How plasma flows in the reconnection diffusion region are modified by the presence of magnetic islands

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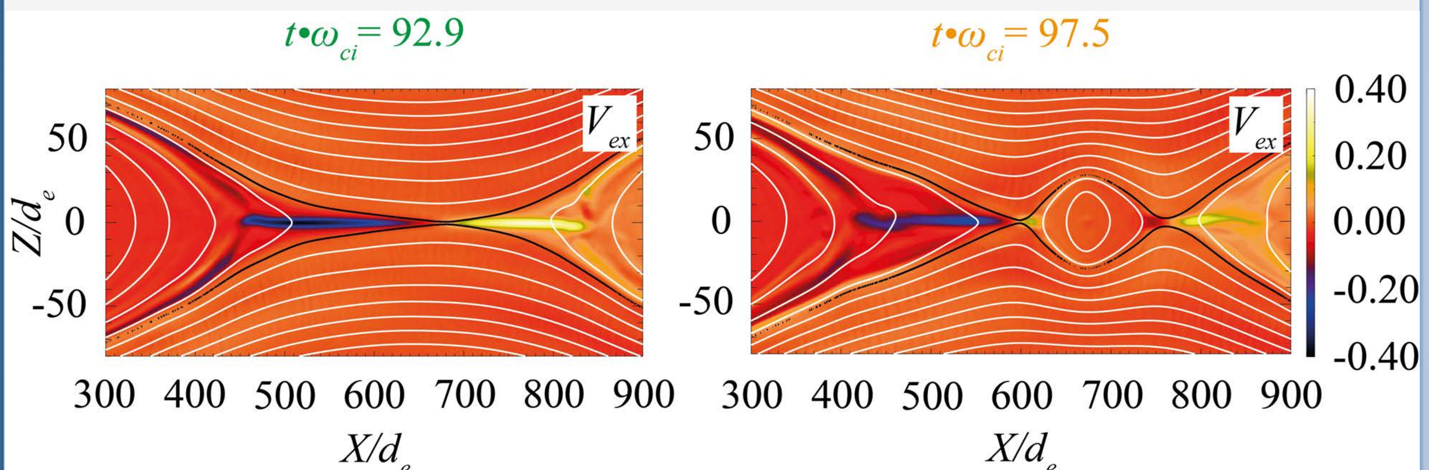
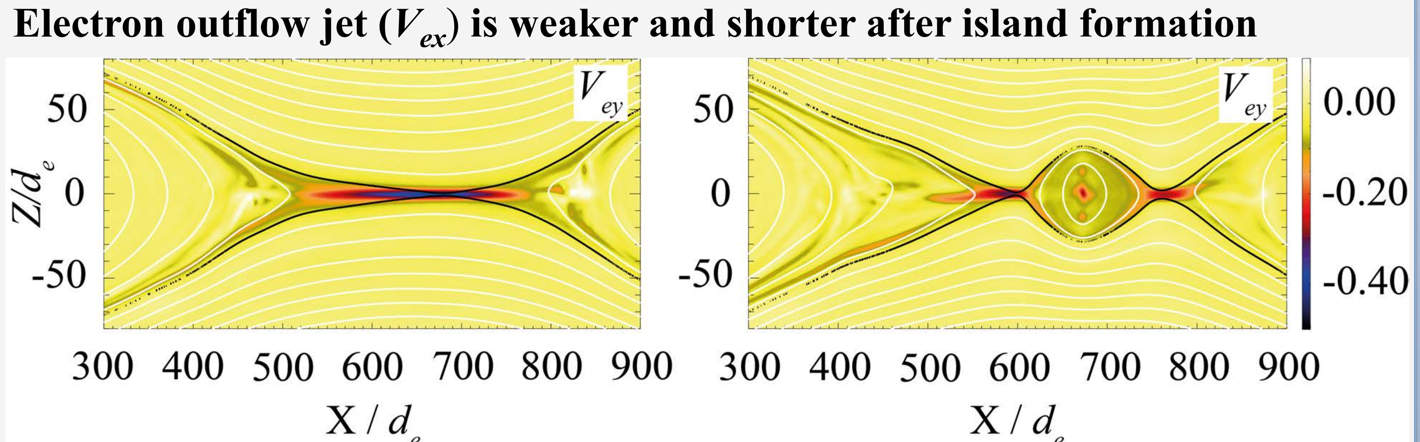
MOTIVATION

- Magnetic islands play an important role in facilitating fast reconnection and accelerating plasma particles in simulations [1]. In nonlinear phase of reconnection, the electron current layer becomes extended and unstable to island formation[2,4].
- Simulations have shown that reconnection rate decreases with elongation of the electron diffusion region[2,3] and increases with island formation [2].
- How the plasma flow and electromagnetic fields respond to the presence of magnetic islands is an important yet largely unexplored problem.
- We use two-and-half dimensional Particle-In-Cell simulation to study the modification of plasma flows and Hall field after island formation. The simulation parameters are:
  - $m_i/m_e = 1836$
  - non-driven and zero guide field
  - Open boundary condition
  - Large simulation domain: $1285d_e \times 857d_e$
  - 5120×6144 cells and 600 particles per cell
  - $T_i/T_e=2$, $n_b/n_0=0.2$, $\omega_{pe}/\omega_{ce}=2$

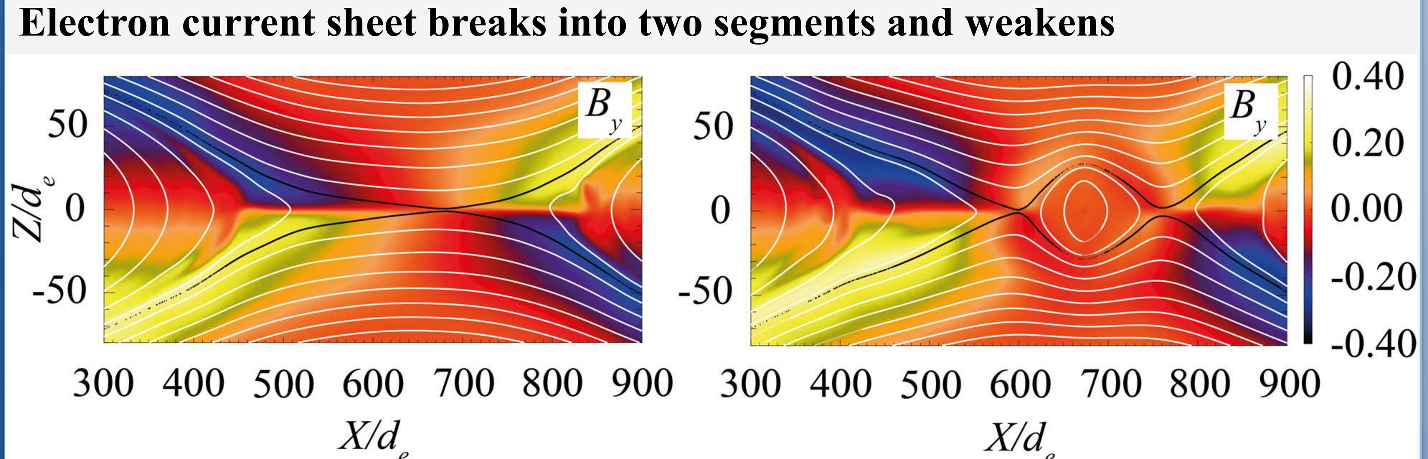
CHANGES IN PLASMA AND FIELDS AFTER ISLAND FORMATION



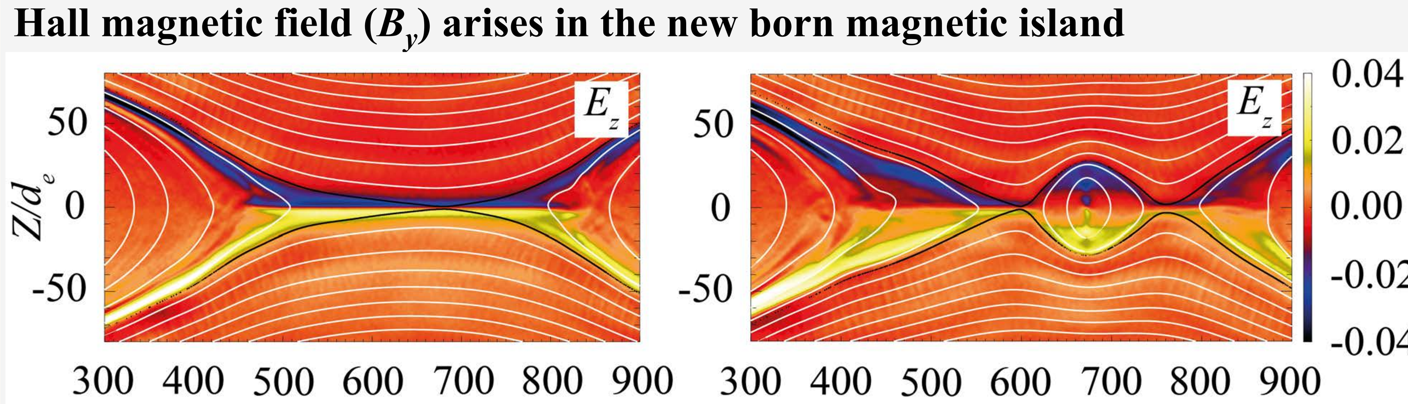
Electron outflow jet (V_{ex}) is weaker and shorter after island formation



Electron current sheet breaks into two segments and weakens



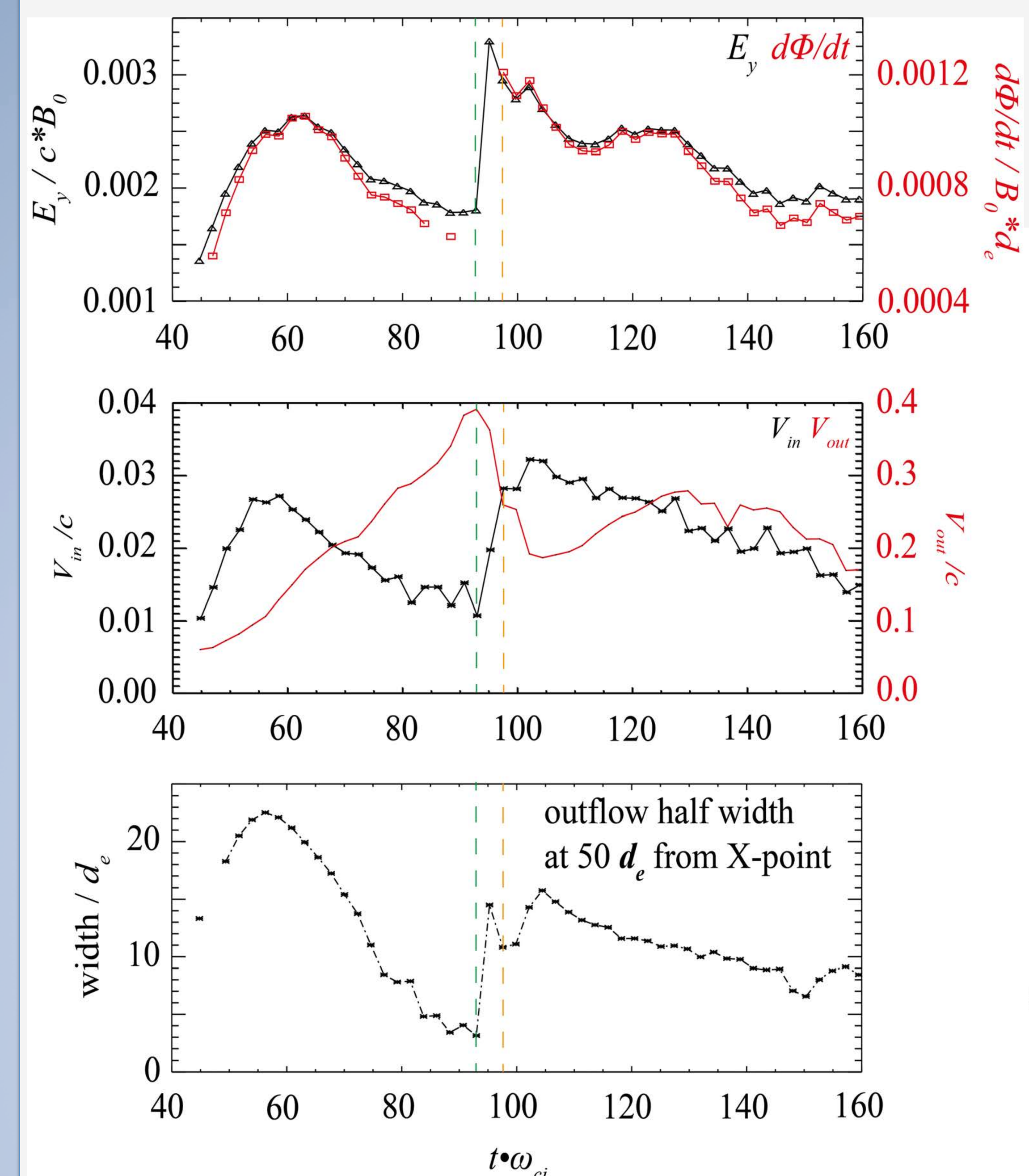
Hall magnetic field (B_y) arises in the new born magnetic island



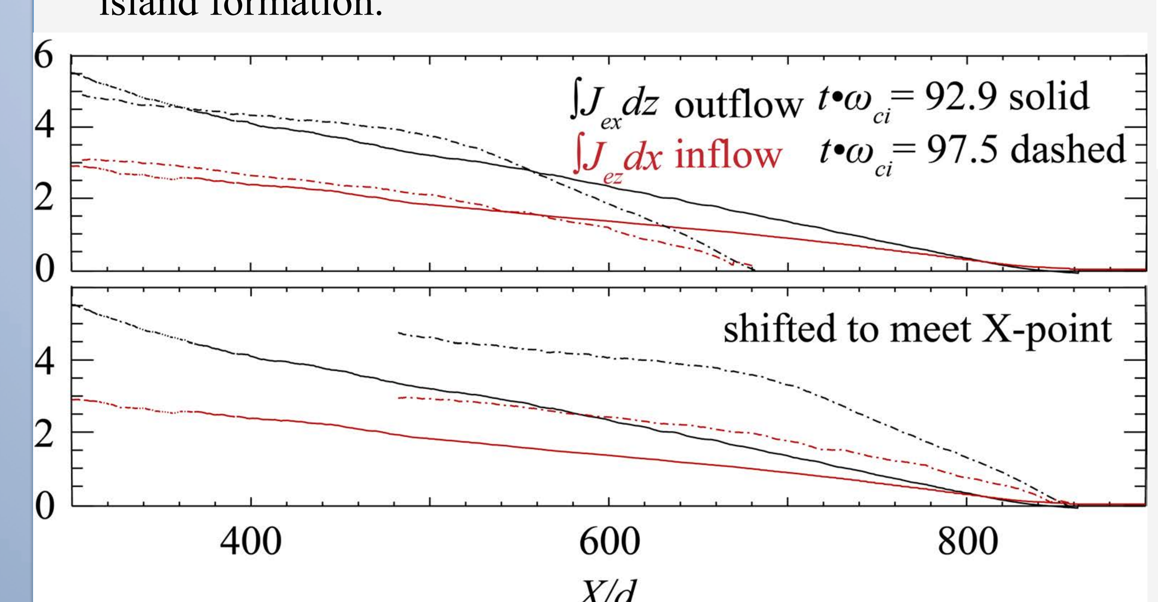
Hall electric field (E_z) decreases at diffusion region and increases in island

EVOLUTION OF E_R, FLOW AND OPENING ANGLE

- The reconnection rate and separatrix opening angle doubled while the peak strength of electron outflow decreases right after island formation.

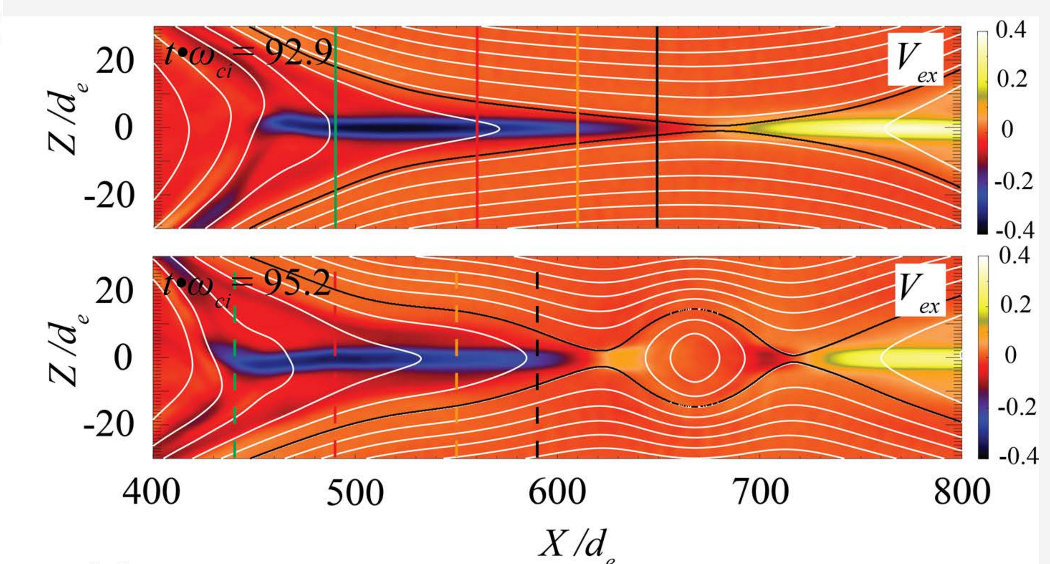


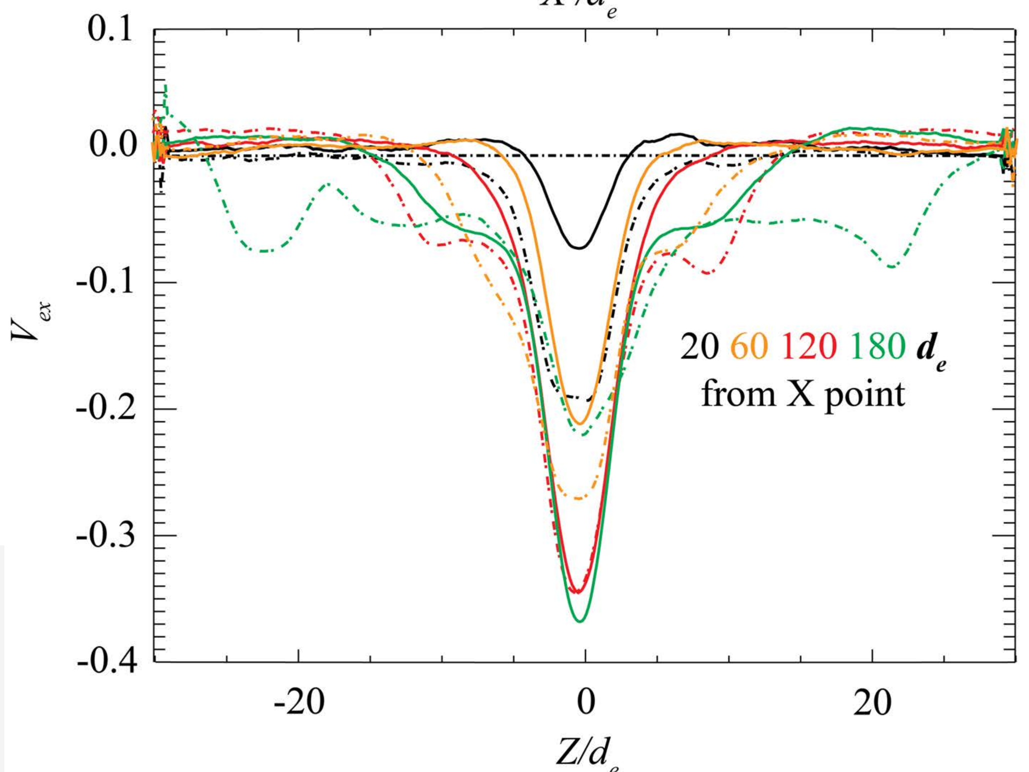
- Integrated inflow and outflow electron fluxes increase after island formation.

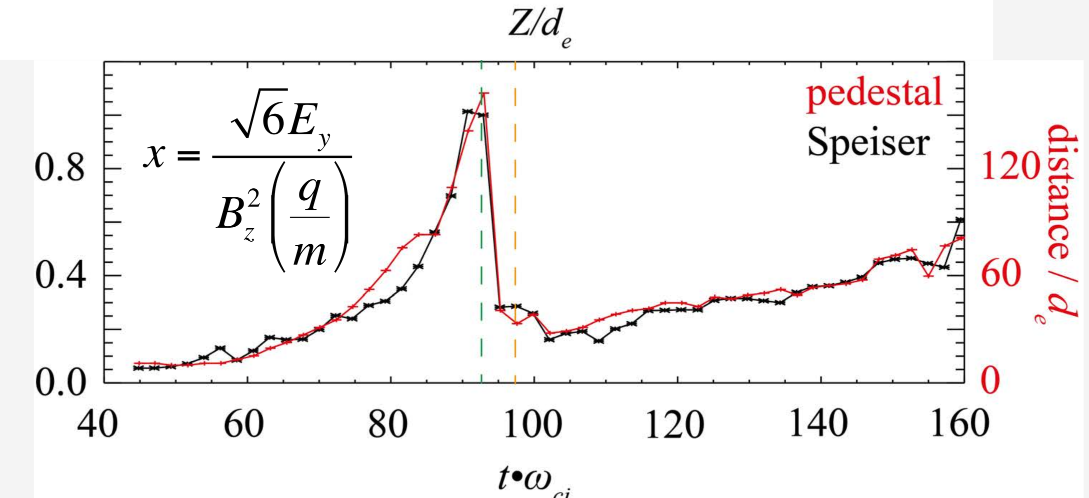


EMERGENCE OF PEDESTAL REGION

- Right after island formation, the shortest distance from pedestal region to the X-point decreases from 170 d_e to 55 d_e.
- The shortest distance between the pedestal region and the X-point has a similar profile with Speiser's ejection equation.

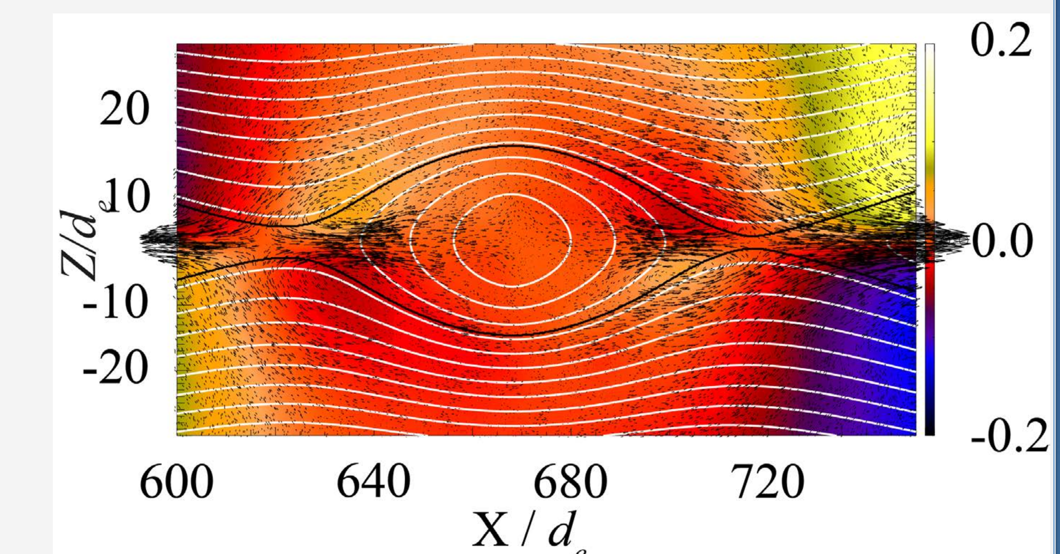


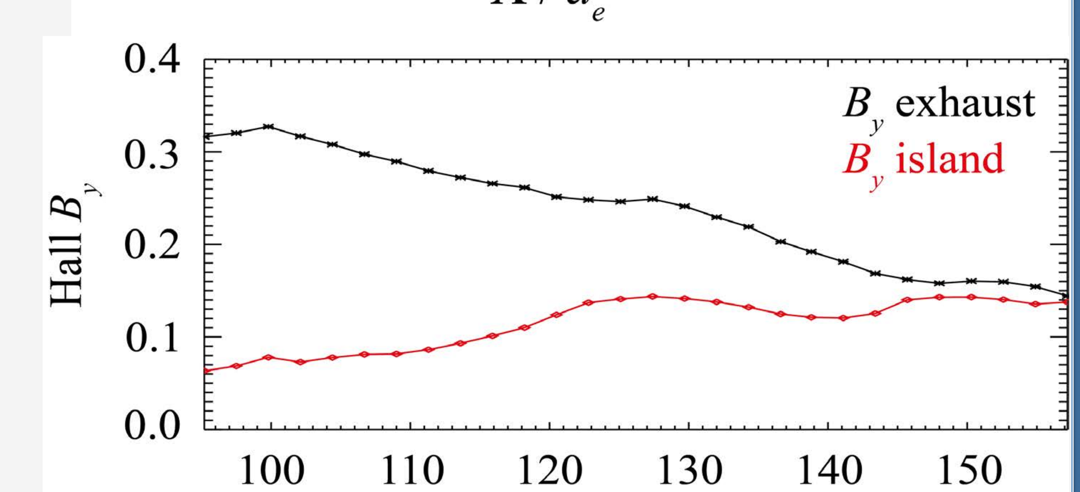




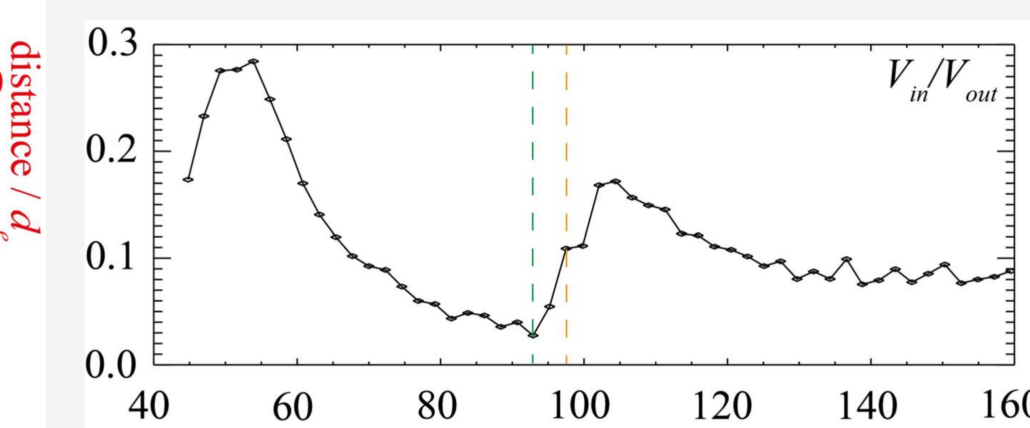
HALL MAGNETIC FIELD AND ELECTRON FLOW

- Electron flow in the newborn island produces a Hall magnetic field.
- The strength of the new Hall field increases as time advances.





- The ratio of the peak electron inflow and outflow amplitudes (V_{in}/V_{out}) does not well represent the reconnection rate.



SUMMARY AND CONCLUSION

- With the birth of secondary island, the plasma flow and field changed dramatically. The reconnection rate and separatrix opening angle doubled.
- The emergence of pedestal region after island formation is much closer to the X-point.
- The shortest distance between the pedestal region and X-point has the same profile with Speiser's ejection equation[5].
- The newborn magnetic island breaks the original electron diffusion region into two pieces, and reforms the electron flow pattern in the new diffusion regions, producing a new Hall magnetic field inside of magnetic island.

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