Structure of a Reconnection Layer Poleward of the Cusp under Extreme Density Asymmetry

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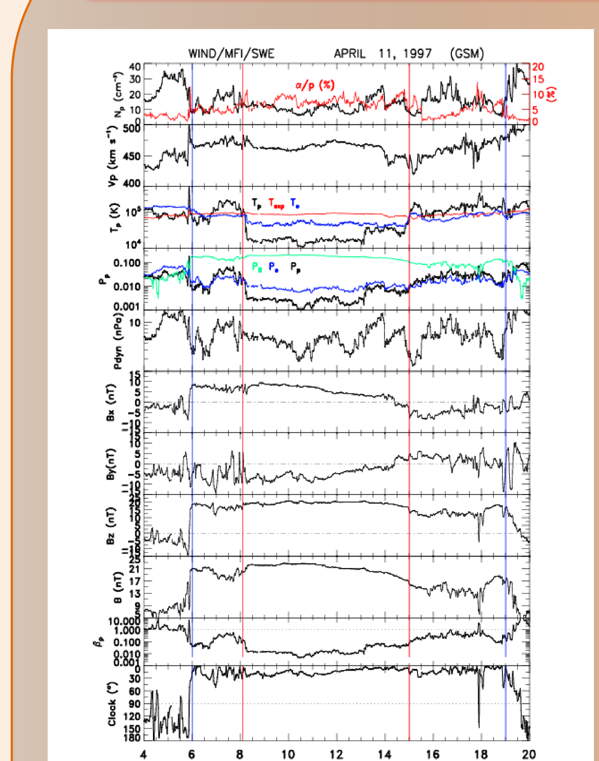
Outline

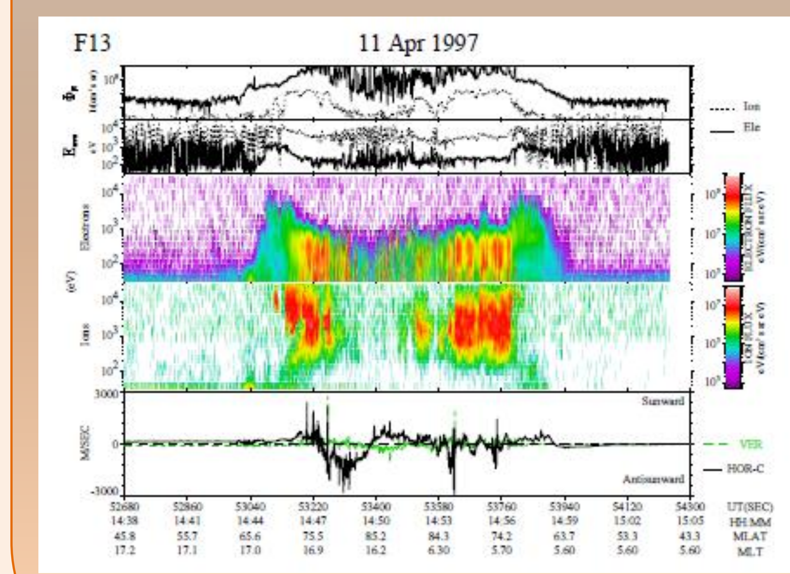
- In situ observations by Polar of a reconnection layer poleward of the northern cusp
- Interplanetary conditions by Wind: ICME with a strongly northward magnetic field lasting for ~13 hrs
- Evidence of continuous reconnection through ionospheric imprints from DMSP data
- Polar recorded an event with extreme density asymmetry (>2 orders of magnitude)
- We examine this crossing in detail
- Compared with 2D simulations with emphasis on density asymmetry and no guide field [Tanaka et al. Ann. Geophys. 26, 2008] and simulations with density and asymmetry and a guide field [Pritchett and Mozer, 2008] separately
- Several features are in good agreement

Interplanetary Observations: Wind



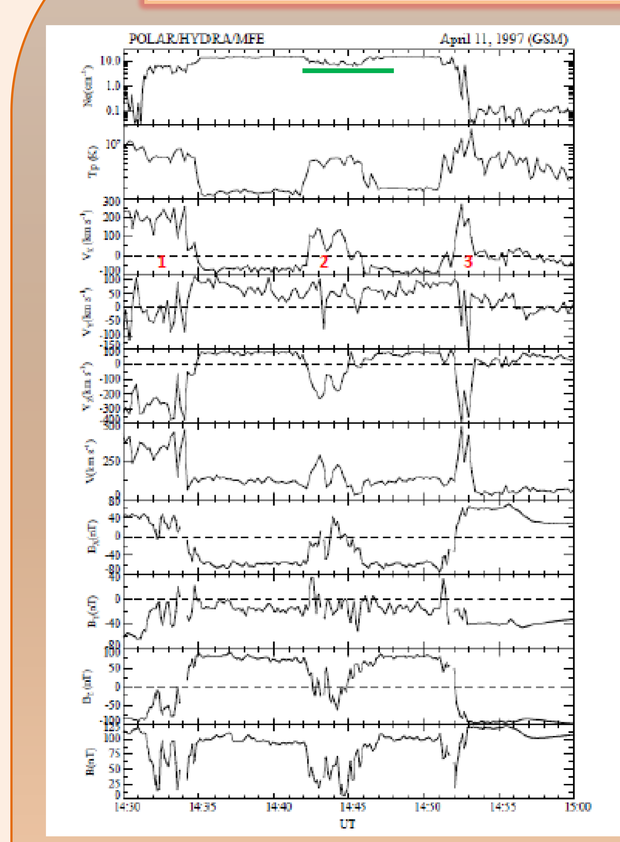
- Case of strong (20 nT), steady and strongly northward (average clock angle 20°) IMF for 13 hrs, 6-19 UT.
- High and variable dynamic pressure Pdyn
- Magnetic cloud embedded in an ICME
- Convection delay time ~53 mins

Direct Evidence of Continued Reconnection: DMSP



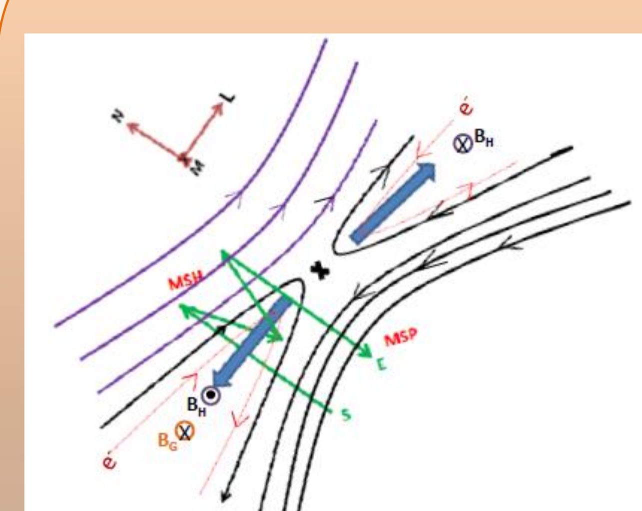
- DMSP F13: ***continuous*** reverse convection (snapshot fashion) from 8-20 UT in the NH [*Maezawa*, 1976; *Crooker*, 1992]
- "Mature" reconnection layer.

Overview of Multiple Crossings: Polar



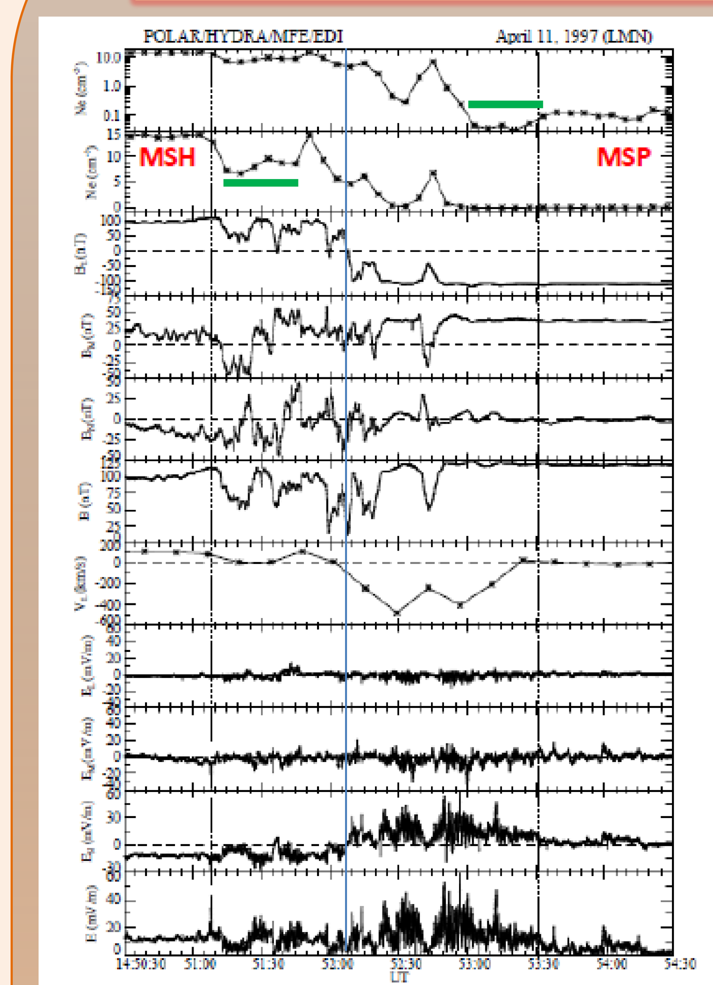
- Polar was at duskside high latitudes, poleward of the cusp
- 1 outbound and 1 inbound crossing
- 3 sunward and southward flowing jets (red labels 1-3)
- Partial entries from the MSH to the MP boundary layer in the interval (green bar)
- Polar is traversing the DR earthward of the X-line

Data from the Magnetic Field Experiment (MFE) [*Russell et al.*, 1995], proton and electron data from the HYDRA instrument [*Scudder et al.*, 1995], and the densities derived the spacecraft potential [*Harvey et al.*, 1995].



- A cartoon to qualitatively interpret the in situ observations
- The trajectory is marked by green arrows, start and end by S and E
- MSH field lines: purple
- MSP field lines: black
- Reconnection jets: thick blue arrows
- Electron flow: dotted red line

Event with Extreme Density Asymmetry



- Cross product, LMN coordinates [Russell and Elphic, 1978]
- Used **E·B=0** to get 3 components of E

N= (0.840, -0.021, 0.541)
L= (-0.541, 0.013, 0.841)
M= (-0.025, -0.999, 0)

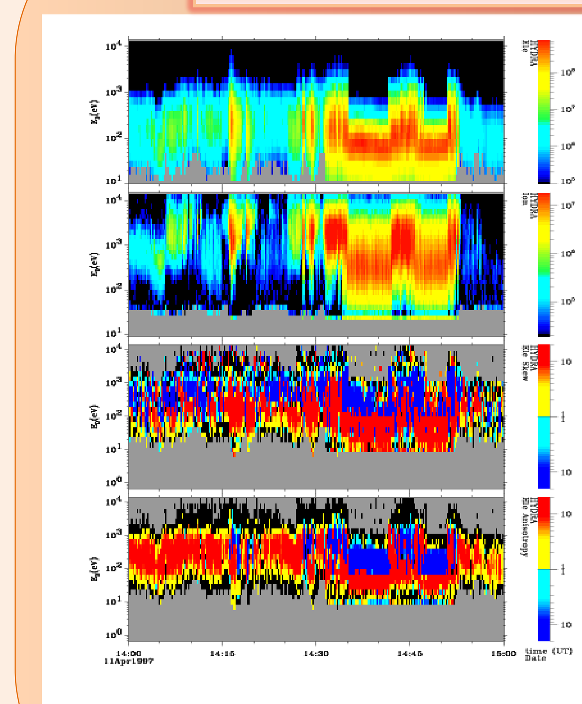
N_{MSH}/N_{MSP} ~ 140

- Complete crossing, B_L reversal: blue line
- Separatrices (prominent density dips) on both sides of the CS: green bars
- Sunward and southward pointing ion jet of 550km/s (biased strongly towards MSP side)
- All components of the E field are larger on the MSP side.
  - E field activity is mostly in E_N
  - E_N peaks at 60 mV/m, during the strong density gradient.
  - E_N points towards the center of the MP (Hall effect)
  - Isolated E_N enhancements on MSH and MSP separatrices
- Out-of-plane B_M is mainly positive on both sides of the CS
  - Unipolar Hall B field (B_M)
  - Except at MSH separatrix where B_M takes (-) values (~13 s)
- Density gradient is not colocated with the B_L reversal

Comparison to Simulation

- Compared with 2D PIC simulations with asymmetry in density and no guide field [*Tanaka et al.*, 2008]
  - Found good agreement
- From ambient MSH and MSP B field values: average guide field B_G ~30nT (25% of the total B field)
- Compared B and E field signatures with 2D PIC simulations with asymmetry in density and a guide field [*Pritchett and Mozer*, 2009]; compared with their Figures 3 and 5
  - Guide field weakens the out-of-plane Hall B field

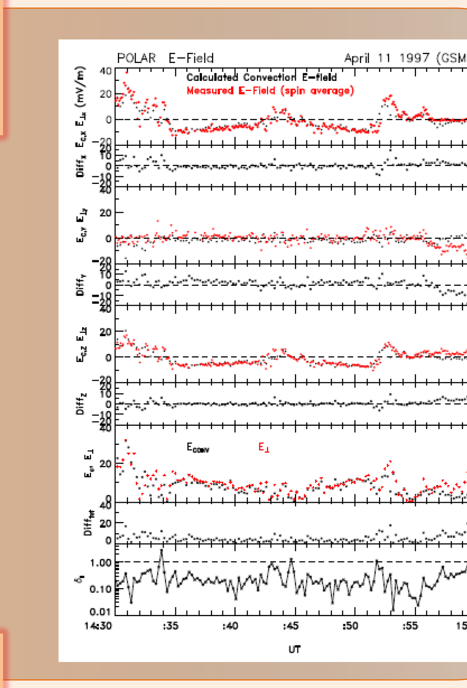
Electron Behavior: HYDRA



- At the MSH separatrix: electrons flow opposed and parallel to **B**, towards the X-line
- At the MSP separatrix: electrons flow aligned and parallel to **B**, away from the X-line.
- Electron behavior matches well with expected Hall B field

Identification of the IDR

Scudder et al.,'s [2008], Adiabatic Expansion Parameter δi, identifies the ion diffusion well.



Conclusions

- High latitude reconnection site poleward of the cusp
- Case of strong, steady and strongly NW IMF for 13 hrs
- Reverse convection lasted for 12 hours → continuous reconnection.
- Analyzed one event with extreme density asymmetry
- Good agreement with expected plasma, E and B features under asymmetric reconnection
- Comparison with simulations showed clear evidence that the guide field has distorted the expected Hall B field even within the large density asymmetry
- Stagnation point and X-line is not collocated [*Cassak and Shay*, 2007]

Acknowledgements

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