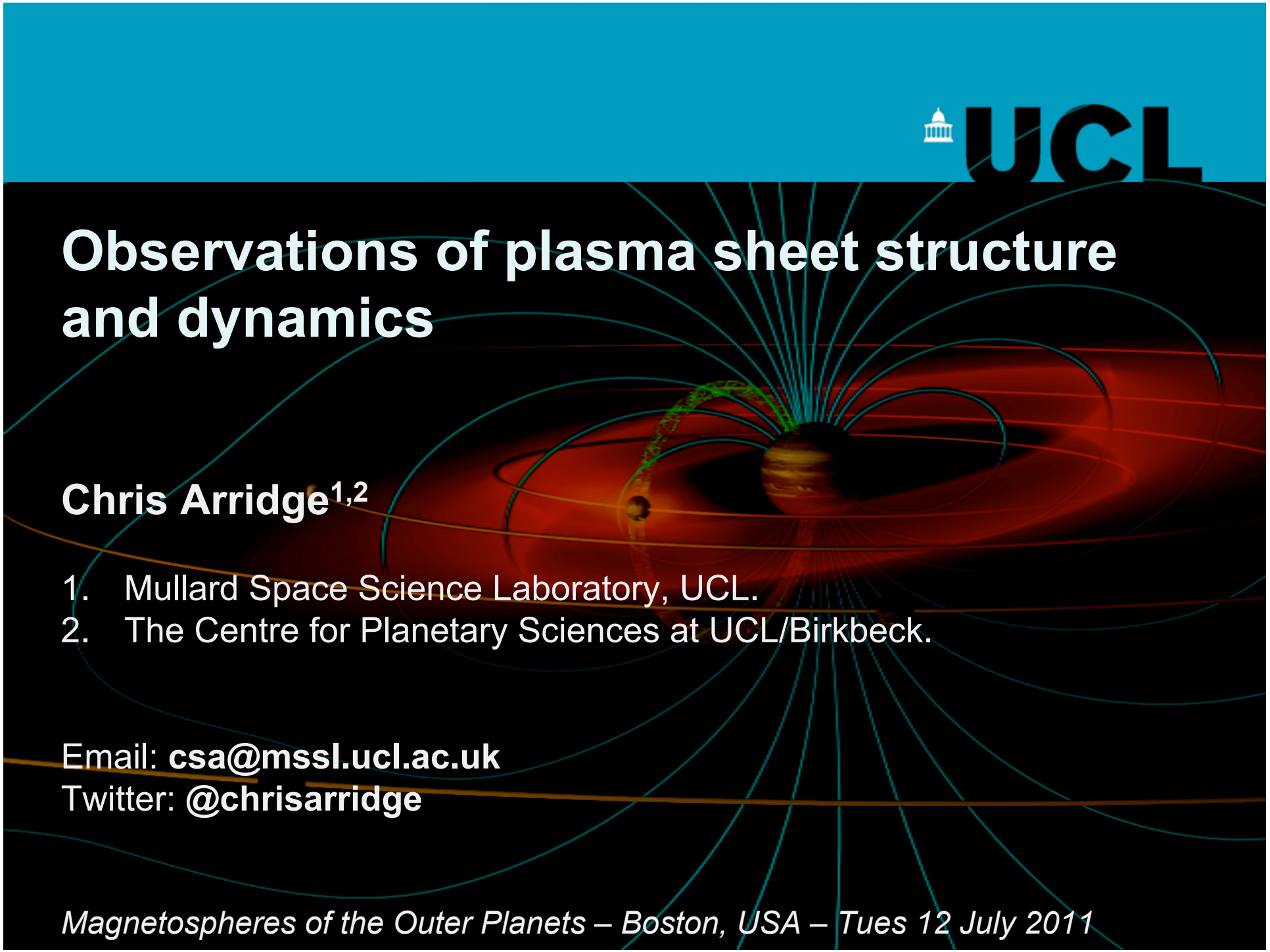

Observations of plasma sheet structure and dynamics

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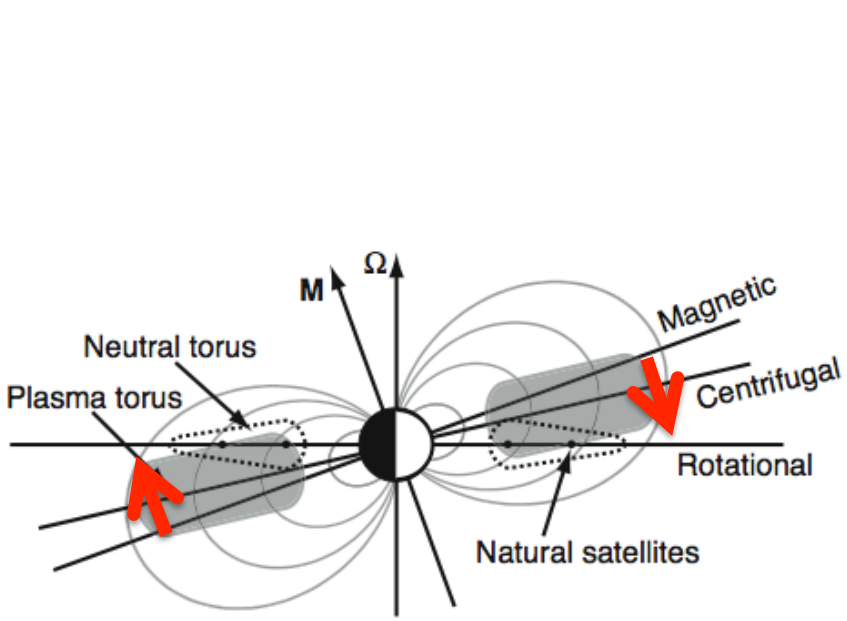
Magnetospheres of the Outer Planets – Boston, USA – Tues 12 July 2011

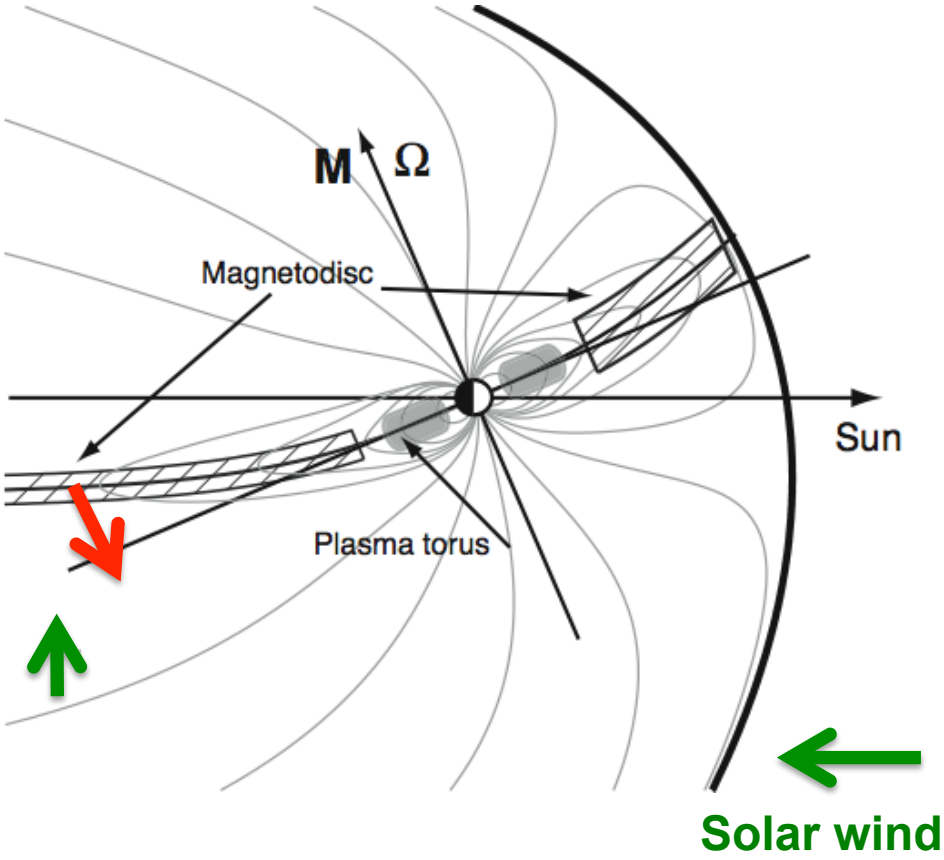
Introduction

- Plasma sheets at Jupiter and Saturn are filled with plasma from internal mass sources.
- Important in regulating transport and loss of plasma and heating plasma and energetic particles.
- Forced both internally and externally.
- Discuss:
  - Plasma sheet global shape and position and observations of its dynamics.
  - Plasma sheet thickness variability.
  - Centrifugal effects on latitudinal structure.
  - Reconnection, periodic plasmoid release and recurrent energisation.
  - Energisation of plasma.
  - Current sheet tearing.
  - Current sheet oscillations and waves.
  - Discrete blobs of plasma.

Plasma sheet shape: forcing

- Global shape of the current and plasma sheet is determined by:
  - Diurnal motion (dipole tilt) / other periodic mechanisms.
  - Centrifugal forcing on plasma offset from the rotational equator.
  - Stresses imposed on the magnetosphere from the solar wind.



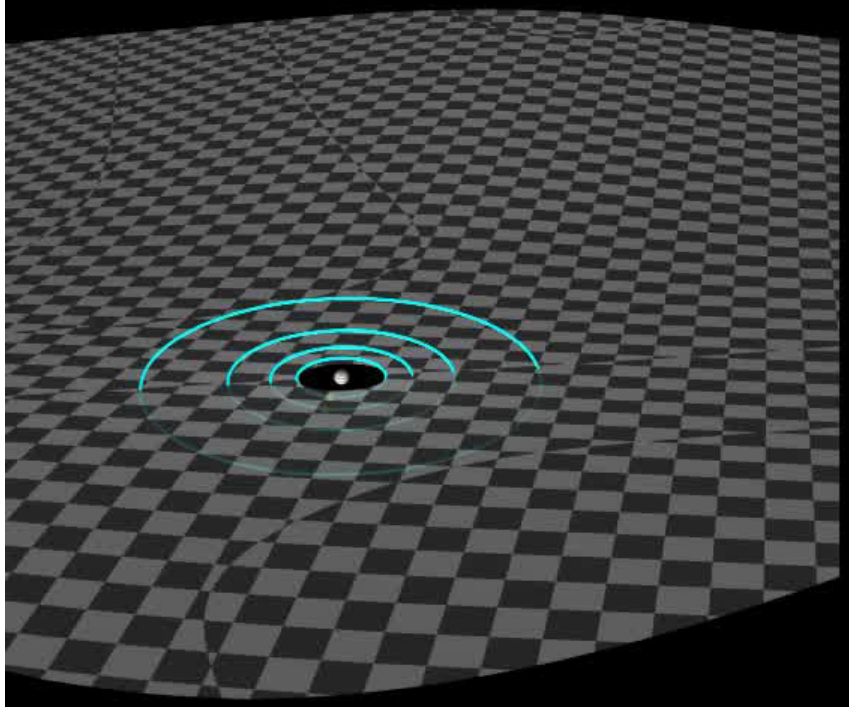


Arridge et al. (2011)

Plasma sheet shape: Jupiter & Saturn

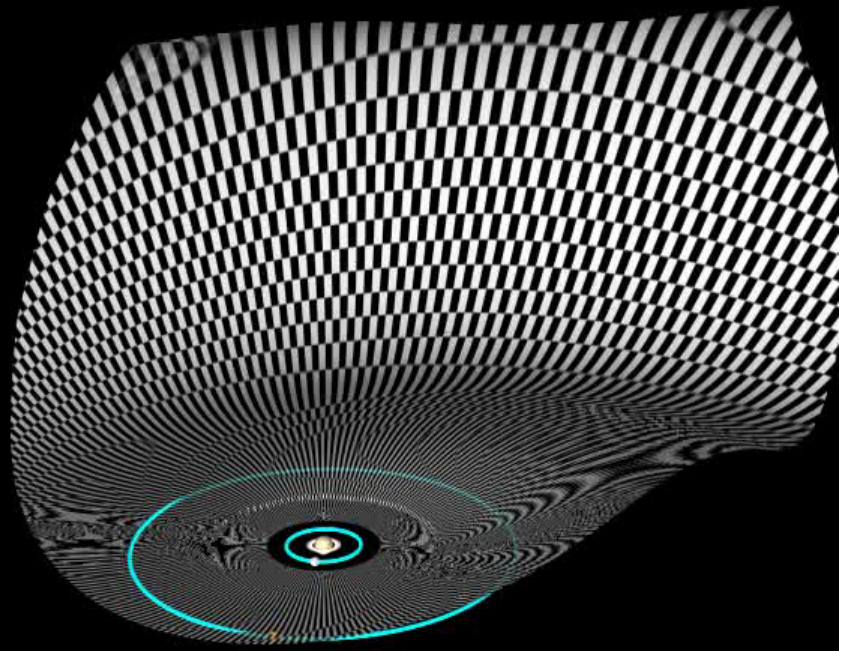
UCL

Jupiter



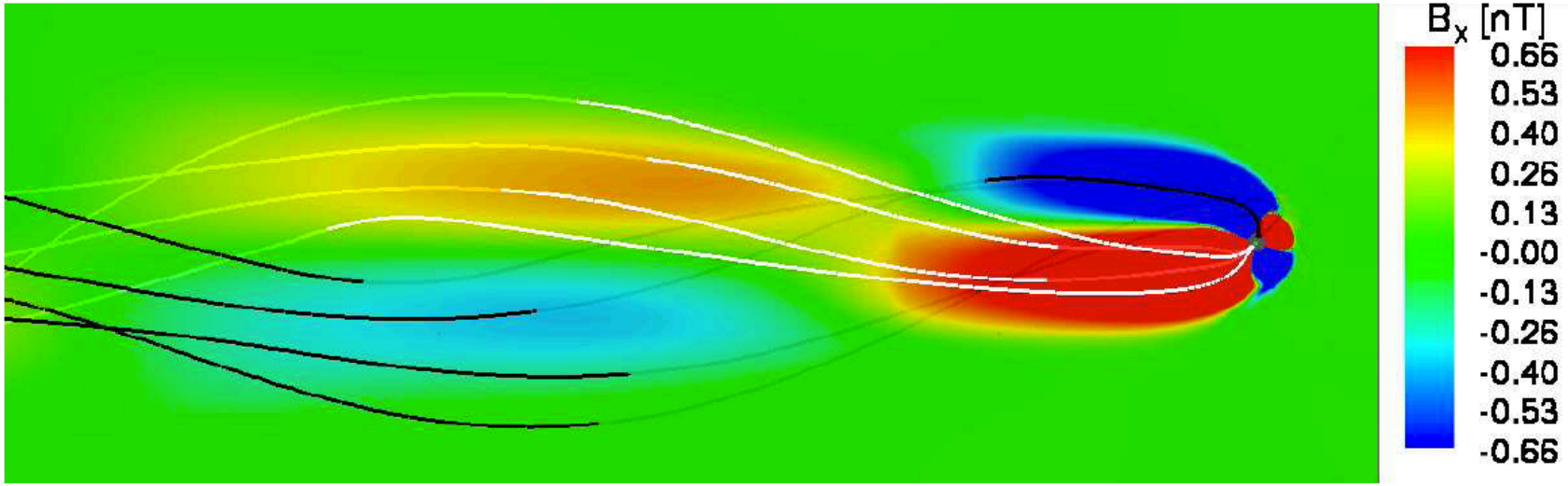
Khurana and Schwarzl (2005)

Saturn

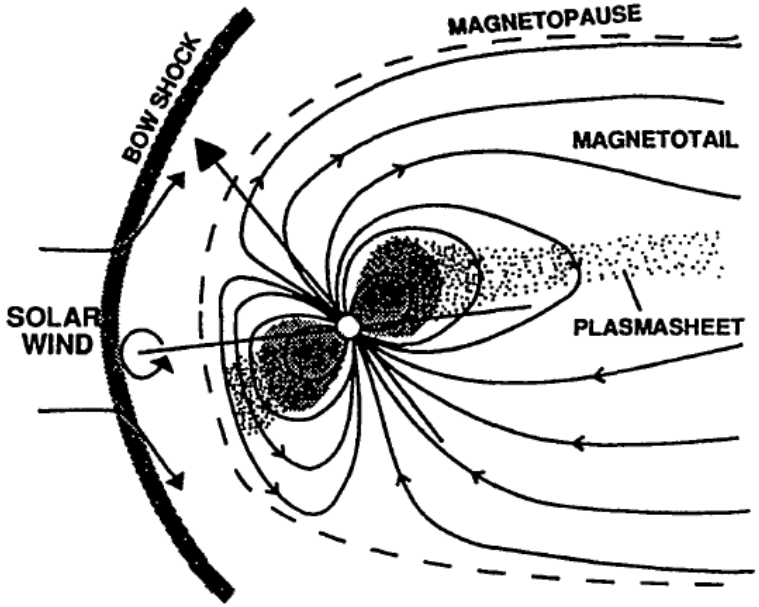


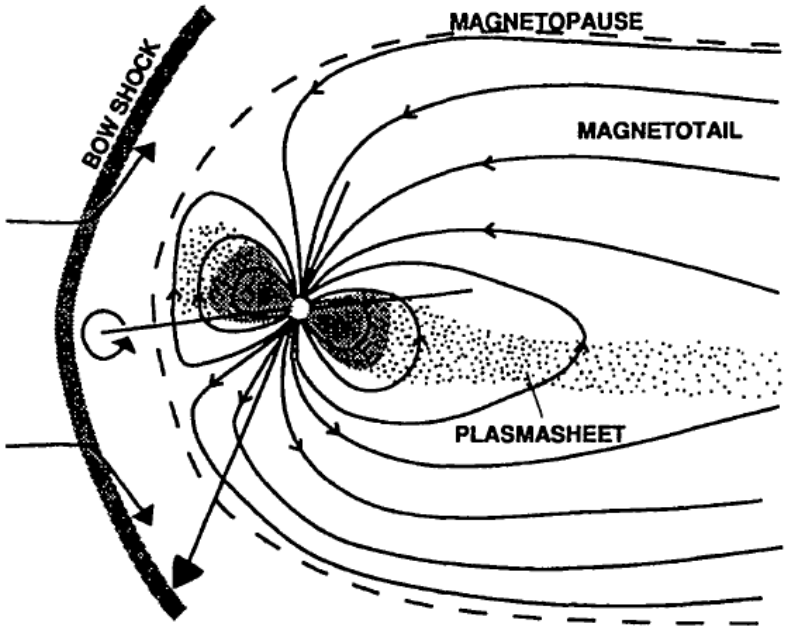
Arridge et al. (2011, submitted)

Plasma sheet shape: Uranus



Tóth et al. (2004)

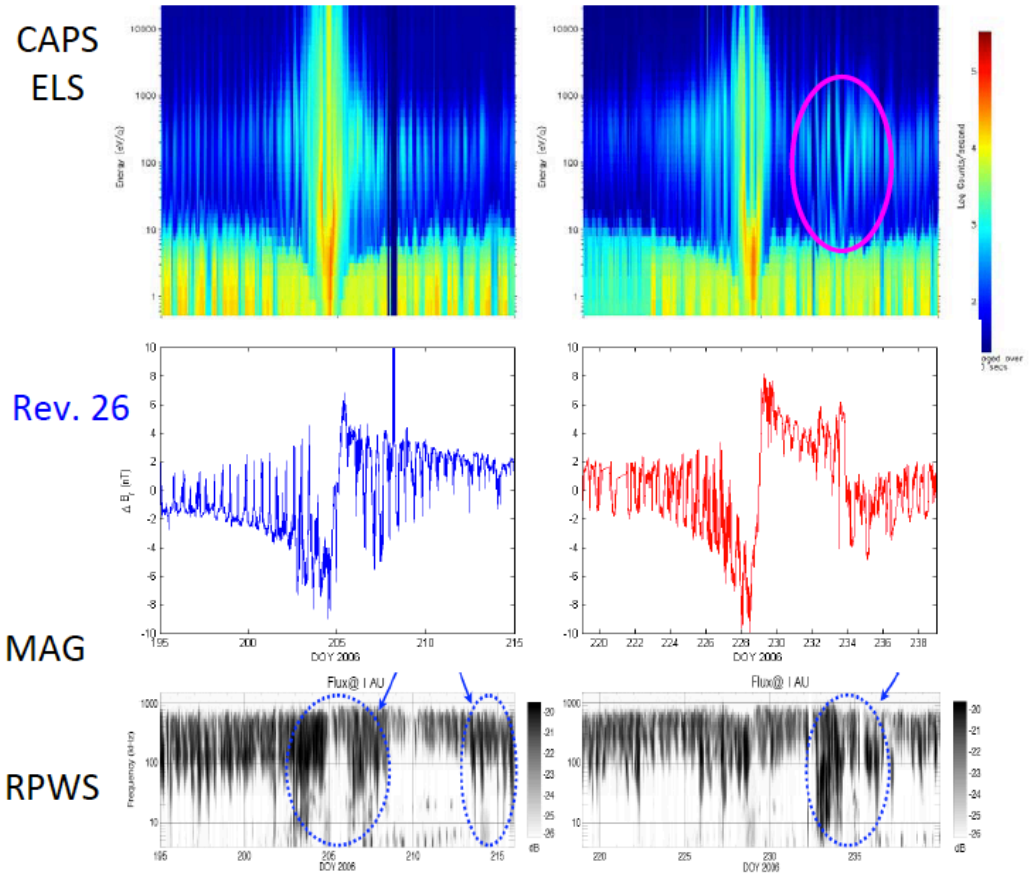




Bagenal (1992)

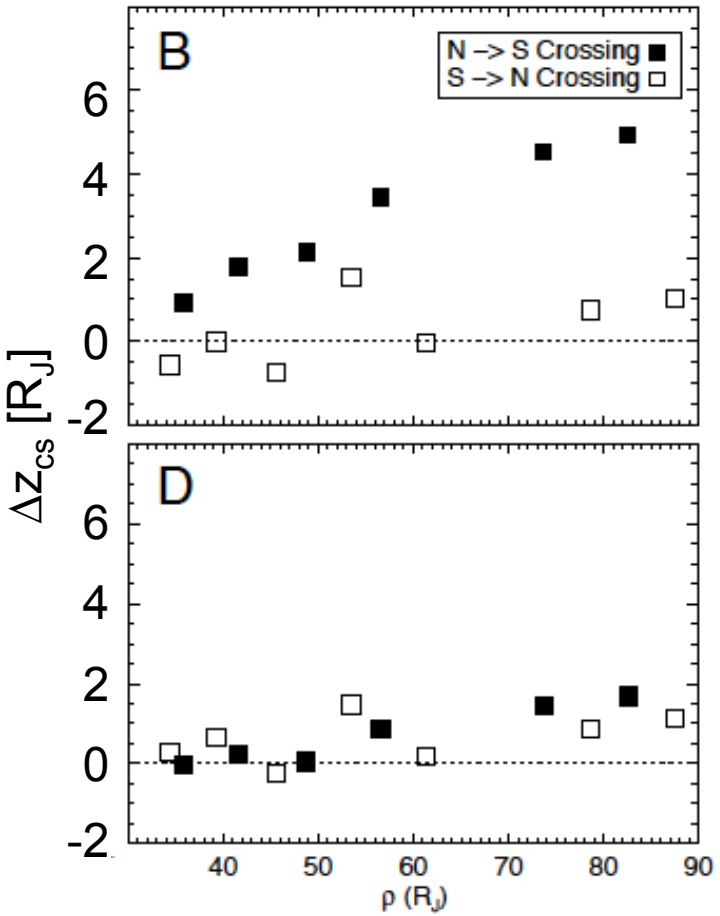
Plasma sheet location dynamics

Saturn (Cassini)



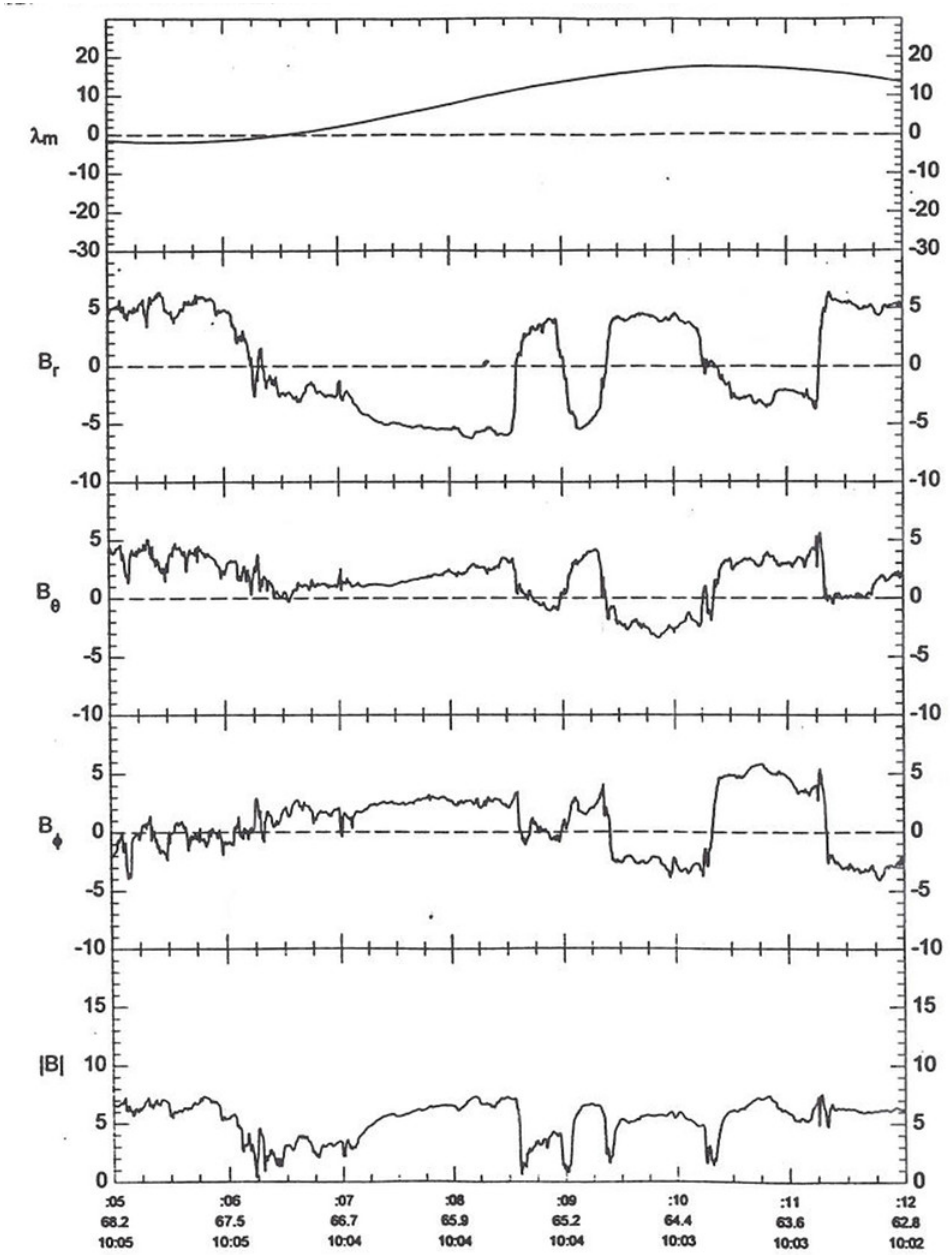
André et al. (in preparation)

Jupiter (New Horizons)



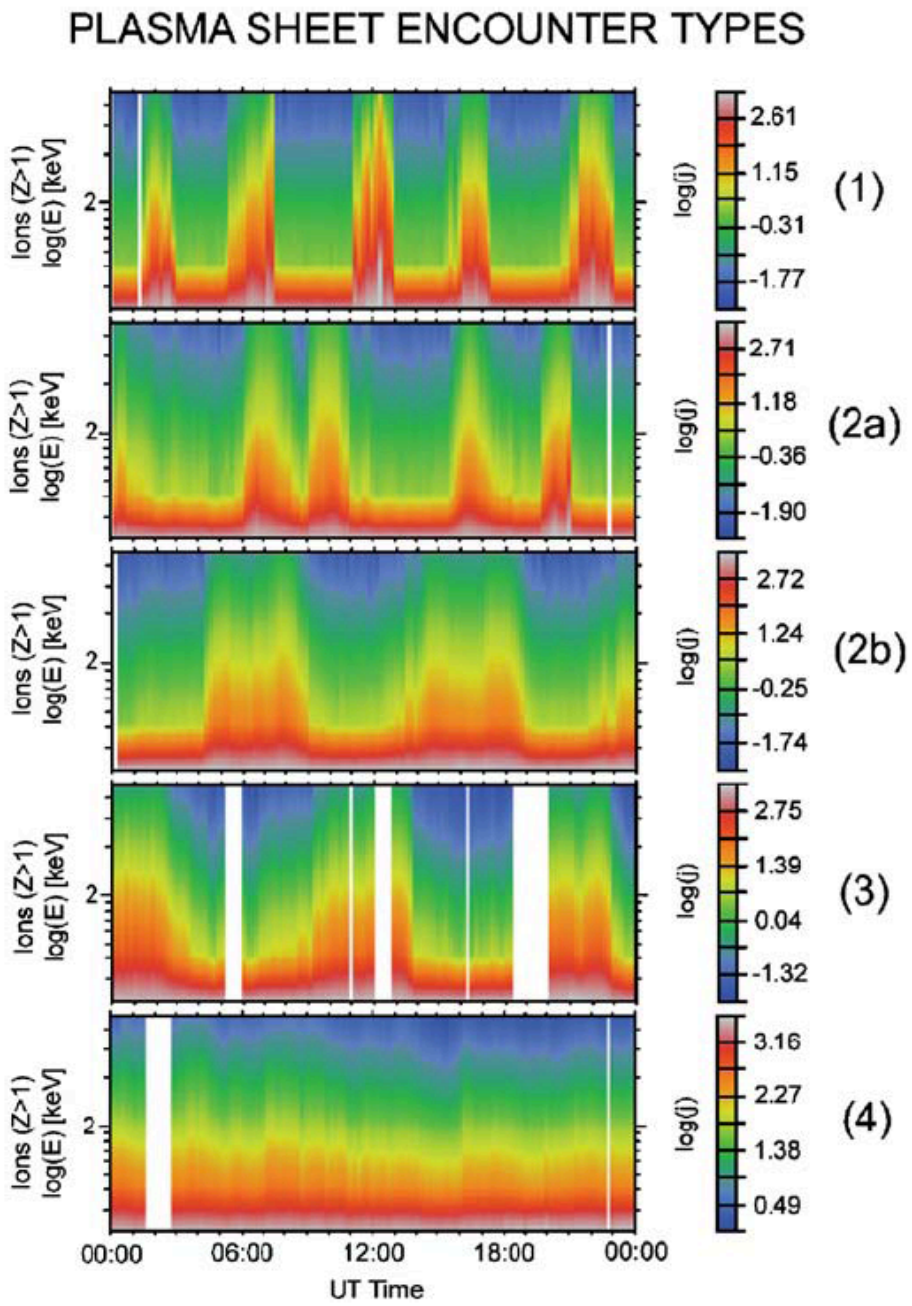
[Steffl et al. this meeting]

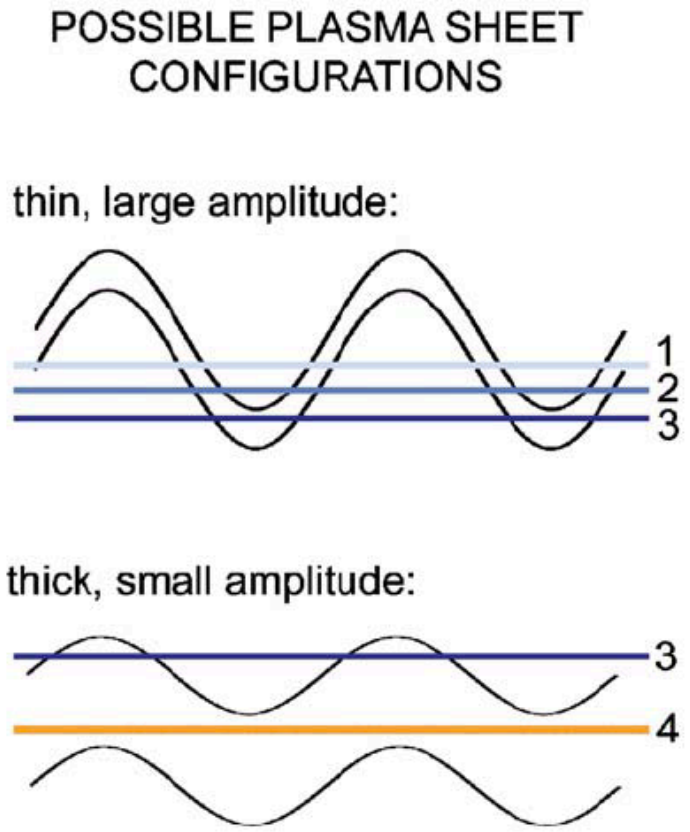
Disordered current sheet location



Haynes (1995)

Dynamical effects on shape & thickness

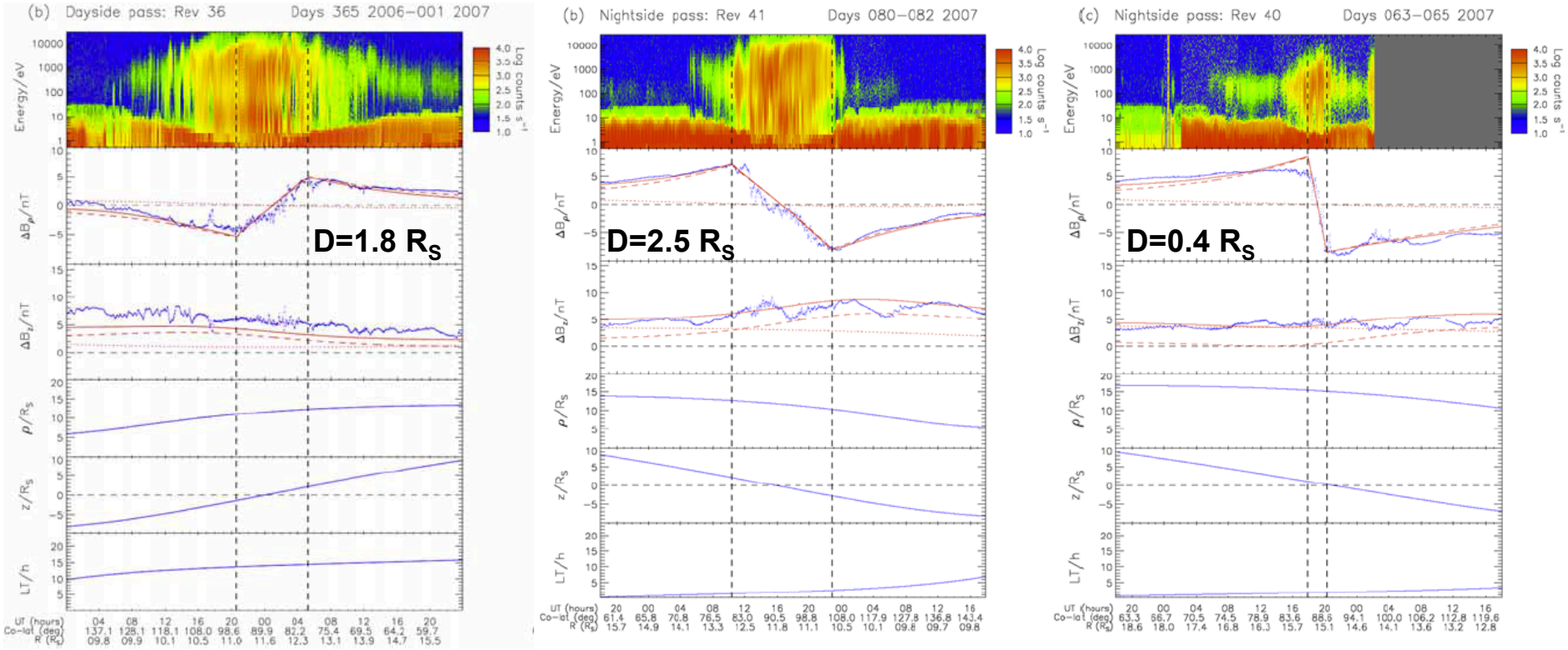




Waldrop et al. (2005)
[see also Vasyliūnas et al. (1997)]

Plasma sheet thickness

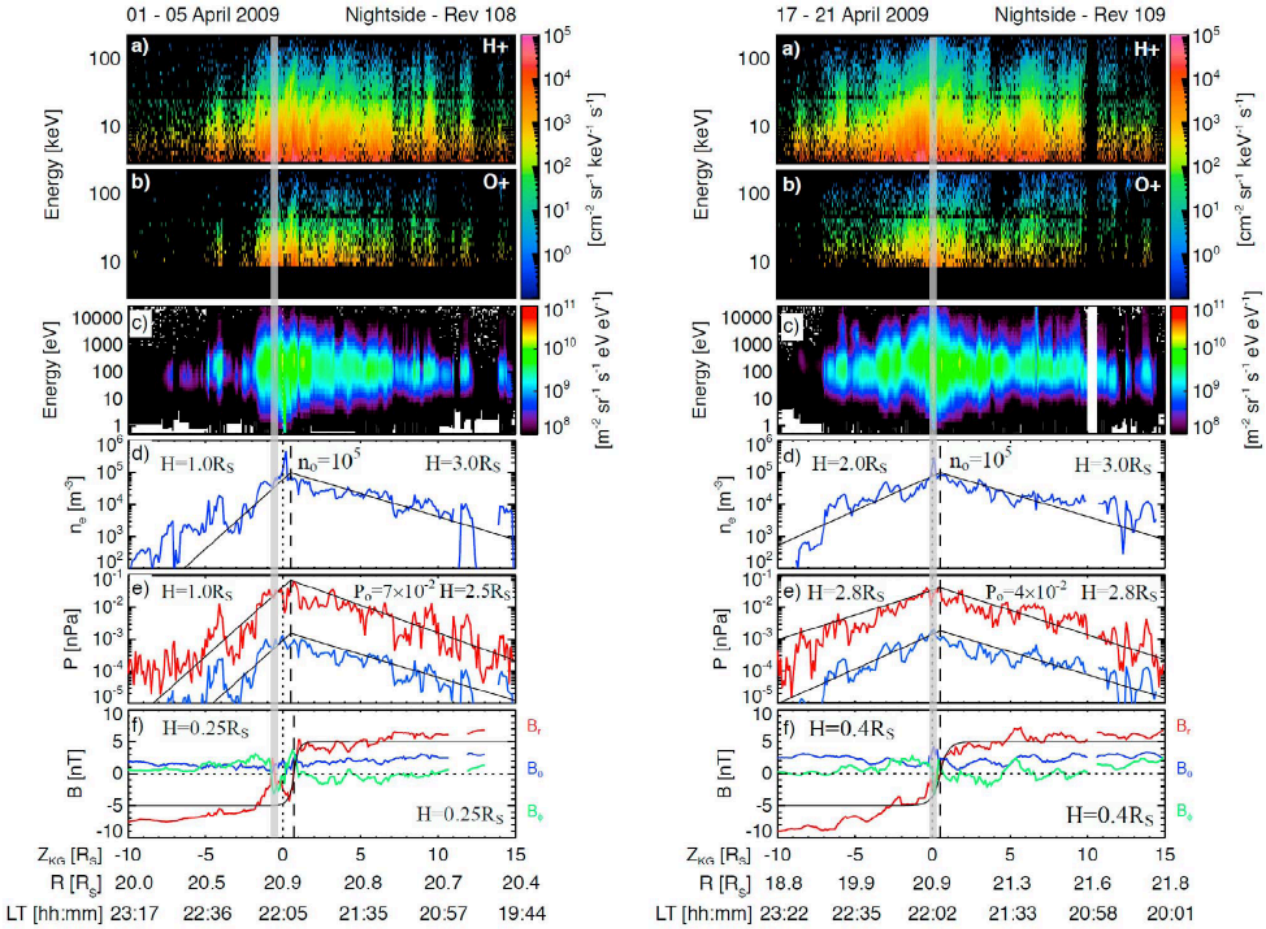
- Inclined orbits of Cassini at Saturn => opportunity to measure sheet thickness.
- Analysis of magnetometer and plasma electron data by Kellett et al. (2009).
- Reasonably consistent plasma/current sheet thickness on the dayside.
- Current layer embedded in more extended region of plasma.
- Disturbed and variable on the nightside.
- Thicker dayside plasma sheet (Krimigis et al., 2007).

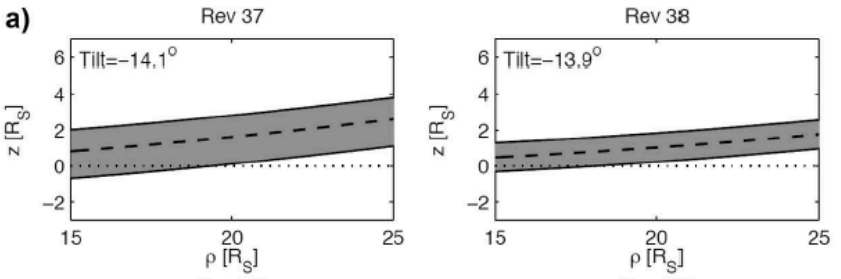


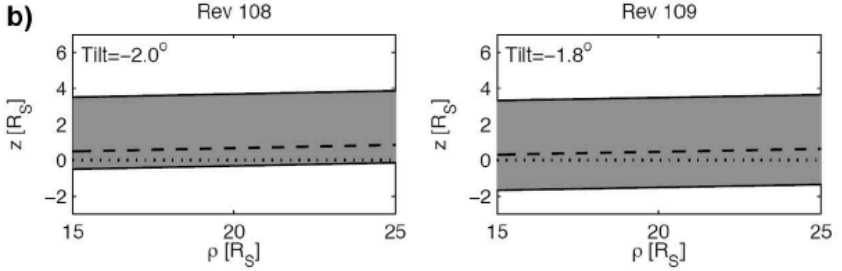
Kellett et al. (2009)

Plasma sheet thickness

- More inclined passes analysed by Sergis et al. (2010) using more data sets.
- Highly variable sheet structure near 20 R_S.
- Asymmetries in plasma sheet.

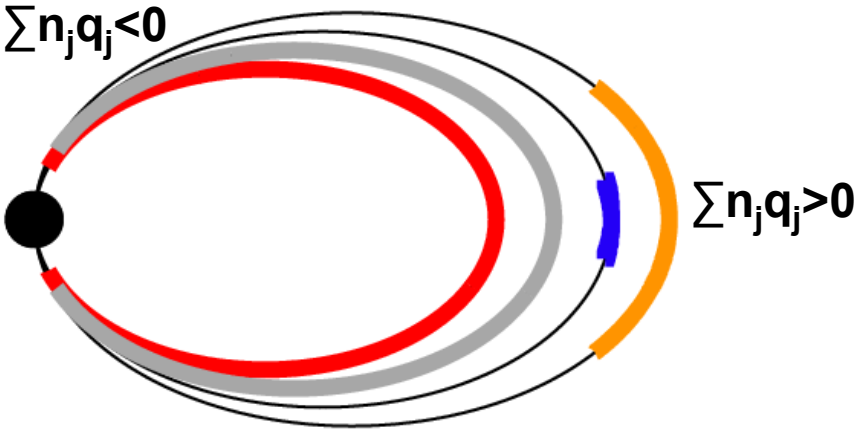




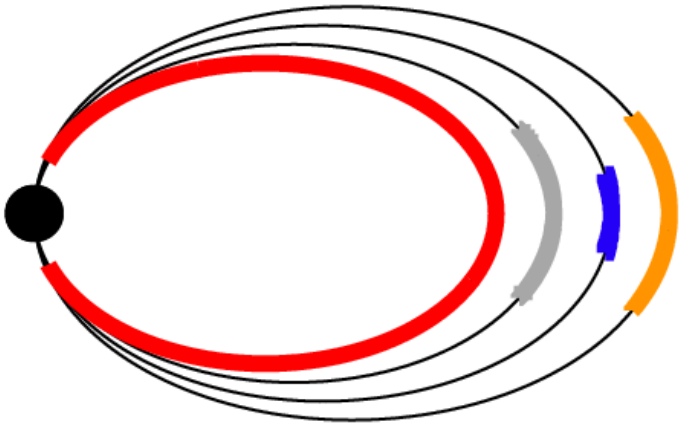


Field-aligned force balance

No $E_{||}$ and $\sum n_j q_j \neq 0$

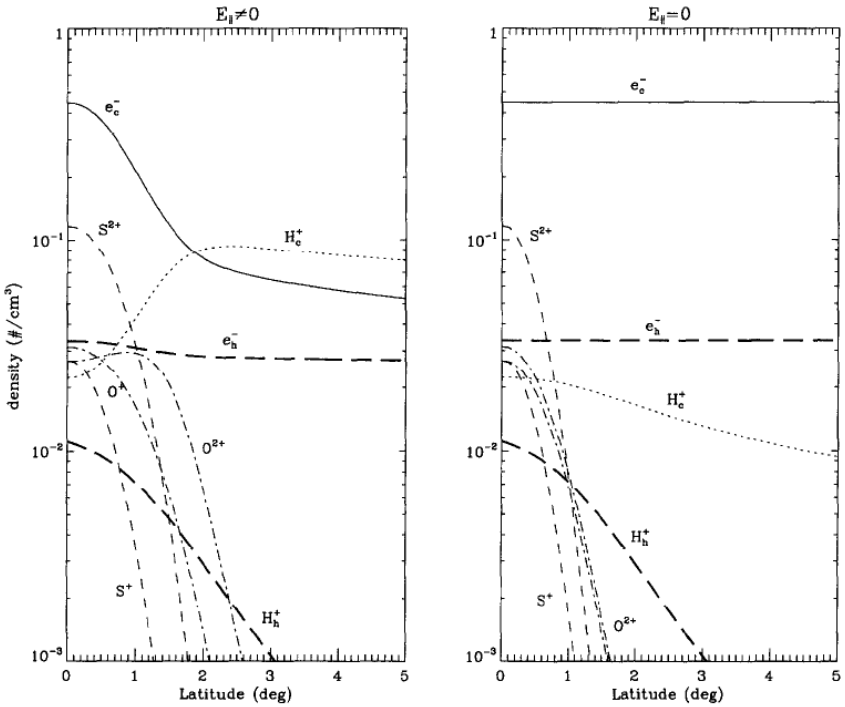


$E_{||}$ and $\sum n_j q_j = 0$



- Multiple (incl. heavy) ion species and centrifugal forces ⟹ heavy ions collect near the equator.
- Quasi-neutrality.
- Field-aligned (ambipolar) electric fields – pull lighter/hotter pop. to equator.

See for example: Persson (1967), Bagenal (1994), Maurice et al. (1997), Moncuquet et al. (2002)



Maurice et al. (1997)

Magnetic reconnection

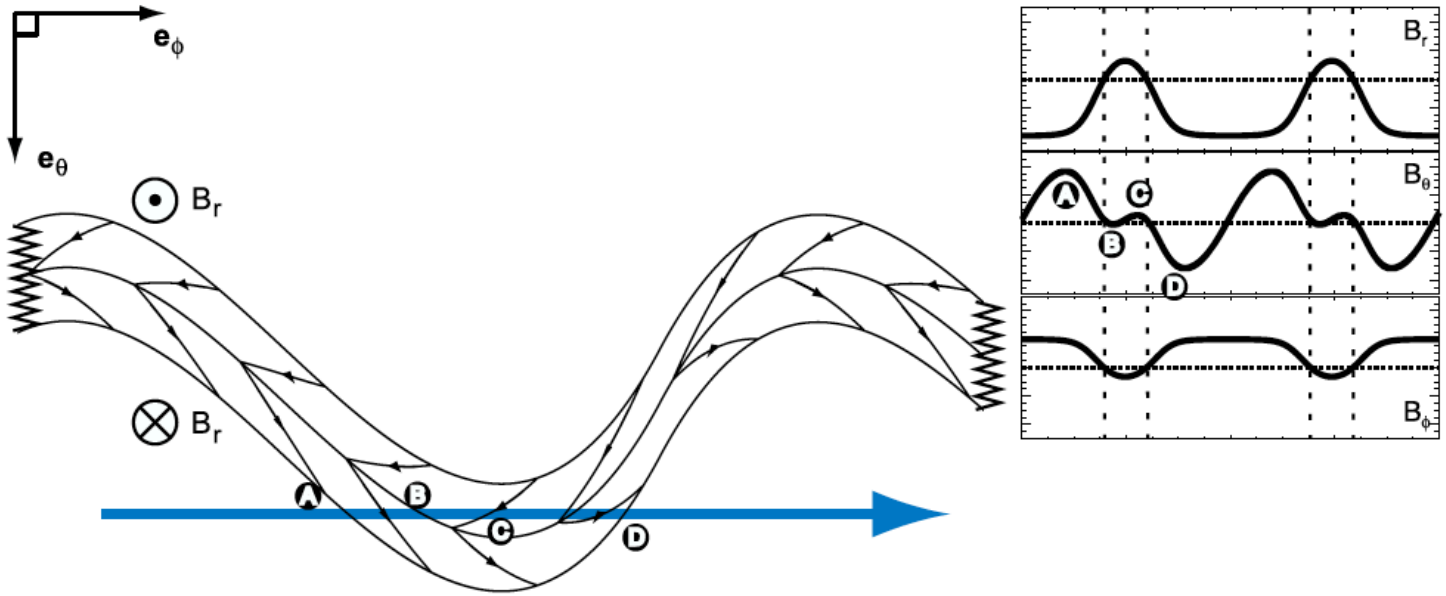
- Detection of **plasmoids, TCRs** and **dipolarisations** (Russell et al., 1998, 2000; Jackman et al., 2007; Hill et al., 2008; Jackman et al., 2008; Vogt et al. 2010; Arridge et al., this meeting; Jackman et al., this meeting).
- **Superposed epoch** analysis of **Saturn plasmoids** (Jackman et al., submitted).
- Comparison of **jovian auroral features** with **insitu reconnection signatures** (Radioti et al. 2008,2011).
- **Angular momentum conservation** (e.g., Hairston and Hill, 1986; Russell et al., 1998; Jackman et al., 2007; Masters et al., 2011).
- Possible **effects of Titan on reconnection** (Russell et al., 2008; Winglee et al., 2009).
- **Ion composition** (e.g., Radioti et al. 2007; Masters et al., 2011; Arridge and Walsh, in preparation).
- Associated **auroral radio emissions** (Jackman et al., 2009; Louarn et al., 1998,2000; Woch et al., 1992).

Periodic plasmoid release

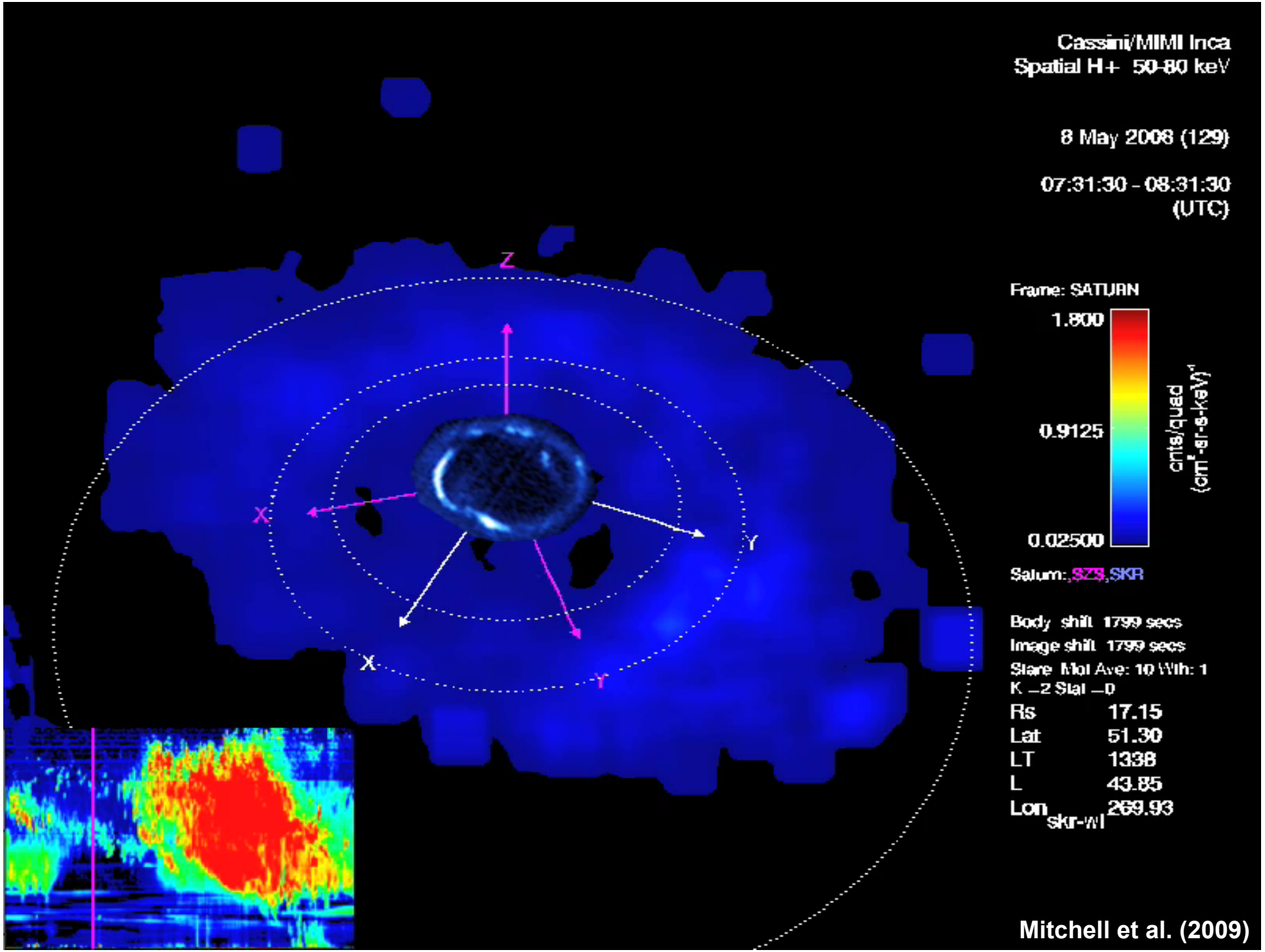
- Periodic plasmoid release has been suggested at Earth (e.g., Freeman and Morley, 2004), Jupiter (Kronberg et al., 2007), and Saturn (Burch et al., 2008; Zieger et al., 2010; Rymer et al., this meeting).

- Accumulate and fire process – accumulate sufficient mass or magnetic flux to thin the current sheet (Freeman et al., in preparation).

- Inherently unsteady process – sufficiently steady to drive global periodicities (Jackman et al., 2009)?



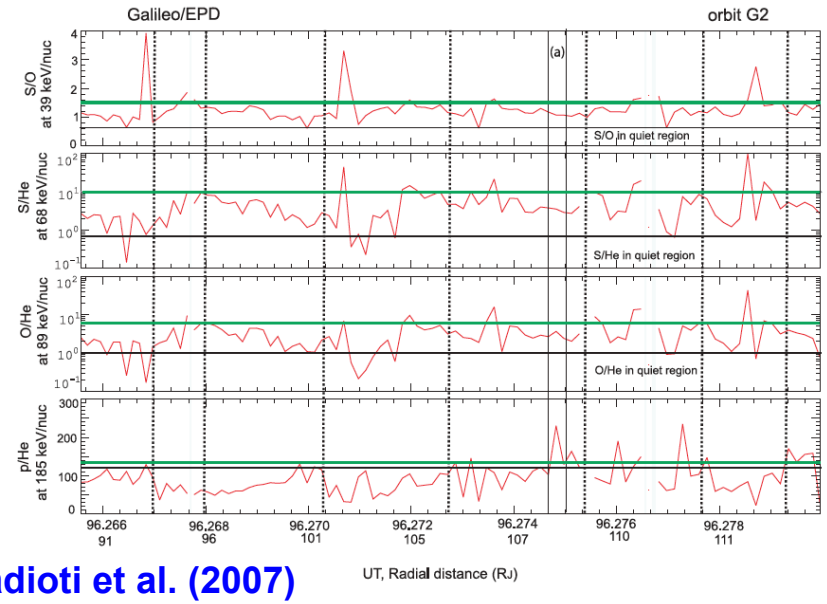
Jackman et al. (2009)



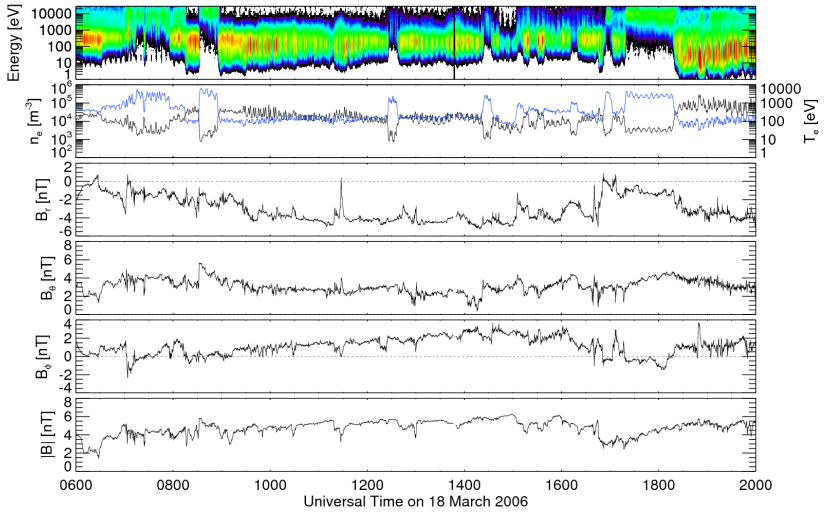
Mitchell et al. (2009)

Tail energisation

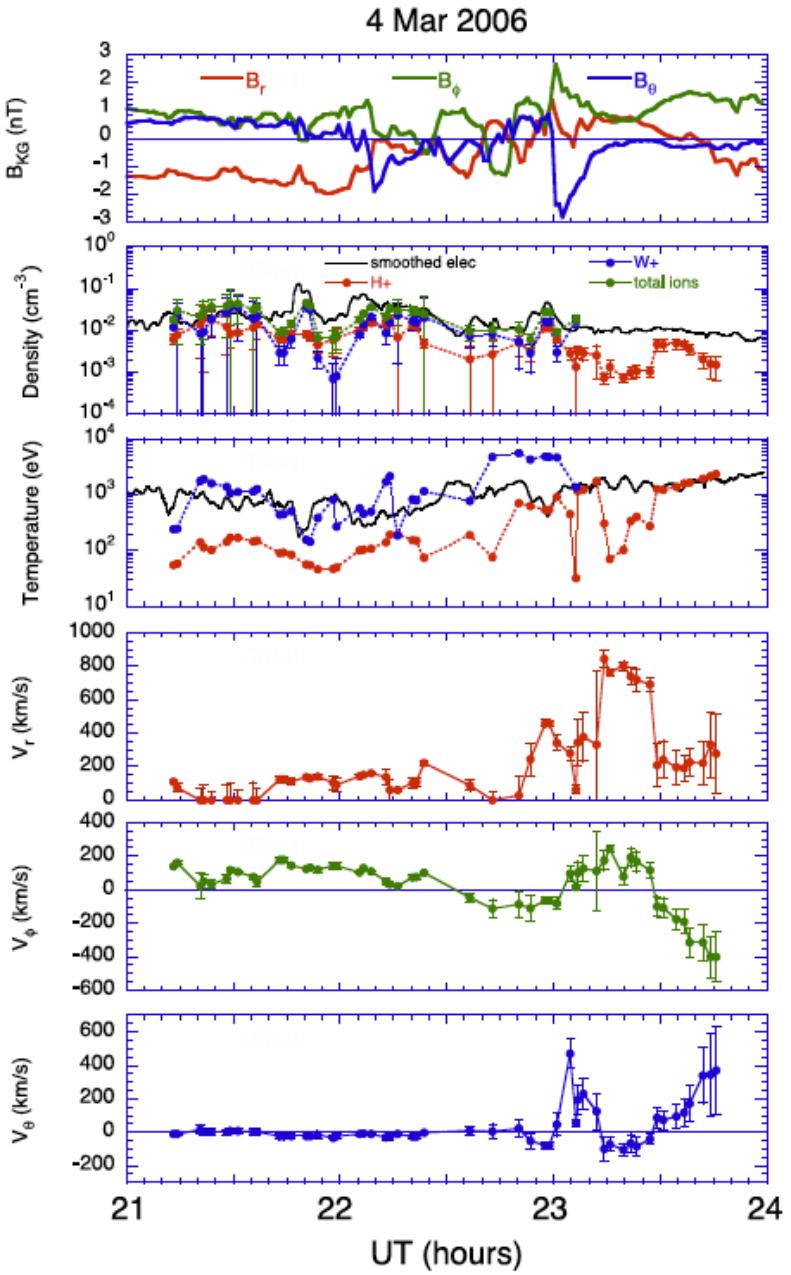
See also Paranicas (this meeting)



Radioti et al. (2007)

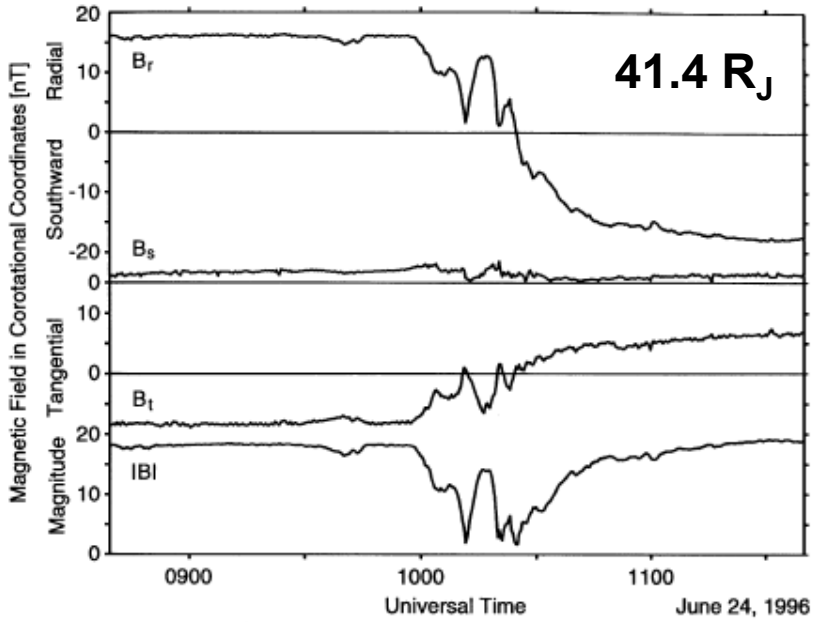


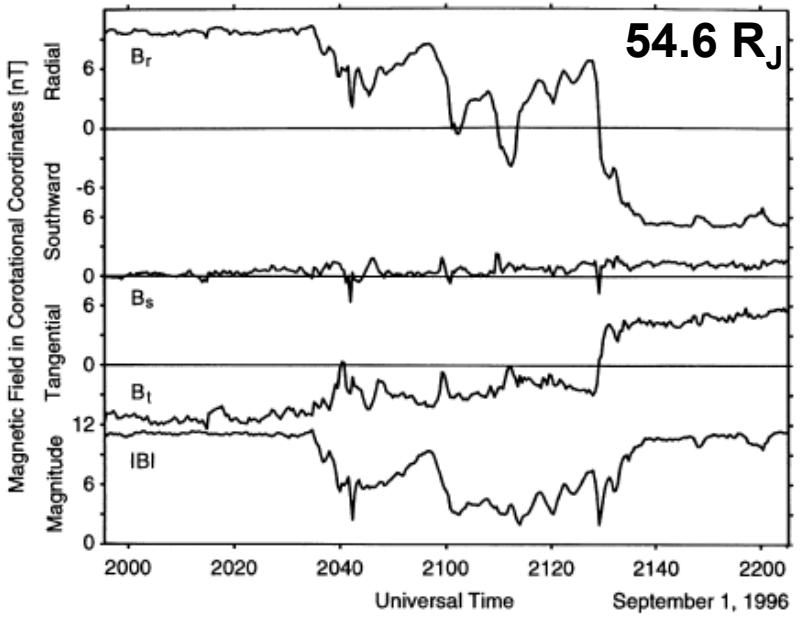
Arridge et al. (this meeting)

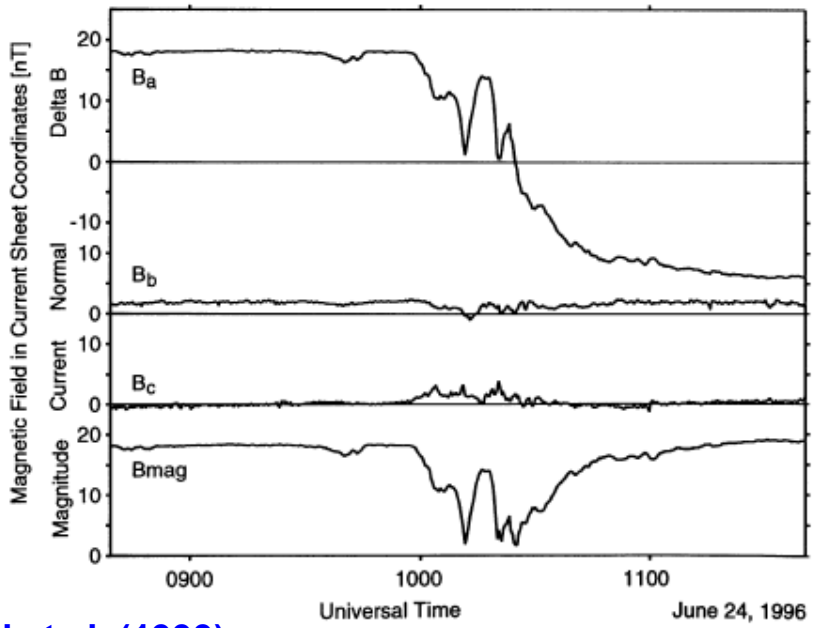


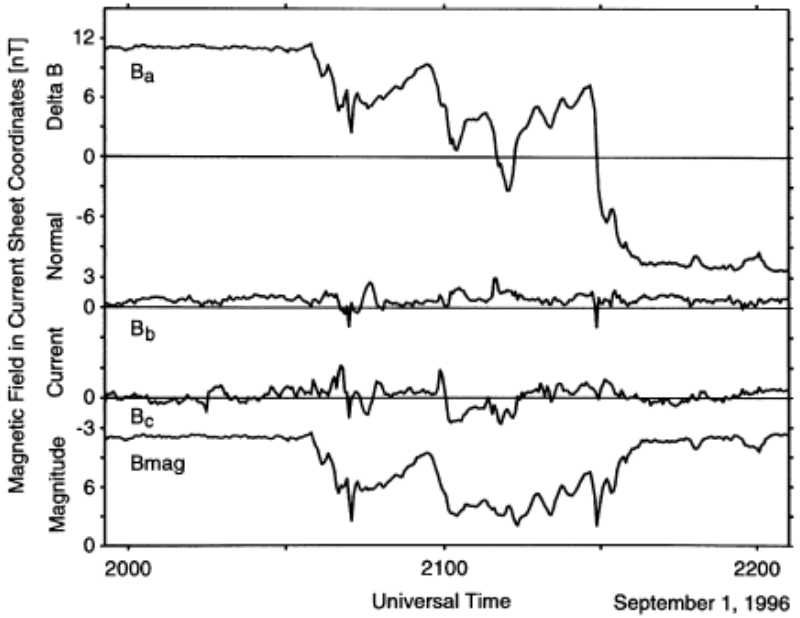
Hill et al. (2008)

Tearing and oscillations





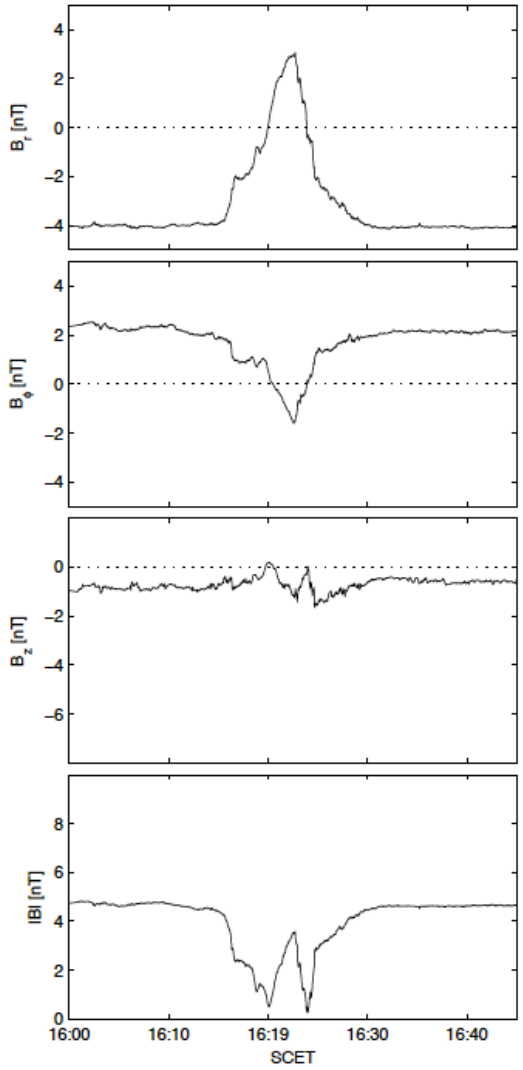


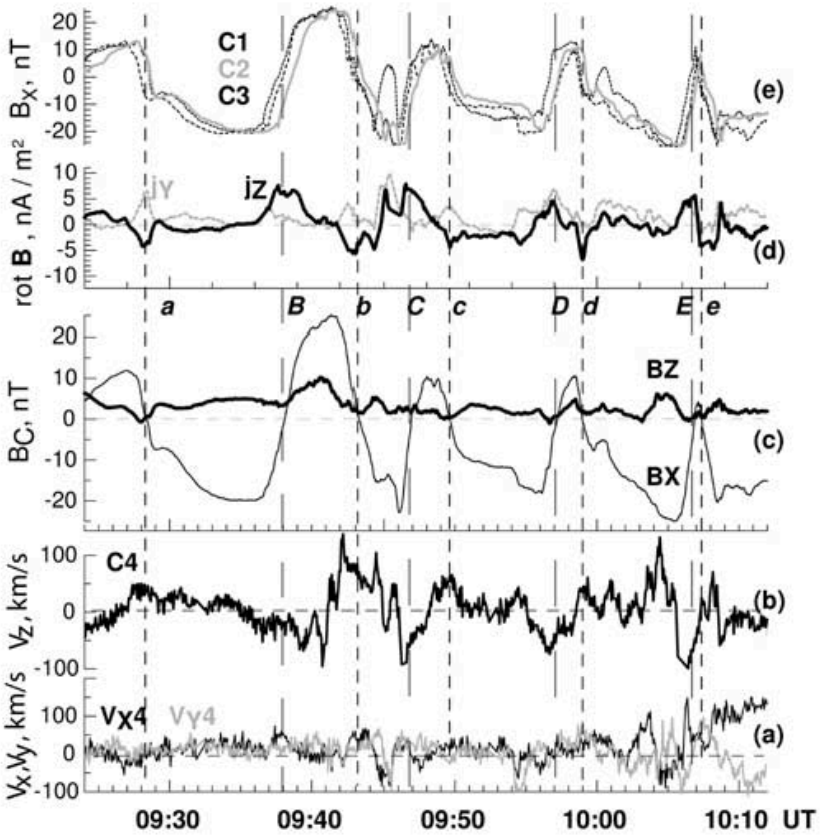


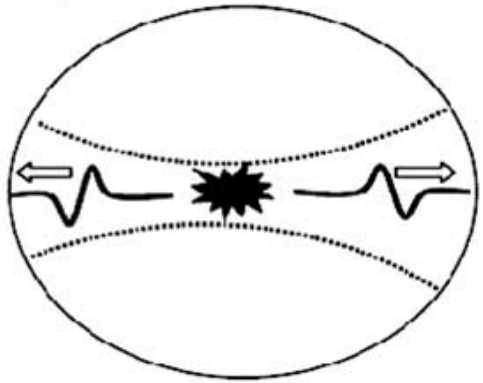
Russell et al. (1999)

Transient waves

Arridge (2007) and Arridge et al. (2007)





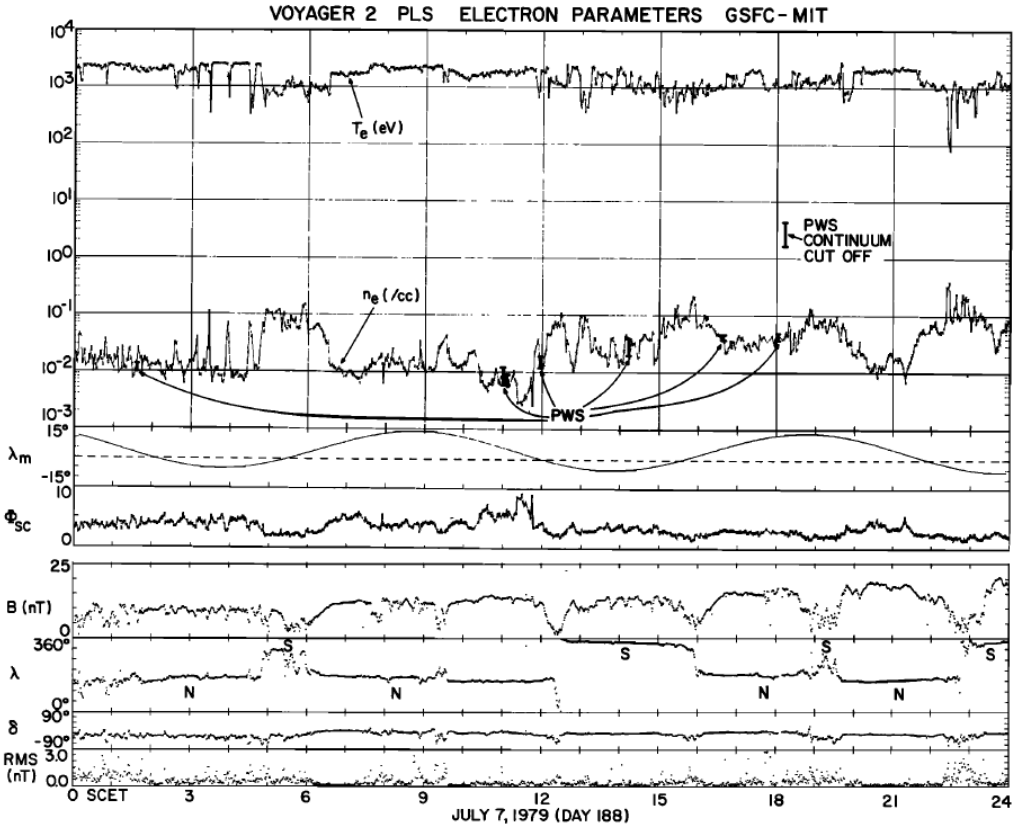


See also Lachin et al. (1997)

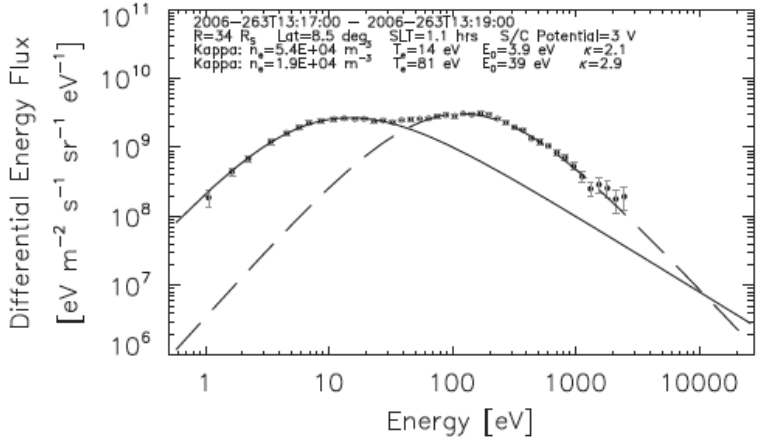
Sergeev et al. (2004)

Cold plasma blobs

- Appearance of transient blobs of cold plasma near the centre of the plasma sheet.
- Also seen in Cassini data at Saturn (Arridge et al., 2009; Rymer et al., 2009; Eviatar et al., in preparation).
- Various interpretations: e.g., local ionisation or rapid (non-adiabatic) outward transport.
- Blobs of plasma also seen in New Horizons tail data from Jupiter – may be result of solar wind interaction.



Scudder, Sittler and Bridge (1981)



Arridge et al. (2009)

What I have not covered

- **Saturn periodicities** and plasma sheet effects: e.g., Morooka et al. (2009), Arridge et al. (submitted), Provan et al. (in preparation, and this meeting), Ramer et al. (this meeting), Mitchell et al. (this meeting), Brandt et al. (2010, this meeting)

- **Injections/interchange** (e.g., Thorne et al., 1997; Kivelson et al., 1997; Russell et al., 2005; André et al., 2005; Kanani et al., this meeting)

- **Plasma sheet angular momentum conservation** and M-I coupling during solar wind compressions/rarefactions and reconnection (e.g., Hanlon et al. (2004), Southwood and Kivelson (2001), Cowley and Bunce (2001), Hill (2001), Cowley et al. (2007), Jackman et al. (2007), Russell et al. (1998).

- **Local time effects, rapid rotation, marginal firehose stability and the loss of plasma** (e.g., Kivelson and Southwood, 2005; Vogt et al., this meeting).

- **Effects from variability of mass sources** (Io / Encleadus): e.g., Brown et al. (1997), Mendillo et al. (1992), Kagitano et al. (this meeting), Yoneda et al. (this meeting), Arridge et al. (in preparation)

- **Global numerical modelling** results showing dynamics (e.g., Fukazawa et al, 2010; Winglee et al., this meeting)

Summary

- Plasma sheets in giant planet magnetospheres are highly dynamic - similar to Mercury and Earth but where additional physical effects come into play:
  - **geometry**, **internal mass/energy sources**, **rapid rotation**.

- Discussed:
  - Plasma sheet global shape and position and observations of its dynamics.
  - Plasma sheet thickness variability.
  - Centrifugal effects on latitudinal structure.
  - Reconnection, periodic plasmoid release and recurrent energisation.
  - Energisation of plasma.
  - Current sheet tearing.
  - Current sheet oscillations and waves.
  - Discrete blobs of plasma.

- Big questions:
  - Interplay between internal and external forcing.
  - Effects due to scale.
  - Plasma transport and changes in time scale as a result of dynamics.
  - Dynamics associated with mass loss.