Continuous Magnetic Reconnection at the Earth's Magnetopause

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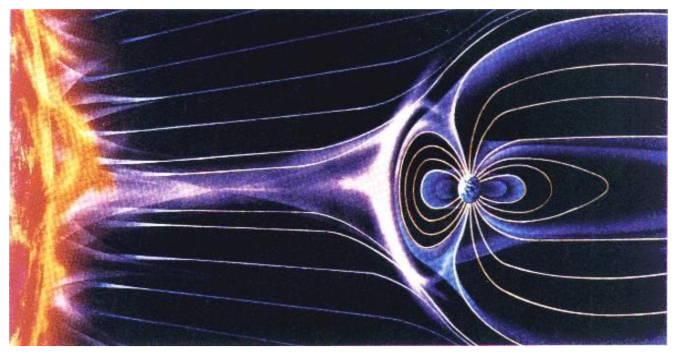
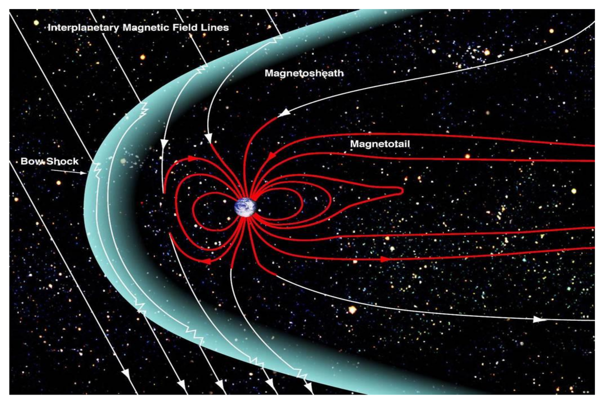
I. Background

Magnetic reconnection is a process where two antiparallel magnetic fields become interconnected[1]. This process occurs in many regions of space, including at the Earth's magnetosphere.



At the magnetosphere, solar wind streams constantly from the sun, and has an interplanetary magnetic field (IMF), which reconnects with the geomagnetic field[2].

Under southward IMF conditions, reconnection at the Earth's magnetopause occurs on the dayside of the field. Ions from the reconnection site stream into the cusp region, and the field line convects backward toward the tail region.

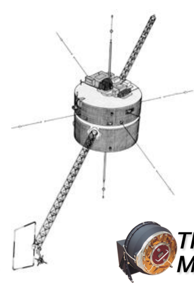


Our research uses observations of continuous ion precipitation into the cusp region to investigate magnetic reconnection in 2 separate cases, and improve our existing reconnection line model for these cases.

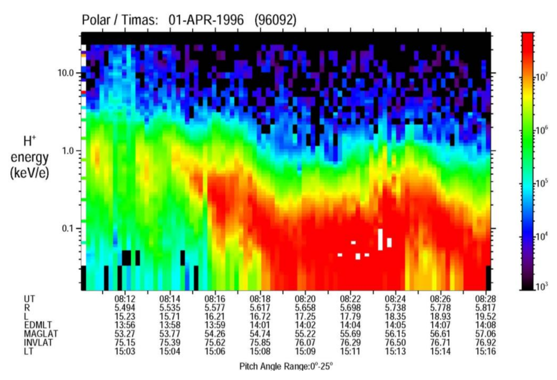
Images courtesy of NASA

II. Instruments and Data

NASA's Polar spacecraft orbited the Earth and took data in the cusp region. One of the instruments on Polar was the TIMAS instrument, which measured ion energy and flux.



TIMAS: The Toroidal Imaging Mass-Angle Spectrograph



Data is presented in a color spectrogram (left), which shows energy versus time and latitude of ions observed by the TIMAS instrument. Color represents the flux of the ions.

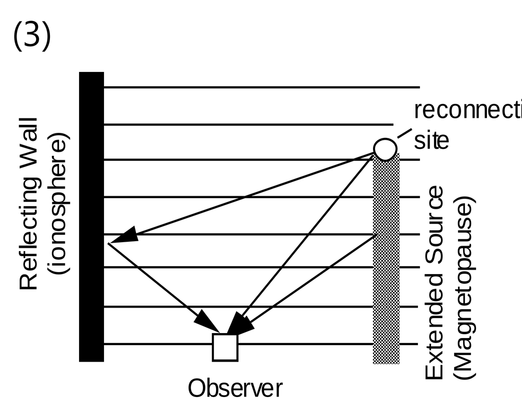
The main organization parameter for the data is the clock angle, which is the angle between the incident IMF field and the Earth's dipole. Since all of our events have a Southward IMF, these angles are between 90 and 270 degrees.

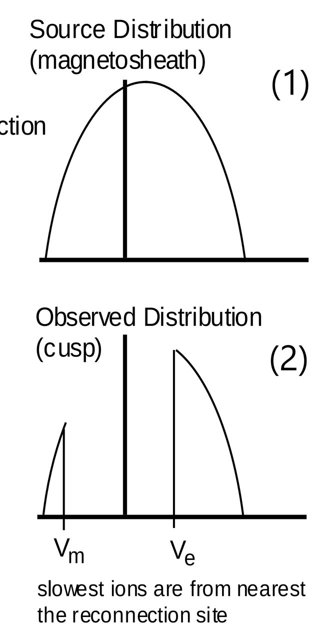
Images courtesy of NASA

III. Modeling the Reconnection Line

The Maximum Magnetic Shear Model is the model that we used to model the reconnection line[1].

Continuous ion flow along the field line produces a source distribution (1). As the ions precipitate into the cusp, some are lost to the atmosphere or are reflected outward, producing two separate observed distributions (2).

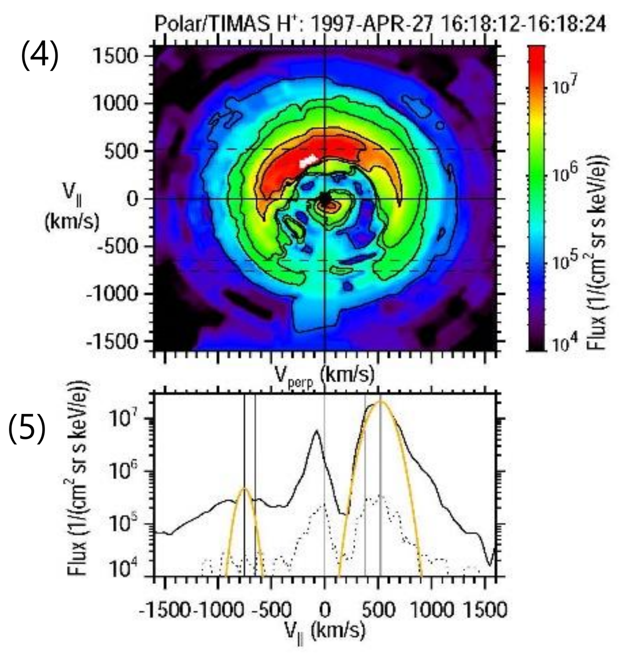




$$\frac{X_r}{X_m} = \frac{2V_e}{(V_m - V_e)}$$

Ions flowing into the cusp are reflected at the ionosphere and flow outward, which produces the negative side of the velocity spectrum. As the ions are reflected, the TIMAS instrument observes both the reflected ions and the precipitating ions simultaneously (3).

Using an IDL program written by Dr. Trattner, ion velocities are fitted to a field-aligned coordinate system (4), from which velocities of the precipitating and reflected ions can be obtained by fitting Gaussian distributions to a cross section of the data (5).

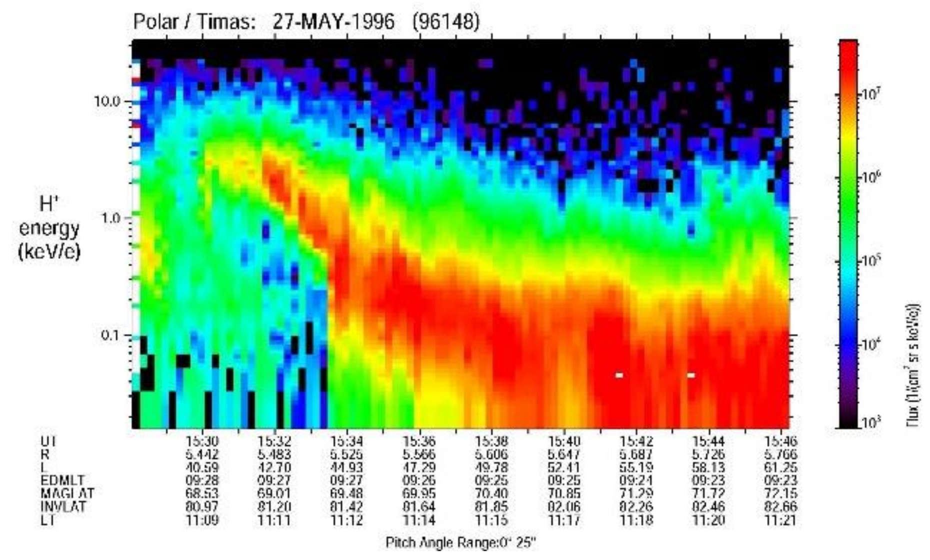


Finally, using the known distance to the ionosphere (X_m) and the values V_m and V_e obtained from the Gaussian distributions, the distance to the reconnection point (X_r) can be calculated.

Equation[1], diagrams courtesy of Dr. Trattner

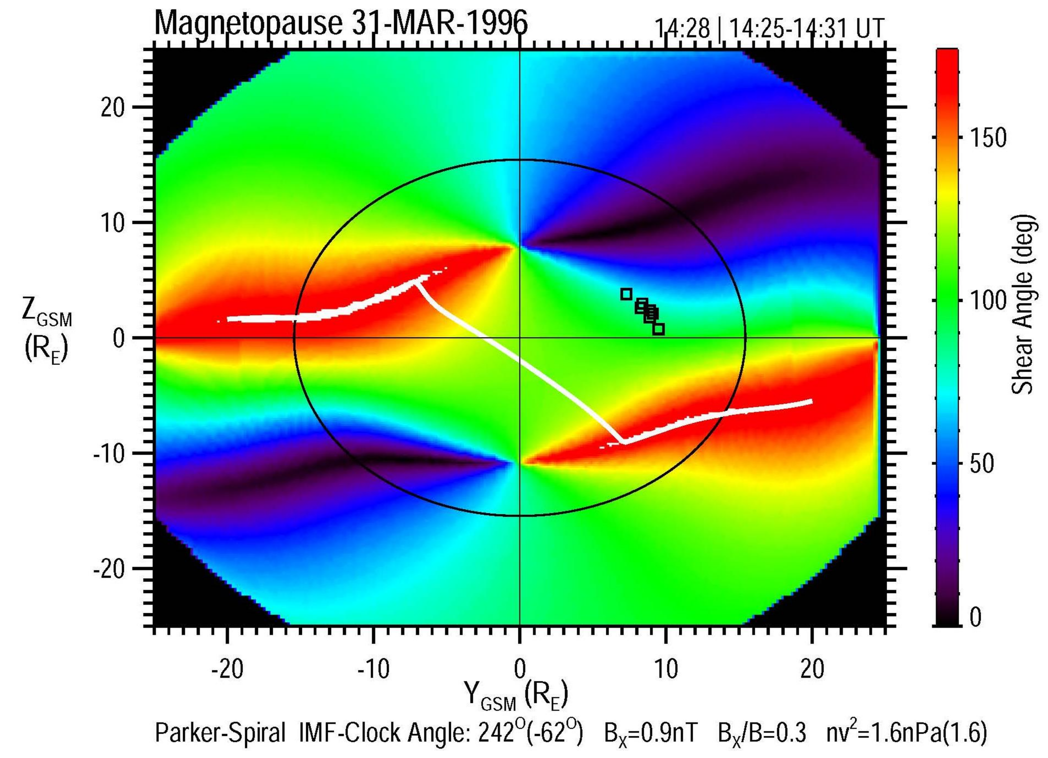
IV. Smooth Single Dispersion Events

Smooth single dispersion (SSD) events are reconnection events that have a single injection of particles from the solar wind into the cusp (right).



When SSD events are observed, they tend to produce anomalies in shear angle plots. The plot below represents one of those anomalies, because the trace points (black) do not line up with the model for the reconnection line (white).

By analyzing SSD events, we aim to improve the existing model in order to predict the reconnection line for these anomaly events.



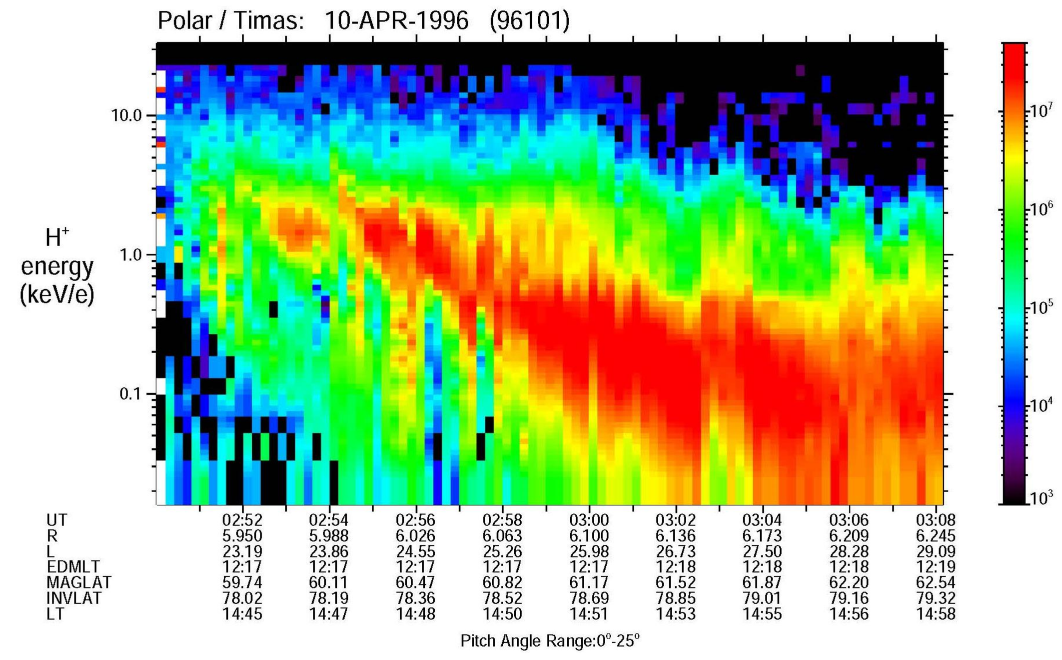
Findings and SSD Trends

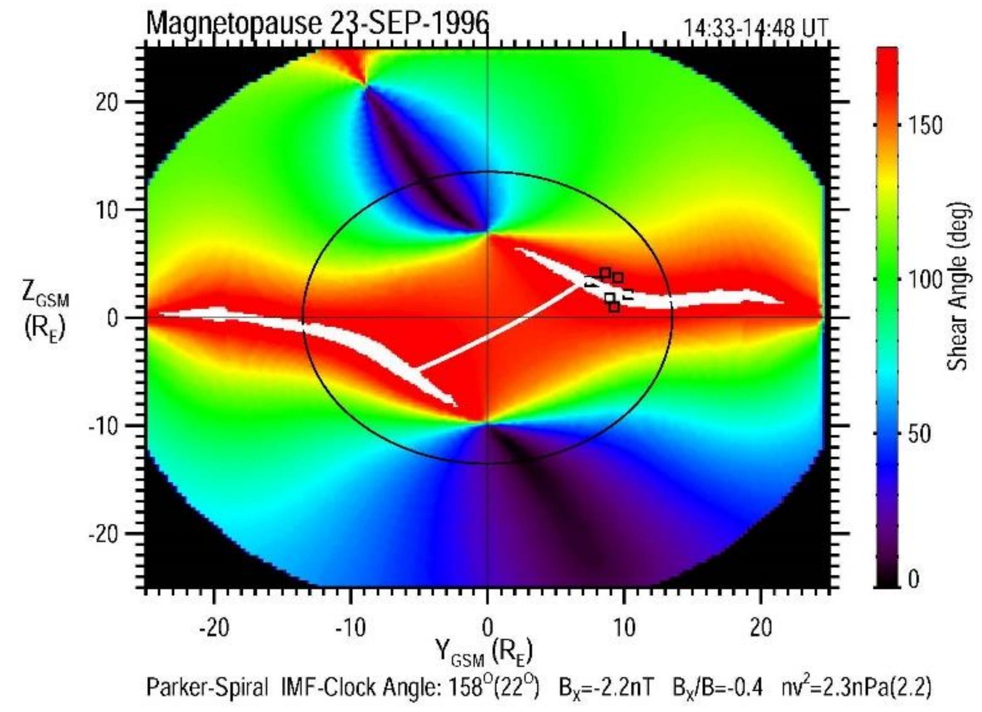
- When analyzing SSD events we found that these events had a very high probability to produce anomaly plots.
- We also observed that although SSD events happen throughout the year, they are concentrated around the Spring Equinox (March 20), and these events tend to have clock angles of 220° to 270°.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Events	0	5	10	7	2	4	3	0	2	2	4	0
220°-270°	-	2	8	3	0	3	0	-	0	0	0	-

V. Local Noon Events

In the magnetic field model, times are associated with the Earth's magnetic field lines, which mark their position with regards to their position. These times are called local magnetic time (EDMLT below).





For local noon field lines there are two points in the model that reconnection is predicted to occur.

By studying these events, we aim to categorize which of these two points is more likely for different events.

Findings and Local Noon Trends

Local noon plots behaved differently with regards to their clock angle:

- 90°-150°: tend to occur late in year (August - November)
- 151°-210°: equally likely to occur in all months, more likely to stay to outer prediction line (not local noon line)
- 211°-270°: tend to occur early in the year (March – May)

Events were also very concentrated March-May, then again September-November.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Events	0	0	17	34	22	7	0	8	23	19	15	0

VI. Future Investigation

This project was intended to study 2 cases where the existing reconnection line model has high uncertainty, and incorporate these results into the model to increase accuracy of the model under local noon and SSD conditions. After our research, these questions remain:

- Why are clock angles between 220 and 270 degrees more common around the spring equinox of each year? To what extent is this due to the tilt of the Earth with regards to the solar wind?
- Why are SSD events focused around March and April?
- Why are local noon events so rare in January, February, July, and December?

VII. Acknowledgements

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All color spectrograms and shear angle plots were produced using an IDL program written by Dr. Trattner.

VIII. References

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).
2. Kivelson, Margaret G. and Christopher T. Russell. *Introduction to Space Physics*. New York: Cambridge University Press. 1995.