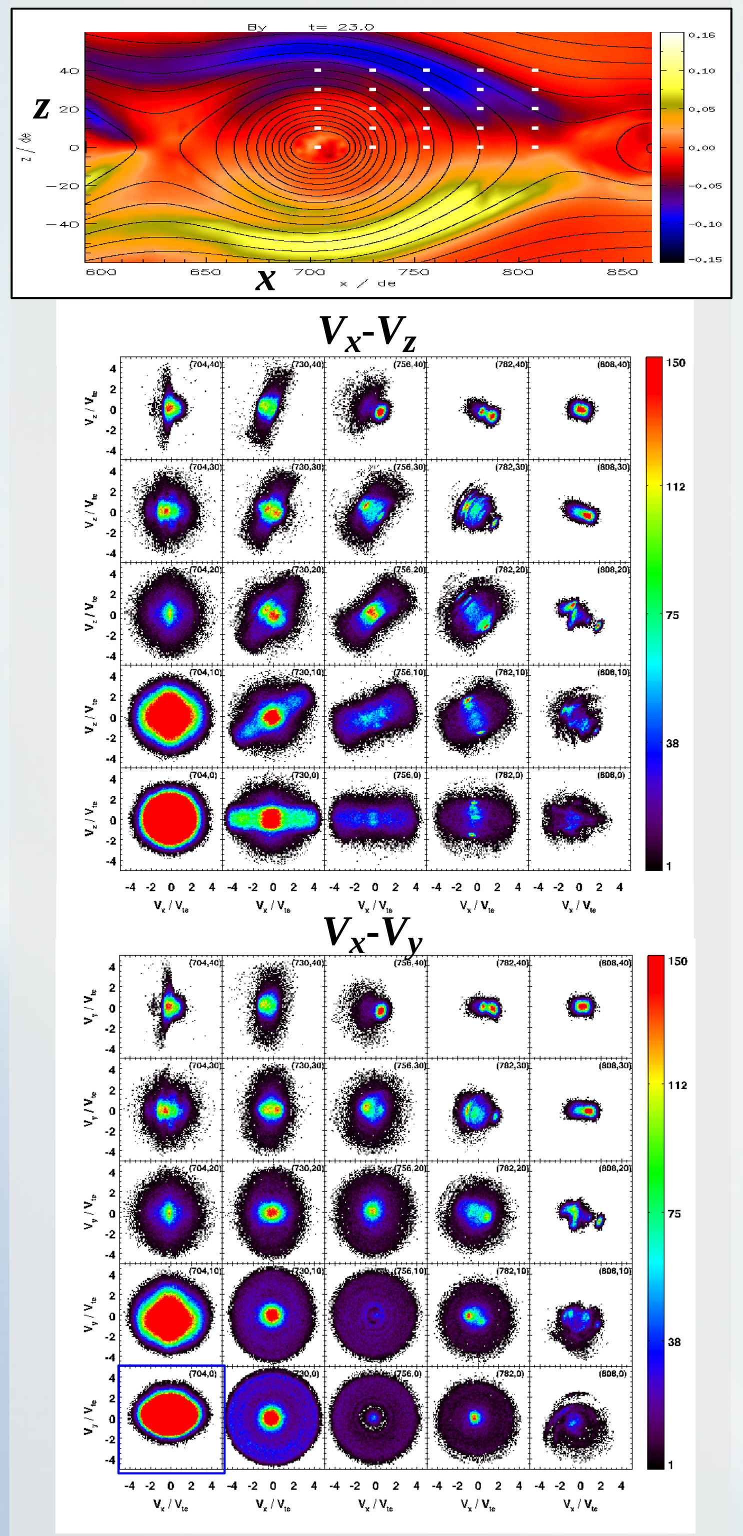
Main Objective

- The main objective of this research is to compare primary and secondary magnetic islands, and establish for the first time distinct features in electron velocity distributions for both types of islands.

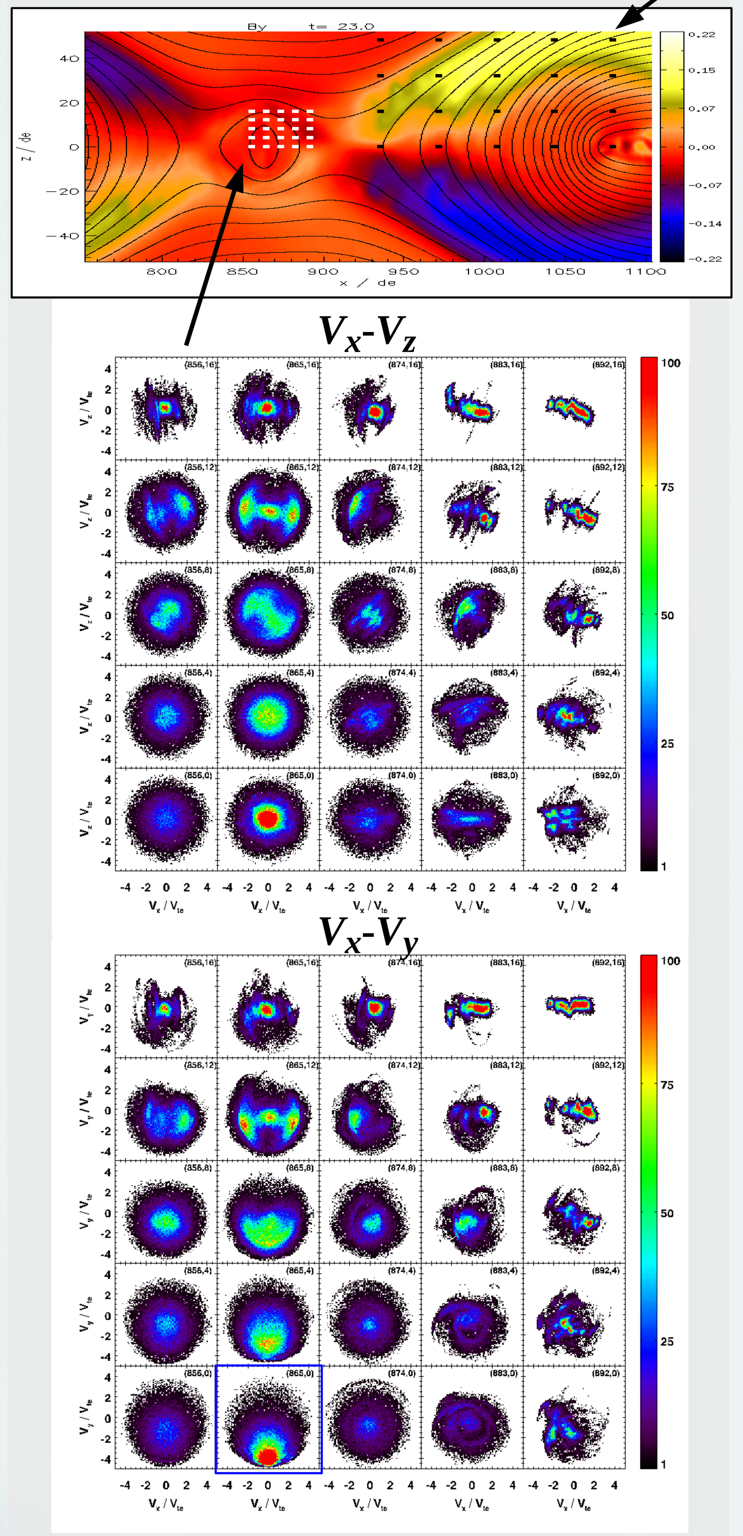
Secondary Objective

- The second objective of this study is to examine the assumption that electron distributions in the interior of magnetic islands are similar to those in the exhaust.

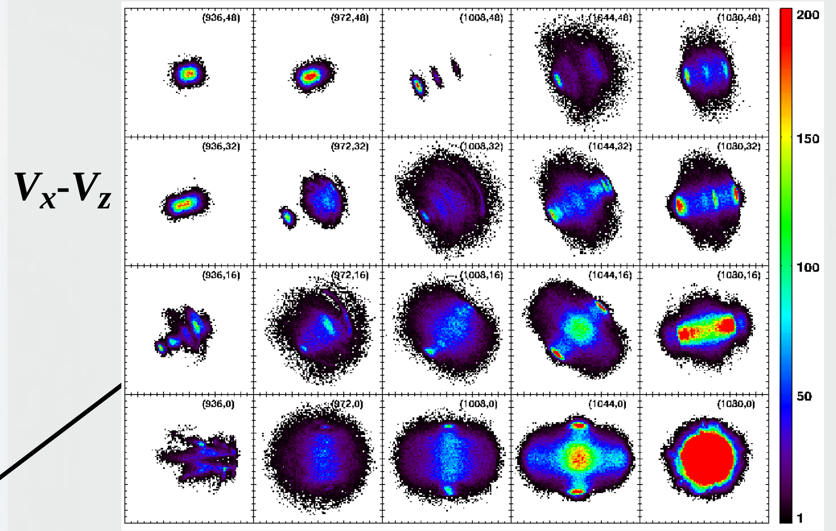
Primary Island: formed due to multiple X lines in unstable ion current sheet.



Secondary Island: born from the electron current layer.

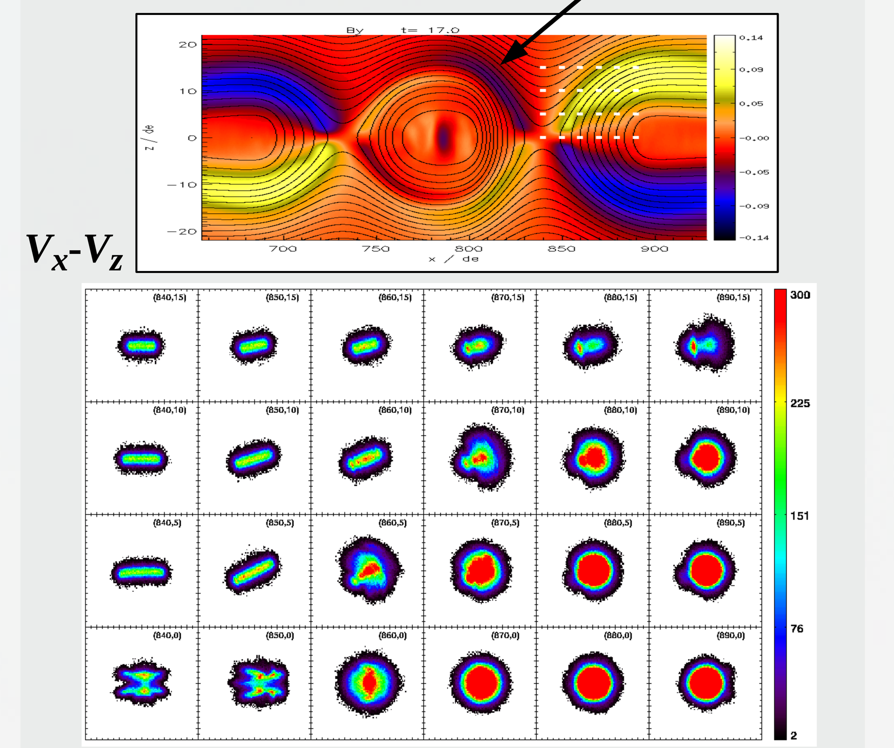


Open Exhaust: electron distribution functions from open exhaust region.



- Hotter, more structured distribution functions than at earlier stage.
- Isotropic distributions only in density pileup and perpendicular heating at B pileup region.

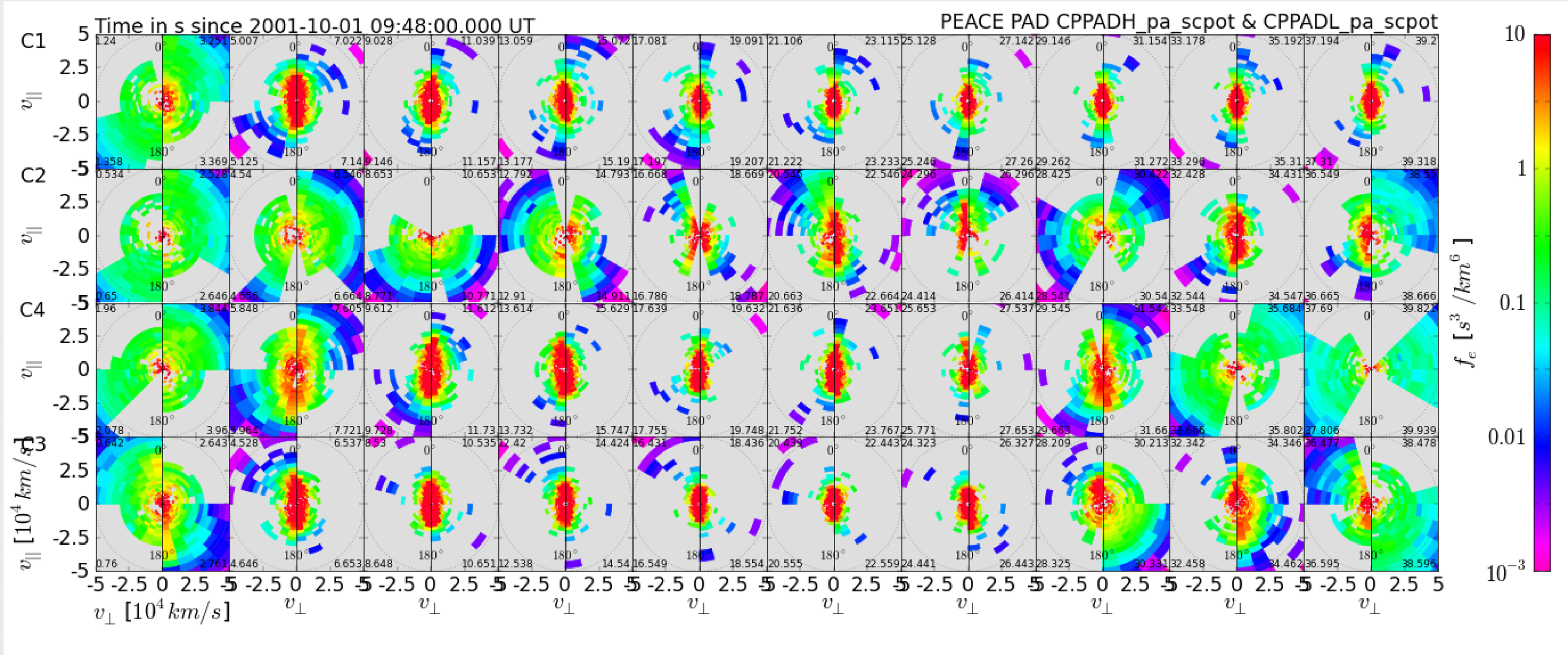
Open Exhaust (earlier stage): *Primary Island*



- Mostly hot and isotropic electrons, consistent with previous results [3].

Cluster Data: visualization of the X line using electron data measured by four spacecraft.

- Electron distributions in inflow are elongated along B; those in exhaust are much hotter.



Similarities and Differences:

- Strong electron flows along the negative *y*-direction *only* in secondary island.
- Colder, dense island cores in both islands.
- Highly dynamic and structured electron distributions in both V_x-V_y and V_x-V_z distribution functions for both islands.

CONCLUSIONS

Simulation Results:

- Strong peak in the negative V_y direction in the secondary island core, but not in primary island.
- Highly structured electron distribution functions in both islands at all evolution stages.
- The assumption that electron distributions within magnetic islands are similar to exhaust electrons is an oversimplification.

Future Work:

- Comparison with Cluster electron measurements from within magnetic islands.
- Comparison with future electron data from Magnetospheric Multiscale (MMS), to launch in 2014, capable of resolving the types of structures revealed in the electrons of this simulation.
- UNH leads an international team of seven institutions by managing the design and construction of instrument suites for the four MMS spacecraft.

ACKNOWLEDGEMENTS:

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