Magnetic Signatures of Plasma Transport around Saturn Using Data from the Cassini- Huygens Mission

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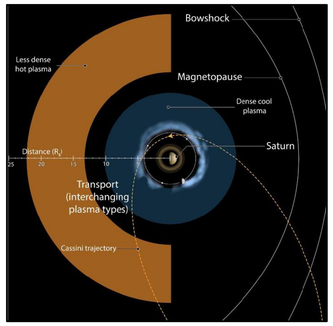
Introduction

- The Cassini Huygens' mission researched Saturn's magnetospheric transport, leading to an understanding of:
  - Two different regions of plasma populations
  - A hot tenuous plasma (~keV+, mostly H^+) in the outer region
  - A dense and cool plasma in the inner region (mostly W^+, water group)
- Saturn's rapid rotation (~10.8 hours) drives a mixing of these plasmas called interchange
- Interchange is a primary source of plasma transport (see Thomsen 2013) at Saturn between 5 - 15 Saturn Radii

Interchange at Saturn is analogous to Rayleigh Taylor instabilities on Earth



Driven by centrifugal force outwards, results in planetward motion of tenuous H^+
Figure credits: Falconieri Visuals, Azari+2020

Driven by gravitational force downwards, results in upwards motion of coffee
Figure credits: Pinterest

The Cassini spacecraft measured hundreds of interchange events with multiple sensors

Increase of **high energy** (> 1 keV) plasma

Evacuation of **low energy plasma**

Enhancement of **magnetic field pressure**

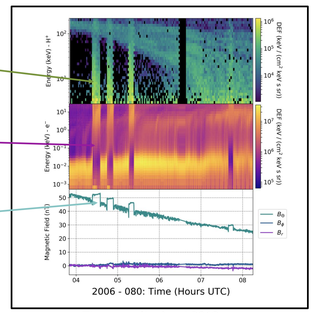


Figure credit: Azari 2018

Enhancement of magnetic field pressure thought to depends on position and be in equilibrium with surrounding background

- In equatorial events

$$P_{total} = \downarrow P_{particle} + \uparrow P_{magnetic}$$

- For off equatorial events

$$P_{total} = \uparrow P_{particle} + \downarrow P_{magnetic}$$

See Lai+2016, Rymer 2021.

Purpose:

There has been disagreement on identification of interchange (e.g. Azari+2018). Our goal is to understand the magnetic field pressure dependence upon spacecraft position and identification method.

Methods

We calculated magnetic field pressure in several interchange events (2006 DOY 080, 2005 DOY 068) that were previously identified in statistical surveys (e.g. Lai+2016, Azari+2018)

Magnetic Field Pressure

$P_{total} = P_{particle} + P_{magnetic}$, $P_{magnetic} = \frac{(B_{total})^2}{2*\mu}$

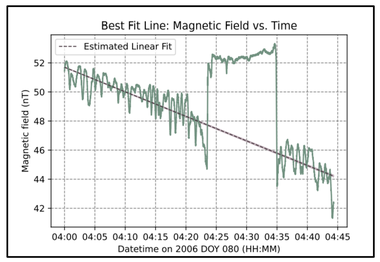
Events: **2006 DOY 080, 2005 DOY 068**

Bootstrapping

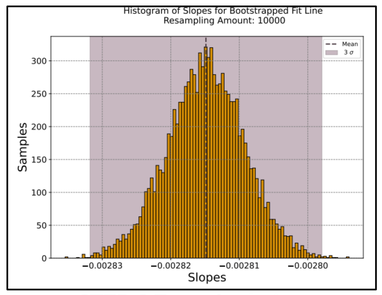
We used bootstrap analysis to estimate errors on our linear fits. Bootstrapping is a type of resampling which is performed on sampling a dataset through replacement.

Linearly Detrended Magnetic Field Pressure Estimation

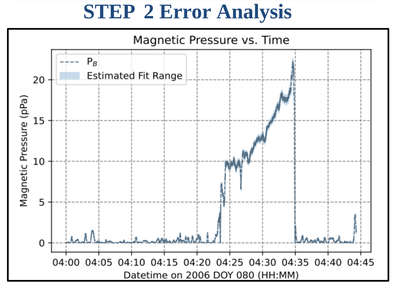
The graphs below show plots from **2006 DOY 080** performed with 10000 bootstrap iterations.



STEP 1 Best Fit Analysis



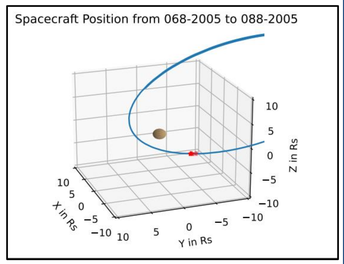
STEP 2 Error Analysis



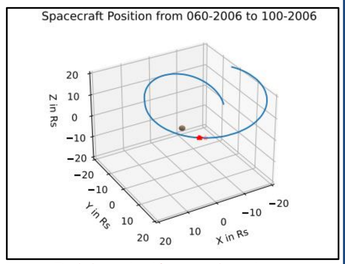
STEP 3 Magnetic Pressure Analysis

Spacecraft Positions for Both Time Periods

2005 DOY 068



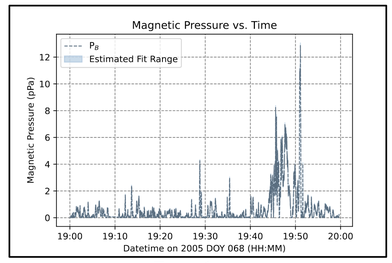
2006 DOY 080



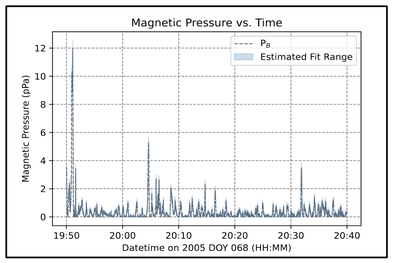
Red dots signify event location

Event 4
Pressure: 12.25 +0.07, -0.07 pPa
Position: -1.74, -7.02, -0.54 Rs

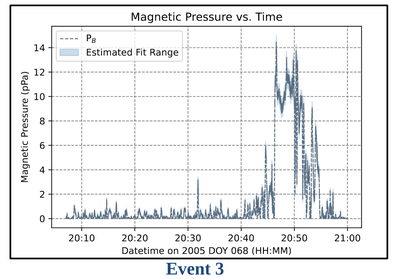
Results



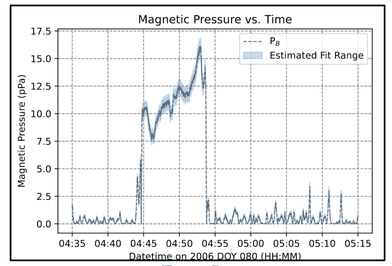
Event 1
Pressure: 2.79 + 0.04, -0.04 pPa
Position: -5.36, -2.93, -2.18 Rs



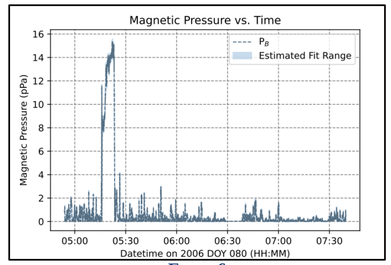
Event 2
Pressure: 0.31 + 0.05, -0.03 pPa
Position: -5.40, -3.13, -2.20 Rs



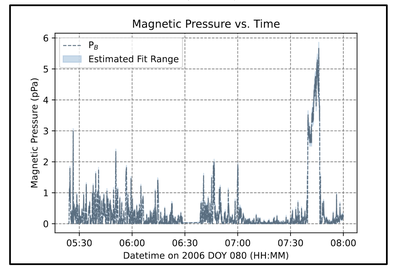
Event 3
Pressure: 5.22 + .20, -.21 pPa
Position: -5.50, -3.64, -2.24 Rs



Event 5
Pressure: 10.75 + .53, -.54 pPa
Position: -1.99, -2.34, -3.95 Rs



Event 6
Pressure: 9.60 + /-0.11 pPa
Position: 2.34, 7.16, -0.73 Rs



Event 7
Pressure: 3.51 + 0.12, -0.13 pPa
Position: -3.95, 7.41, -1.25 Rs

In the plots above, the magnetic pressure vs. time is shown for the events.

Future Work & Conclusions

- Average pressure in events analyzed range from 0.3 pPa to 12.23 pPa, likely depending on location around Saturn
- Results tentatively confirm previous estimates from Lai+2016
- Additional work can be pursued in developing estimations between inclination and radial distance dependence on pressure equilibrium in interchange events

Future Work
- Analyze more events with bootstrap analysis from surveys
- Estimate particle pressures

Contact

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References

Azari et al 2018 Journal of Geophysical Research: Space Physics, 123, 4692-4711. https://doi.org/10.1029/2018JA025391
Lai et al 2016 *J. Geophys. Res. Space Physics*, 121, 3050–3057, doi:10.1002/2016JA022436.
Rymer et al 2021 https://doi.org/10.1002/9781119815624.ch30
Thomsen 2013 *Geophys. Res. Lett.*, 40, 5337–5344, doi:10.1002/2013GL057967.