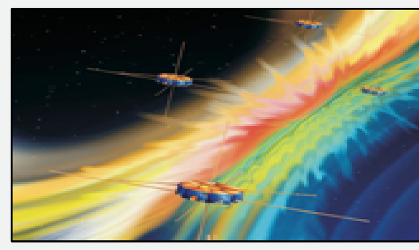
Electron Anisotropy in the Open Exhaust Region of Reconnection

SM21B-2289

NASA's Magnetospheric Multiscale



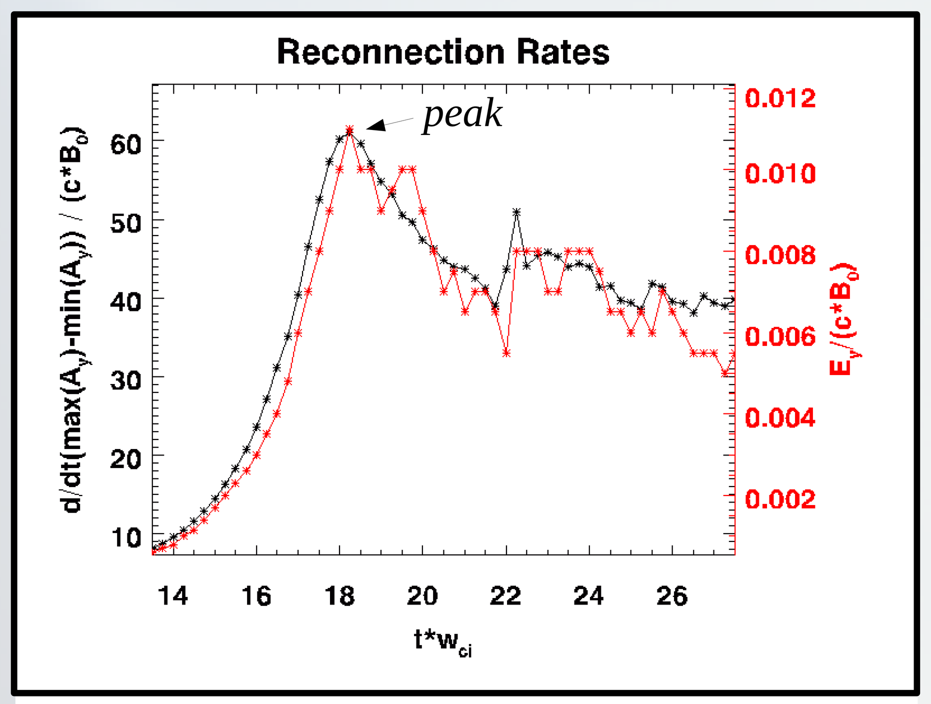
Jason R. Shuster[1] (jrf63@wildcats.unh.edu), **Li-Jen Chen**[1], **William S. Daughton**[2], **Lou C. Lee**[3], **Kun Han Lee**[3], **Roy B. Torbert**[1], **Guanlai Li**[1], **Matt Argall**[1]

[1]Space Science Center, University of New Hampshire, Durham, NH 03824, U.S.A. [2]Los Alamos National Laboratory, Los Alamos, NM 87545, U.S.A.
[3]National Central University, Jhongli City, Taiwan.

INTRODUCTION

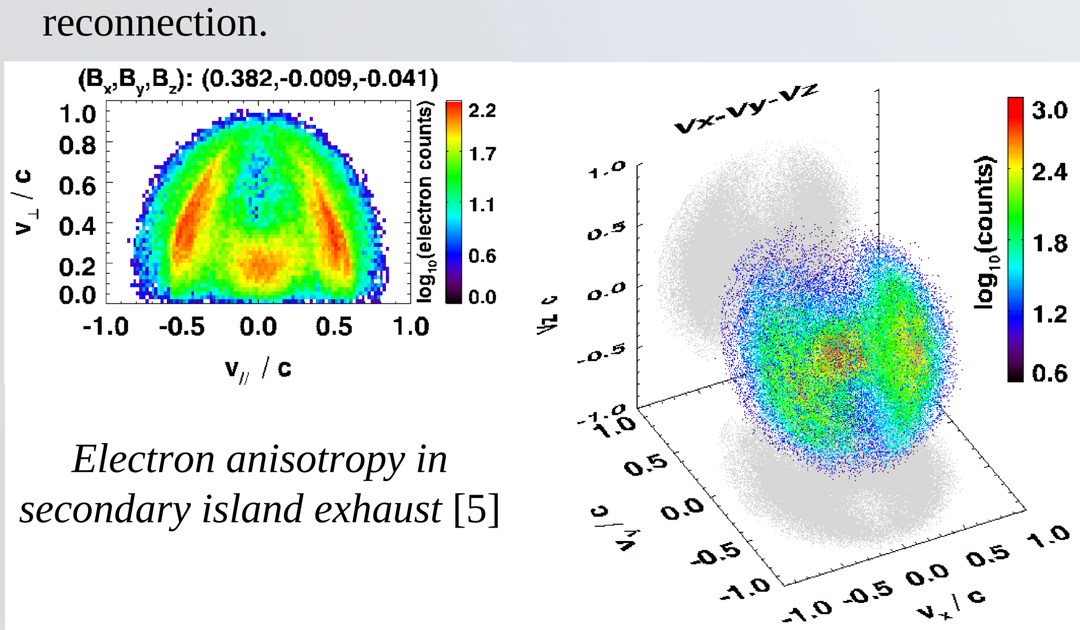
Motivation and Context:

♦ **The purpose of this poster is to report the discovery that electron anisotropy develops throughout the open exhaust region after the reconnection rate peaks.** Previous studies [1,2] concluded that electron distributions in the exhaust are relatively isotropic based on simulations that did not run beyond when the reconnection rate peaks. This poster reports on a simulation that runs for over 10 Ω_{ci}^{-1} after the reconnection rate peak. Using these simulation results, new types of anisotropic electron velocity distributions are discovered and highlighted in this presentation.



Evolution of two measures of the reconnection rate: E_y, the out-of-plane electric field ***(red)****, and the time rate of change of the reconnected flux* ***(black)****.*

Recent Work: Magnetic islands (plasmoids) play a crucial role in electron energization [2,6]. Our recent study focusing on simulated magnetic islands discovered notable electron anisotropy in island exhaust regions [5]. Prior to our work, electron distributions from island exhausts and open exhausts were assumed to be roughly similar. Our findings showed that this assumption is only valid for early evolution stages of reconnection.



Electron anisotropy in secondary island exhaust [5]

Particle-in-Cell (PIC) Simulation Parameters:

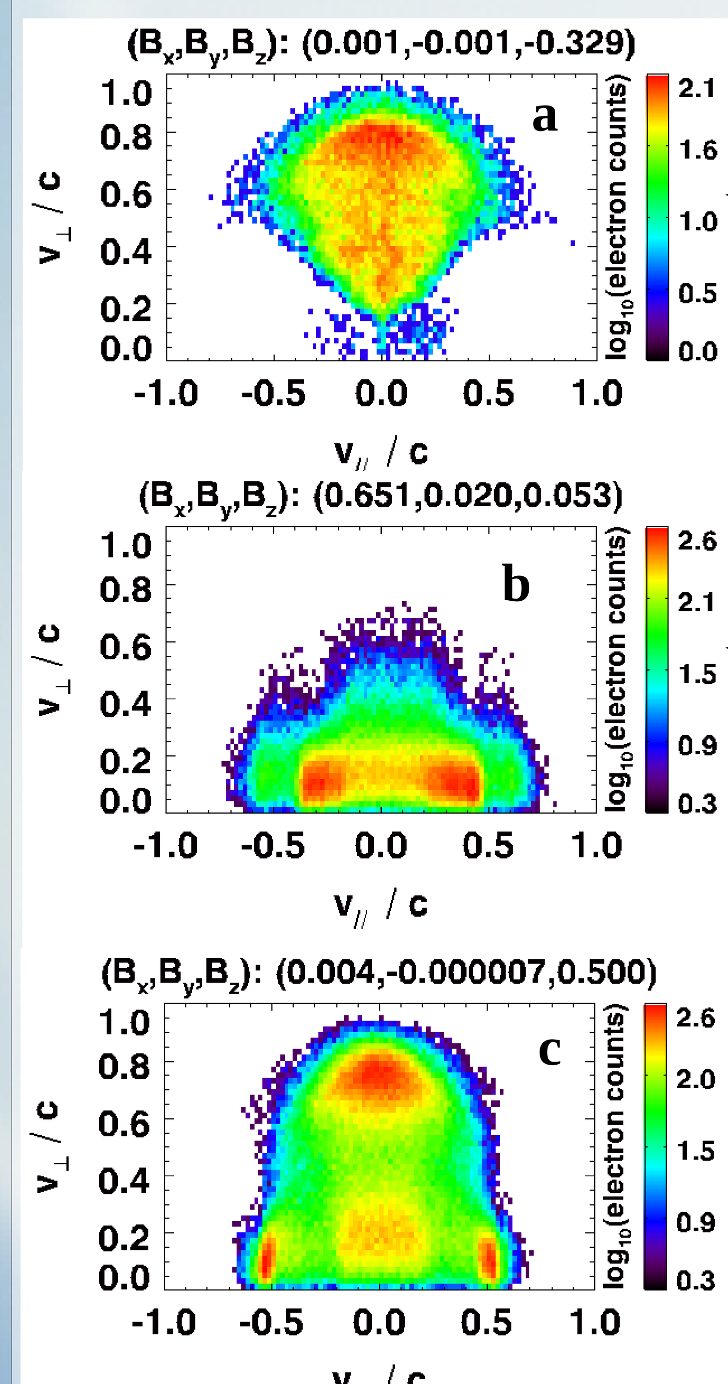
- collisionless, undriven reconnection, with no guide field
- open boundary conditions, perturbation to seed single X-line
- lobe appropriate beta: 0.0028, N_b / N_o = 0.05, T_b / T_o = 0.333
- T_i / T_e = 5 (Harris population), ω_{pe} / Ω_{ce} = 2, L / d_i = 0.5
- m_i/m_e = 400, number of particles: ~3.1 x 10^{10}
- particles per cell: 600, number of cells: 10240 x 2560

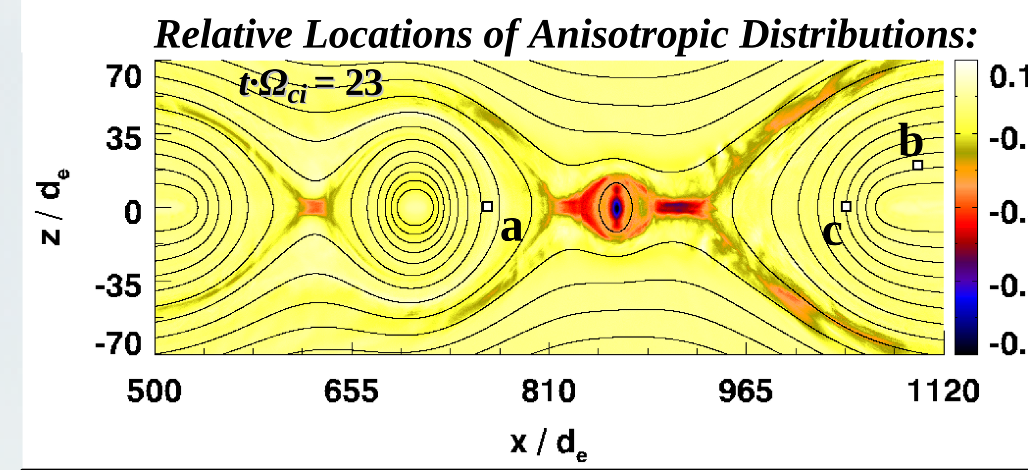
RESULTS

Electron Anisotropy

♦ ***Before*** *the reconnection rate peaks: exhaust electrons are fairly isotropic, consistent with previous studies [1].*

♦ ***After*** *the reconnection rate peaks: electron anisotropies develop throughout the open exhaust.*

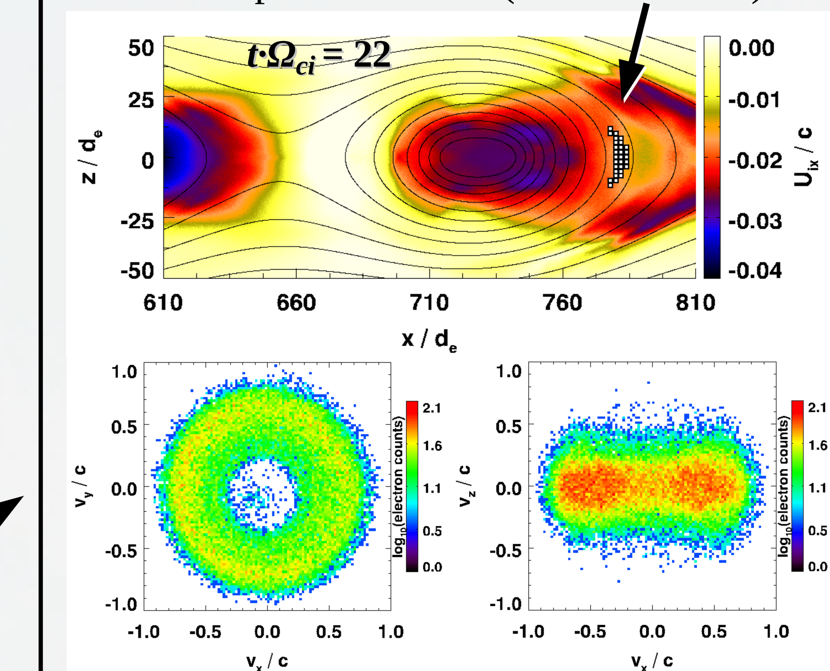




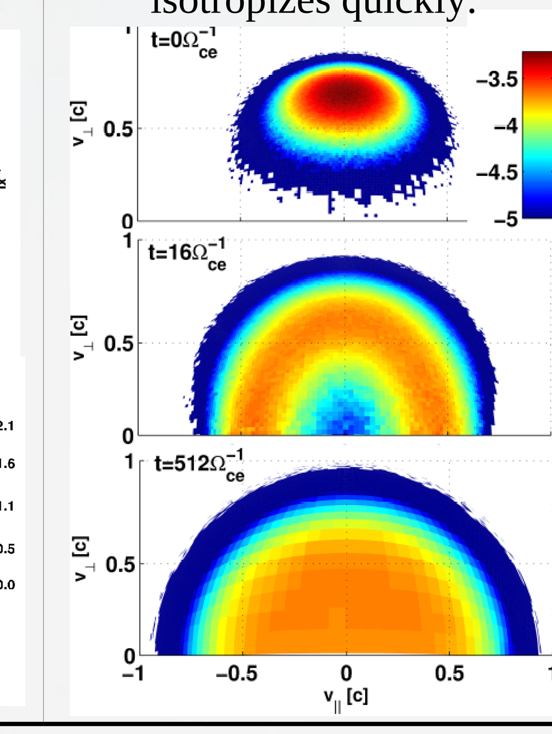
Ring Distribution:

♦ Appears as a distinct ring in v_x-v_y velocity space (*x-y* plane is ⊥ to ***B*** whose *z*-component dominates).
♦ Found in semi-open field-line region.
♦ Appears after $t\cdot\Omega_{ci}$ = 17 and begins to diffuse by $t\cdot\Omega_{ci}$ = 23.
♦ Stability analysis shows distribution is unstable to whistler waves [7,8].

Region of Ring Distribution: along semi-open field lines (see white bins).



Instability Analysis: isotropizes quickly.



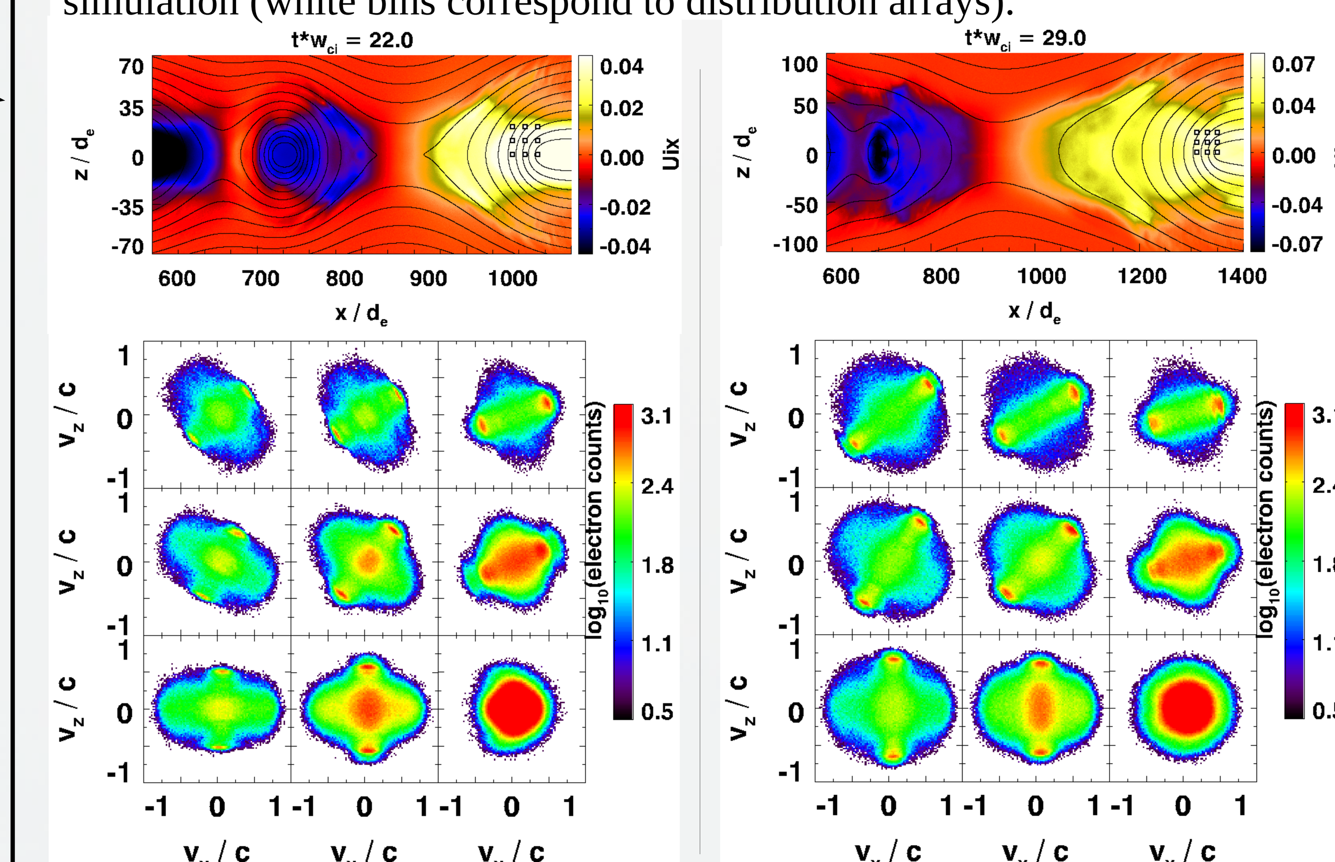
Counter-Streaming Distribution:

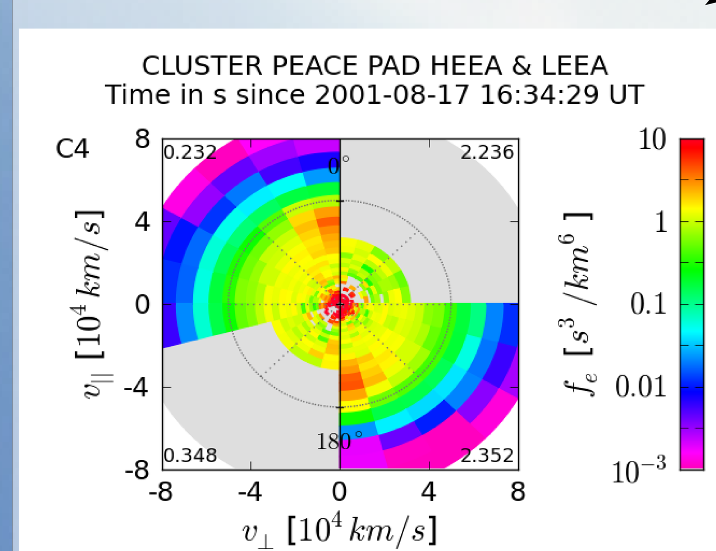
♦ Exhibits temperature anisotropy with $T_{e//} > T_{e\perp}$ and two counter-streaming populations.
♦ Found throughout exhaust region, indicating the existence of a reflection mechanism.
♦ Appears after $t\cdot\Omega_{ci}$ = 17 and persists for the rest of the run.

Multi-Component Distribution:

♦ Four distinct populations: one with temperature anisotropy $T_{e\perp} > T_{e//}$, one colder background population, and two counter-streaming beams parallel to ***B***.
♦ Found deep in the exhaust at ***B***-pileup region where B_z and E_y are largest, unlike recently reported exhaust anisotropy closer to the separatrix [3].
♦ Appears after $t\cdot\Omega_{ci}$ = 17 and persists for the rest of the run.
♦ Consistent with Cluster spacecraft velocity distributions.

Persistence of Anisotropy: after developing, anisotropies last long as the simulation (white bins correspond to distribution arrays).





Cluster Data:

♦ Electron velocity distribution from a magnetotail reconnection exhaust in an ion outflow jet where minimum variance analysis shows $B_X \approx B_Z$.
♦ Counter-streaming beams parallel to ***B***.
♦ Temperature anisotropy: $T_{e\perp} > T_{e//}$

CONCLUSIONS

New Results:

♦ **After the peak in the reconnection rate occurs, electron anisotropy develops and persists throughout the open exhaust.**
♦ Consistent anisotropies as predicted by the simulation are found in Cluster data.

Future Work:

♦ Further understand kinetic physics by employing particle tracing codes and Liouville phase-space mapping to track individual electron orbits and reconstruct these anisotropic distributions.
♦ Comparison with future data from NASA's Magnetospheric Multiscale (MMS) mission, whose state-of-the-art time resolution is capable of resolving these fine structures predicted by simulation.

ACKNOWLEDGEMENTS:

This research is supported in part by NSF grant PHY-0903923, DOE grant DE-FG02-07ER54941, NASA grant NNX11AH03G, and a UNH CEPS Graduate Fellowship.

REFERENCES:

[1] Chen et al., J. Geophys. Res., **113**, A12213, 2008.
[2] Chen et al., Nature Phys., **4**, 19-23, 2008.
[3] Egedal et al., Nature Phys., **8**, 321-324, 2012.
[4] Asano et al., J. Geophys. Res., **113**, A01207, 2008.
[5] Shuster et al., AGU poster, SM23B-2053, 2011.
[6] Drake et al., Nature Phys.,**443|5**, 553-556, 2006.
[7] K. H. Lee et al., Phys. Plasmas, **18**, 092110, 2011.
[8] K. H. Lee et al., Phys. Rev. Lett., **103**, 105101, 2009.