

# AURORAE AT JUPITER: RECENT FINDINGS



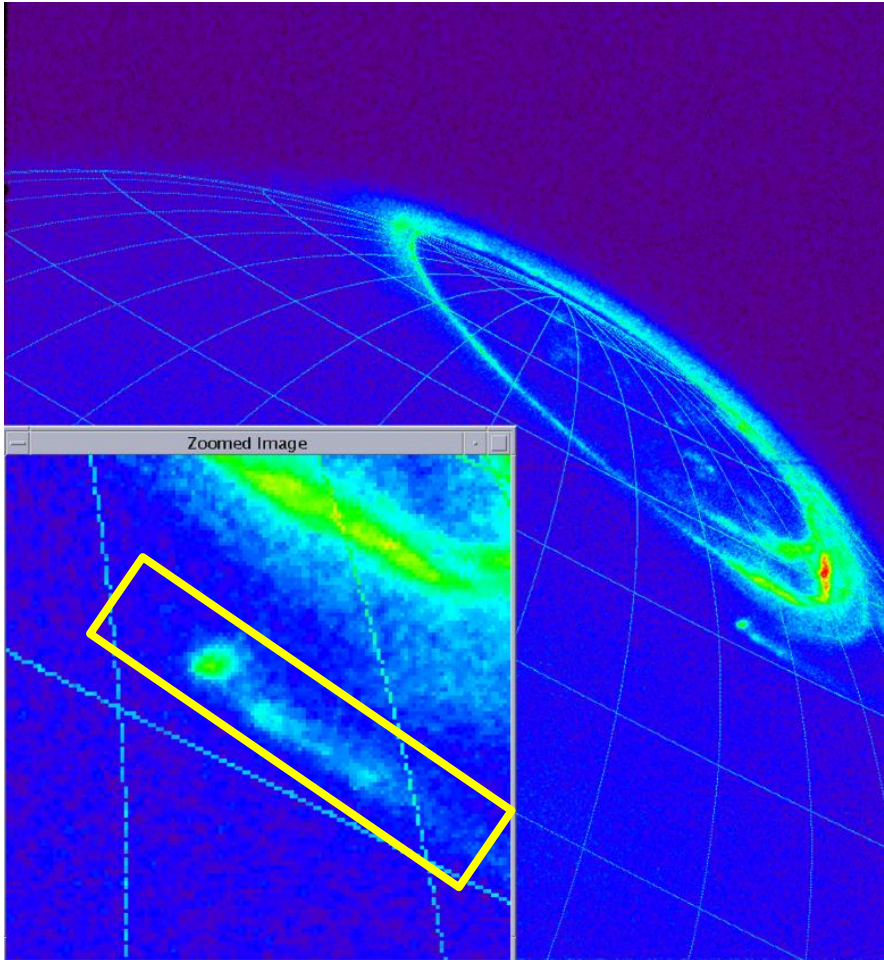
Bertrand Bonfond - LPAP/ULg



# The satellite footprints

# What is a satellite footprint?

3

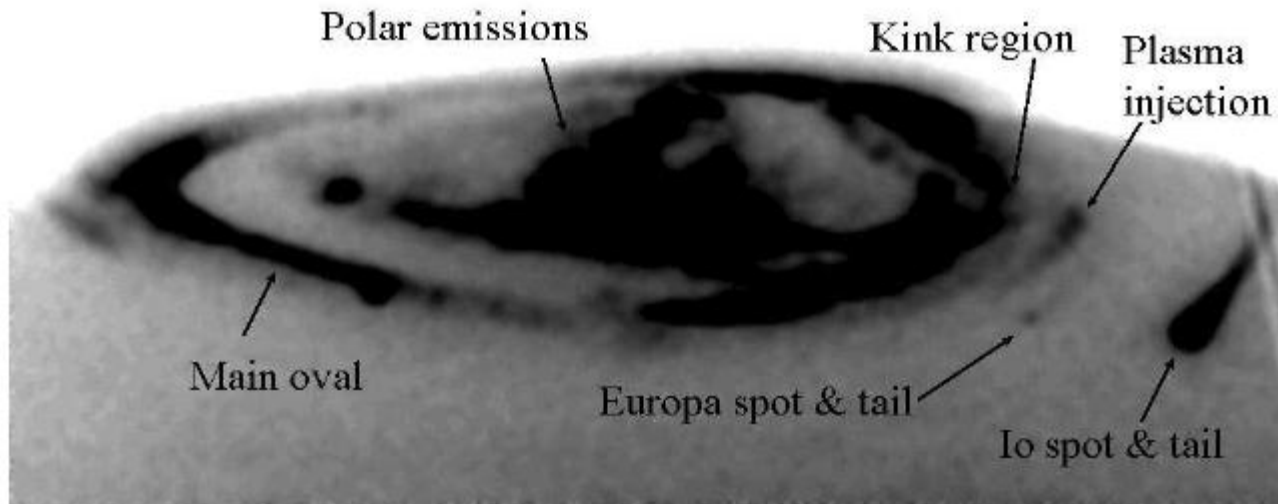


- The Io footprint is formed of
  - ▣ several spots
  - ▣ a trail

# The Europa tail

4

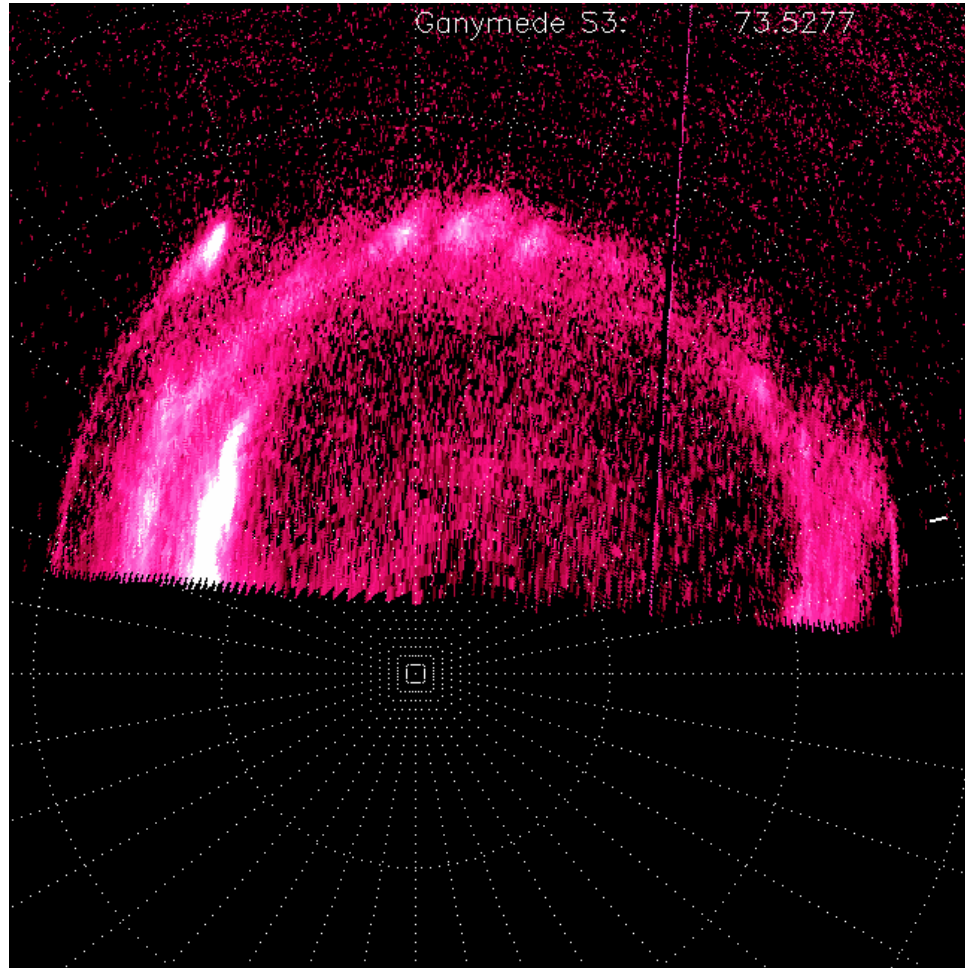
- The Io footprint is not the only footprint to have a tail



*Grodent et al., 2006*

# The multiple spots of the Ganymede footprint

5

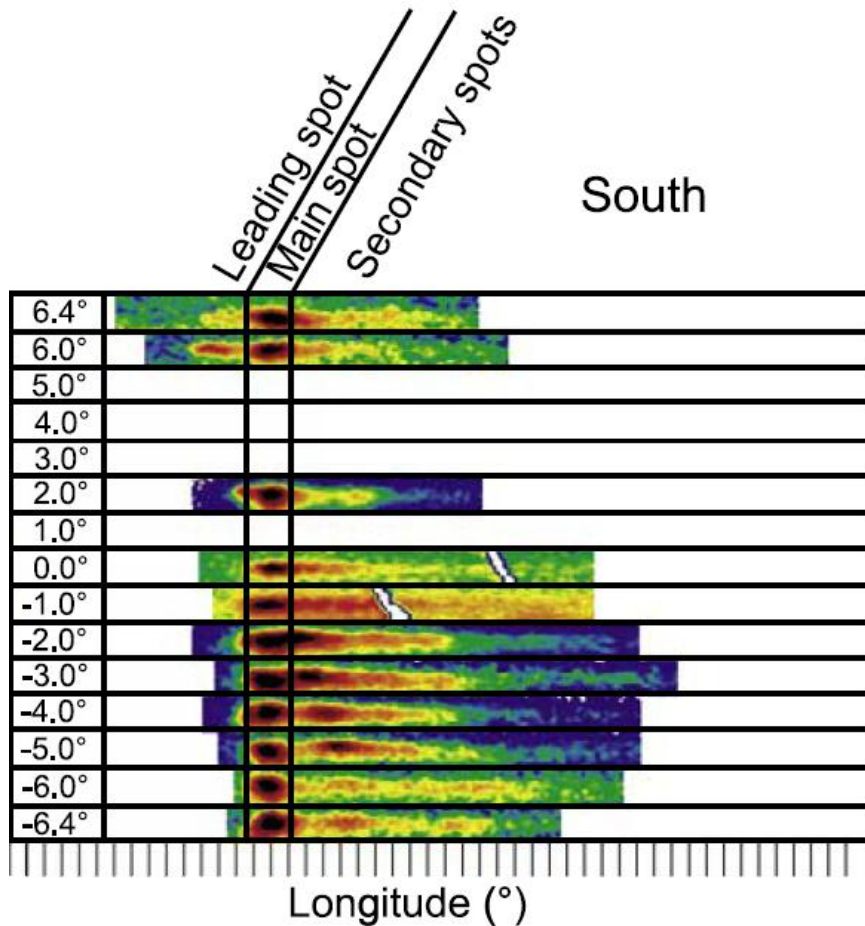


*Bonfond et al., MOP meeting, Boston, 2011*

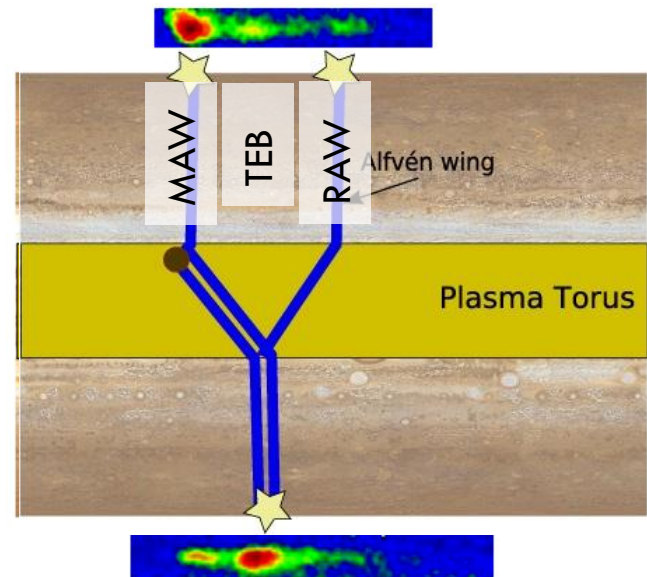
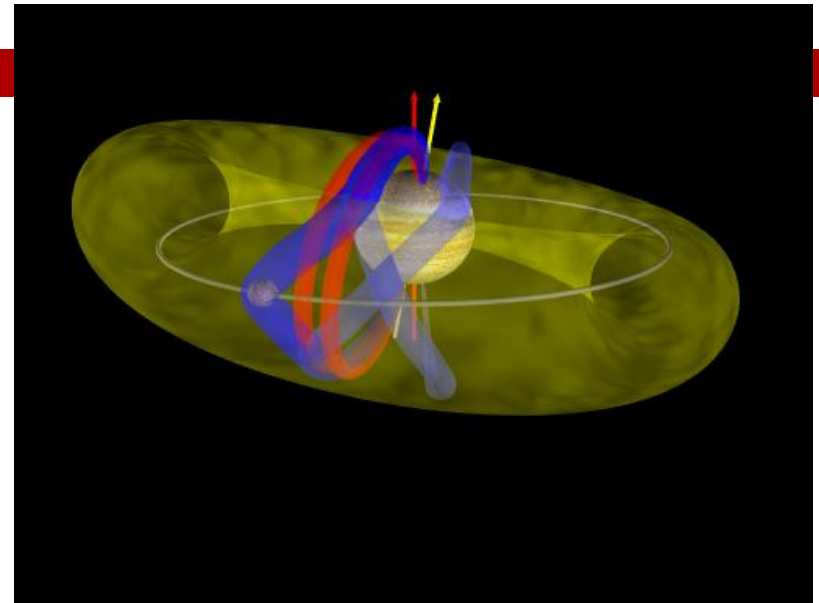


# Spots multiplicity evolution

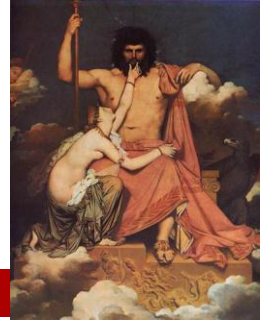
6



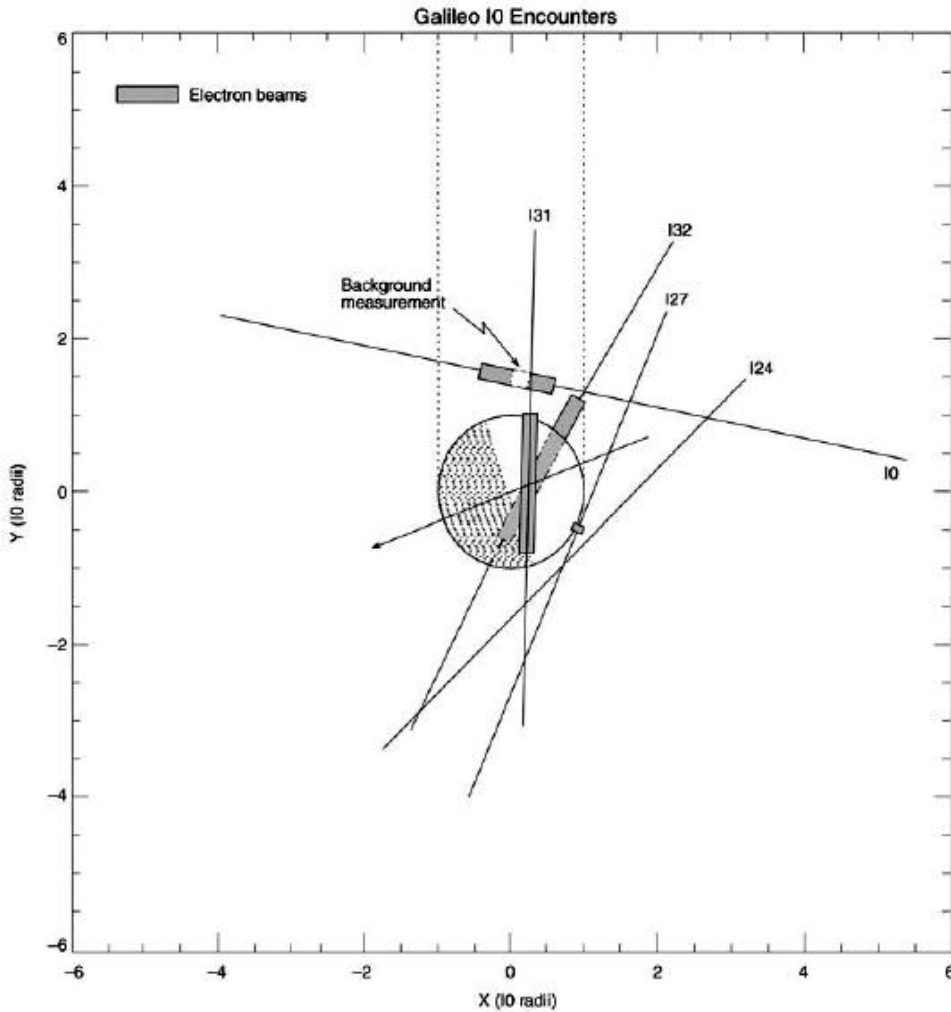
Bonfond et al., 2008



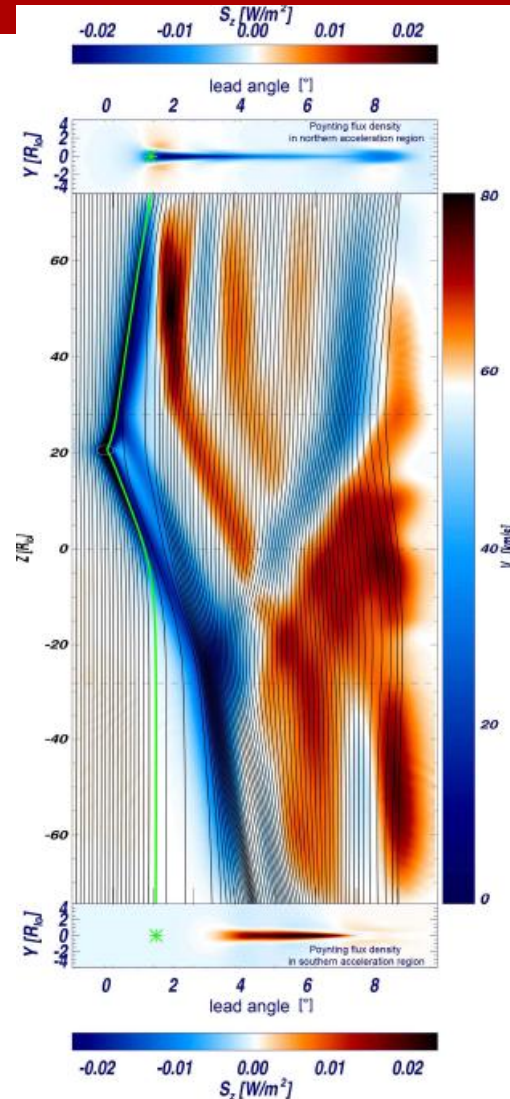
# Electron beam on Io



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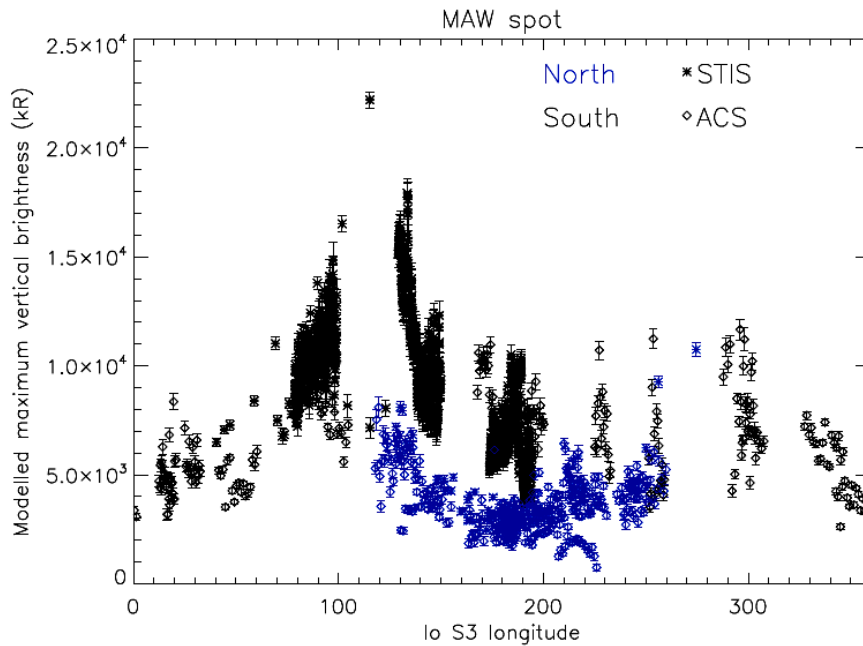
Williams et al., 2003



Jacobsen et al., 2010

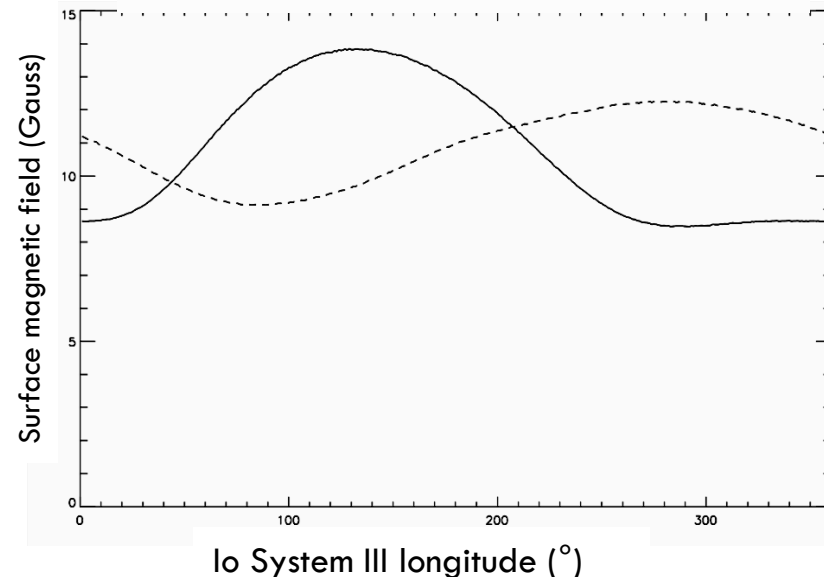
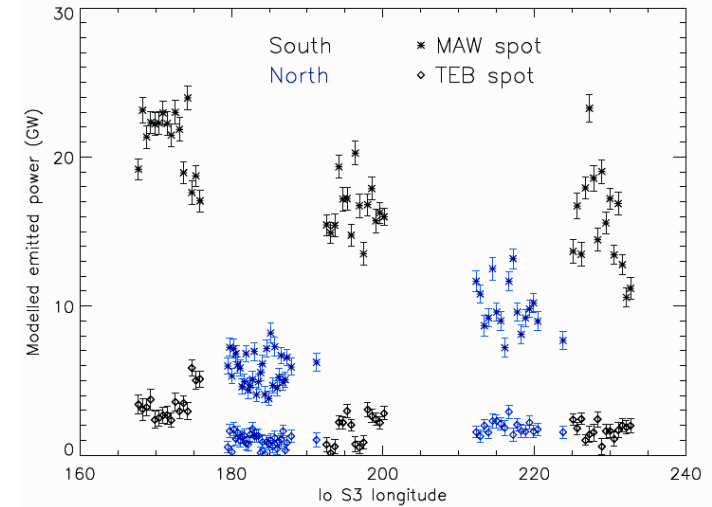
# System III spots brightness variations

8



*Bonfond et al., submitted*

- Influence of the magnetic field:
  - Transmission through the torus boundary
  - Electron acceleration process
  - Altitude of the mirror point

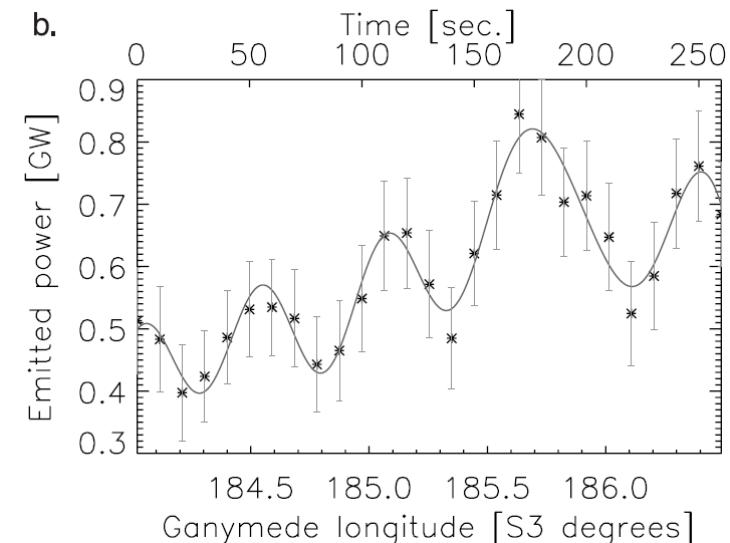
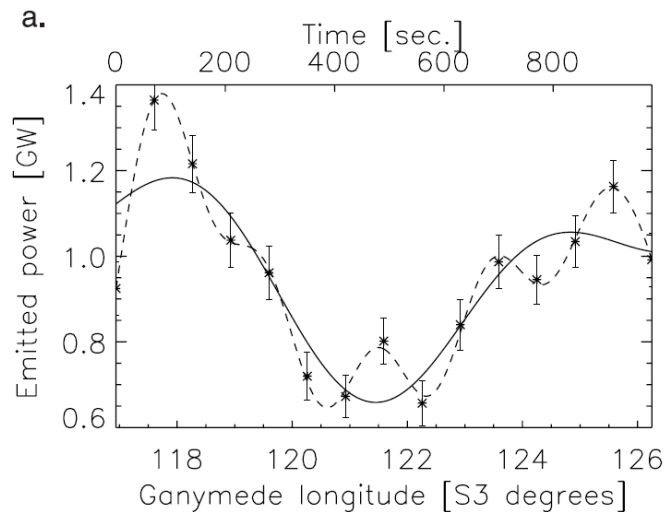
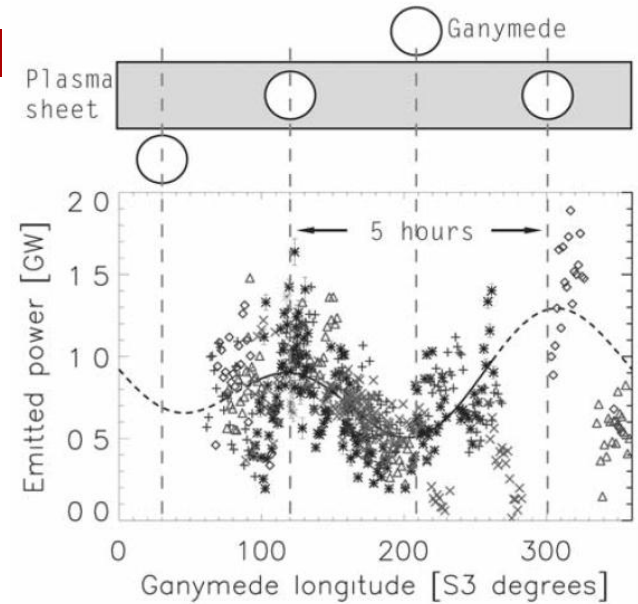




# Ganymede footprint brightness variations

9

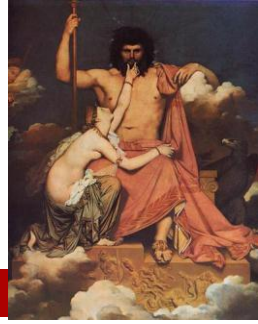
- 5 hours – System III
  - Flapping of the current sheet
- 10-40 minutes
  - Related ton injections?
- 100-seconds
  - Bursty reconnections at Ganymede?
  - Double layer generation



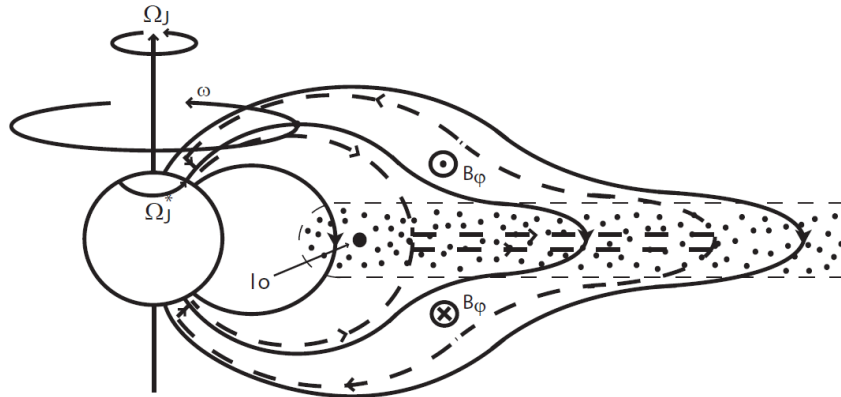
Grodent et al., 2009

# The outer emissions

# The whole story

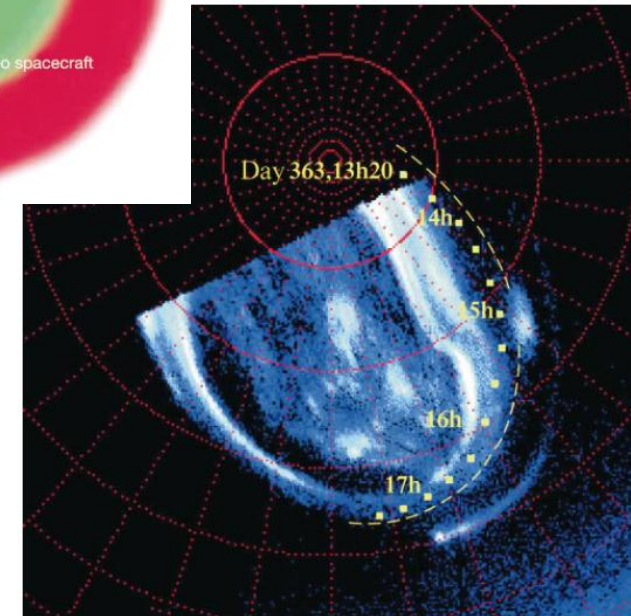
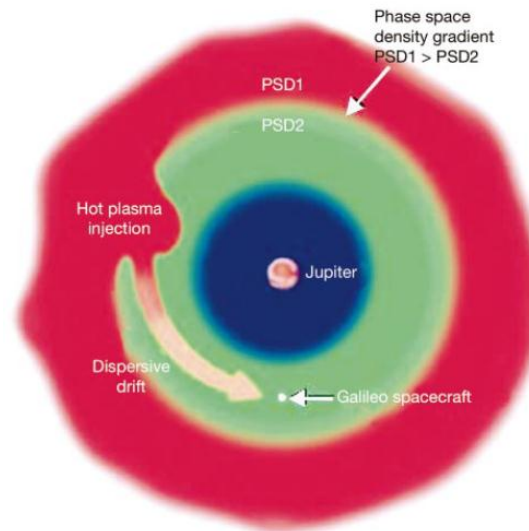


- Heavy flux tubes go out



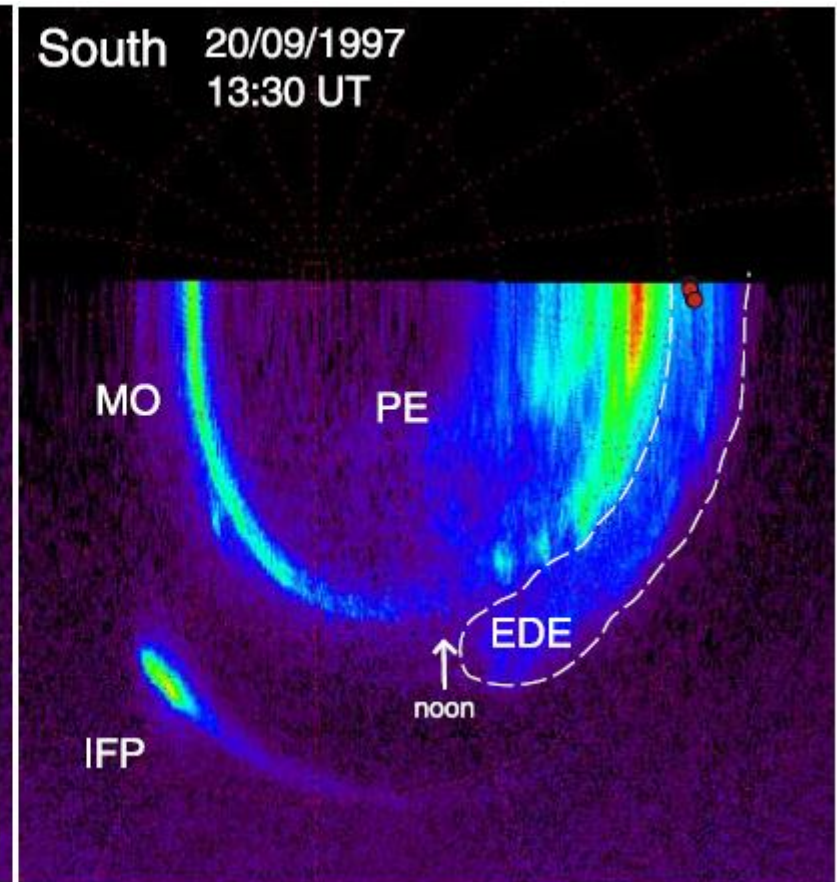
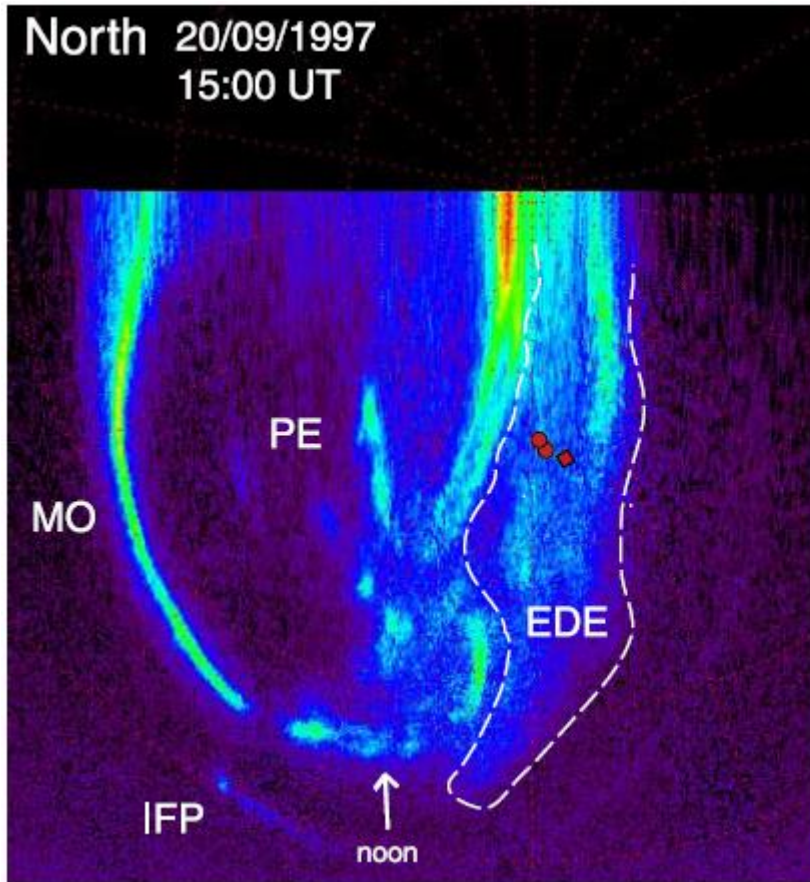
Cowley and Bunce, 2001

- Emptied flux tubes go in

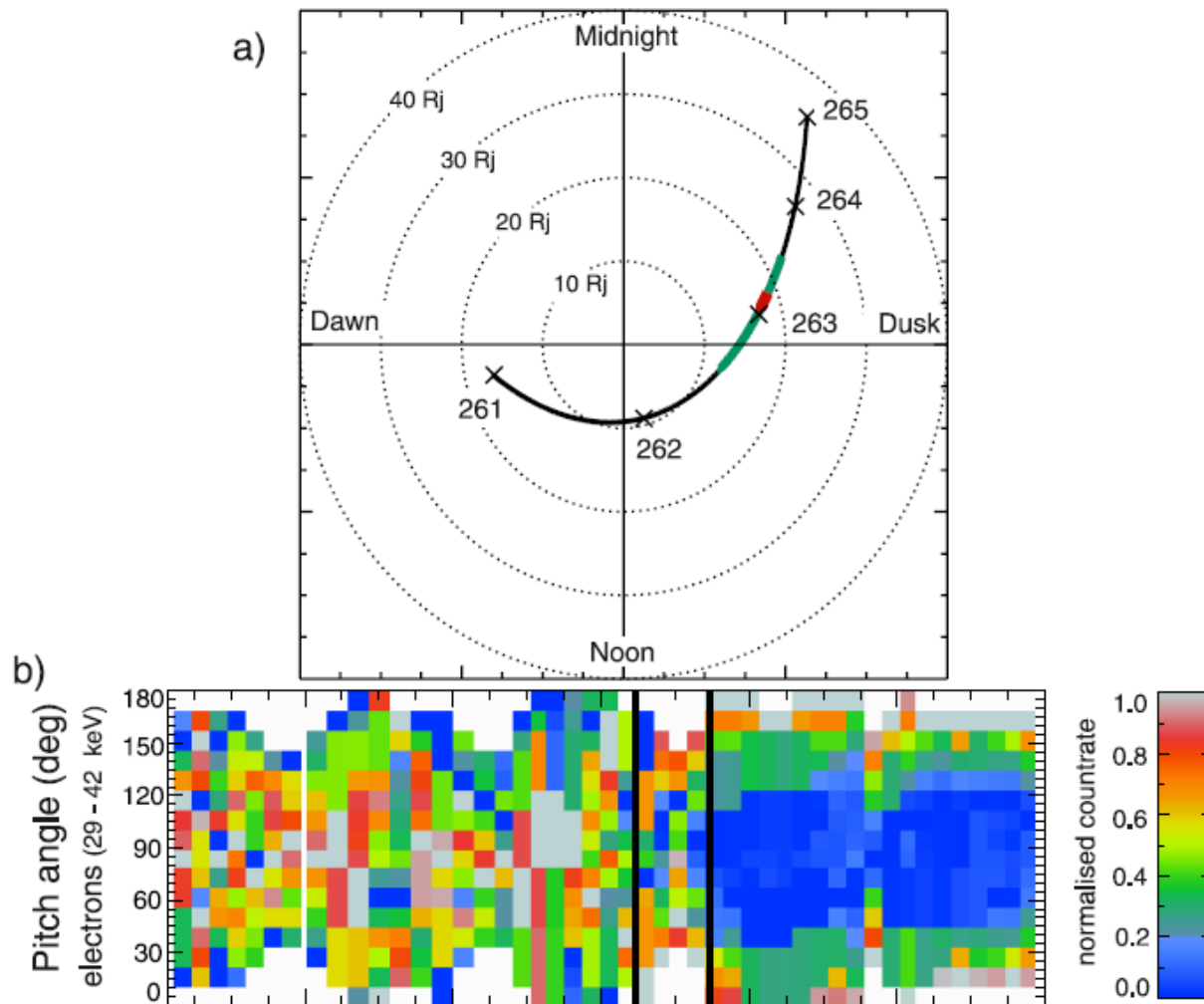
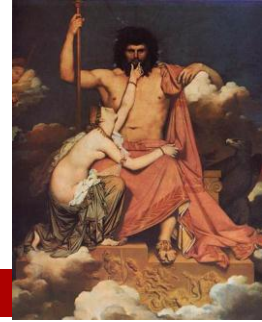


Mauk et al., 2002

# Equatorial diffuse emissions



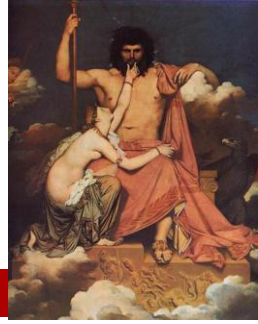
# Equatorial diffuse emissions



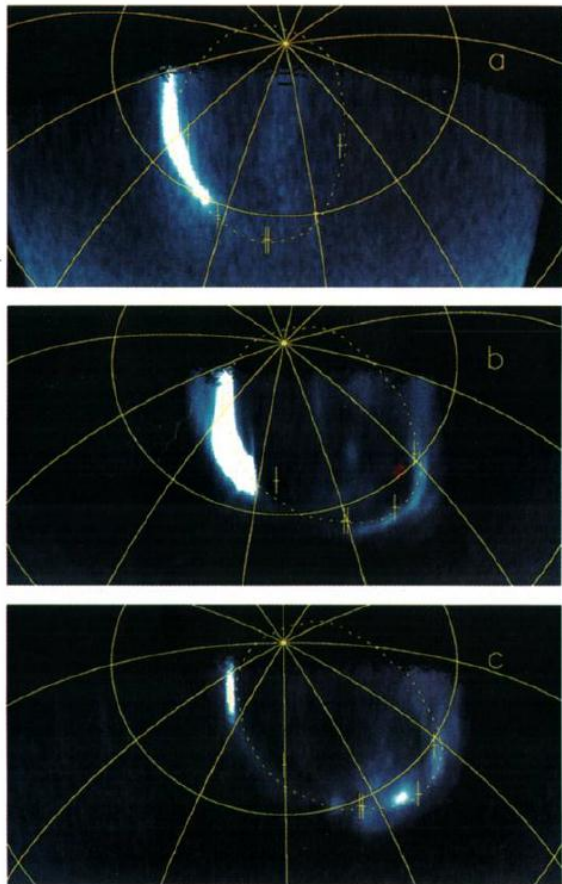


The main oval

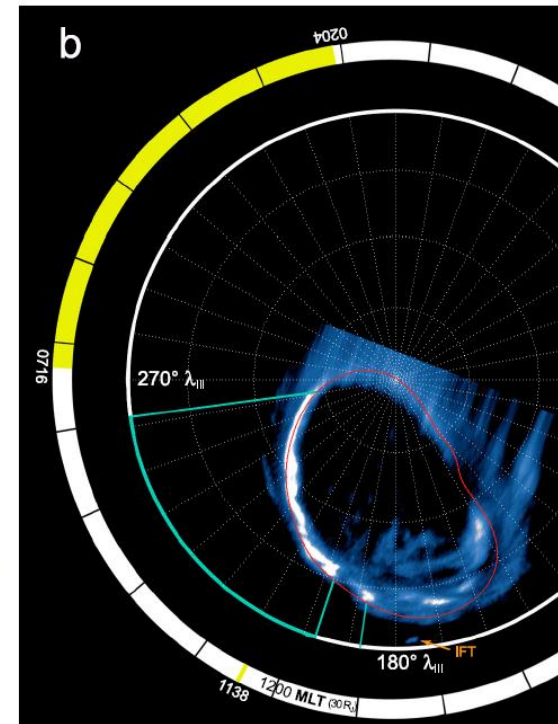
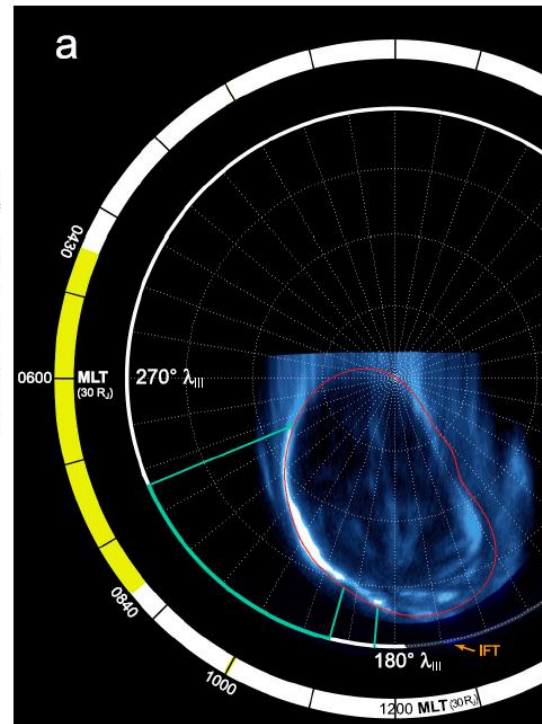
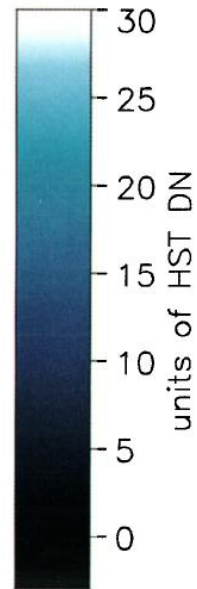
# Dawn storms



Dawn Storms Projected

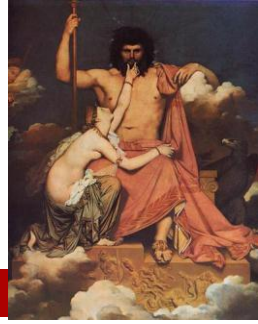


Clarke et al., 1998

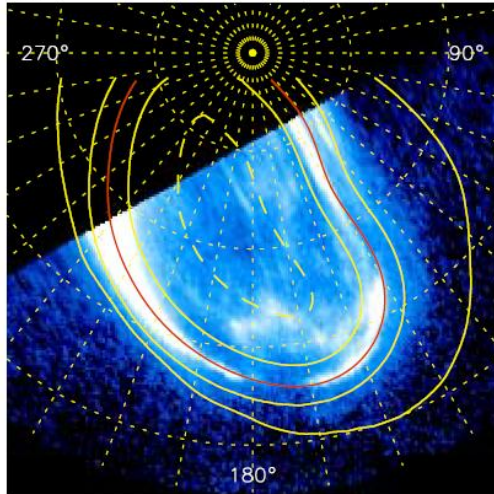


Gustin et al., 2006

# Dawn storms



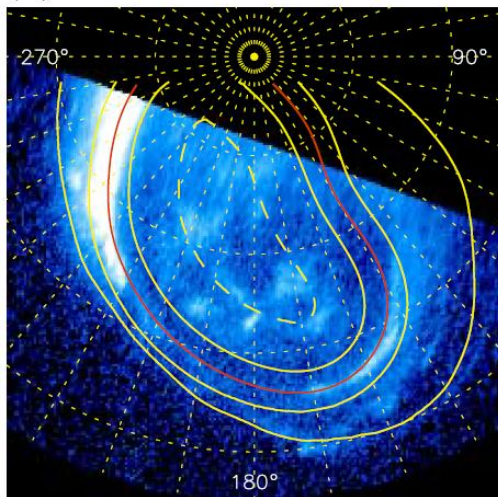
(i) 069 04:38:37 CML=151.2



Compressed magnetosphere

- No apparent solar wind trigger for them

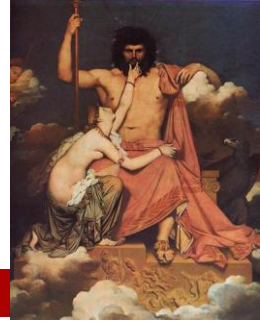
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Expanded magnetosphere

Nichols et al., 2009

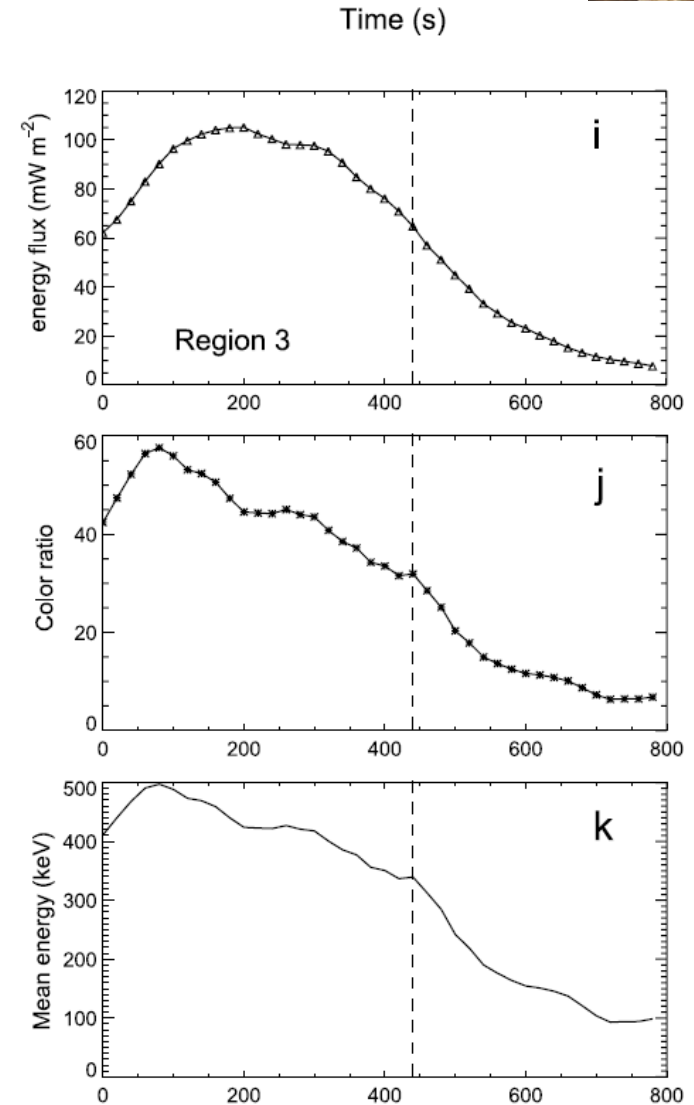
# Dawn storms



Gustin et al., 2006

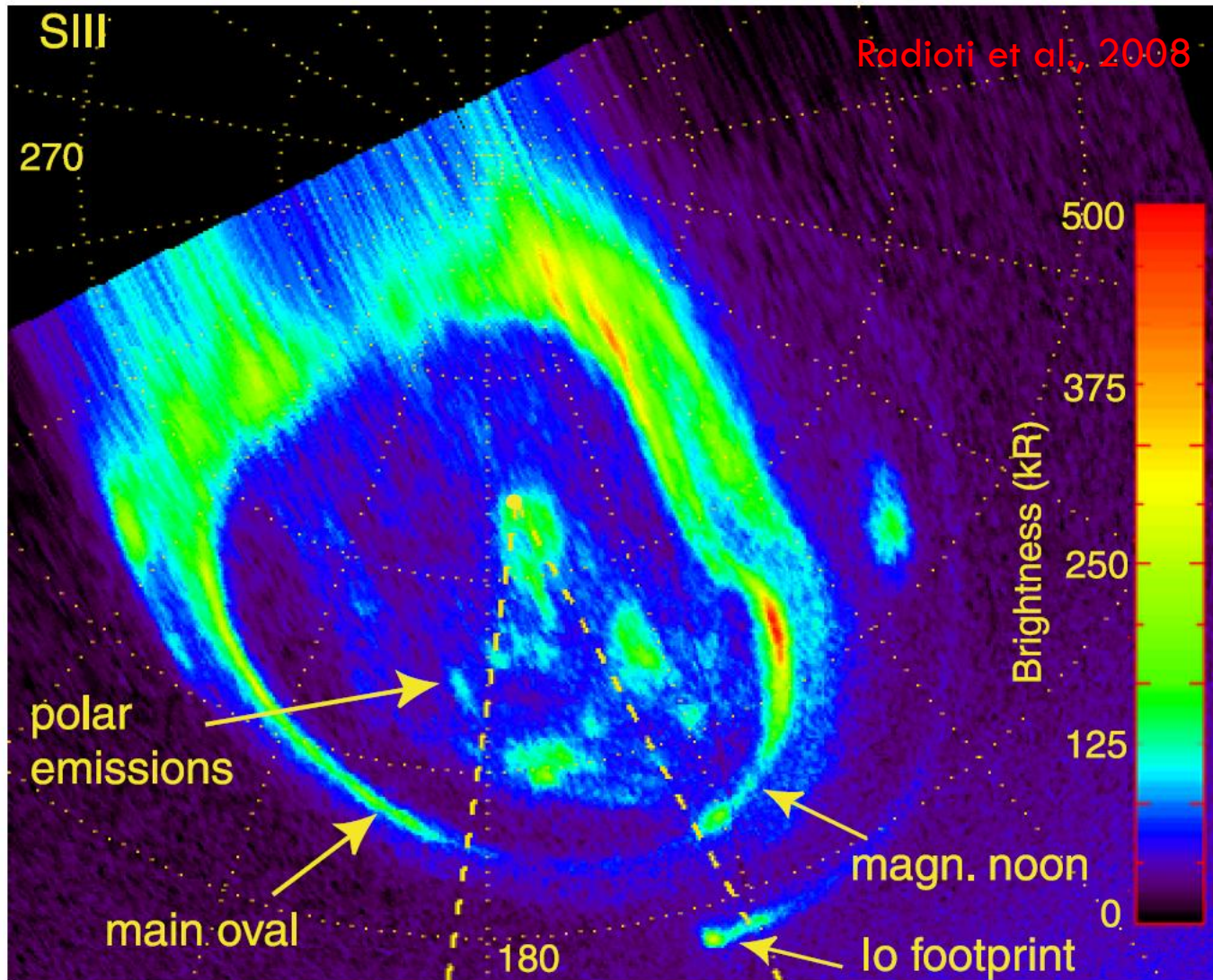
1	$\theta = 71.1$	$\lambda_{III} = 222.9$
2	$\theta = 65.8$	$\lambda_{III} = 212.8$
3	$\theta = 63.7$	$\lambda_{III} = 207.2$
4	$\theta = 61.6$	$\lambda_{III} = 202.5$

- Color ratios up to 62
- $E^-$  energy above 400 keV



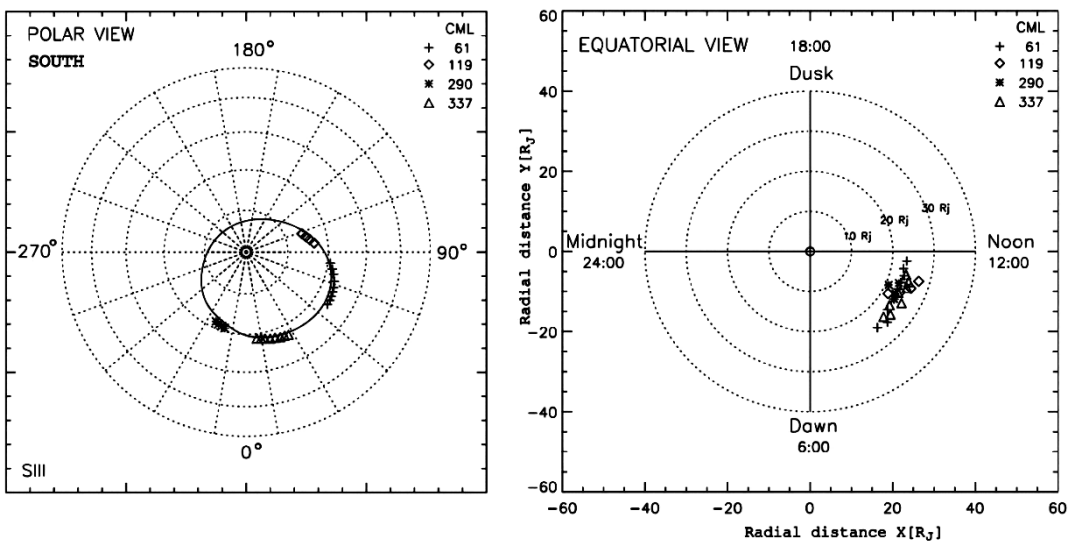
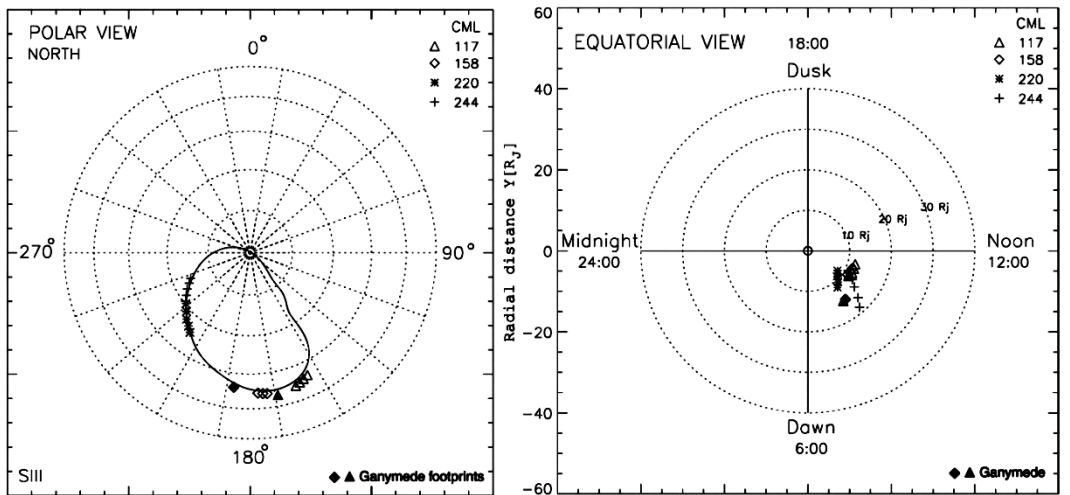


# Discontinuity

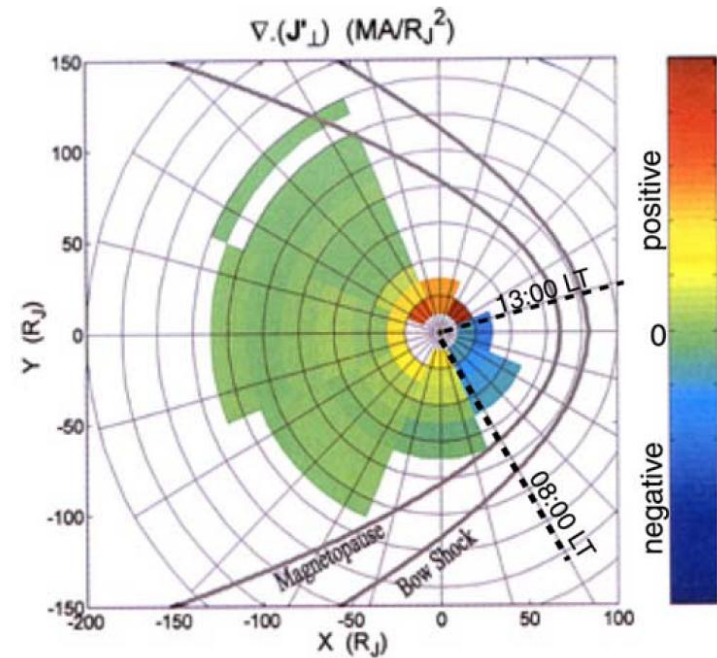




# Discontinuity

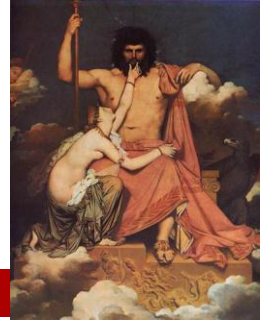


□ Maps to the pre-noon sector



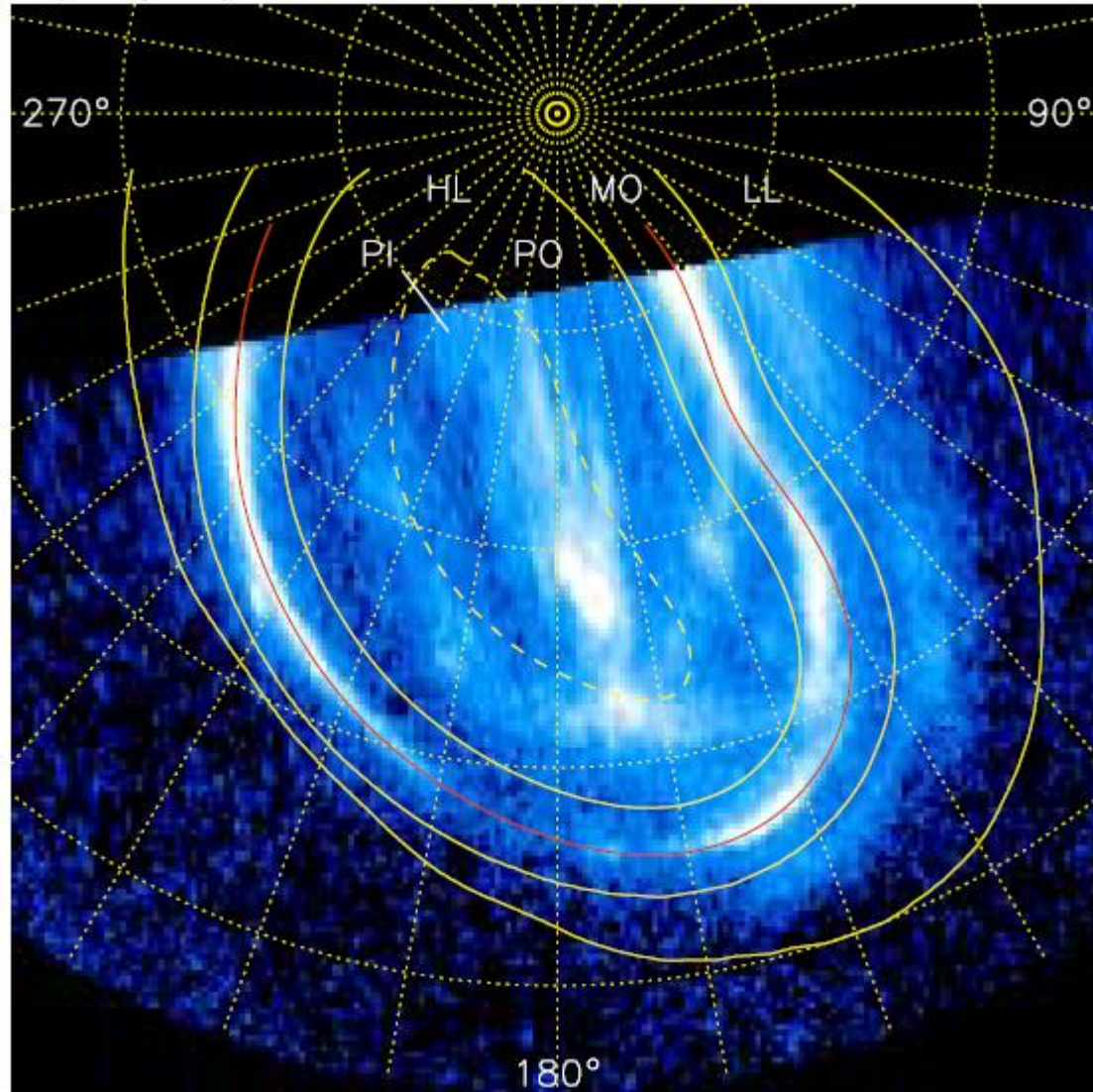
Radioti et al., 2008; Khurana et al., 2004

# Brightness variations

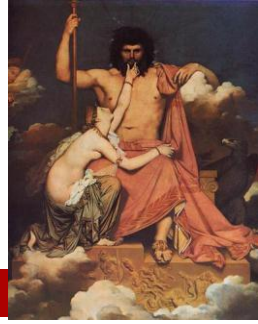


27/02(058) 11:06:46 B7.012

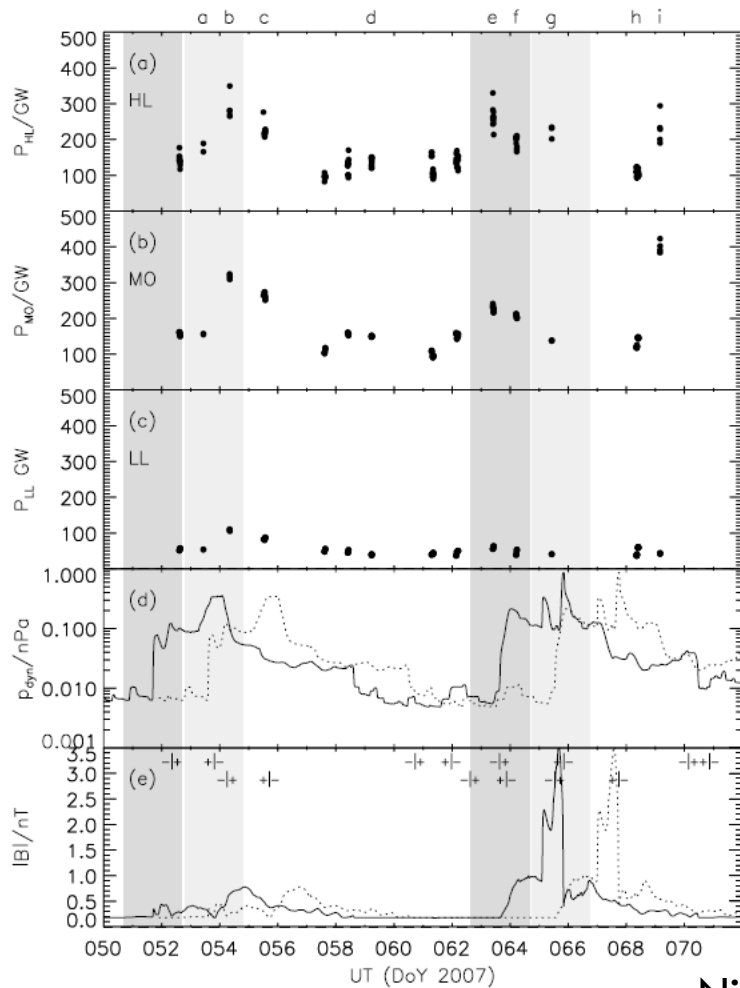
CML=170.1



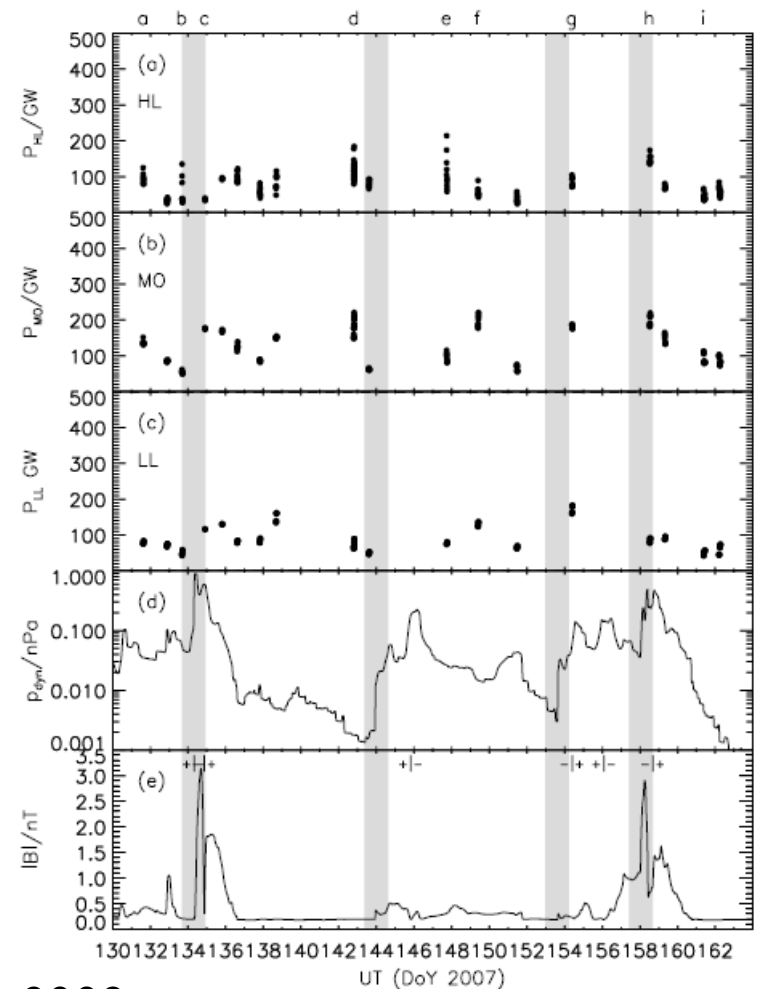
# Brightness variations



February/March 2007

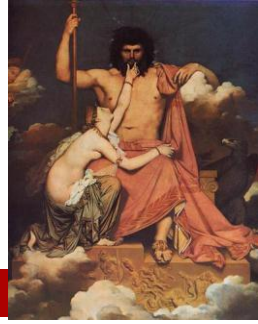


May/June 2007

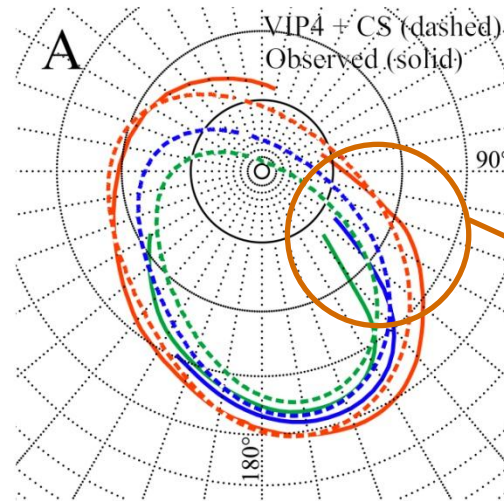
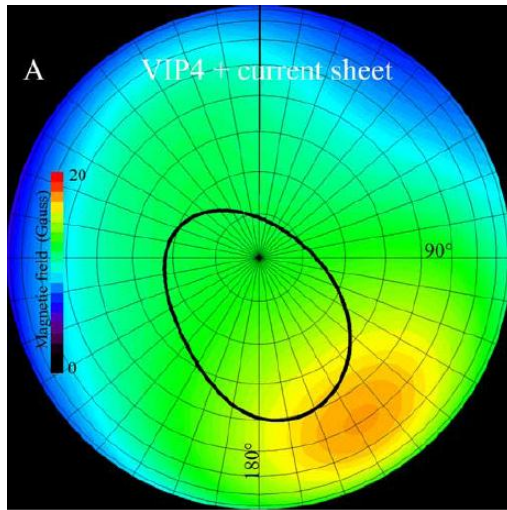




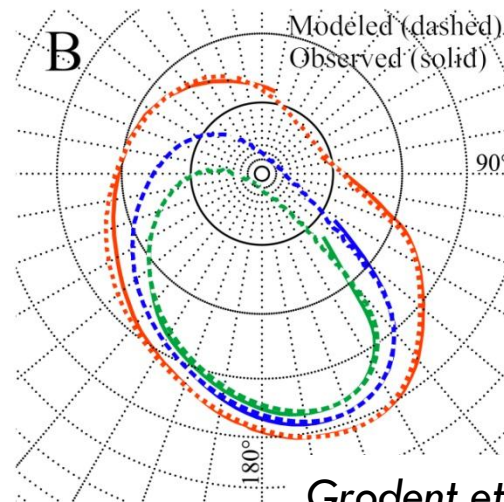
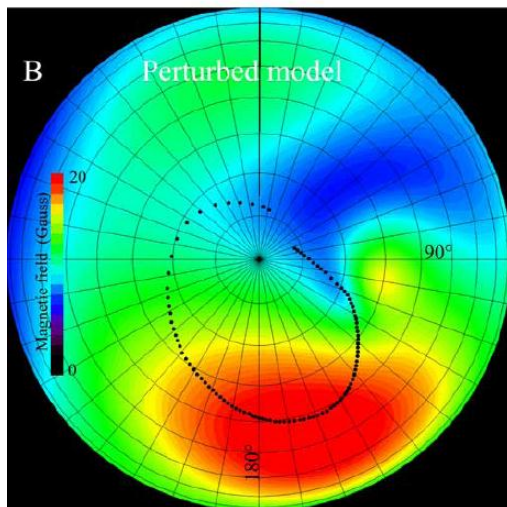
# Magnetic field models



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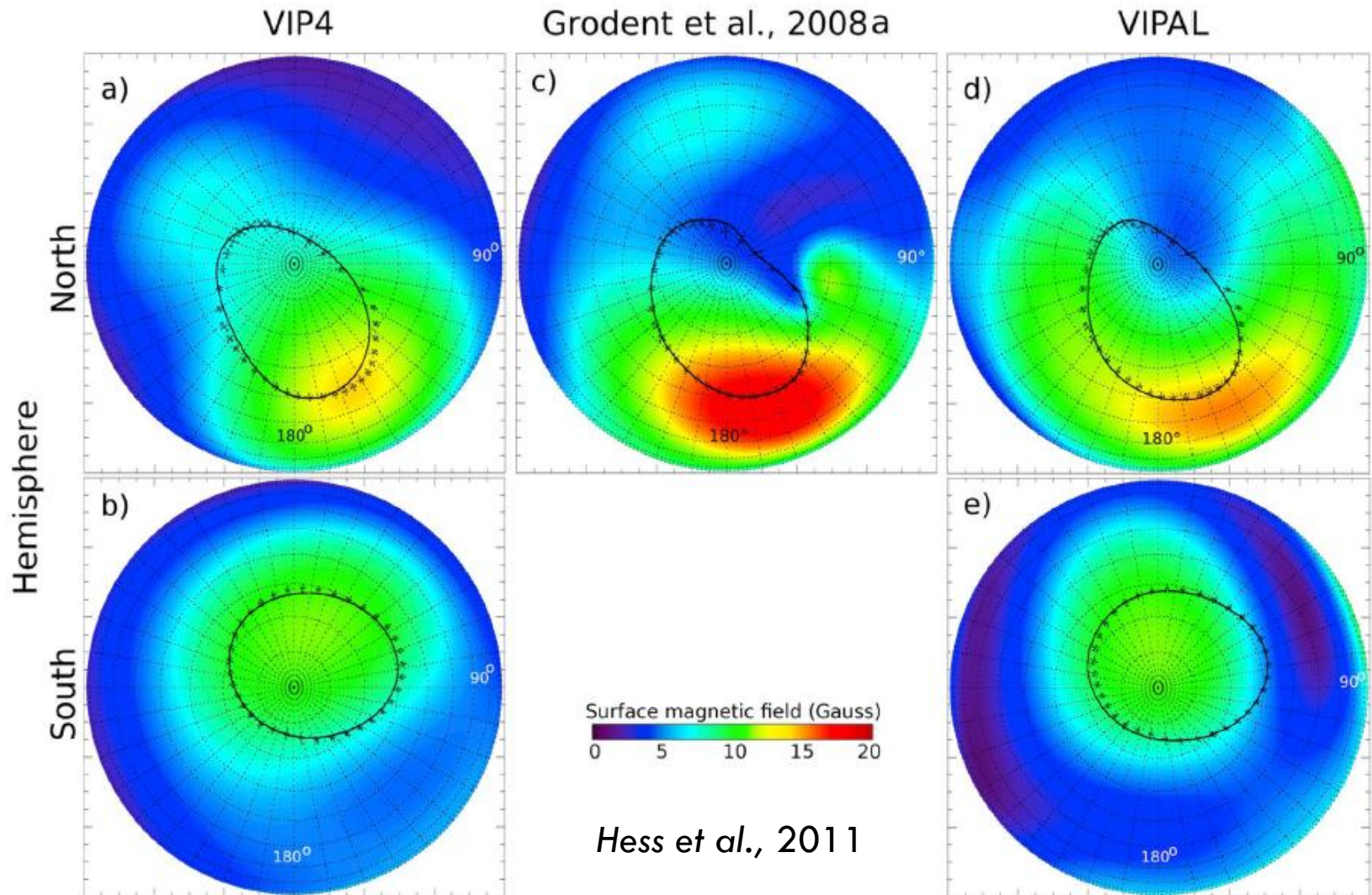
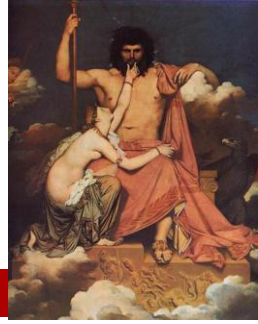
■ Magnetic anomaly



■ New model:  
4th order multipole  
+ dipole

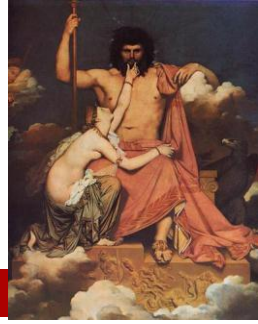
Grodent et al., 2008

# Magnetic field models

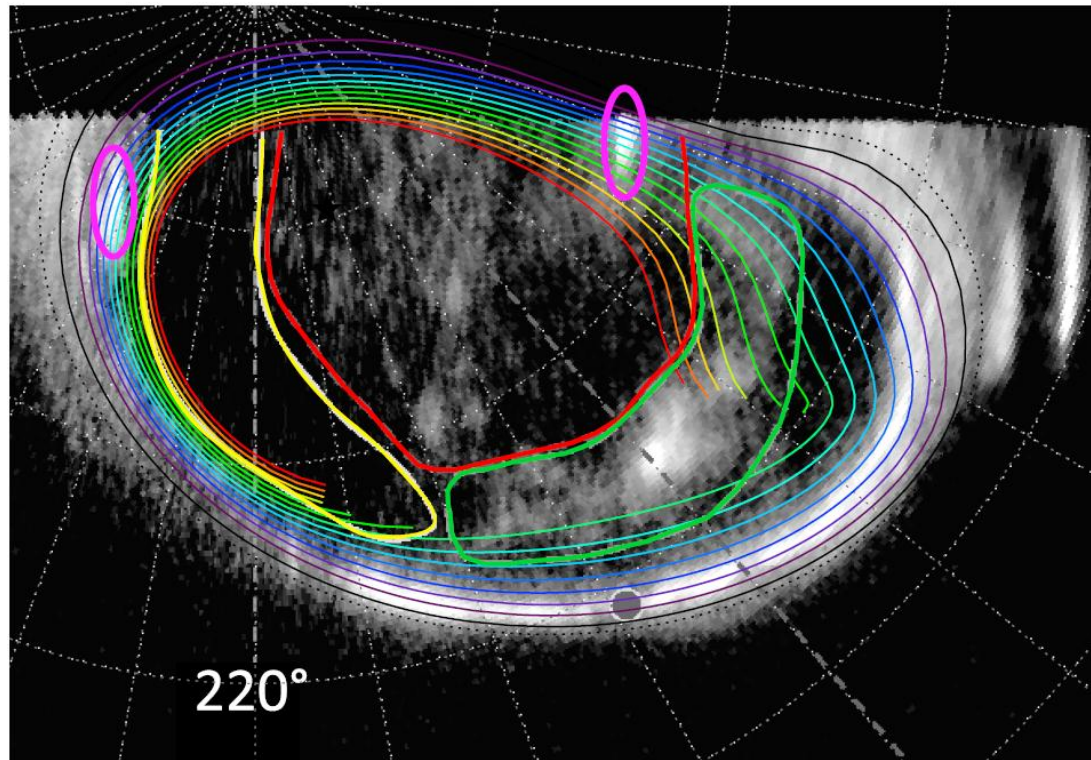




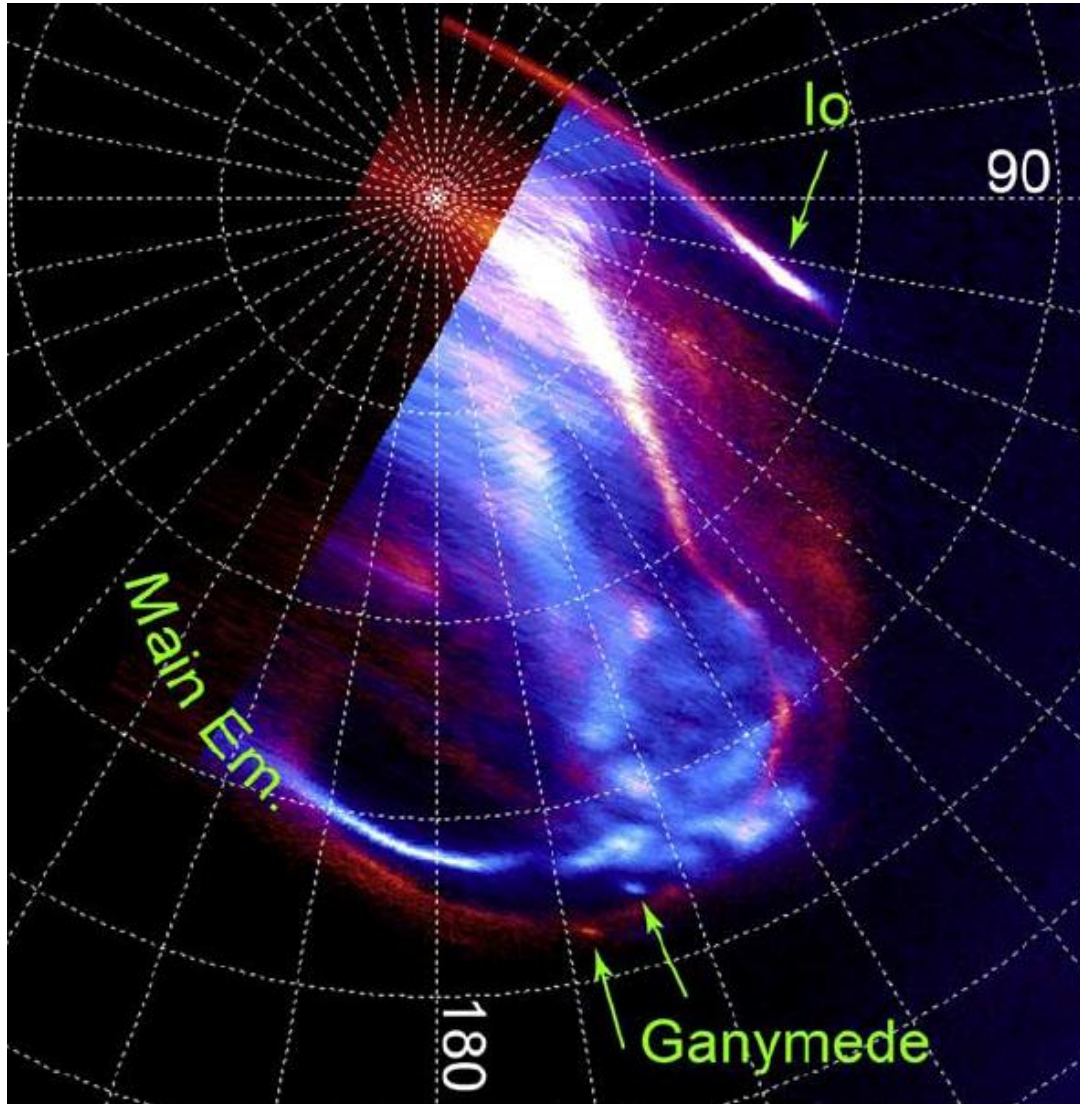
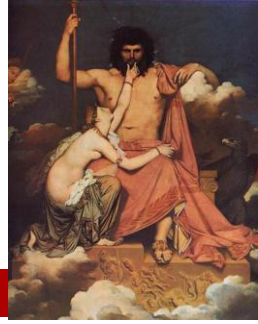
# Local time variations



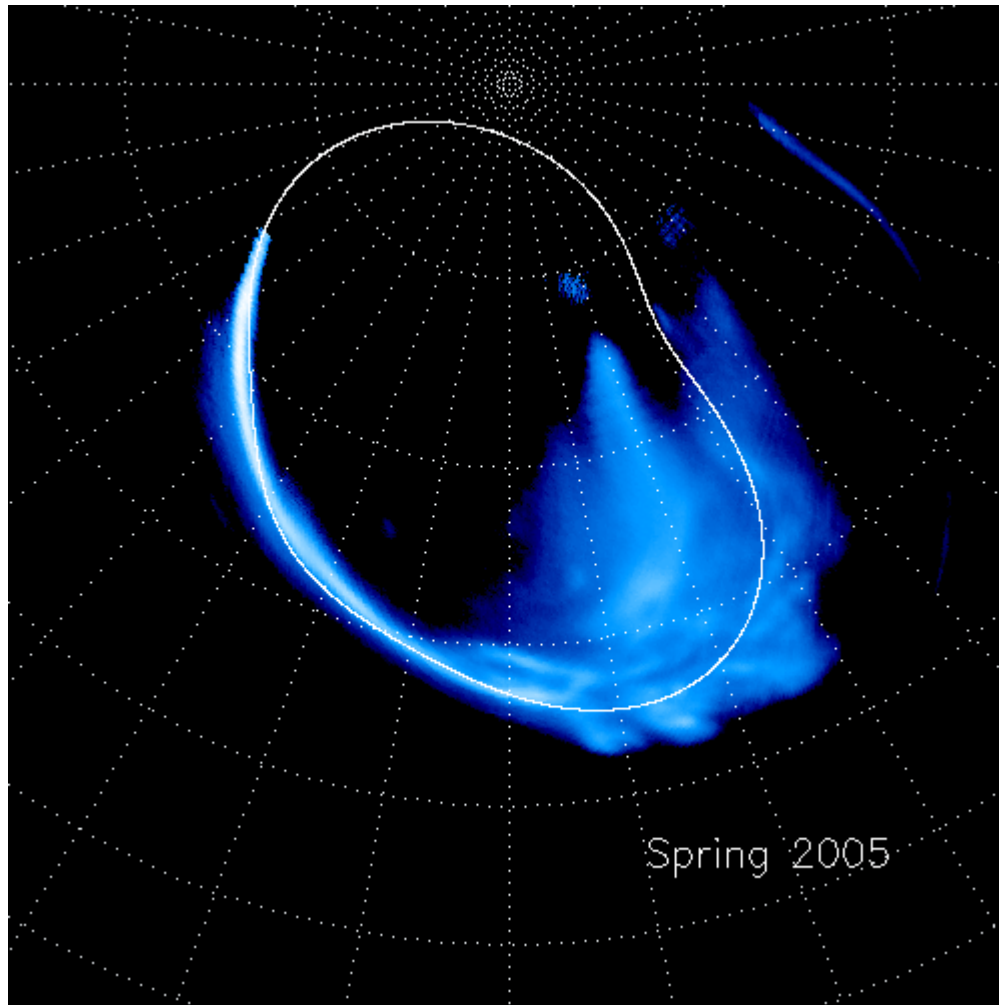
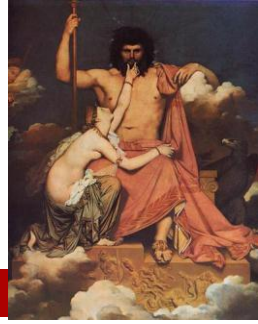
## E. Composite of Mapping Results and UV Auroral Observations



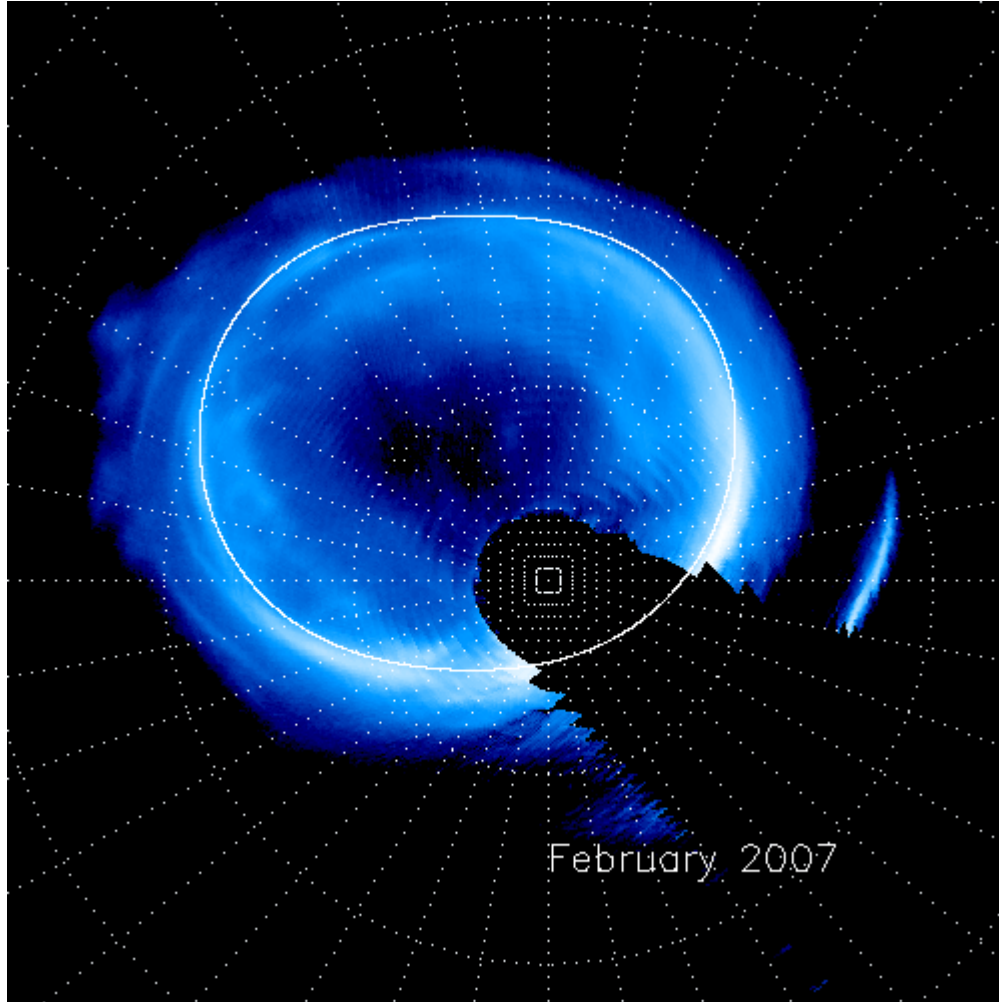
# Main emission and GFP motion



# Main oval expansion



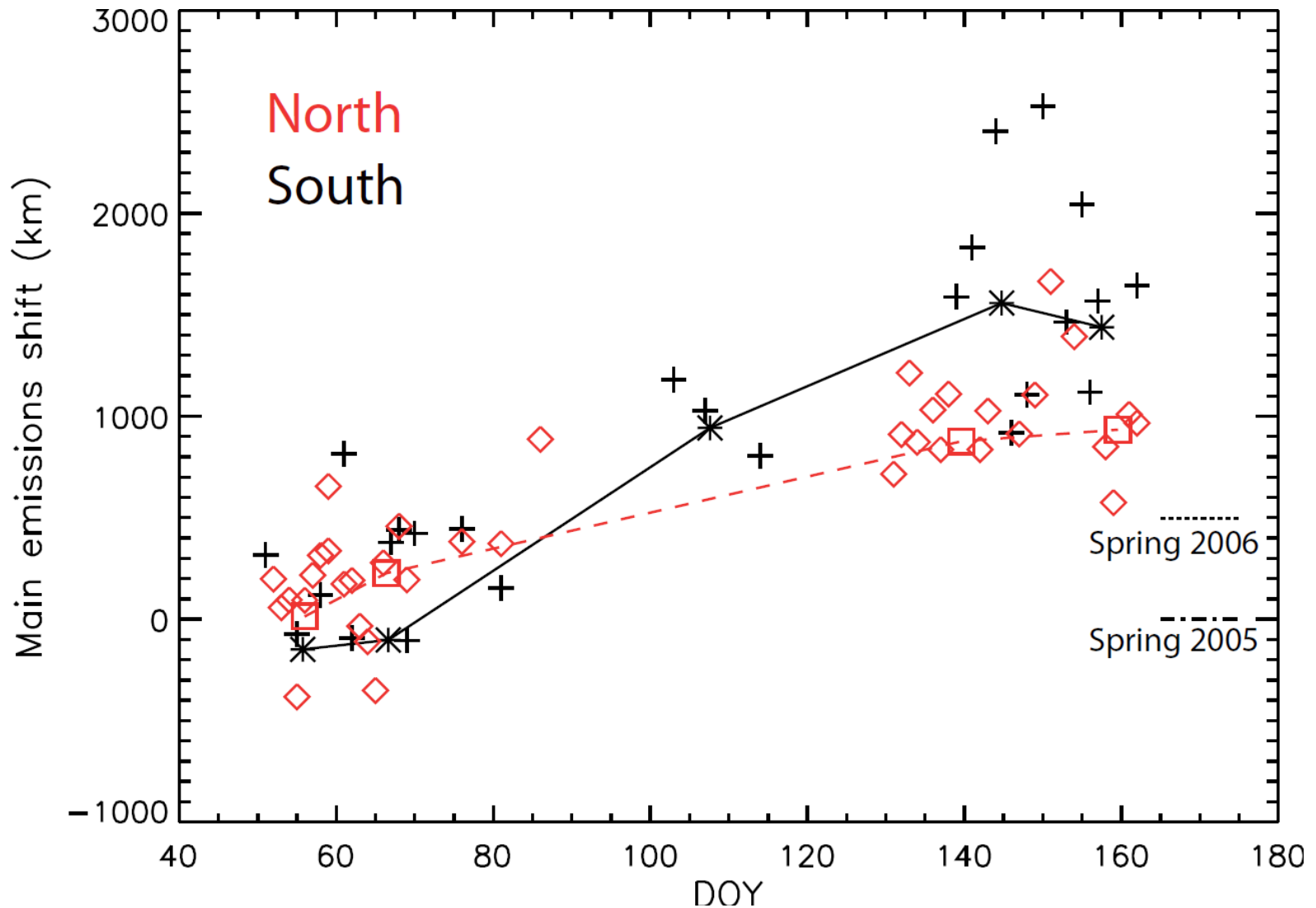
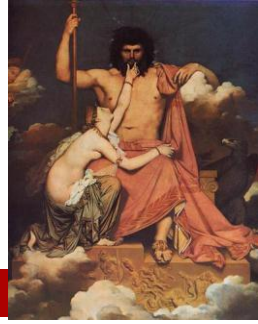
# Main oval expansion



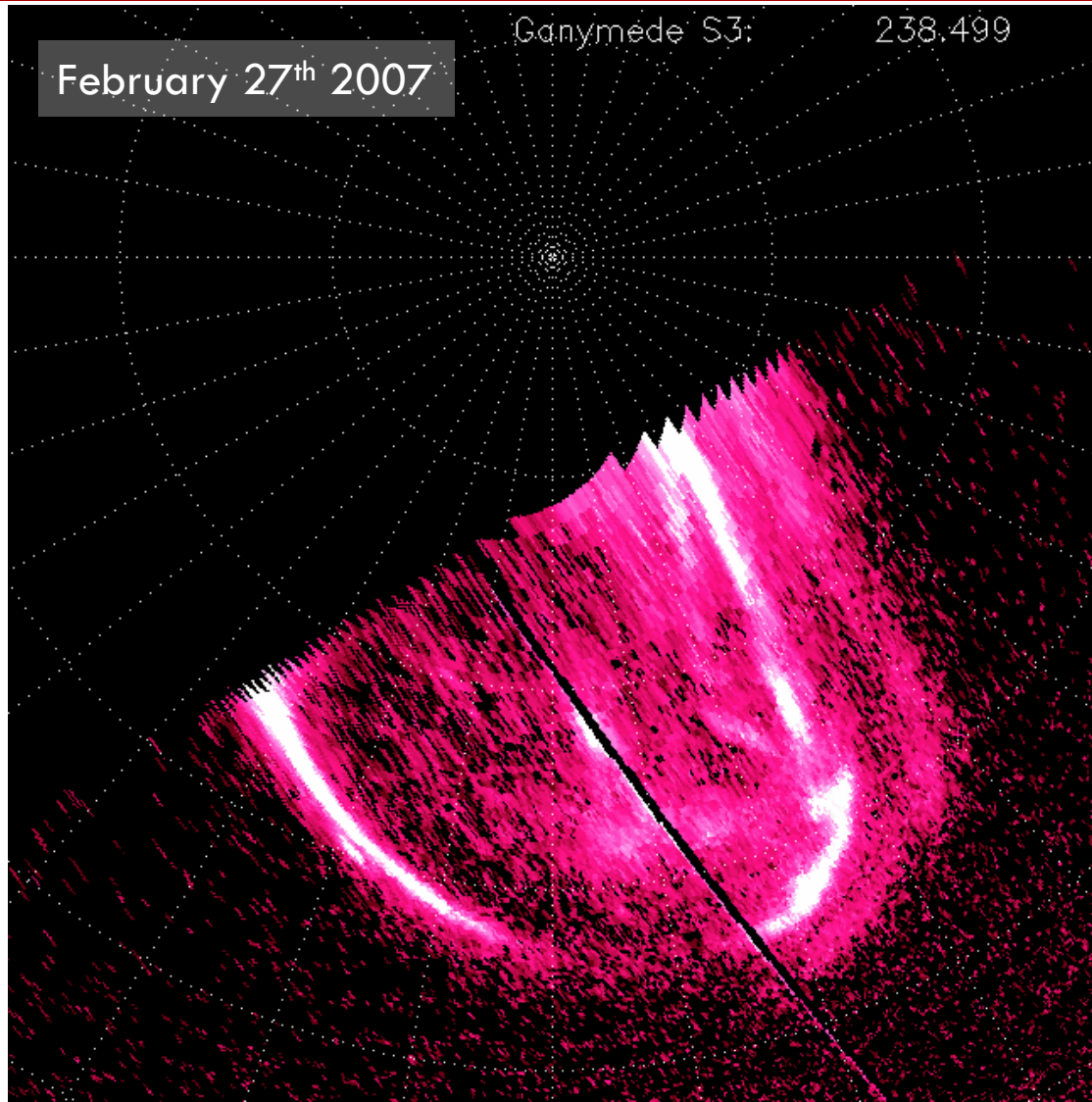
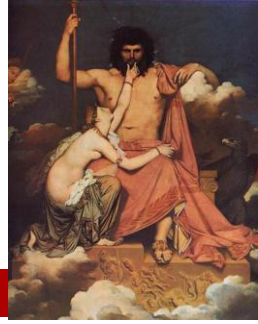
+250GWb according  
to VIPAL  
(Hess et al., 2011)



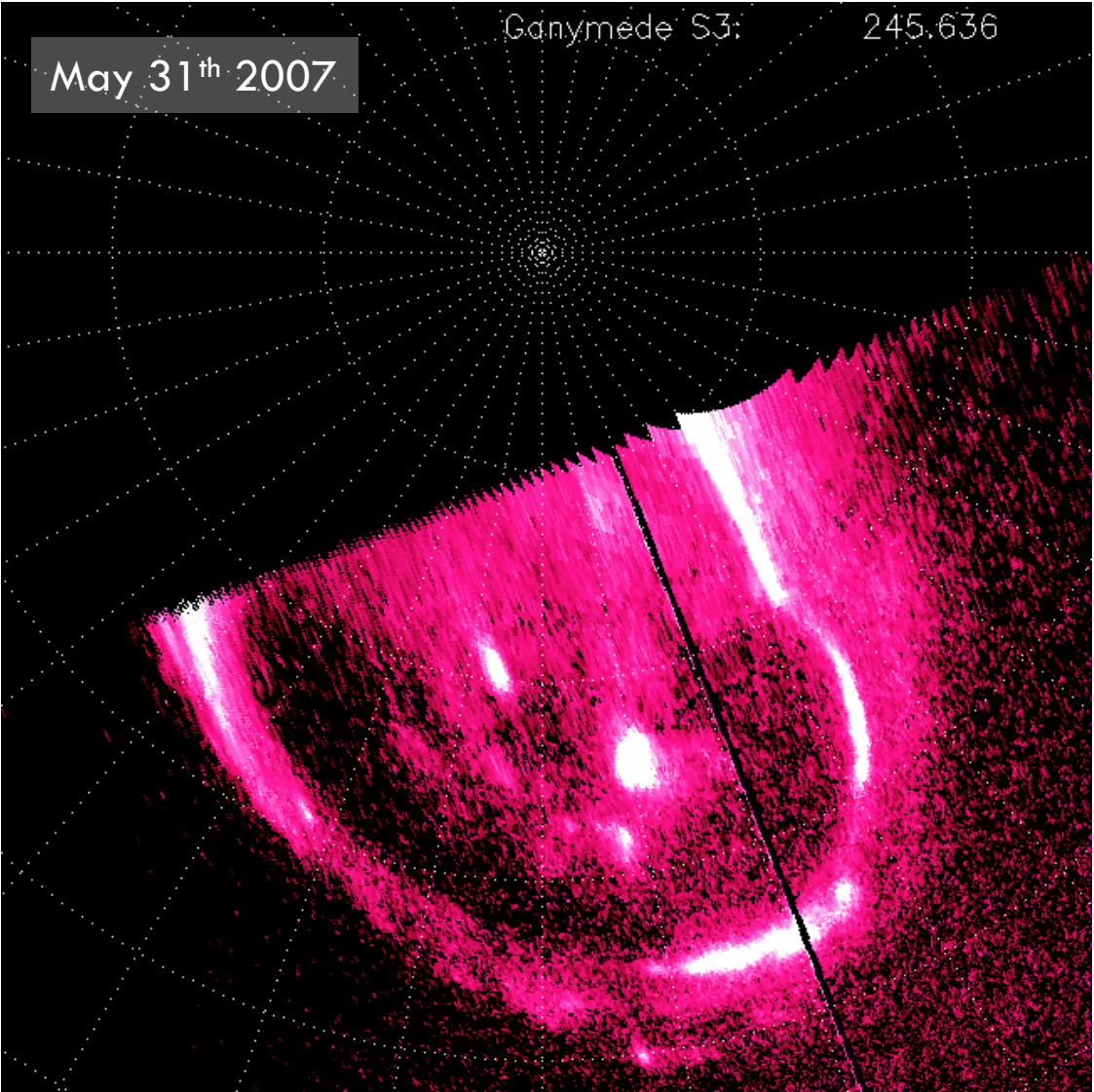
# A consistent long term trend



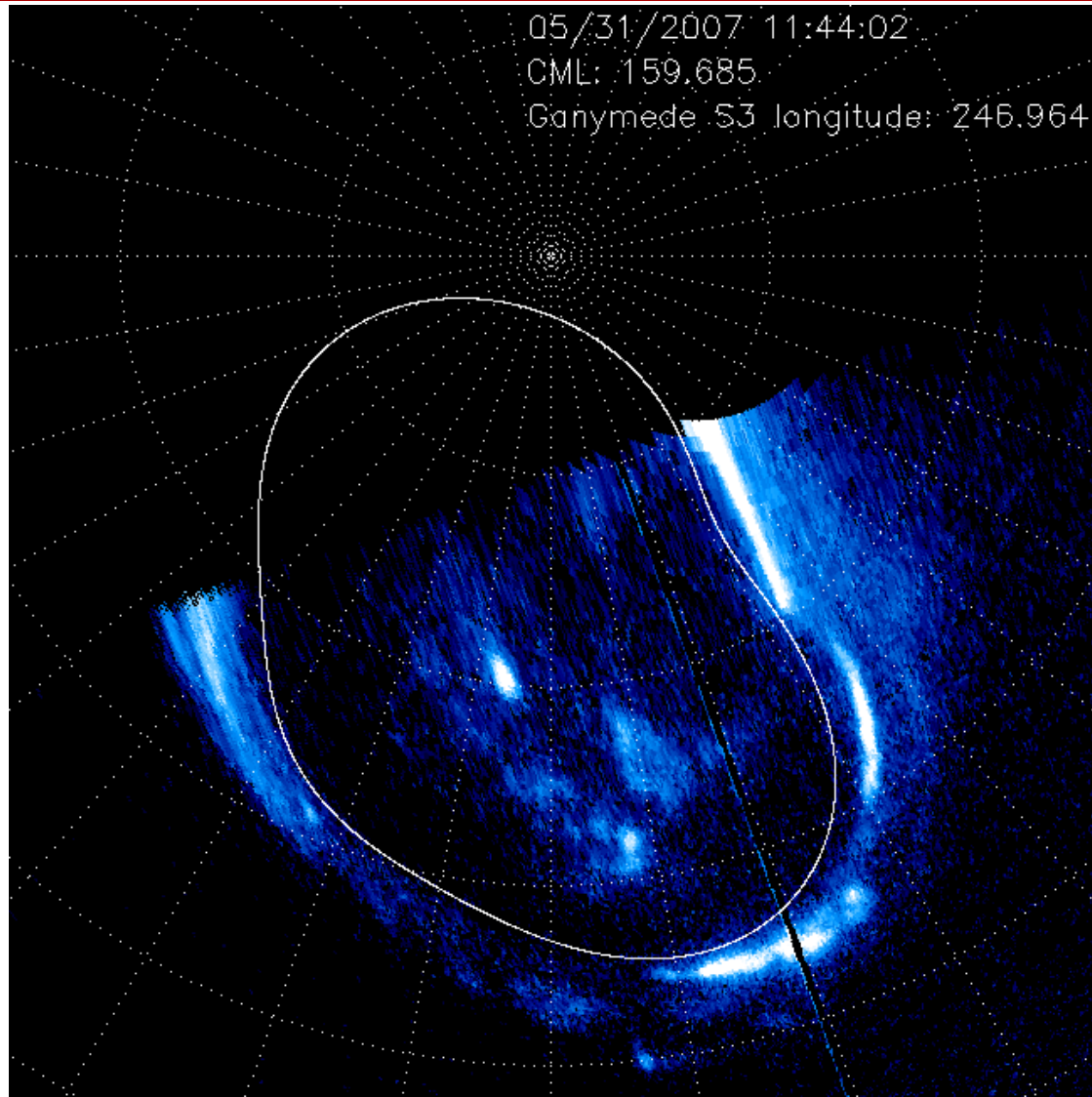
# The usual case



# An unusual case

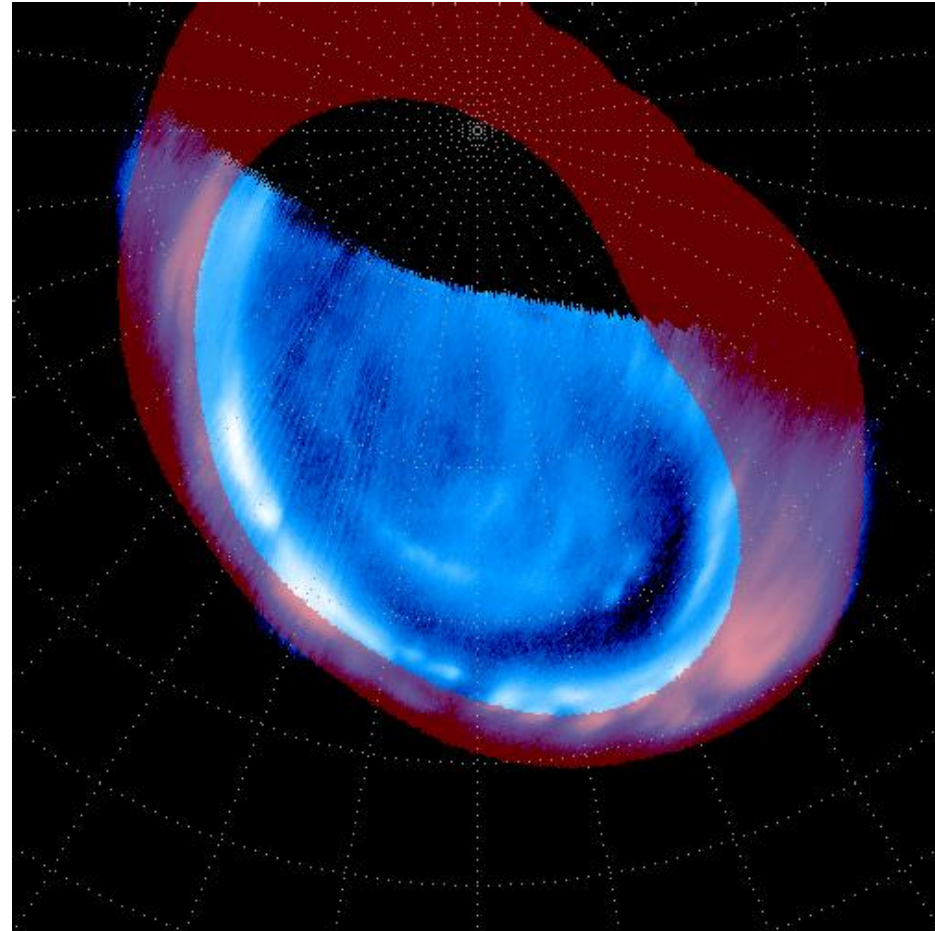
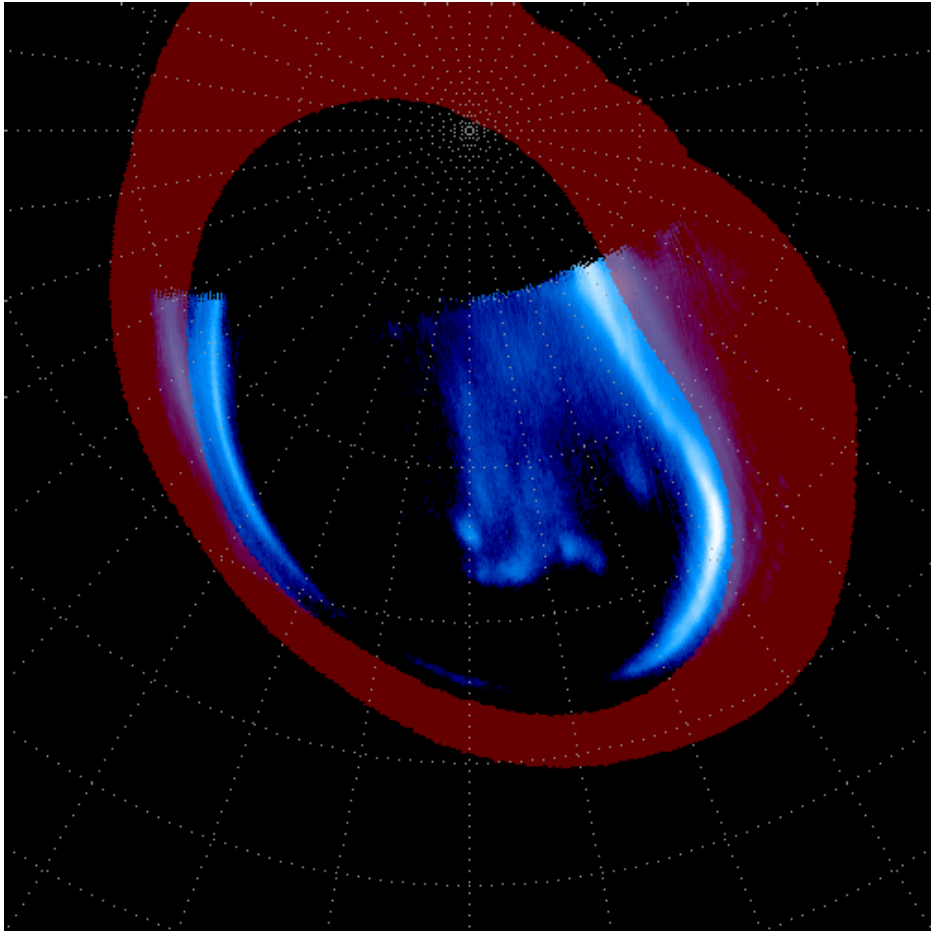
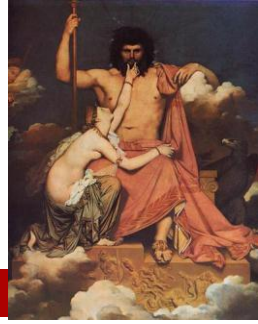


# Comparison

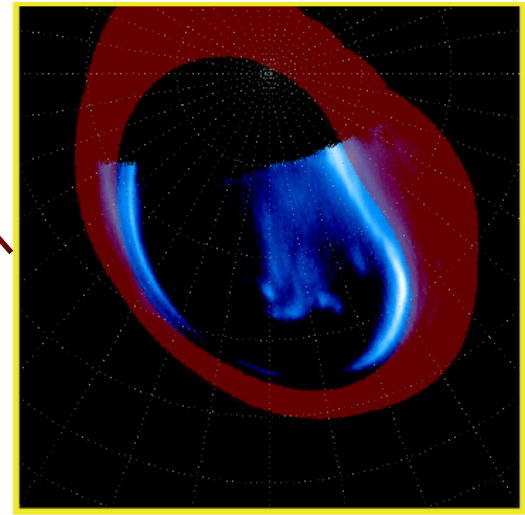
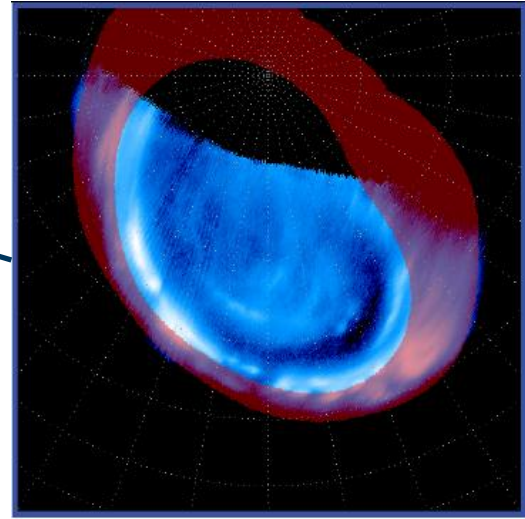
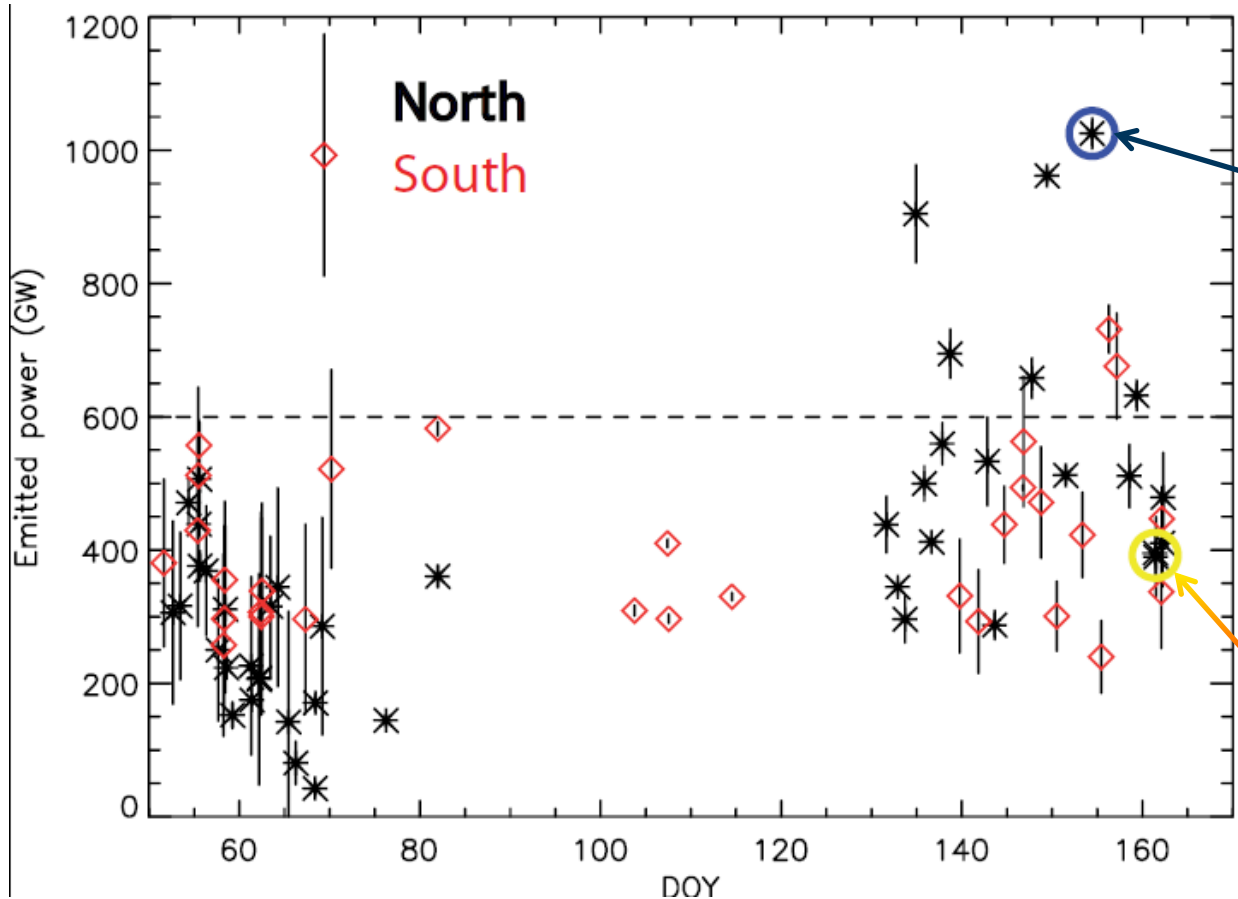
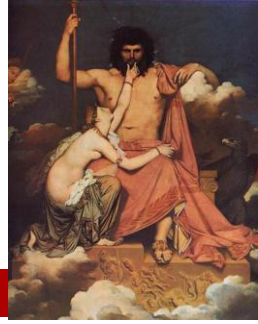




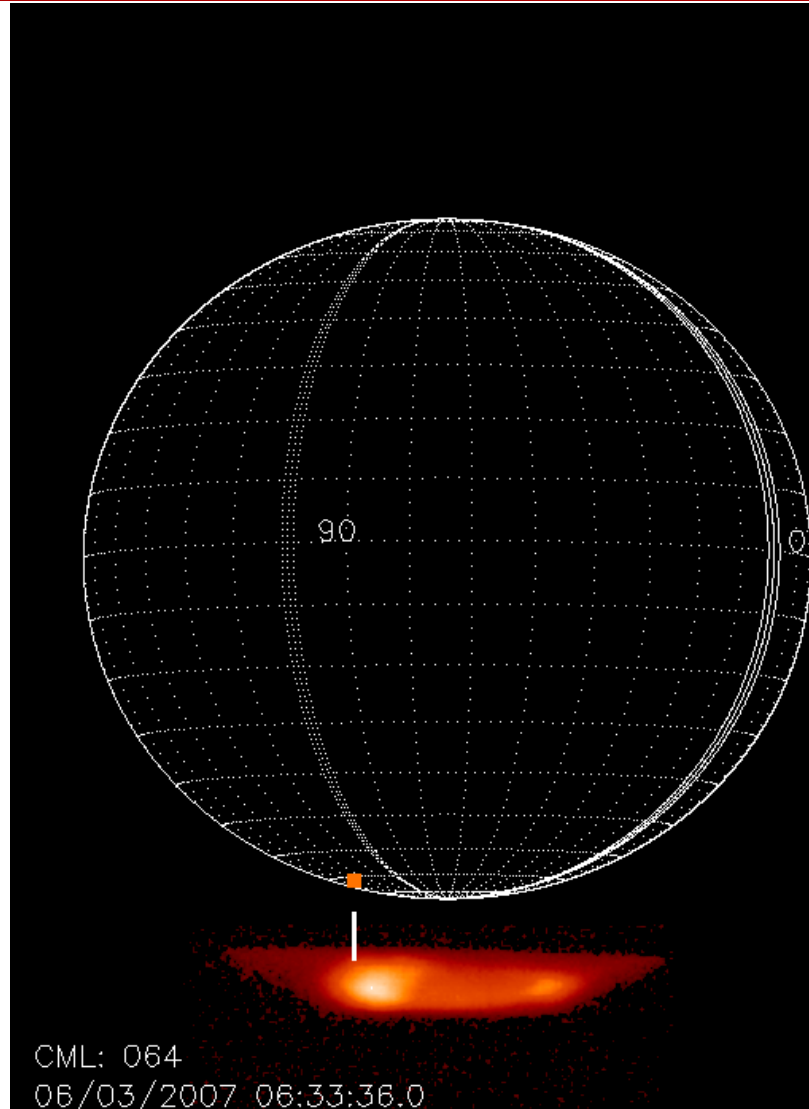
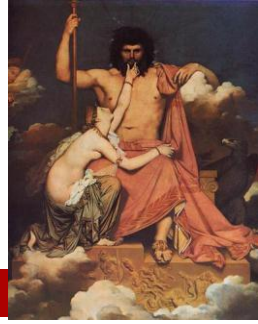
# Outer emissions



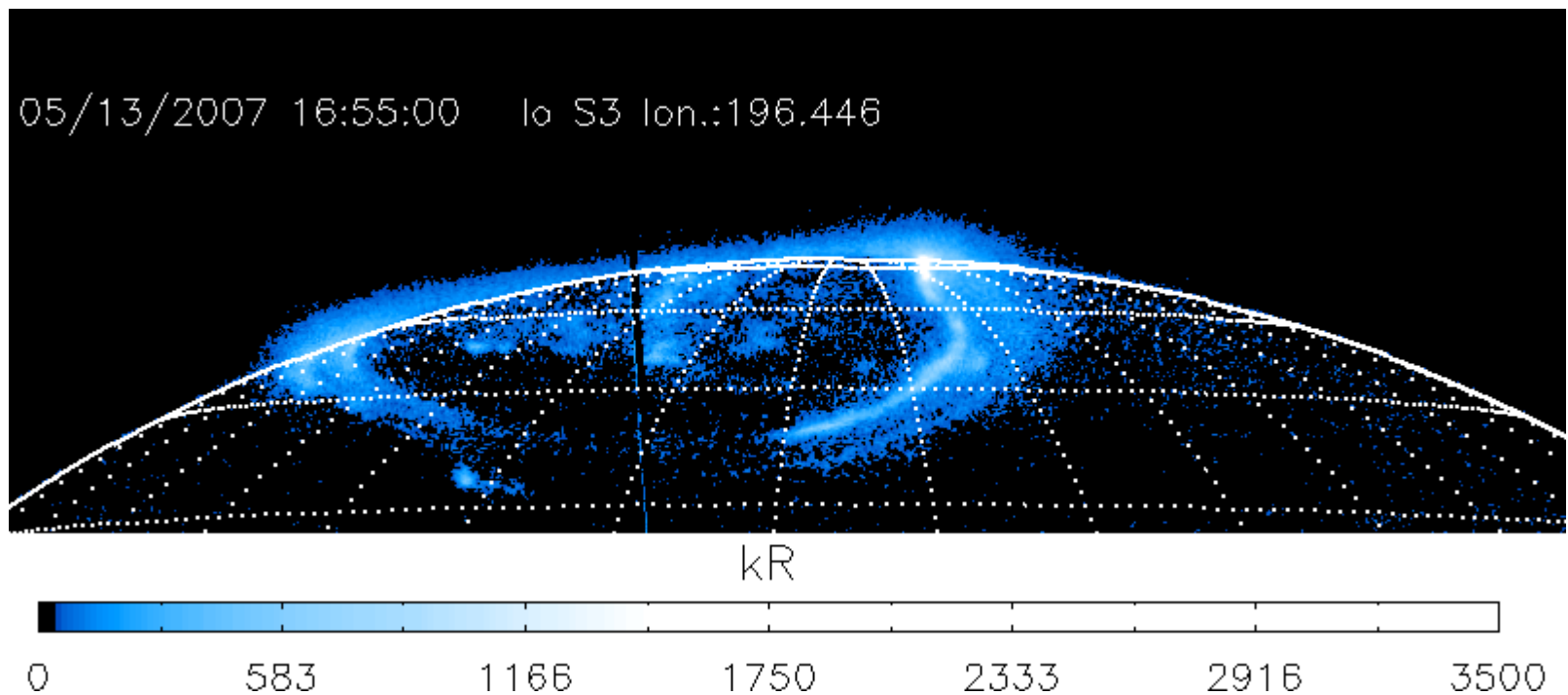
# Outer emissions: Spring 2007



# Injection blobs in the IR

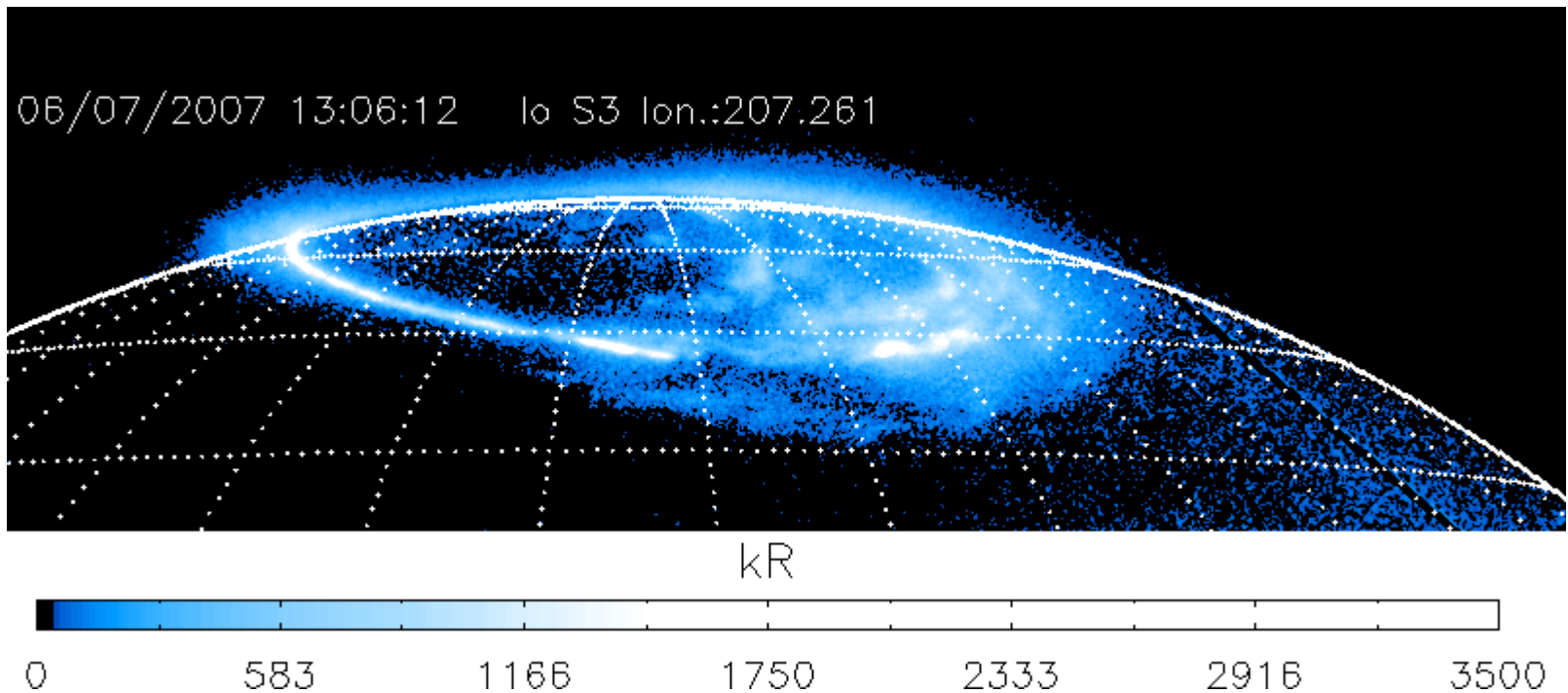
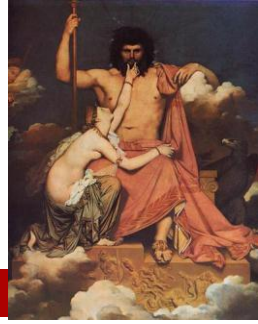


# The usual case

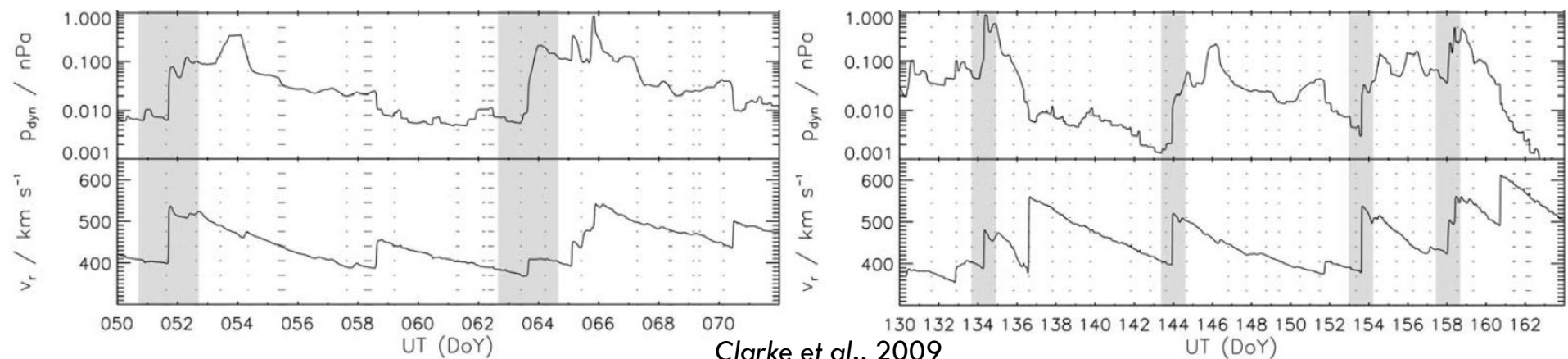
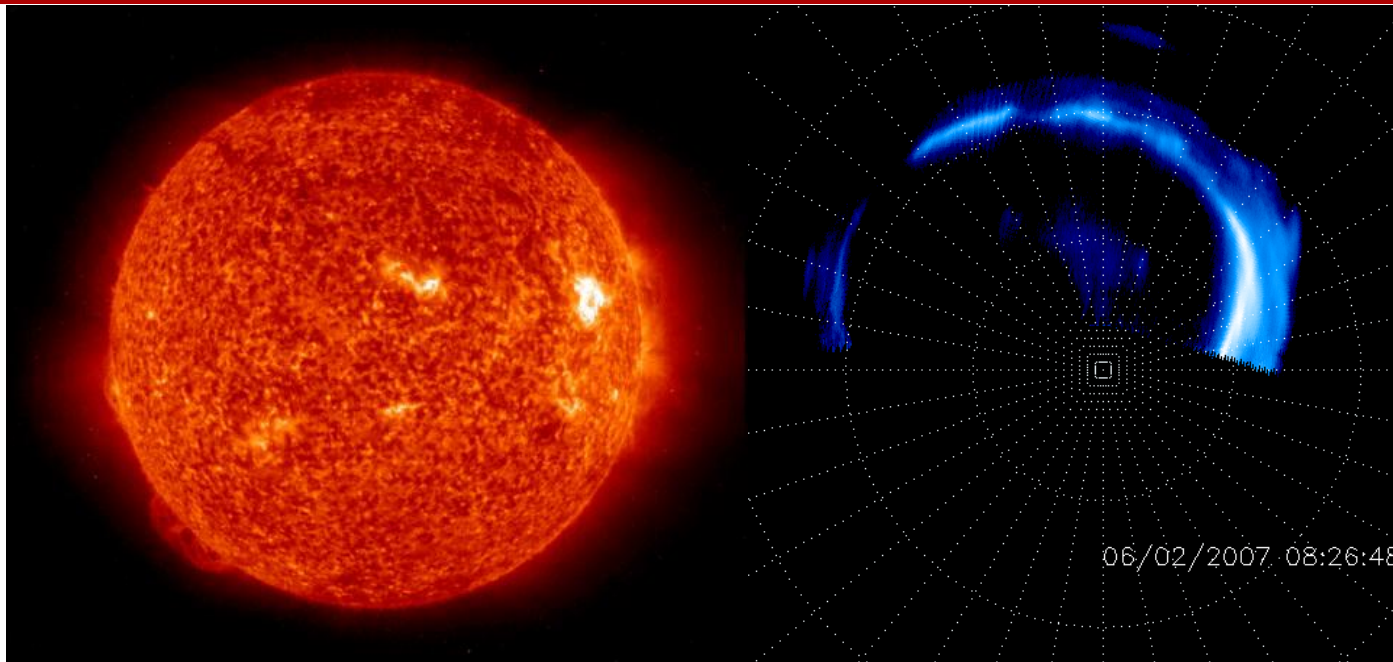
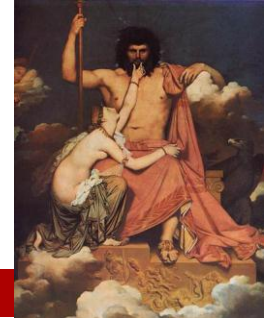




# An unusual case

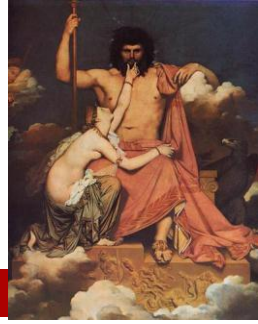


# Solar wind driven changes?

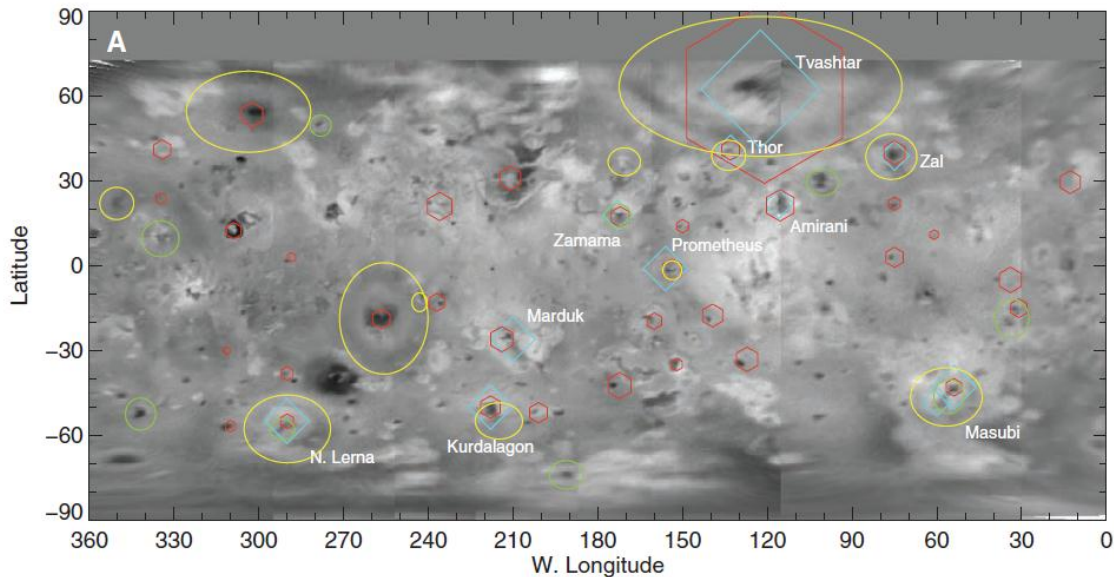
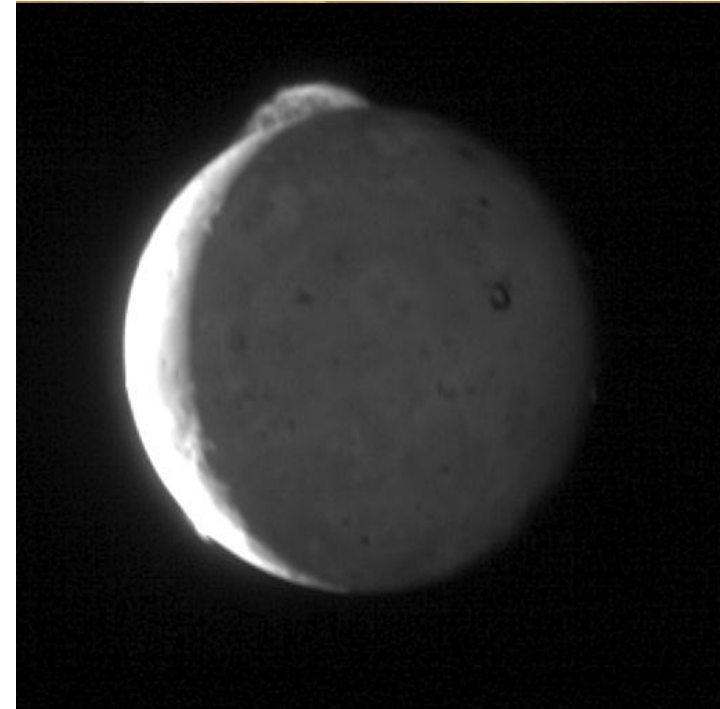


Clarke et al., 2009

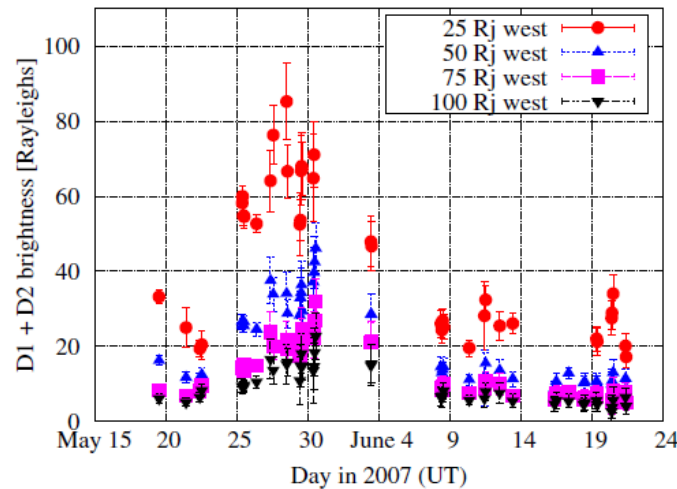
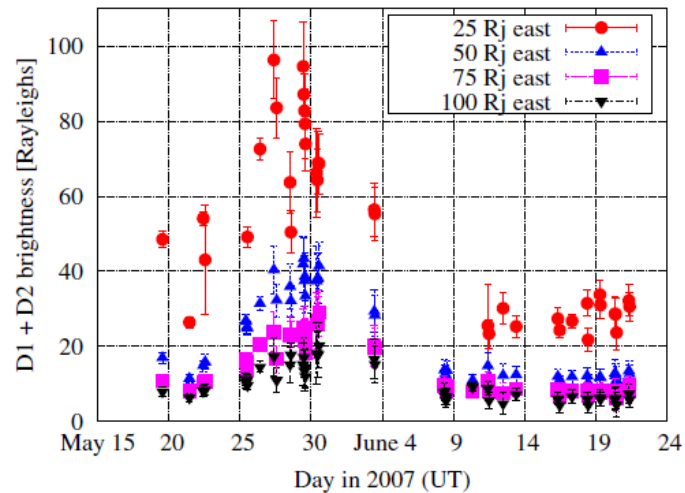
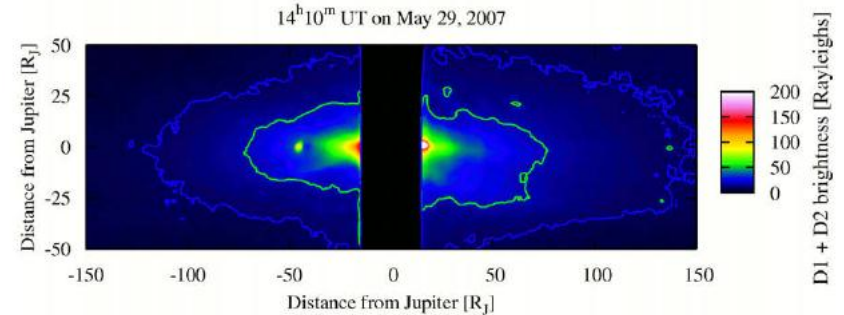
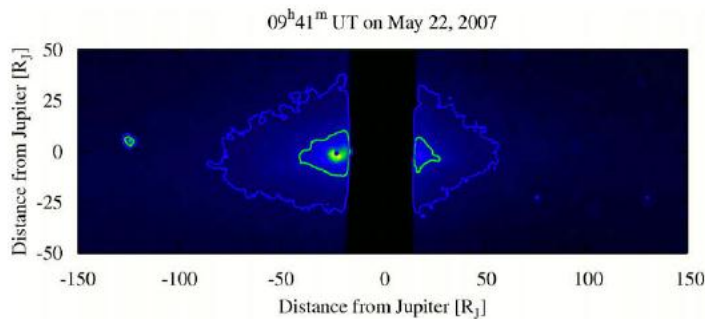
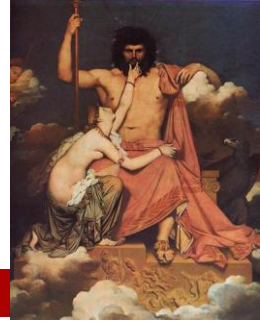
# Internally driven changes



- **Tvashtar:**
  - ▣ Quiet since 2001
  - ▣ Some signs of activity in 2006
  - ▣ Giant plume in late February 2007
- **Masubi:**
  - ▣ active in March 2007



# Sodium “Mendillosphere”



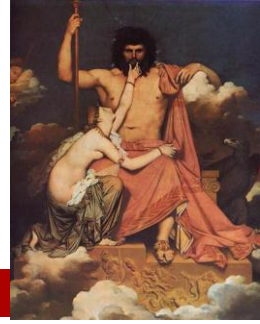
- Variability of the plasma torus
- Sodium nebula

Fig. 1. Daily variations in  $D_1 + D_2$  brightness of sodium nebula on eastern side (left) and western side (right).

*Yoneda et al., 2009*



# HOM emissions



Yoneda et al., 2013

Nakagawa et al., 2000

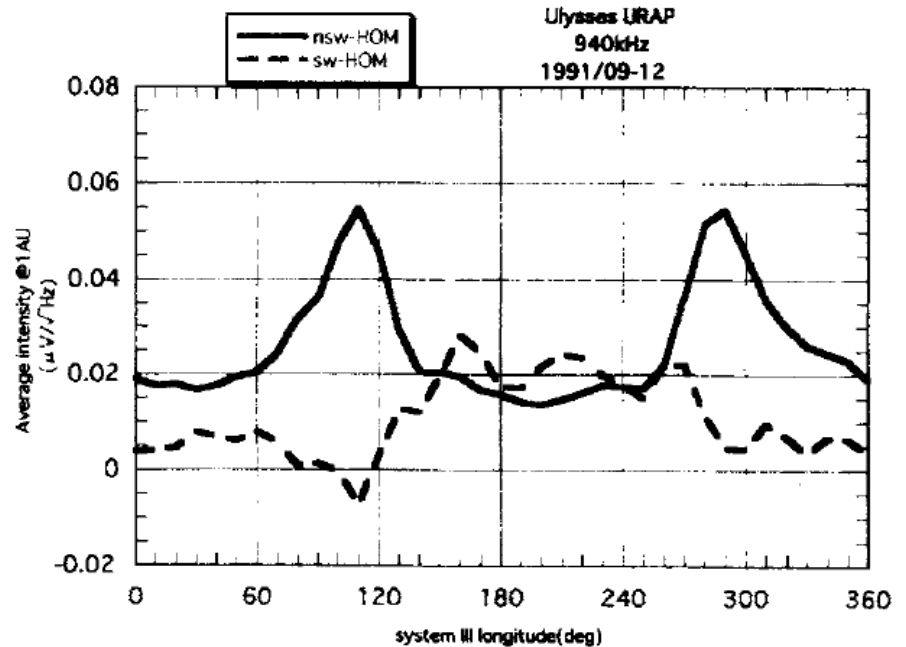
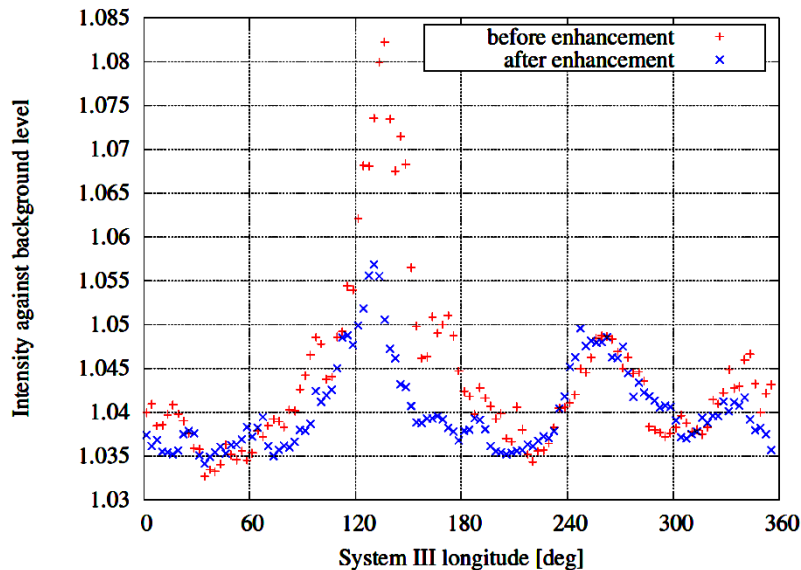
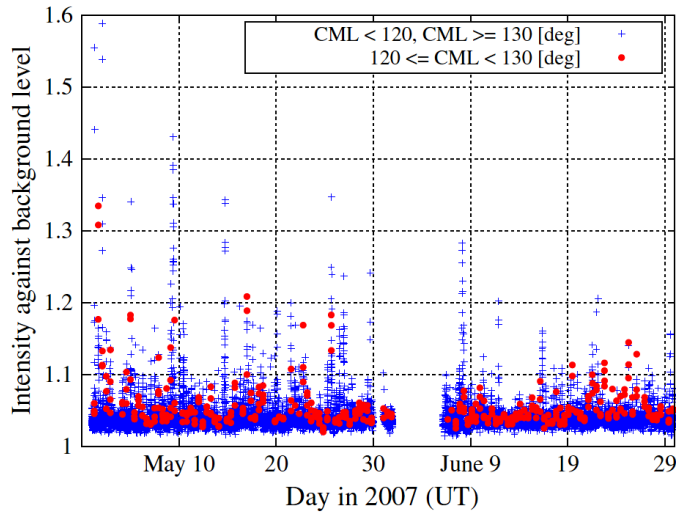
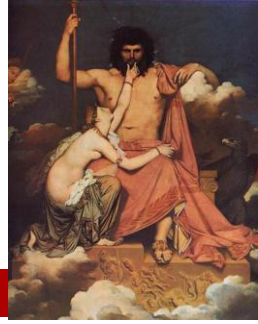


Fig. 4. Occurrence characteristics of nsw-HOM (solid line) and sw-HOM (dashed line) in system III longitude, respectively.

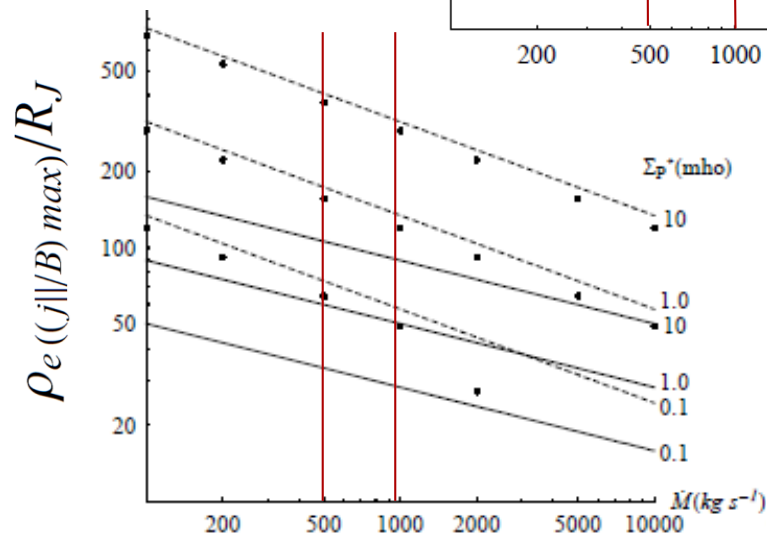
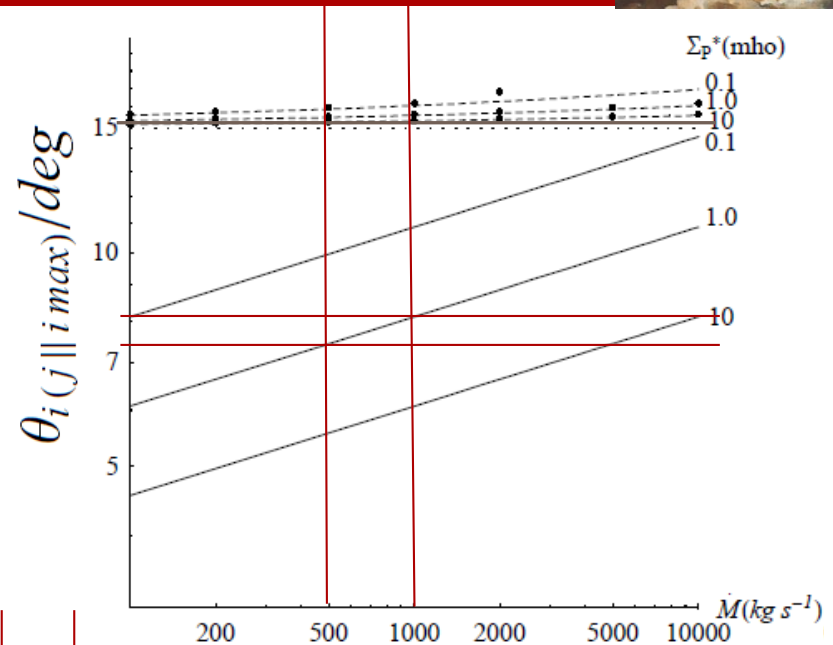
# $\dot{M}$ and the main oval



$$L_o \equiv \left( \frac{\pi \Sigma^* B_j^2 R_j^2}{\dot{M}} \right)^{1/4}, \quad (1)$$

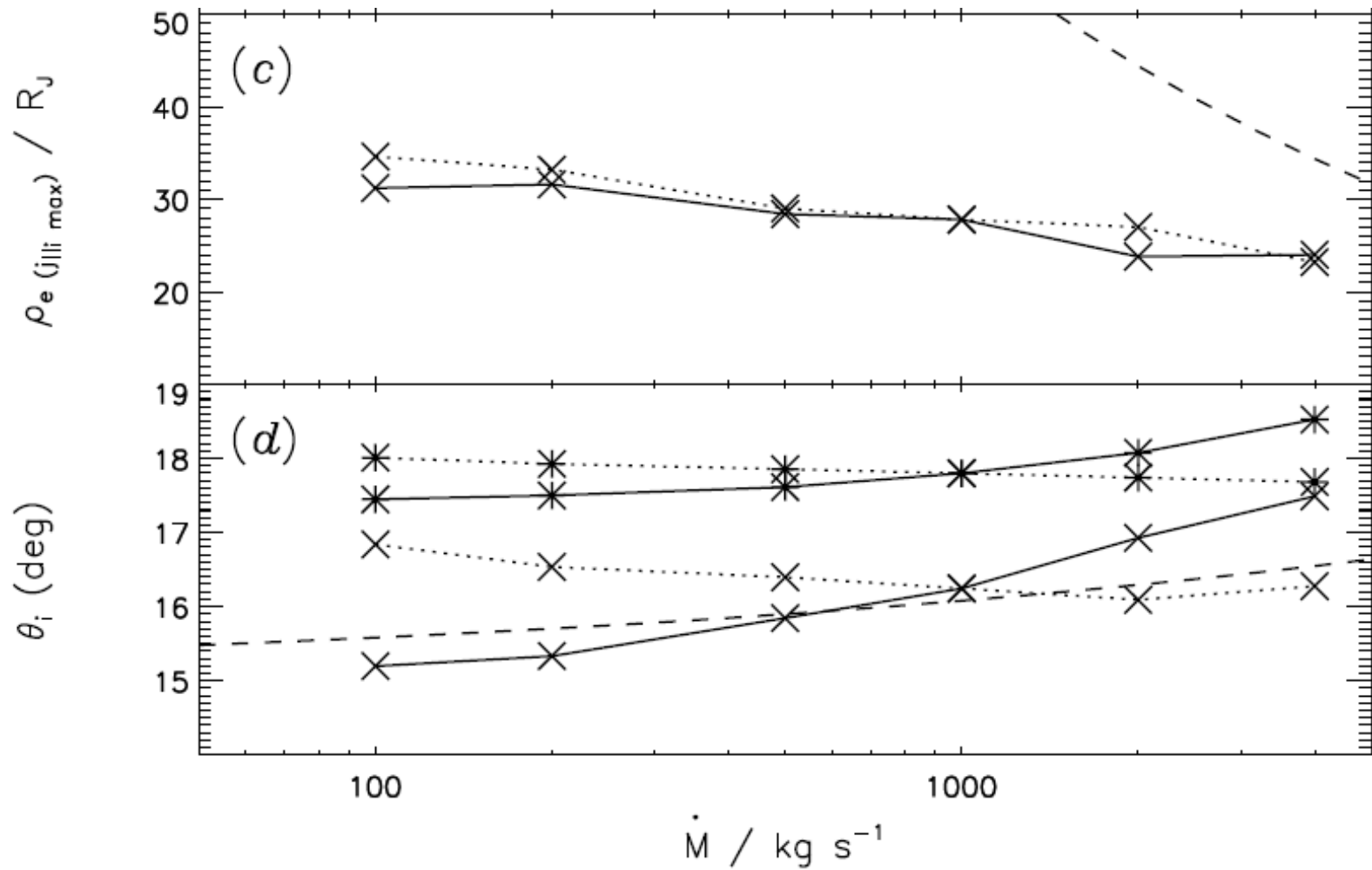
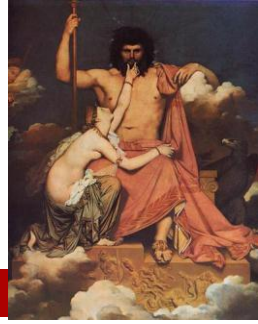
According to (1), the surface colatitude  $\theta_o = \arcsin(L_o^{-1/2})$  is approximately proportional to the 1/8 power of  $\dot{M}$ , so a factor of 2 variation of the latter would produce a  $1^\circ$  variation of the former, which may be marginally detectable at present.

Hill, 2001



Nichols and Cowley,  
2003

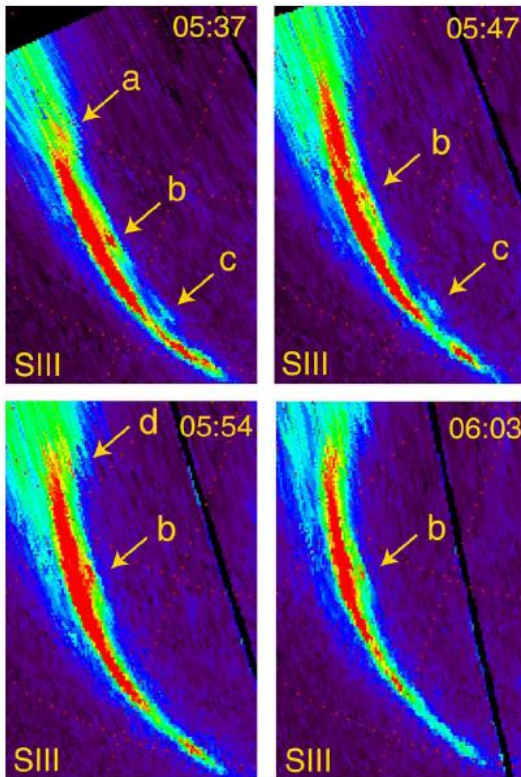
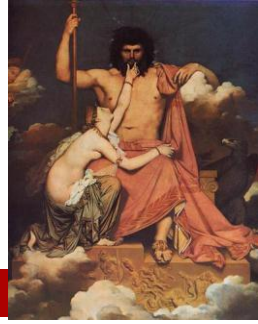
# $\dot{M}$ and the main oval



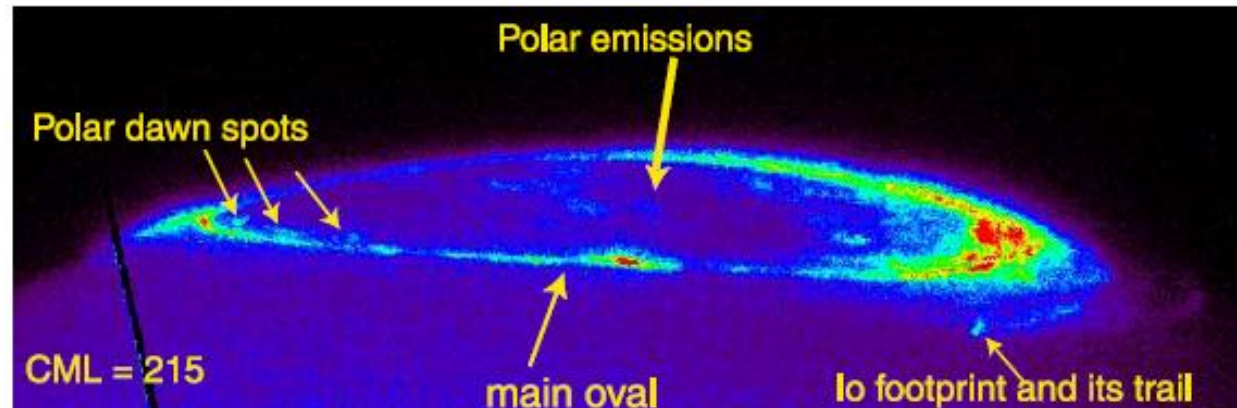
# The polar emissions



# The polar dawn spots

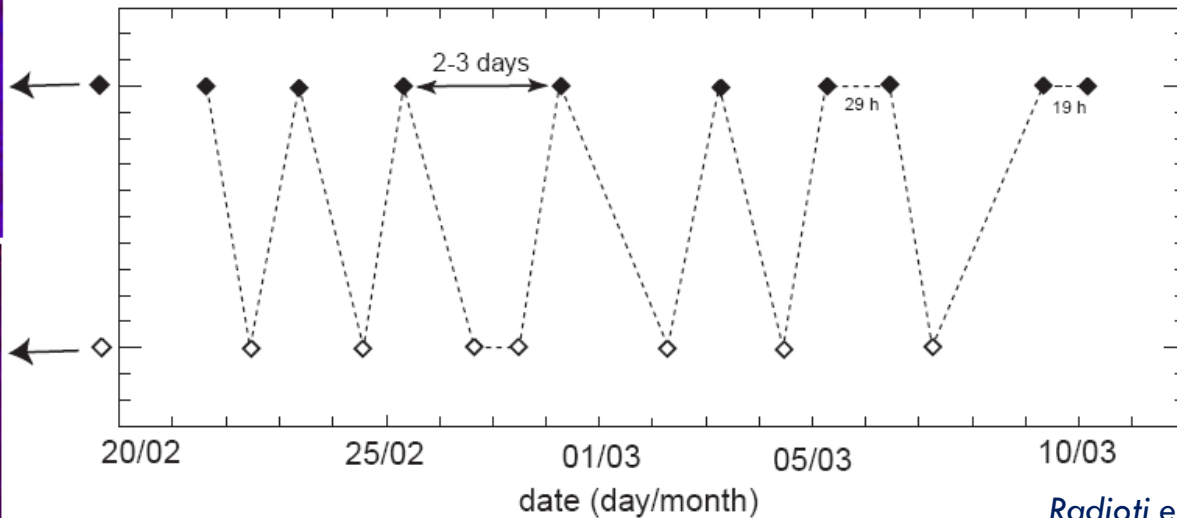
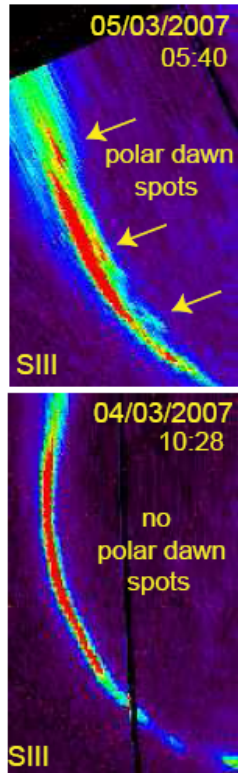
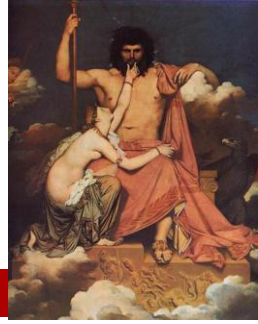


Radioti et al. 2008



- Duration: from 10 min to 1 hour
- Spatial dimensions:  $\sim 3000 \times 1000$  km
- Power: 1 Giga Watt
- Magnetically maps to the night and predawn sectors

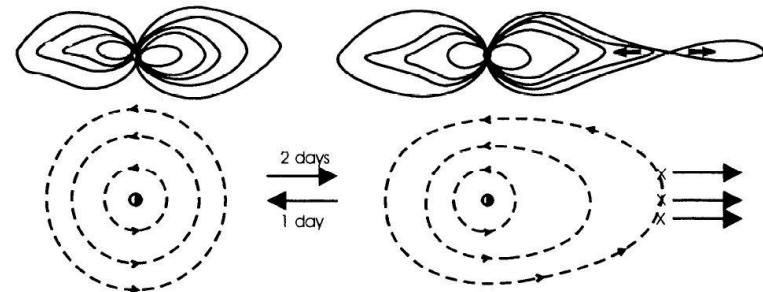
# The polar dawn spots



*Radioti et al. 2008*

"Dipolarization"

Plasma Sheet Thinning and Plasmod Formation



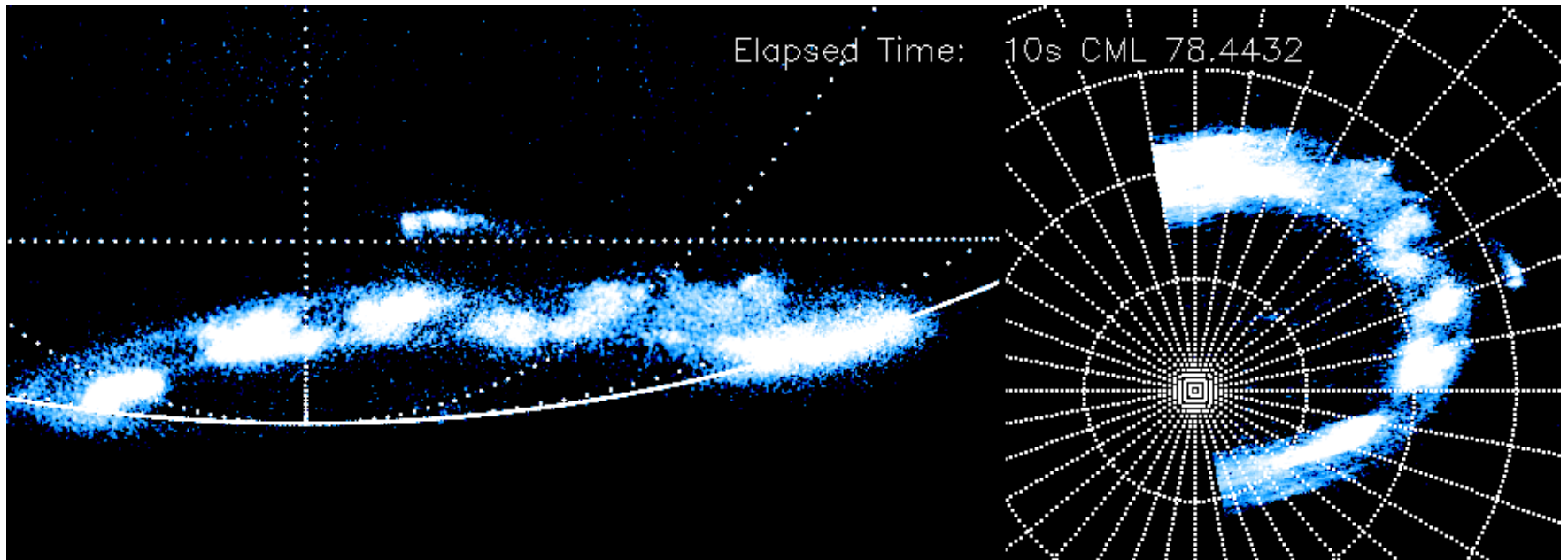
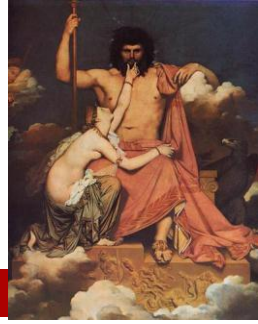
- 2-3 days re occurrence rate
- Observed location (pre-dawn)



Internally driven reconnection

(Woch et al. 1998, Kronberg et al., 2007)

# Quasi-periodic polar flares

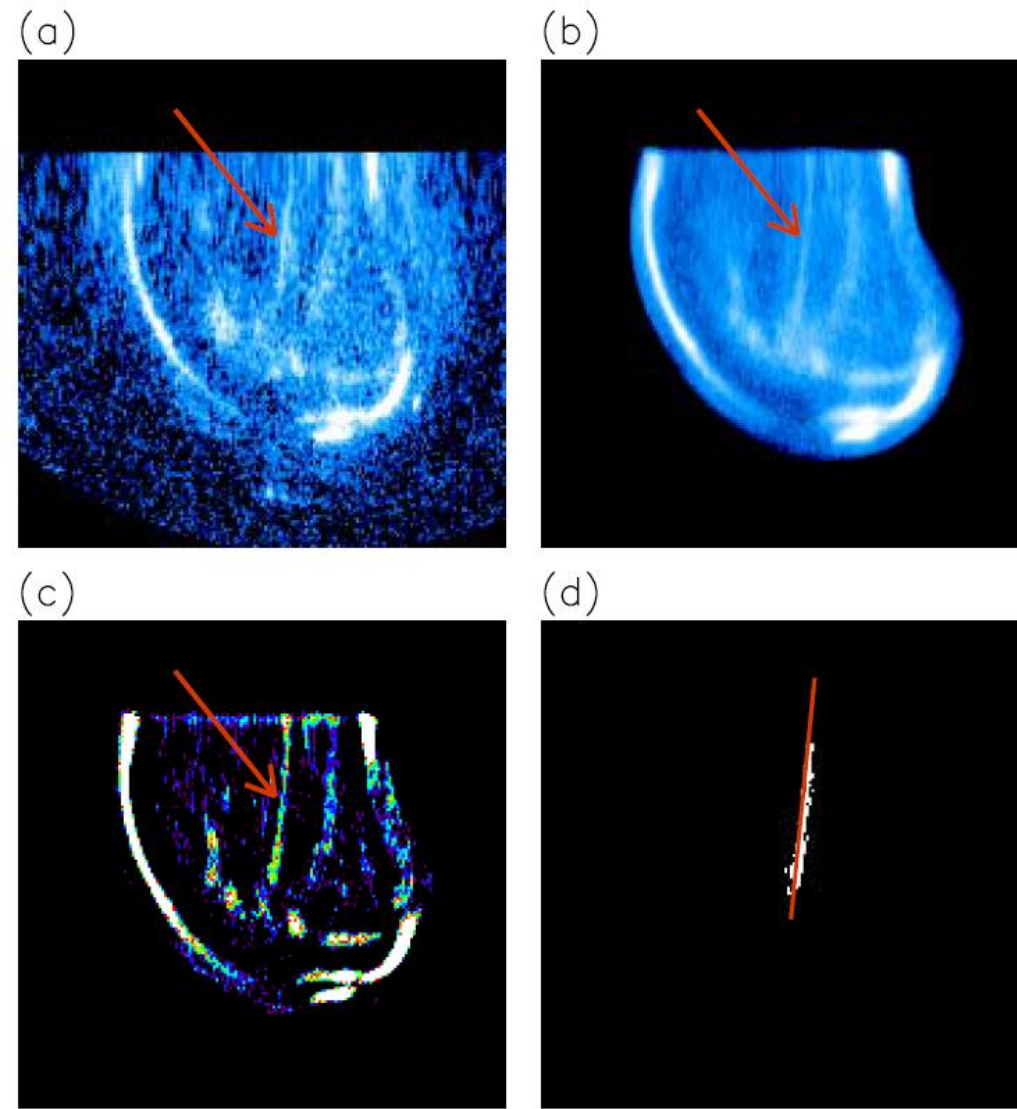


Bonfond et al., 2011

## Origin?

- Pulsed reconnections at the dayside magnetopause
- Related to the high energy electron beams

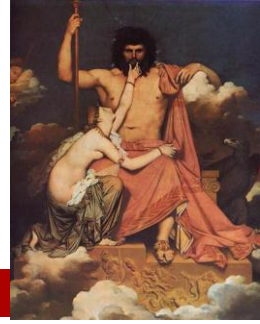
# Polar auroral filaments



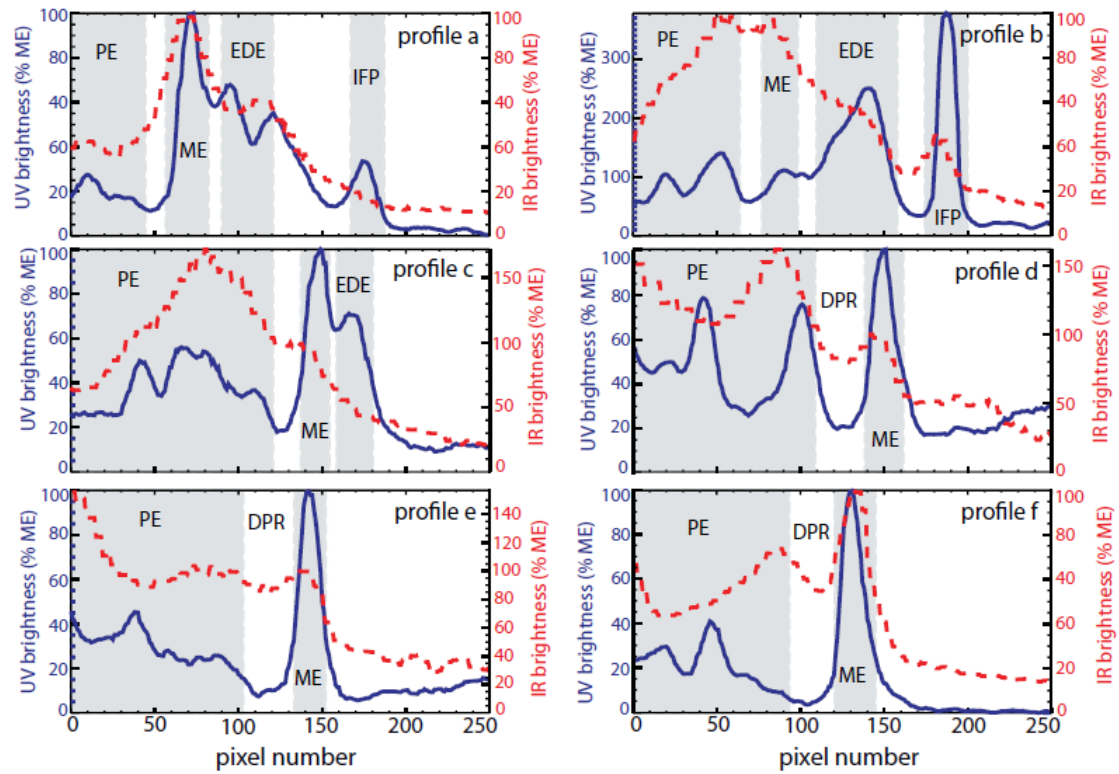
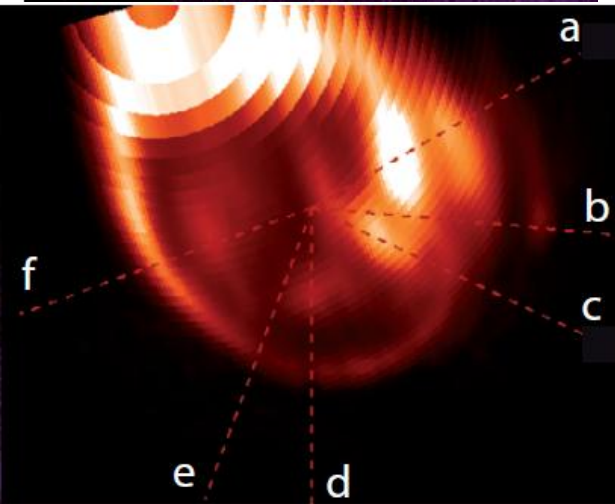
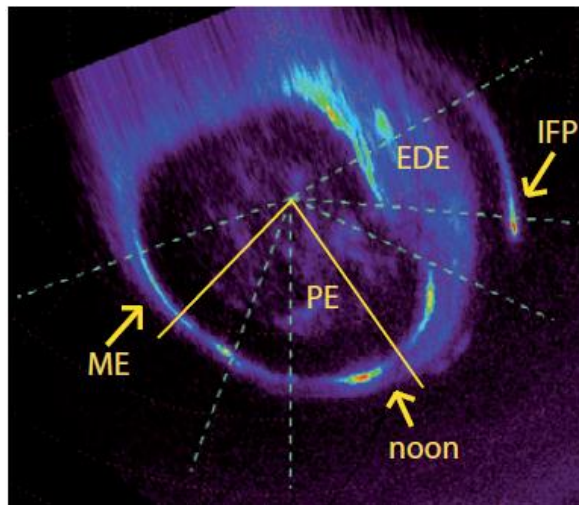
- Long-lived, quasi-sun-aligned polar auroral filaments
- Brightness of 100 kR
- Presumably map to the tail region, implying a relation to the tail dynamics.



# UV-IR comparison



Radioti et al., in press



Co-location of auroral features

Feature	Co-location in UV and IR
Main emission	Co-located
Main emission discontinuity	Exists in UV but not clear if present in IR
Polar emission	Not always co-located
Dark polar region	Co-located
Equatorward emission	Co-located
Io footprint	Co-located