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

The diagram shows the hourly variations of proton and helium ion fluxes as a function of energy on May 7, 1996. The energy is displayed on a logarithmic scale, ranging from $10^{-7}$ to $10^{7}$ (cm$^2$/s keV/e). The data was collected by the Polar/TimAS instrument. The table below lists the UT, R, L, EDMLT, MAGLAT, INVLAT, and LT values for different hours of the day.
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

- Magnetopause (ACE) 02-MAR-2004
  - Observed: 87.8°
  - ACE: 92.9°

- Magnetopause (ACE) 22-MAY-2004
  - Observed: 154.1°
  - ACE: 165.0°

- Magnetopause (WIND) 14-FEB-2005
  - Observed: 63.7°
  - WIND: 78.2°

- Magnetopause (ACE) 09-APR-2004
  - Observed: 165.9°
  - ACE: 165.8°
Magnetospheric Multiscale Mission (MMS)

80% of all X-lines encounters are within 2 Re of the predicted X-lines.
Modeling the X-Line

Ions are reflected when they reach the ionosphere

\[ X_m = \text{Distance to ionospheric mirror point, calculated using Tsyganenko 1996 model (known value)} \]

\[ V_m = \text{cutoff velocity of mirrored ions} \]

\[ V_e = \text{cutoff velocity of earthward propagating ions (precipitating)} \]

\[ X_r = \text{distance to reconnection point (Calculated by program)} \]

Assumes: “Instantaneous” acceleration

Simple Field Line Structure
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

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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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