Cusp Structures and Magnetic Reconnection at the Magnetopause

JACQUELINE JENSEN

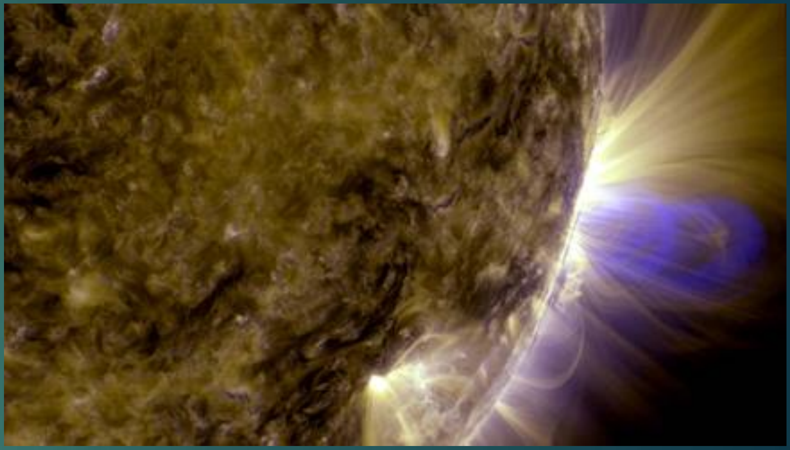
UNIVERSITY OF CENTRAL FLORIDA

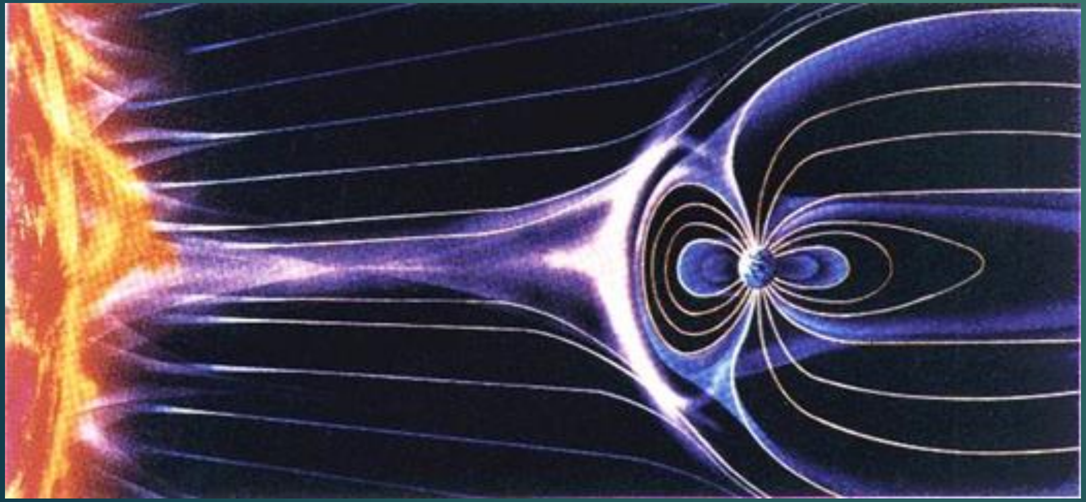
LASP BOULDER, CO

MENTOR: KARLHEINZ TRATTNER

Why Study Magnetic Reconnection?

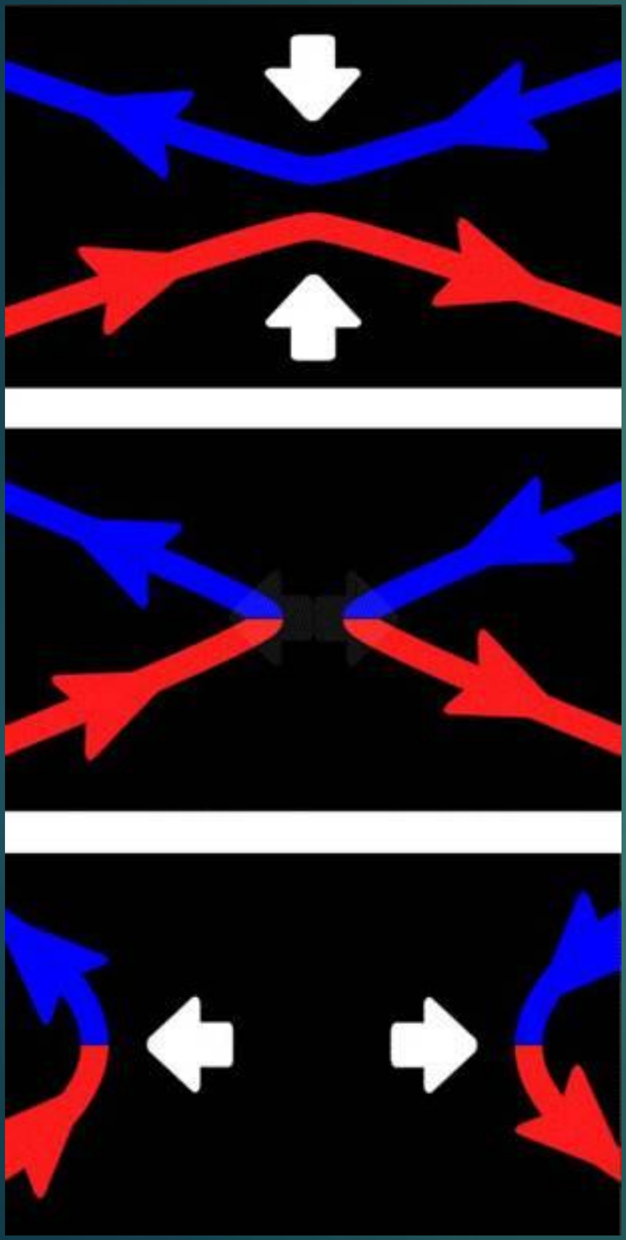
- Fundamental process
- Sun: Solar Flares, CMEs, Flare Loops
- Earth: Plasma Entry, Auroras, Magnetic storms

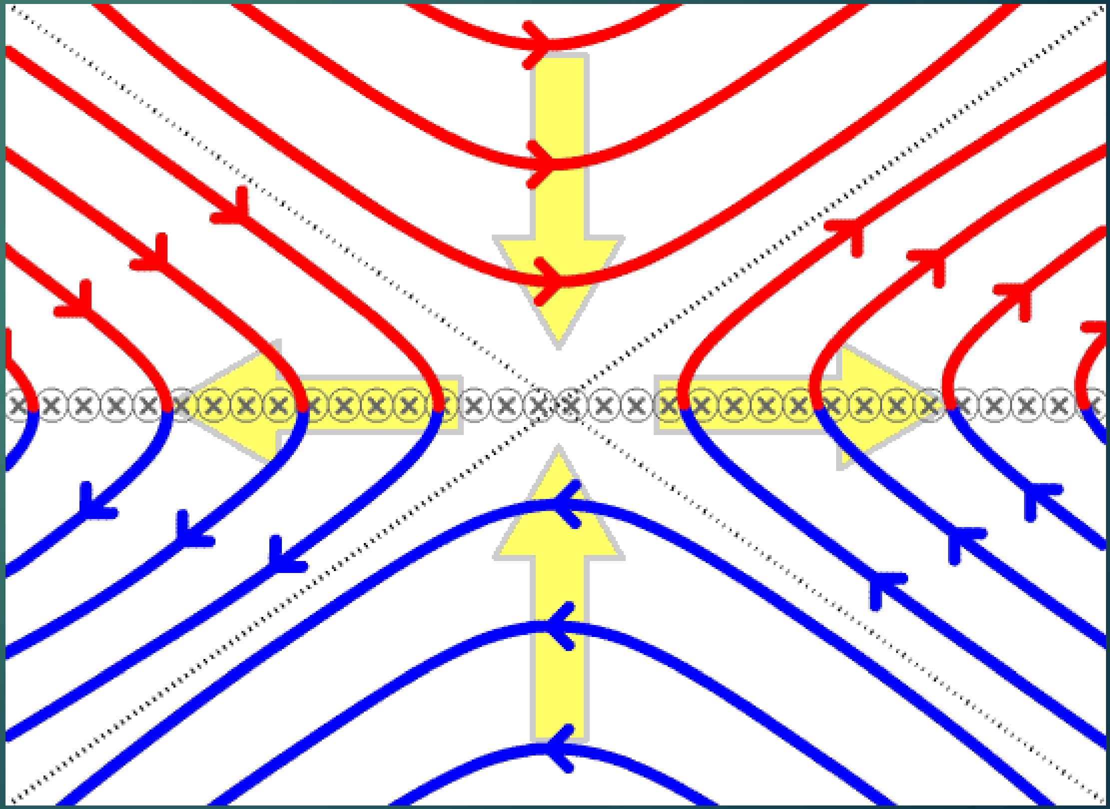




Ultimate Goal: Observe magnetic reconnection in situ through predictions of reconnection site in model

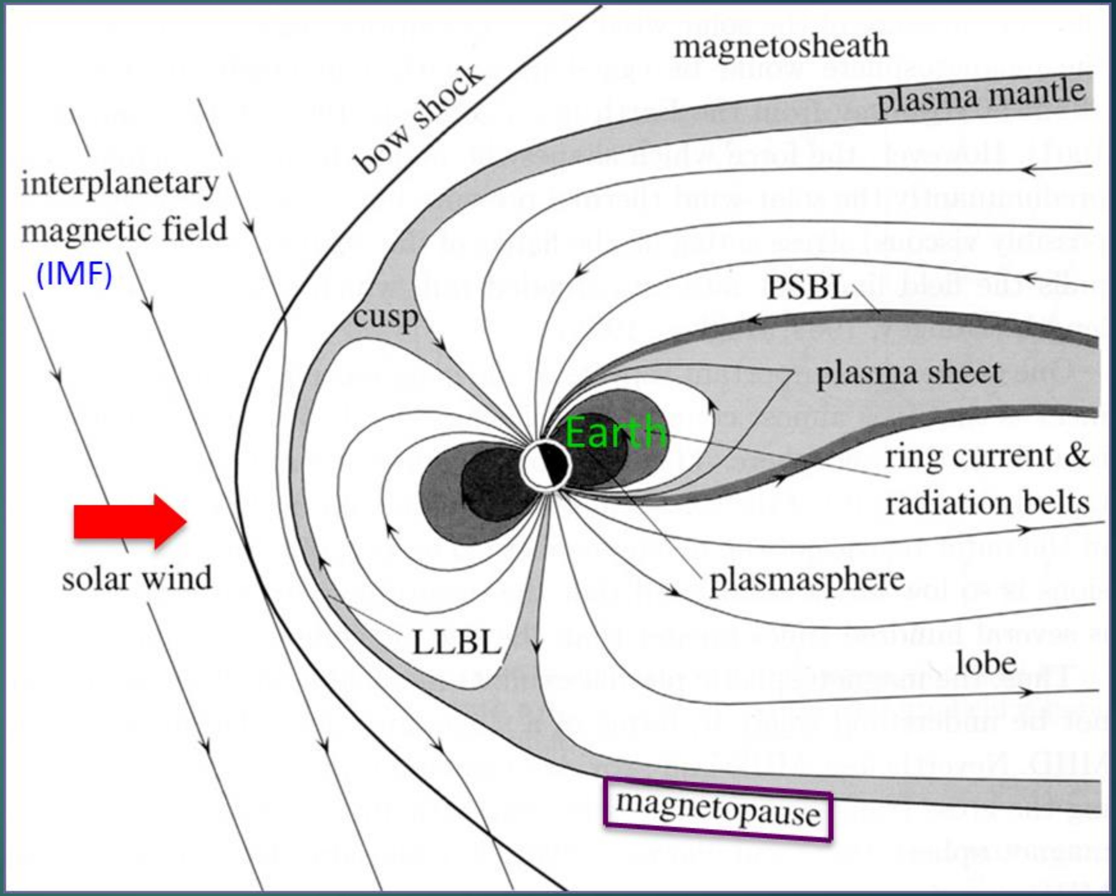
Magnetic Reconnection



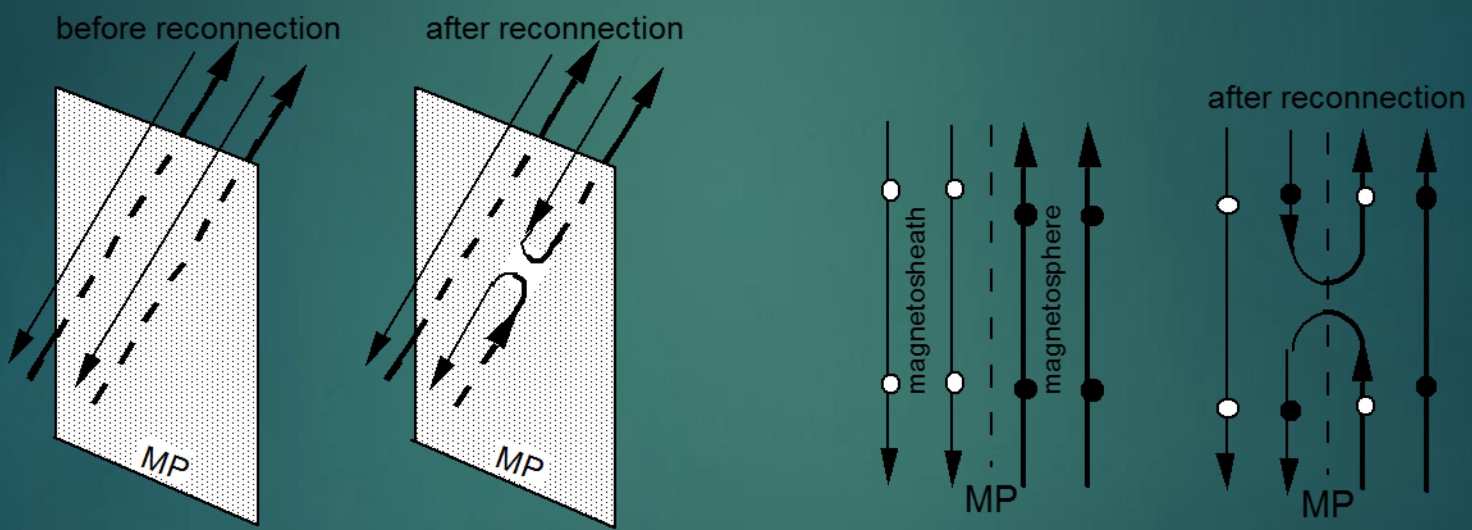


The Magnetosphere

- **Solar wind:** made up of plasma particles. Field distortion caused by pressure
- **Bow shock:** shock wave before Earth's magnetic field
- **Magnetosheath:** region of higher density shocked plasma
- **Magnetopause**: Boundary between the solar wind and Earth's magnetic field
- **Cusp region:** region with open field lines and direct solar wind access to upper atmosphere

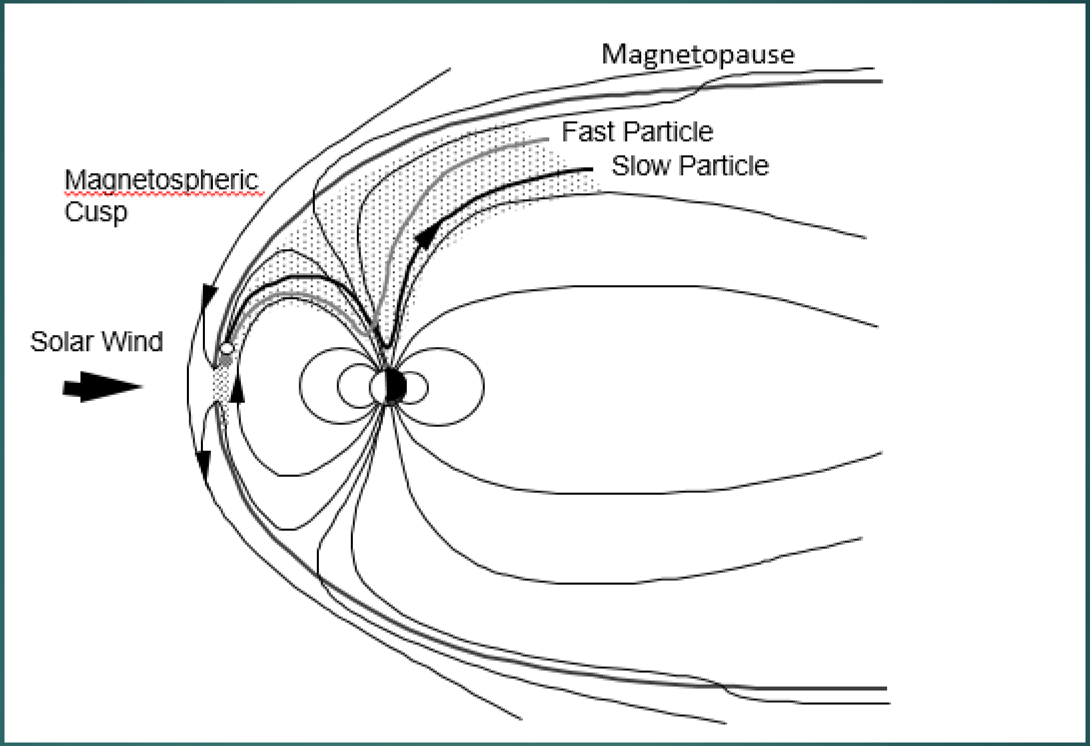


Reconnection at the Magnetopause



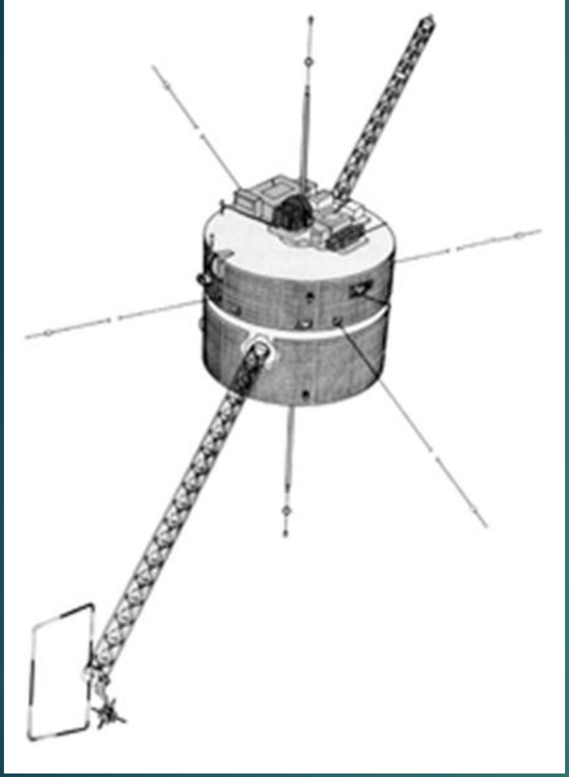
Two magnetized plasmas separated by a current sheet:
Magnetic reconnection allows plasma transfer across the current sheet

Plasma Entry

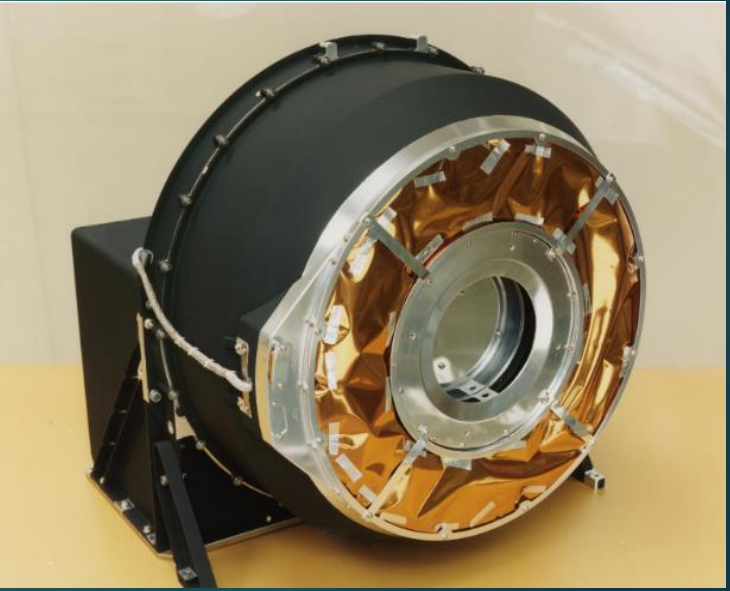


Precipitating cusp ions experience a velocity filter effect with lower energies
convecting further poleward

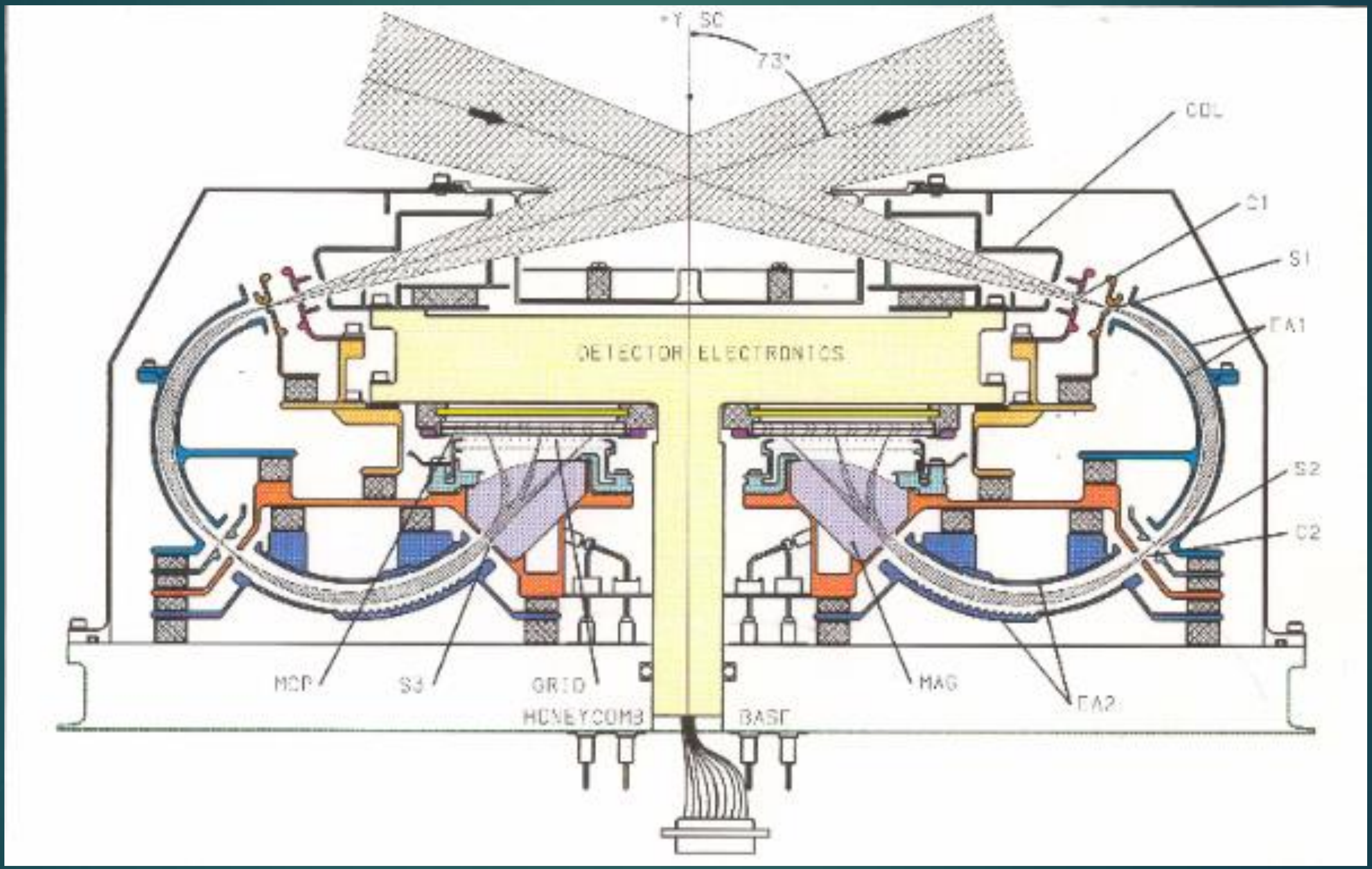
Instrument Overview



- Polar's TIMAS Instrument
- Mass spectrometer
- Collects data on He^+, He^{++}, O^+, and H^+
- Focused on H^+ data
- Measures 3D velocity distributions

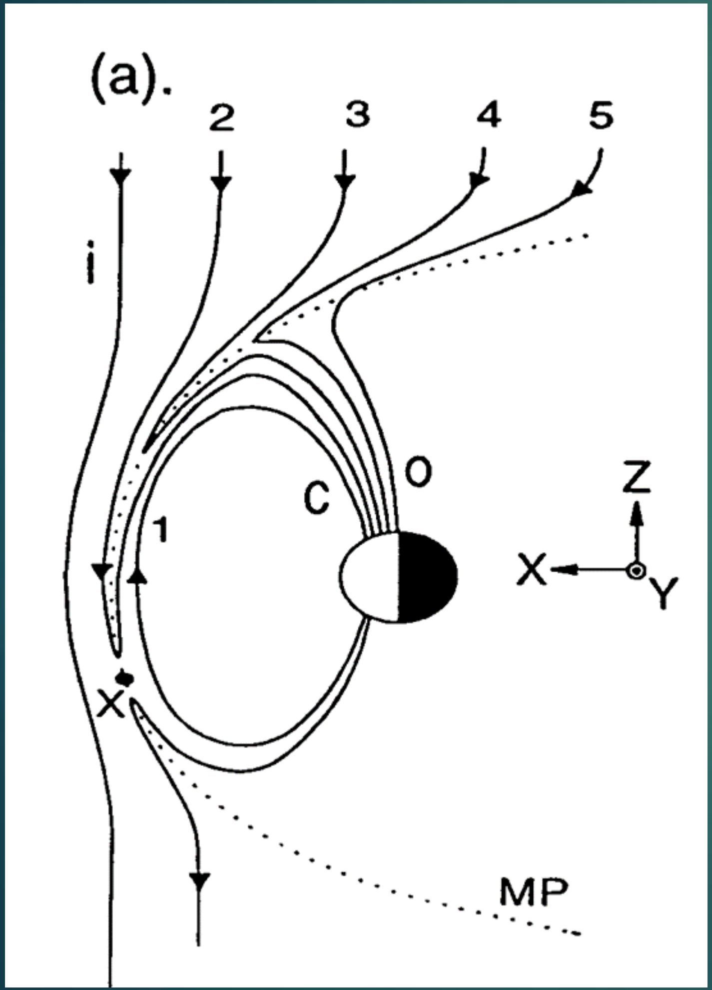


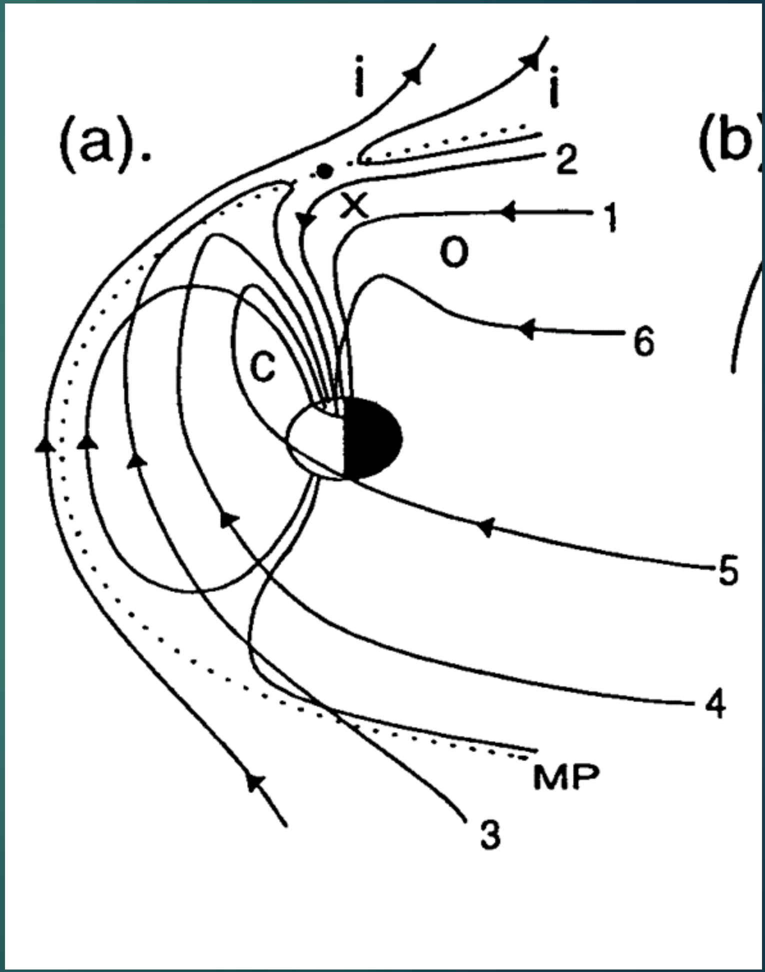
TIMAS Schematic



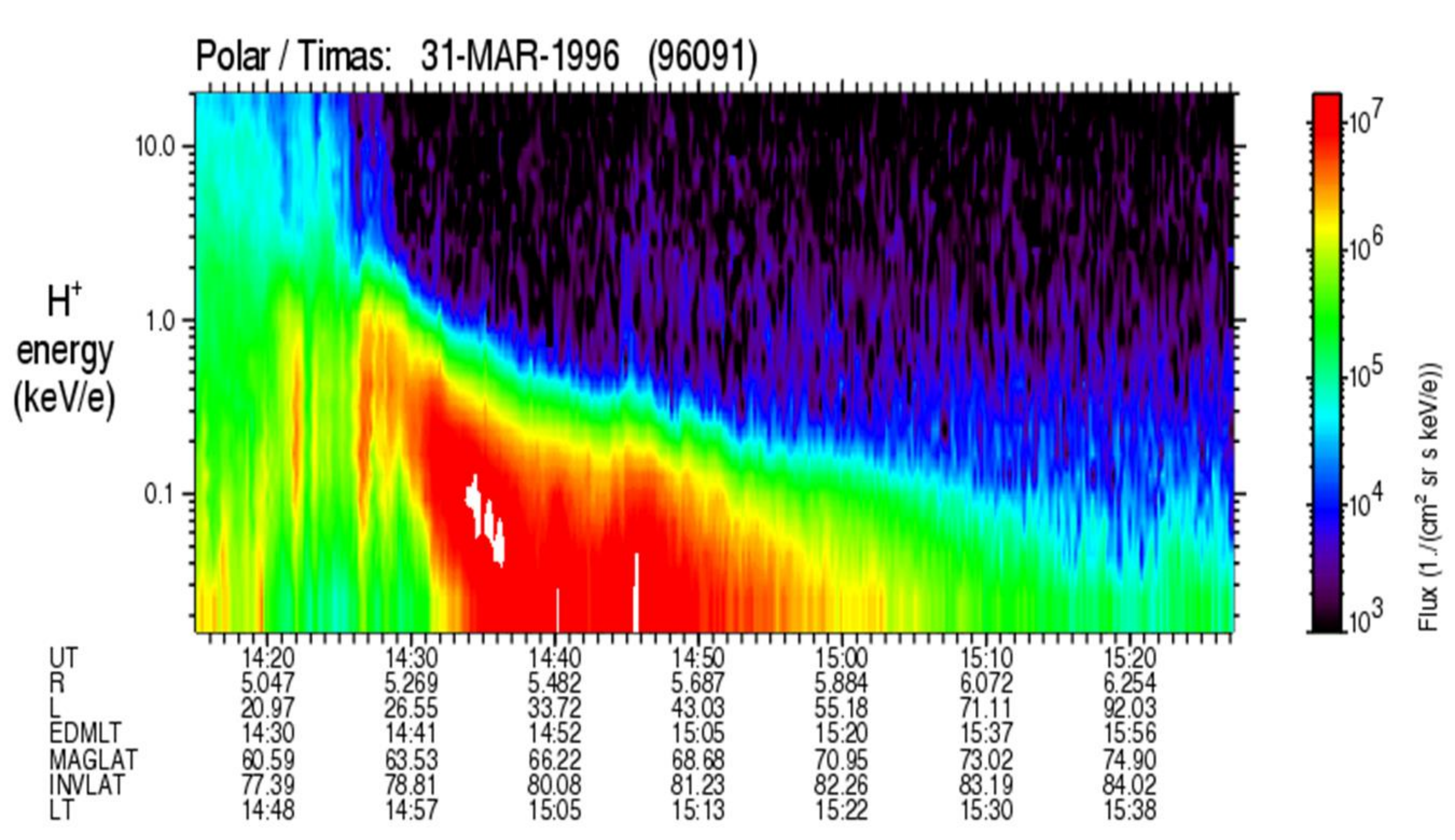
Southward IMF Reconnection

Northward IMF Reconnection

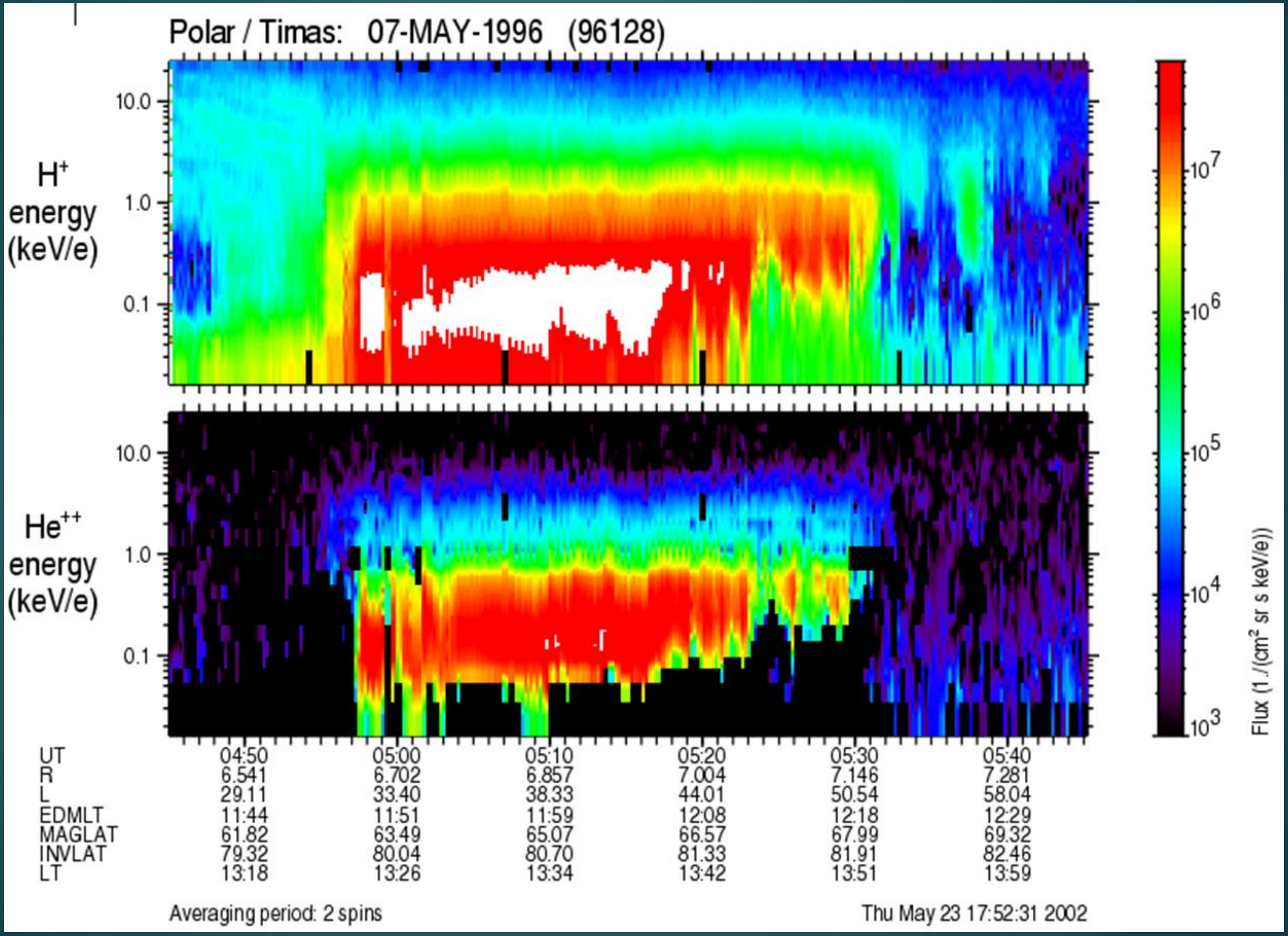




Southward IMF

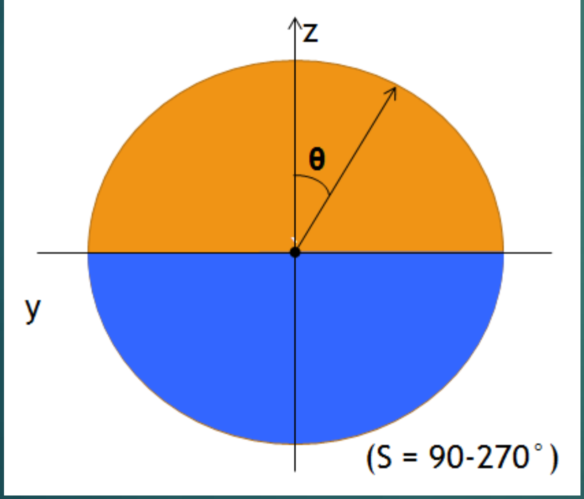


Northward IMF

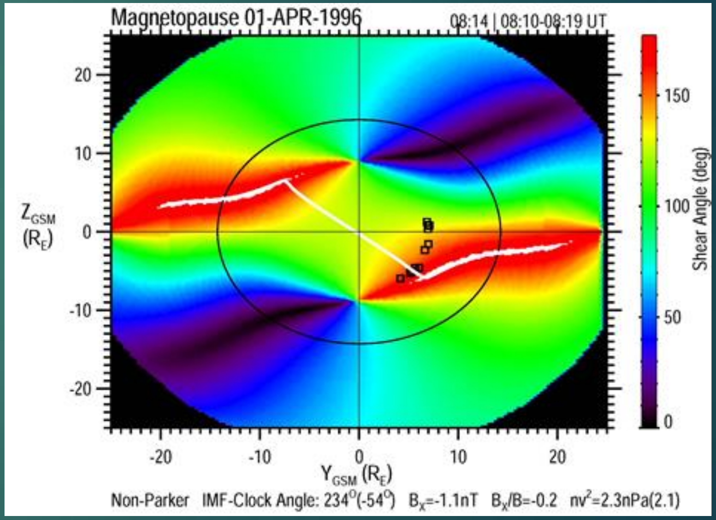


Not Just When, But Where?

- Maximum Magnetic Shear Model
- Predicts where reconnection is most likely to occur
- Correct 80% of the time

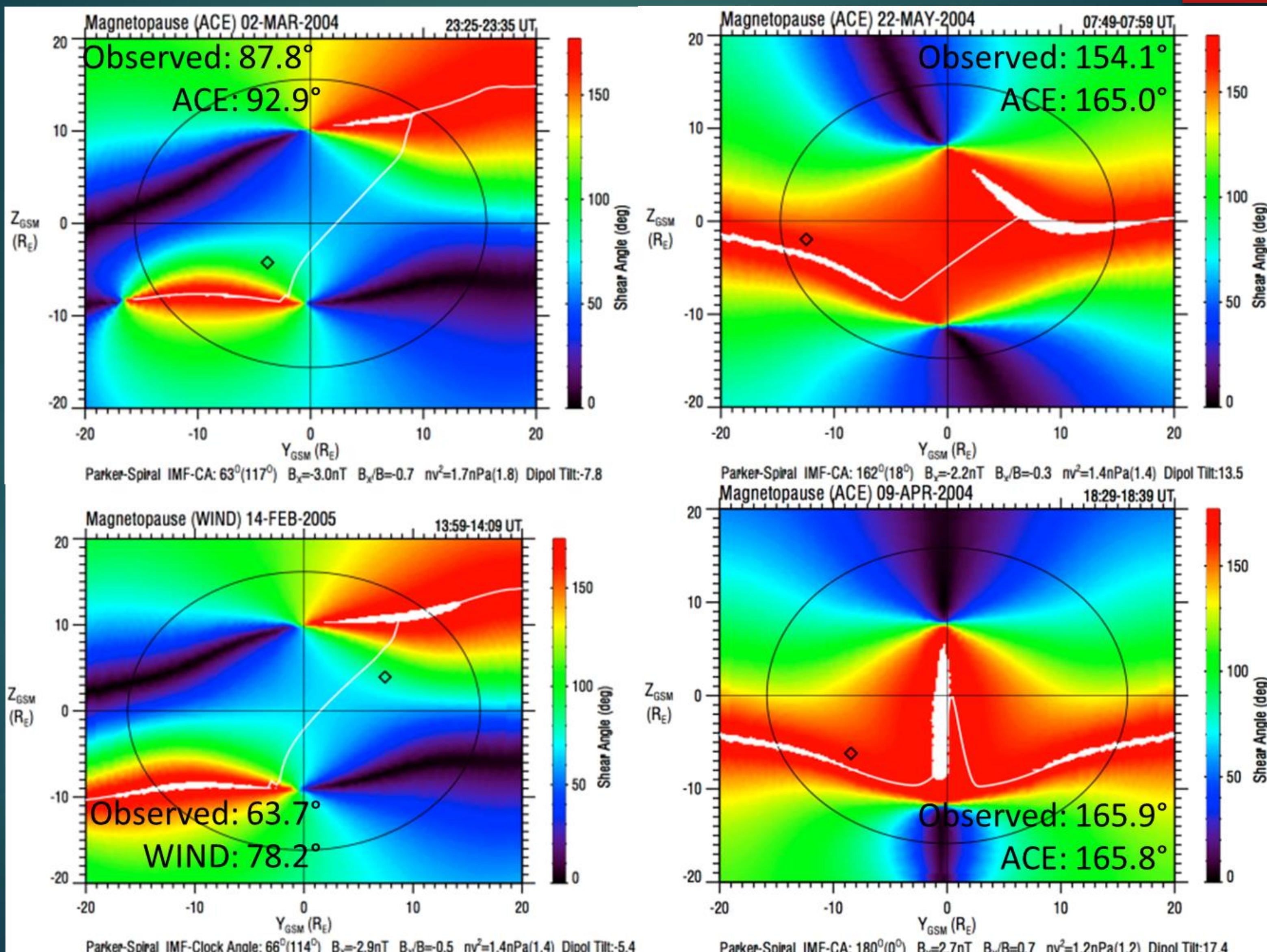


IMF clock angle:
Organizational parameter for plots

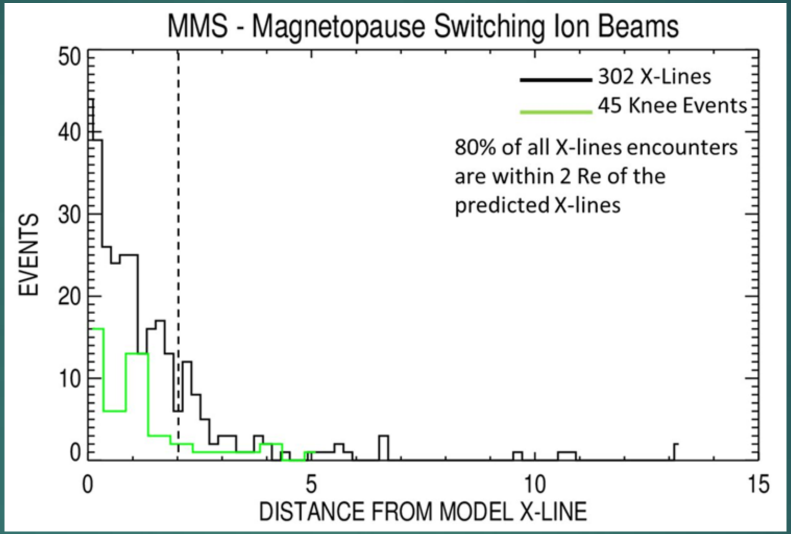


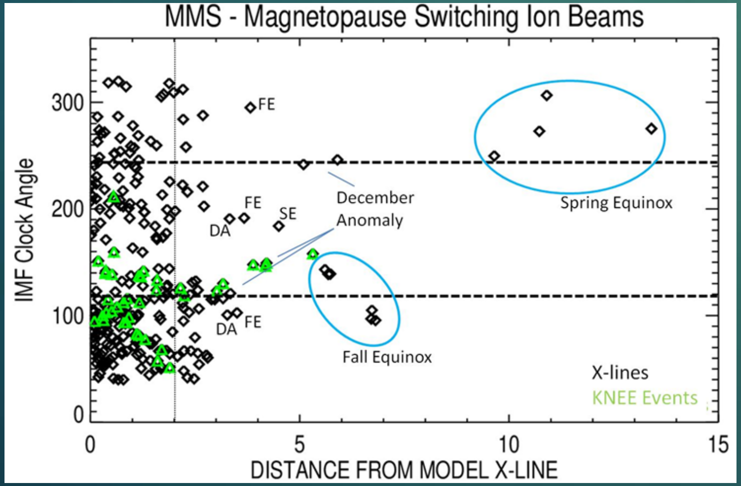
Shear angle plot:
Angle between solar wind magnetic field and earth's magnetic field lines

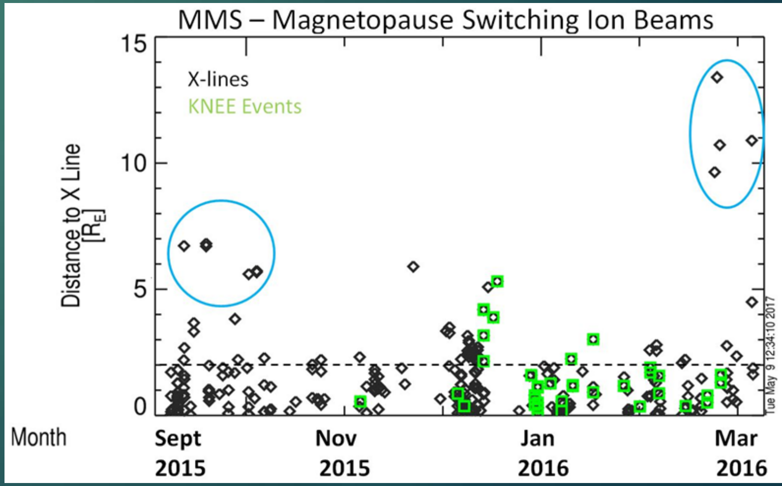
Maximum Magnetic Shear



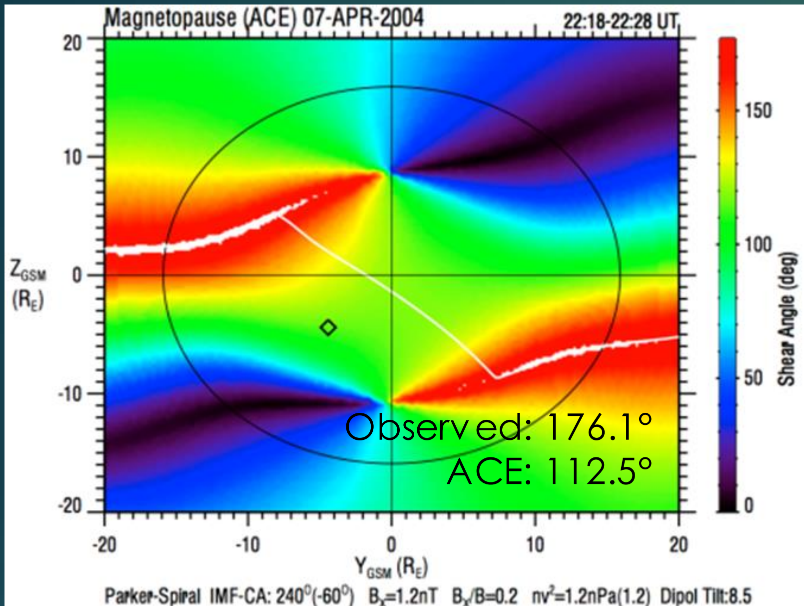
Magnetospheric Multiscale Mission (MMS)

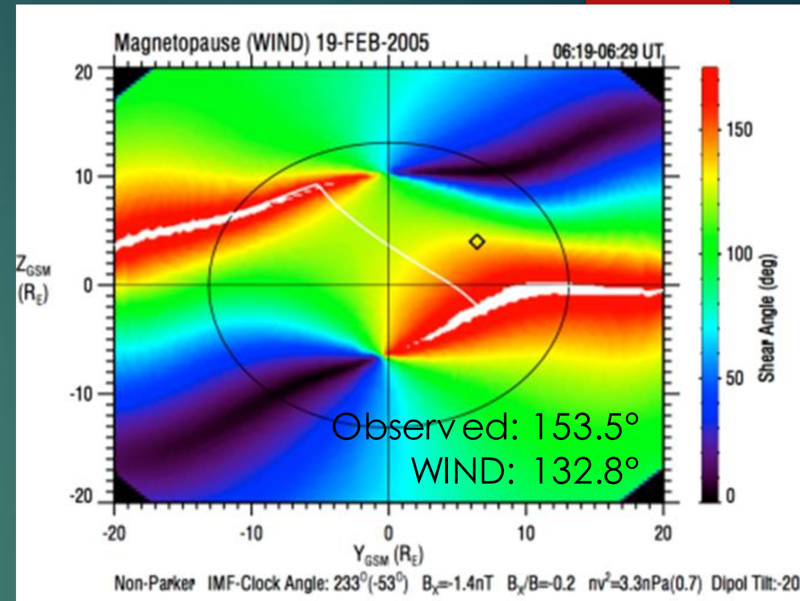


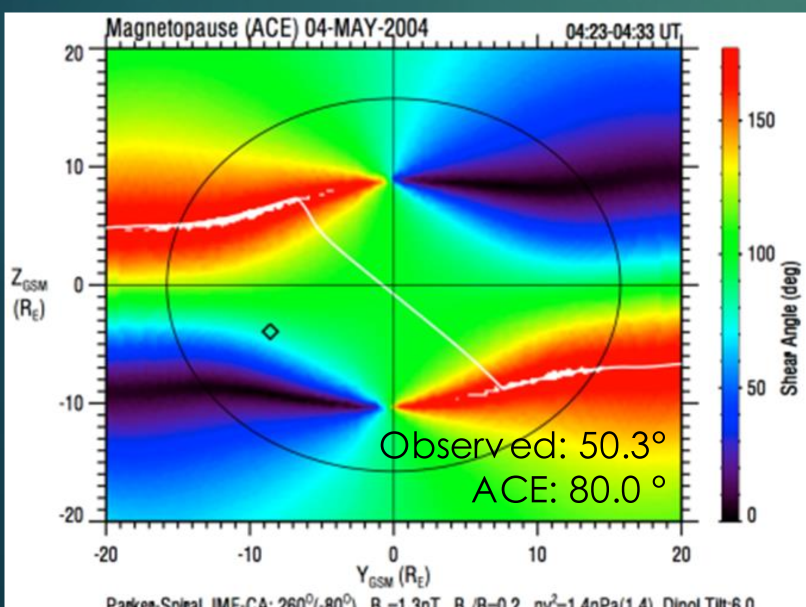


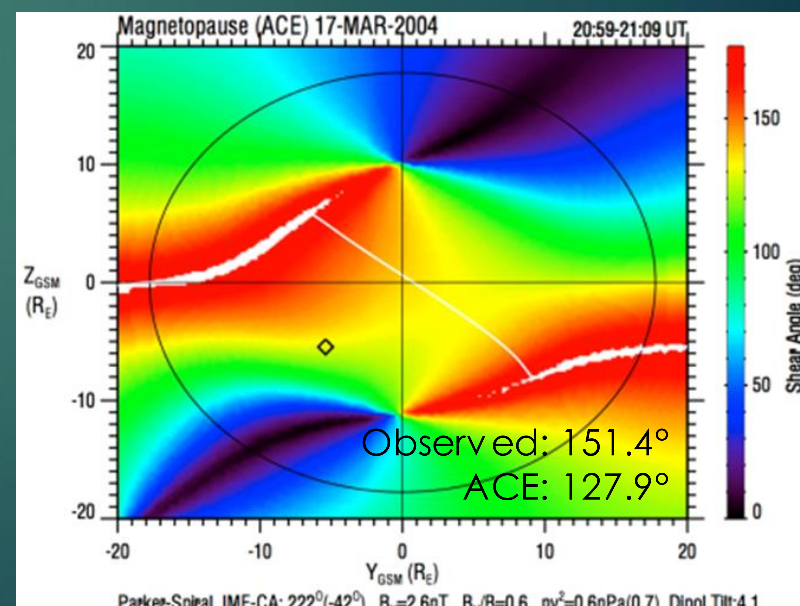


Anomalies

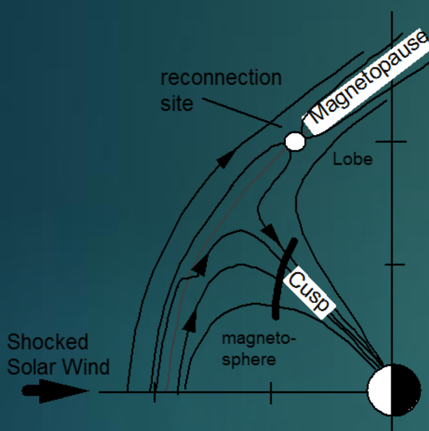

Magnetopause (ACE) 07-APR-2004
22:18-22:28 UT
Observed: 176.1°
ACE: 112.5°
Z_GSM (R_E)
Y_GSM (R_E)
Shear Angle (deg)
Parker-Spiral IMF-CA: 240°(-60°) B_x=1.2nT B_x/B=0.2 nv²=1.2nPa(1.2) Dipol Tilt:8.5

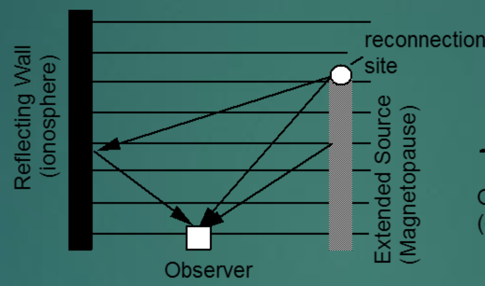

Magnetopause (WIND) 19-FEB-2005
06:19-06:29 UT
Observed: 153.5°
WIND: 132.8°
Z_GSM (R_E)
Y_GSM (R_E)
Shear Angle (deg)
Non-Parker IMF-Clock Angle: 233°(-53°) B_x=-1.4nT B_x/B=-0.2 nv²=3.3nPa(0.7) Dipol Tilt:-20.8


Magnetopause (ACE) 04-MAY-2004
04:23-04:33 UT
Observed: 50.3°
ACE: 80.0 °
Z_GSM (R_E)
Y_GSM (R_E)
Shear Angle (deg)
Parker-Spiral IMF-CA: 260°(-80°) B_x=1.3nT B_x/B=0.2 nv²=1.4nPa(1.4) Dipol Tilt:6.0

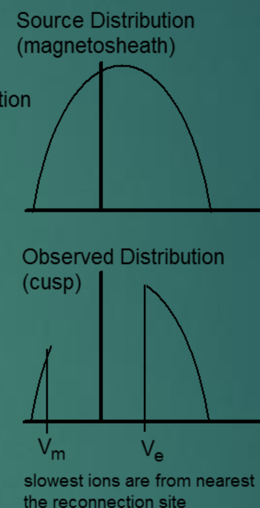

Magnetopause (ACE) 17-MAR-2004
20:59-21:09 UT
Observed: 151.4°
ACE: 127.9°
Z_GSM (R_E)
Y_GSM (R_E)
Shear Angle (deg)
Parker-Spiral IMF-CA: 222°(-42°) B_x=2.6nT B_x/B=0.6 nv²=0.6nPa(0.7) Dipol Tilt:4.1

Modeling the X-Line





$$\frac{X_r}{X_m} = \frac{2V_e}{(V_m - V_e)}$$

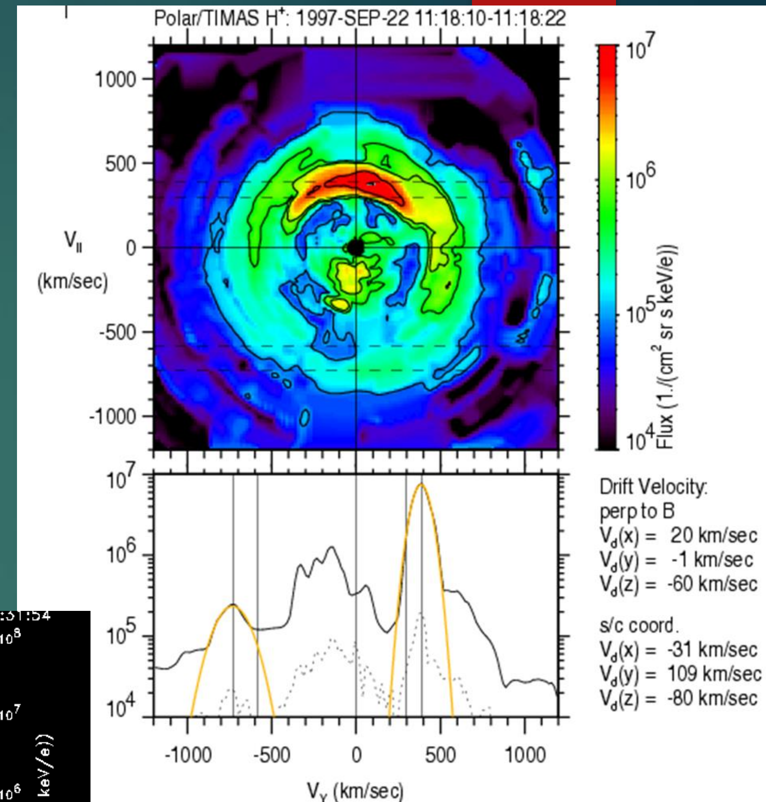


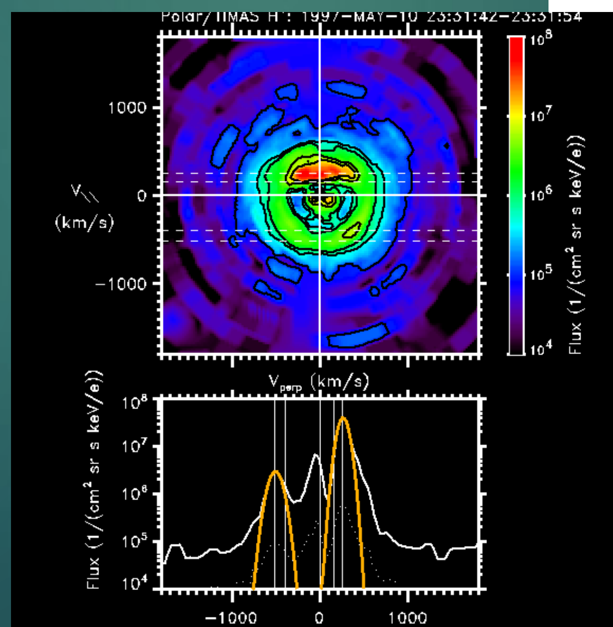
Assumes: "Instantaneous" acceleration
Simple Field Line Structure

- Ions are reflected when they reach the ionosphere
- Xm = Distance to ionospheric mirror point, calculated using Tsyganenko 1996 model (known value)
- Vm = cutoff velocity of mirrored ions
- Ve = cutoff velocity of earthward propagating ions (precipitating)
- Xr = distance to reconnection point (Calculated by program)

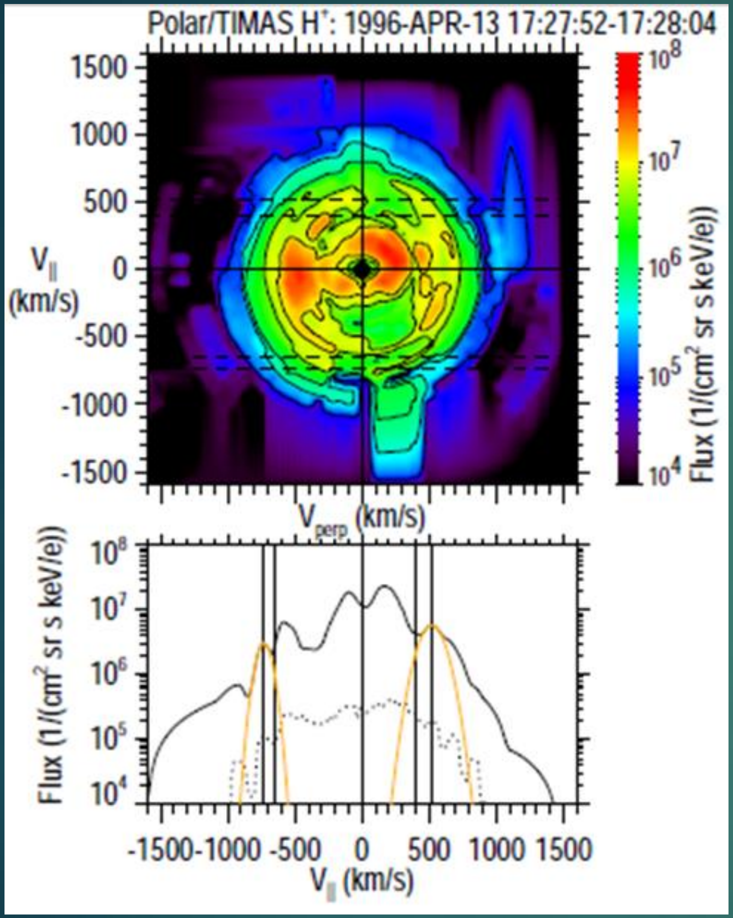
Modeling X-Line Part 2

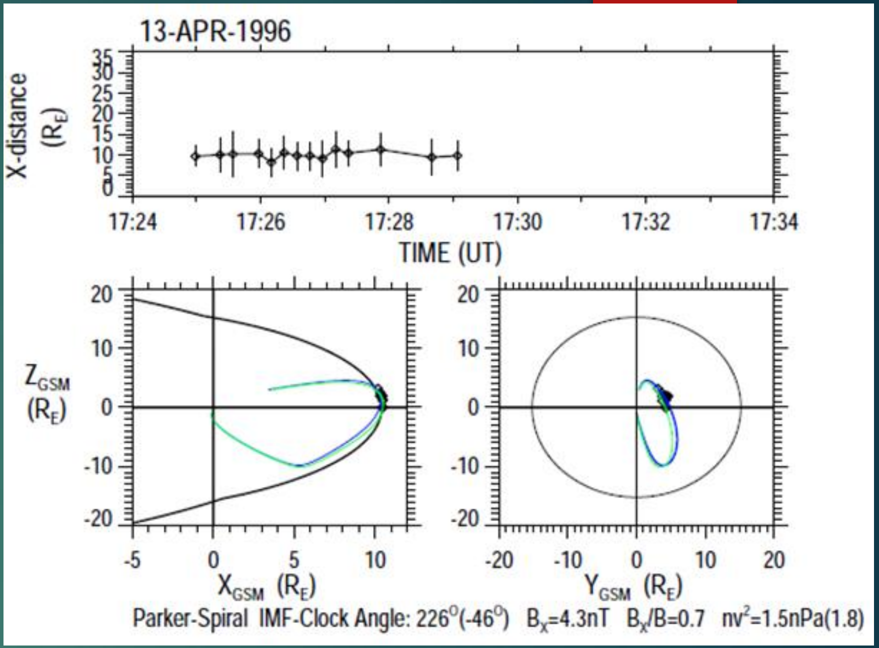
- TIMAS data is presented in a field-aligned coordinate system
- Gaussian distributions are fitted to the peaks
- Cutoff velocities are determined from Gaussian fits

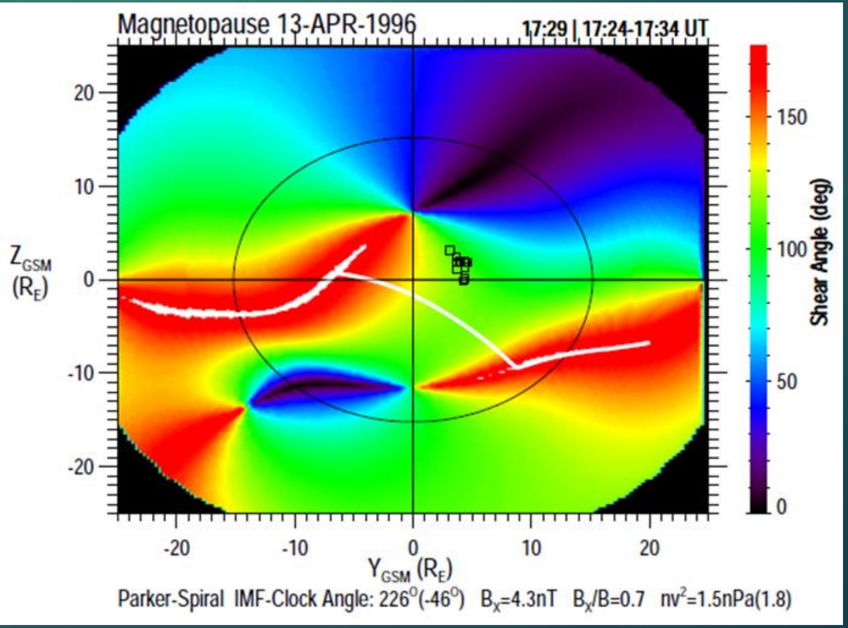




Reconnection X-Line

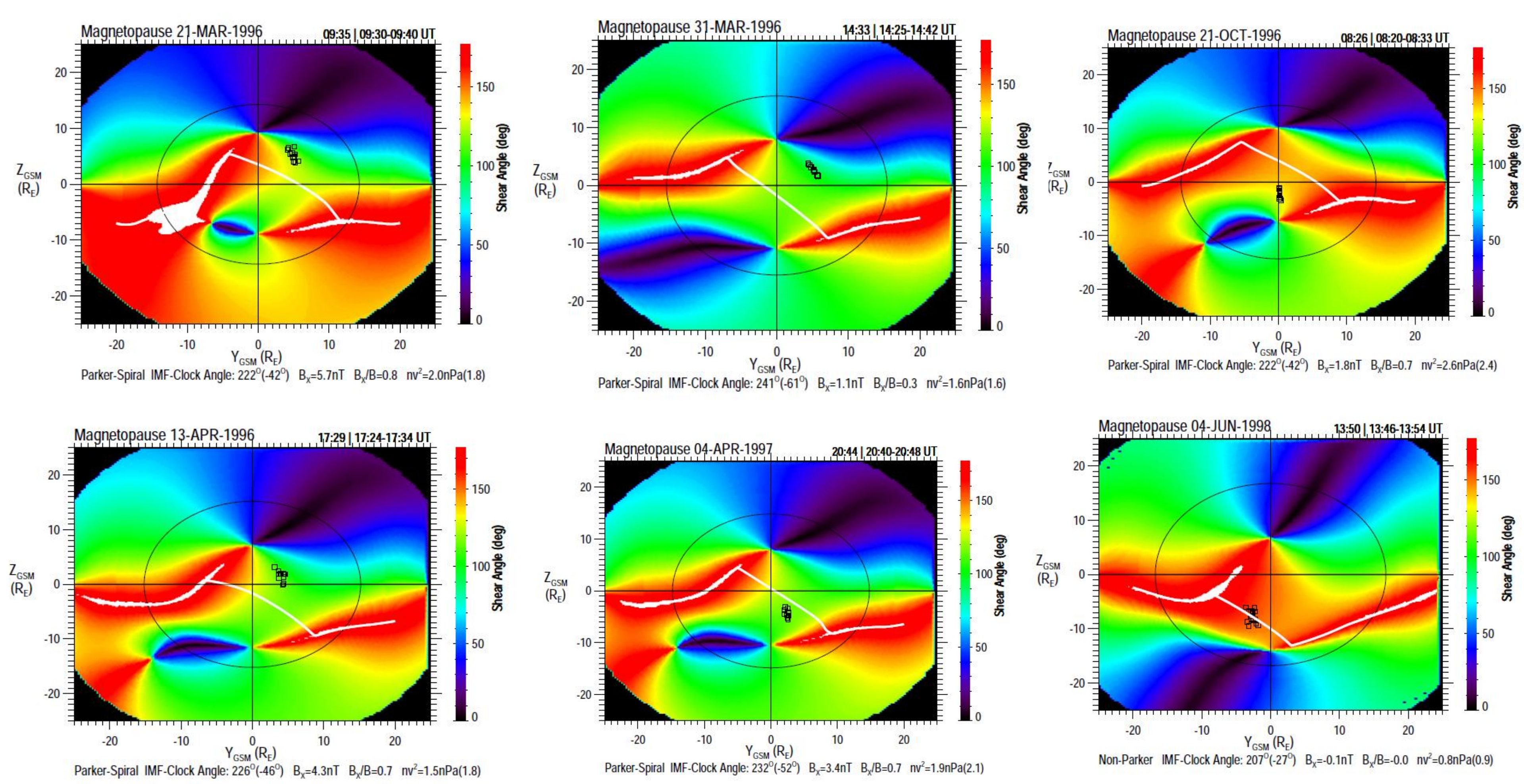






Clock Angle 200-260

- Anomalies arise between 200° and 260°
- Occurs all year but predominately in spring time
- Unknown why anomalies occur within this range



Data and Trends

- 58 events analyzed
- No events in main duration of winter and summer
- Most events occurring in spring

Data and Trends

- 32.8% on target with model
- Predominately above in March
- Even statistics in April
- Predominately below after April
- Statistics for Bx value were even
- Distribution of Clock Angles was even

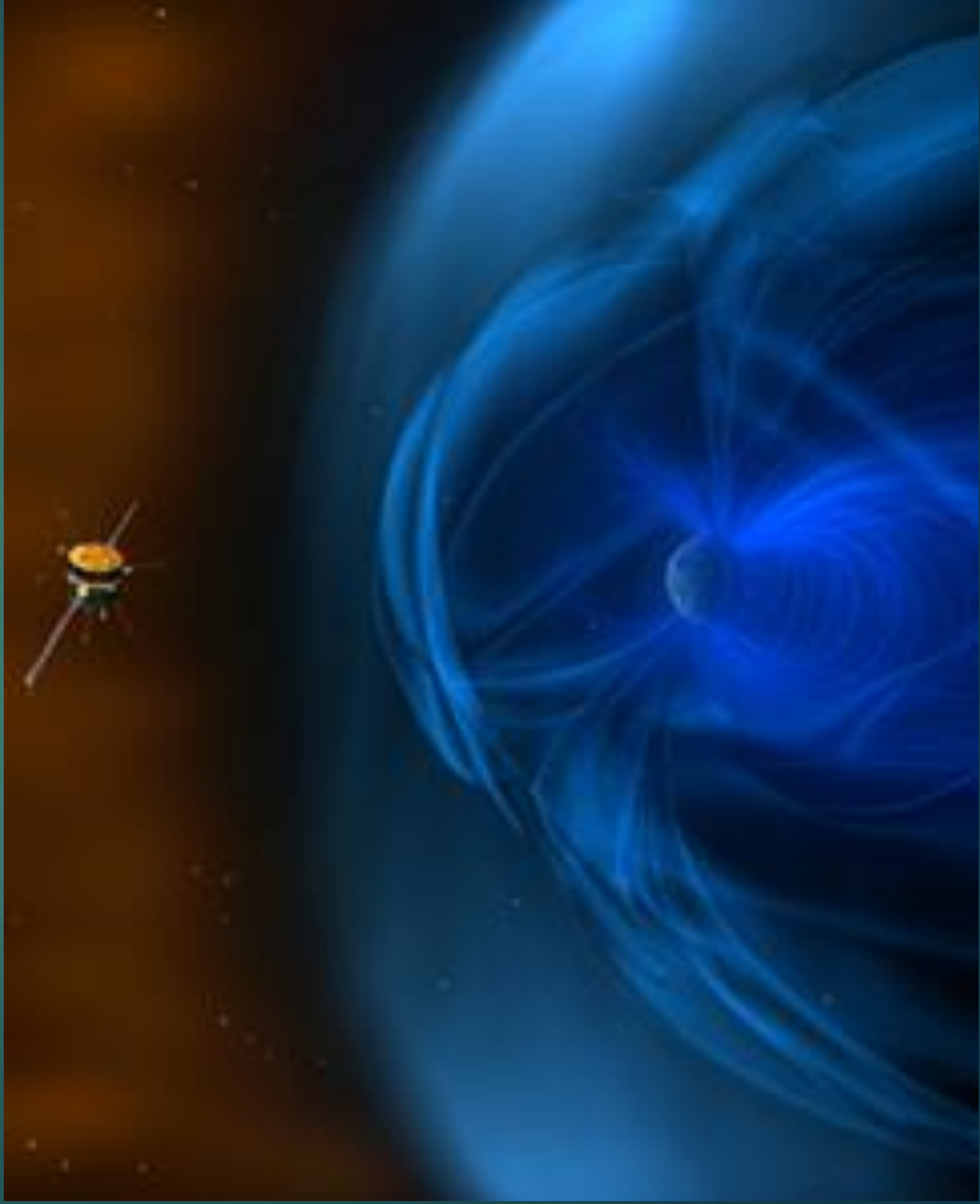
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Events	0	0	14	13	14	5	0	0	3	7	2	0	58
Above	0	0	9	5	0	0	0	0	0	1	0	0	15
Below	0	0	1	3	10	2	0	0	1	5	2	0	24
On Target	0	0	4	5	4	3	0	0	2	1	0	0	19

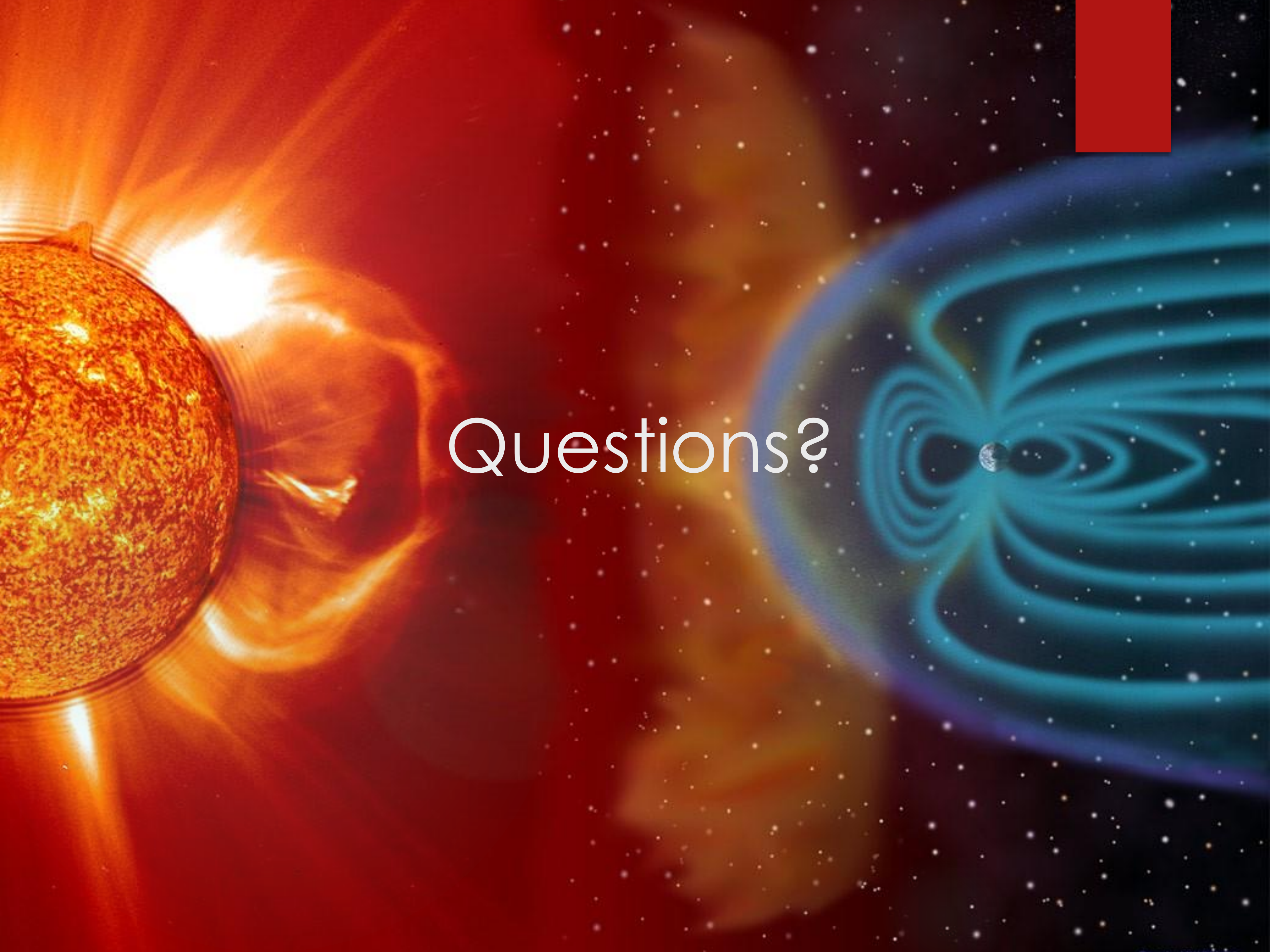
Conclusion

- March events occur predominately above the predicted x-line
- April statistics are about even
- All months after April seem to occur below the predicted x-line
- April seems to be the turning point for this change
- No other parameter yielded any trends

Future Investigation

- Plot more events within this range
- Does the pattern still occur?
- Investigate other Magnetopause parameters
- Alfven Velocity
- Plasma Beta




Questions?

Acknowledgements and References

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All pictures courtesy of NASA. All plots and spectrograms were produced using an IDL program written by Karlheinz Trattner.

1. Trattner, K.J., S. A. Fuselier, and S. M. Petrinec. “Location of the reconnection line for northward interplanetary magnetic field.” *J. Geophys. Res.* 109 (2004)