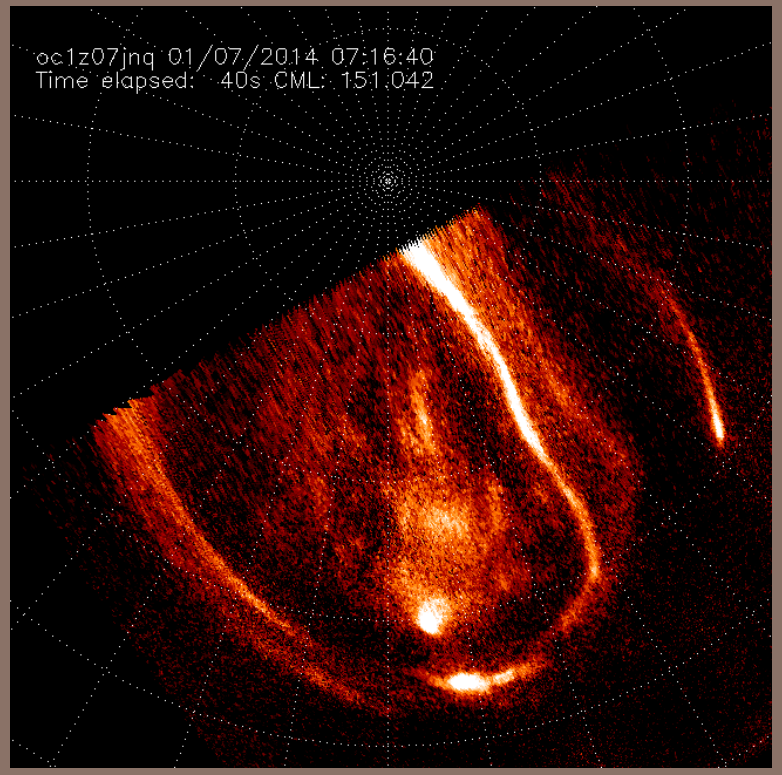
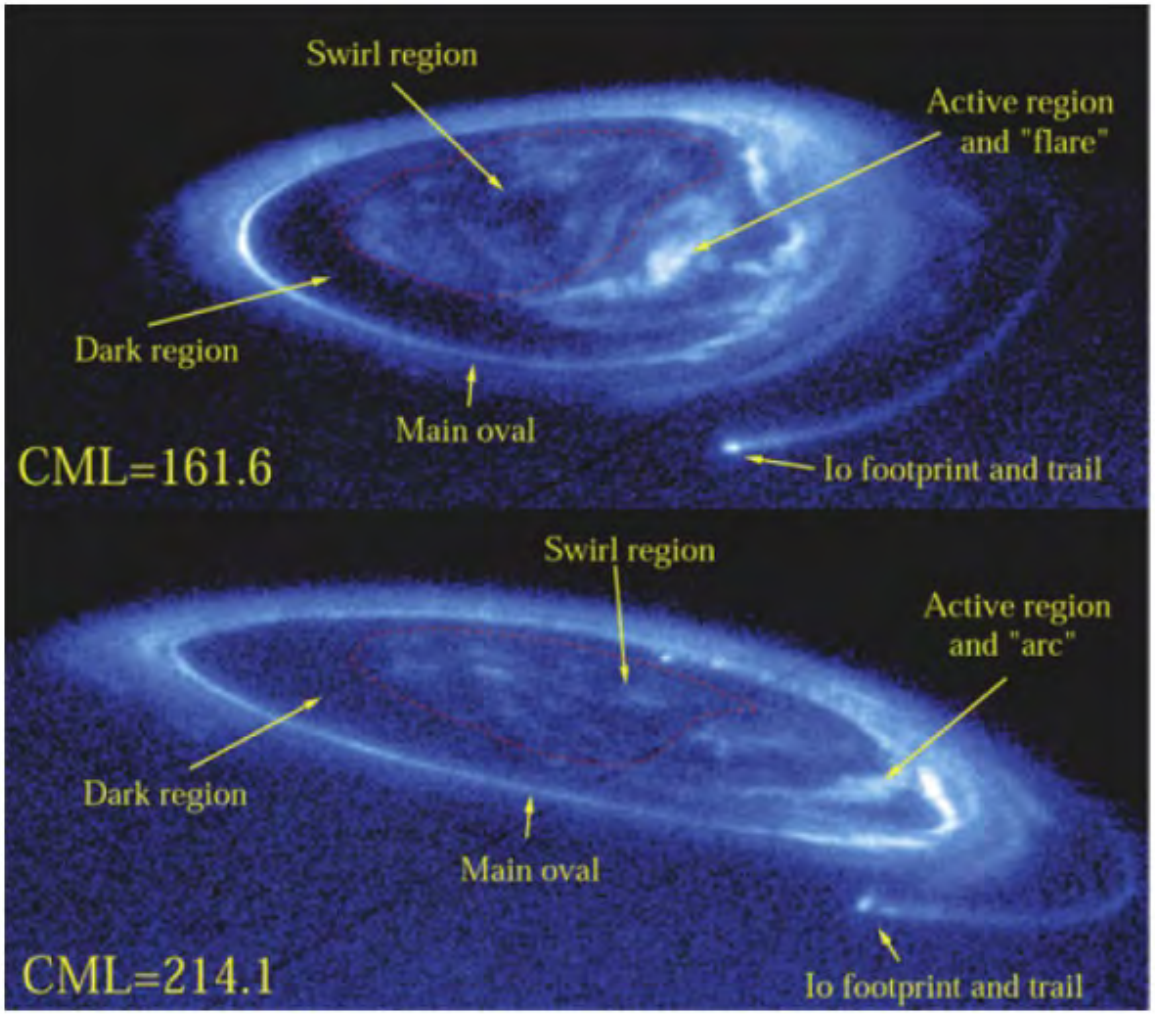
THE MANY AURORAE OF JUPITER:

AURORAL FILAMENTS, FLARES, TRANSIENT FEATURES OF THE MAIN OVAL, SWIRLS, POLAR DAWN SPOTS, INJECTION SIGNATURES AND SATELLITE FOOTPRINTS



Bertrand Bonfond

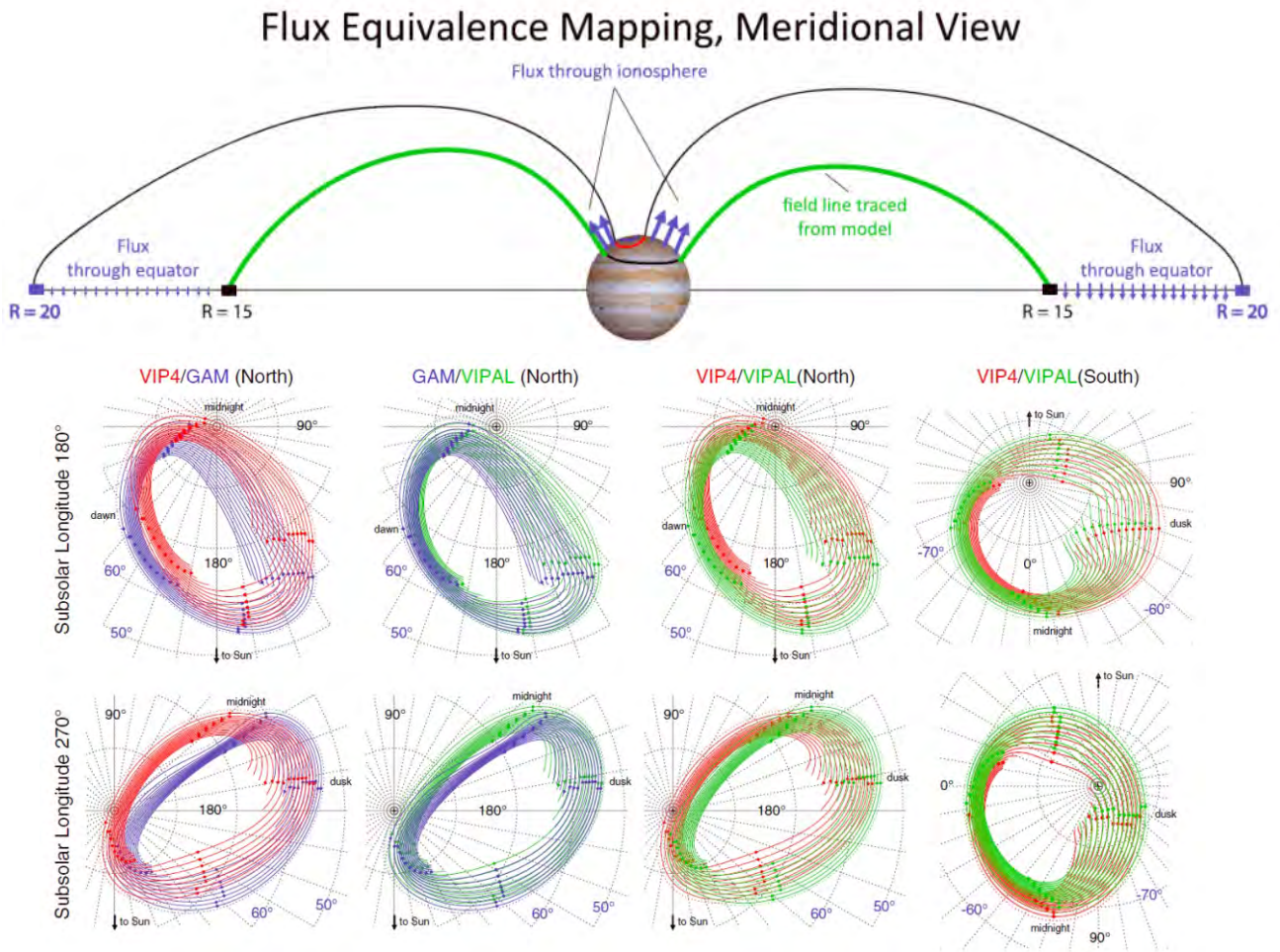
Sub-regions of the polar region



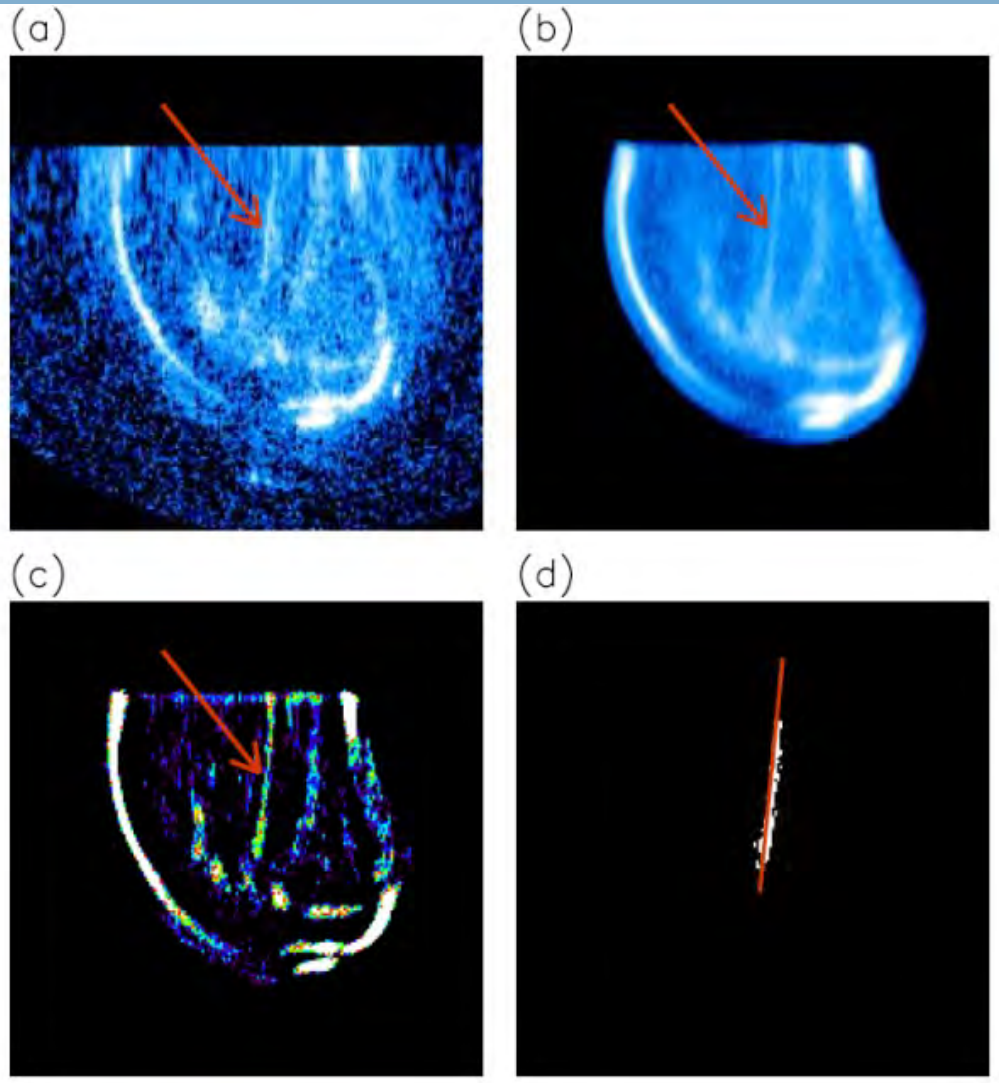
Grodent et al. 2003

How big is the polar cap?

- Vogt et al., 2011, 2015

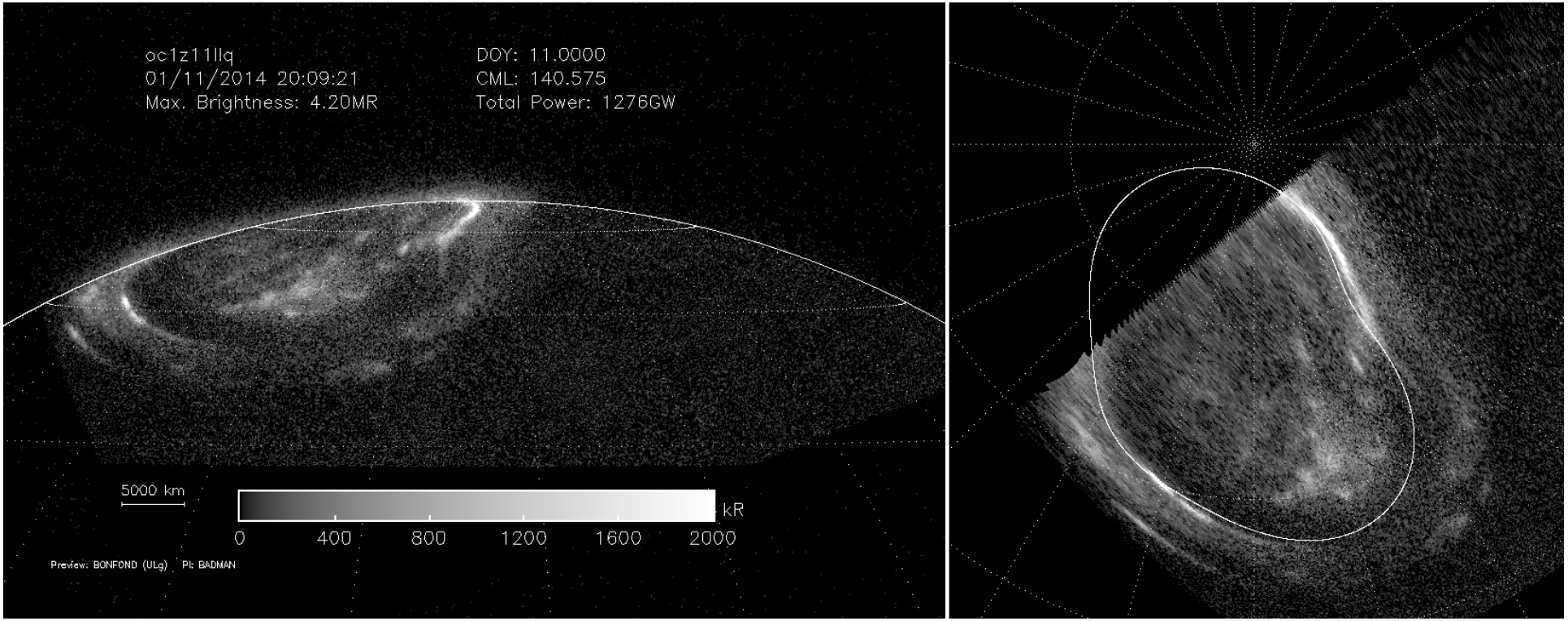


Auroral filament

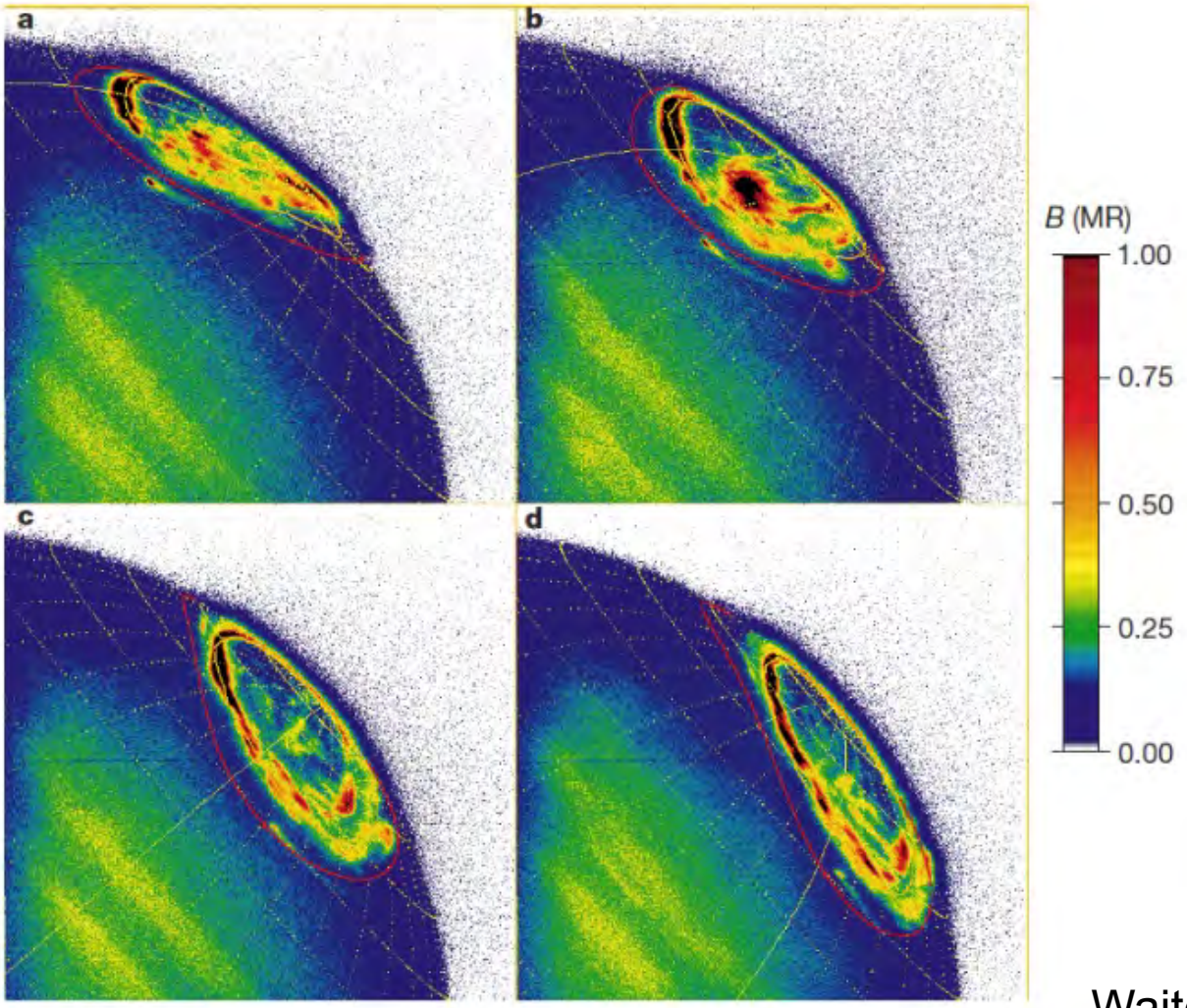


Nichols et al., 2009

Swirl region

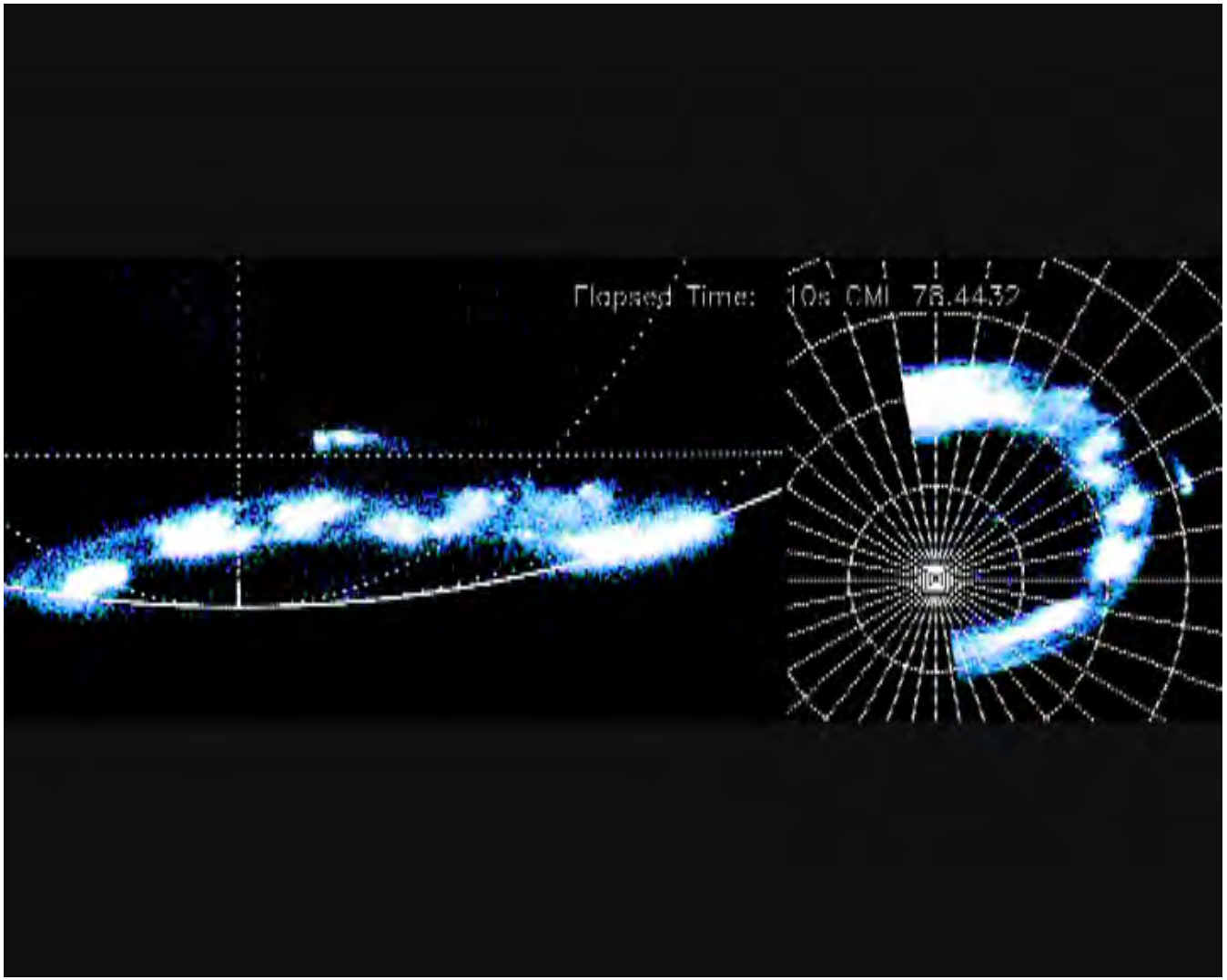


Flares



Waite et al., 2001

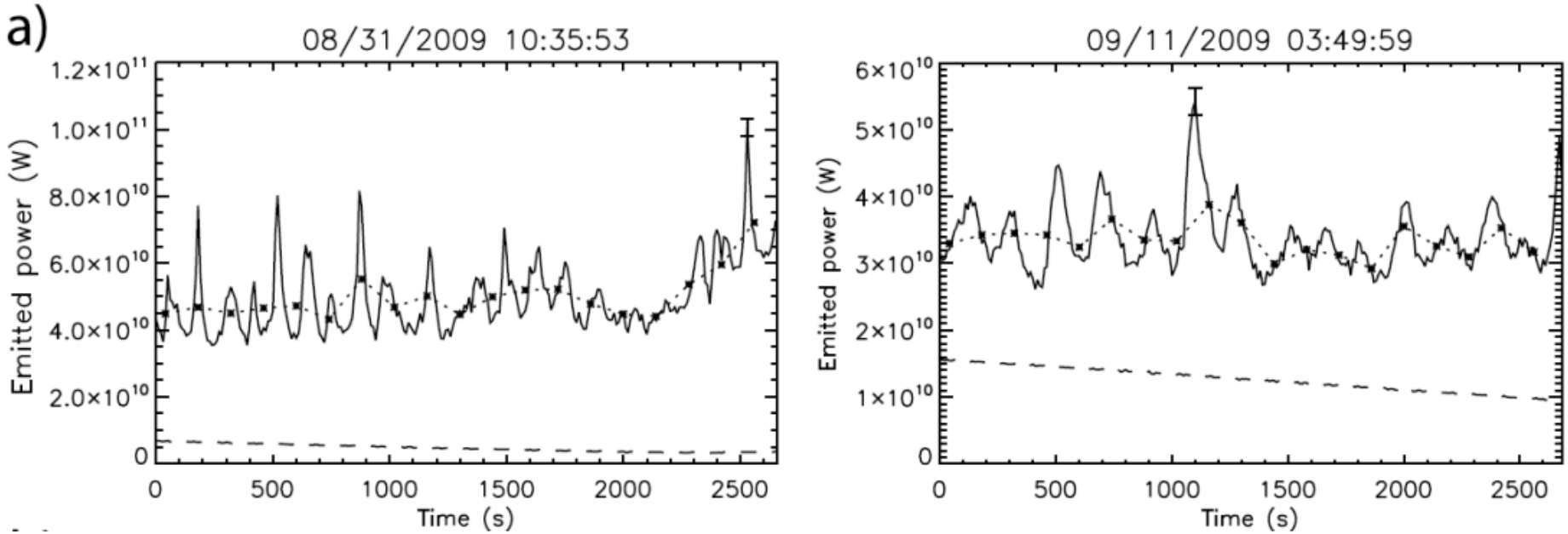
Quasi-periodic polar flares



Bonfond et al., 2011

Quasi-periodic polar flares

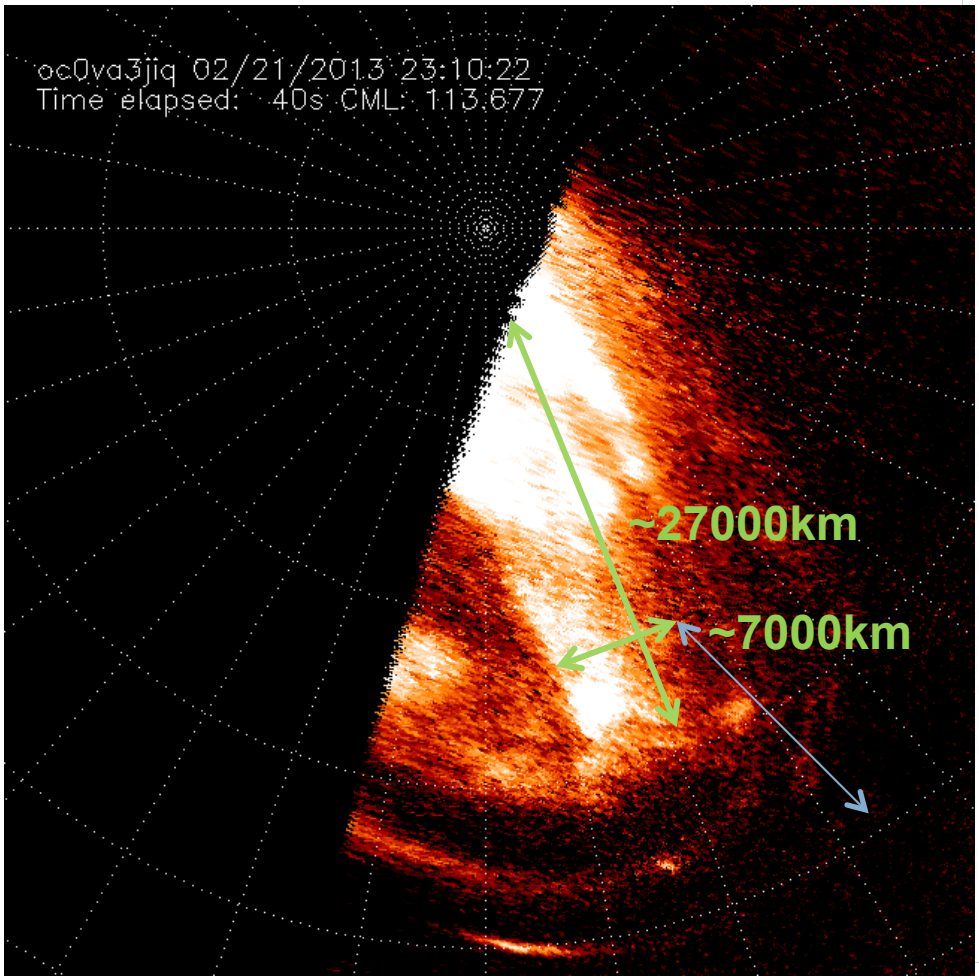
- The quasi-periodicity can only be seen on long time-tag sequences

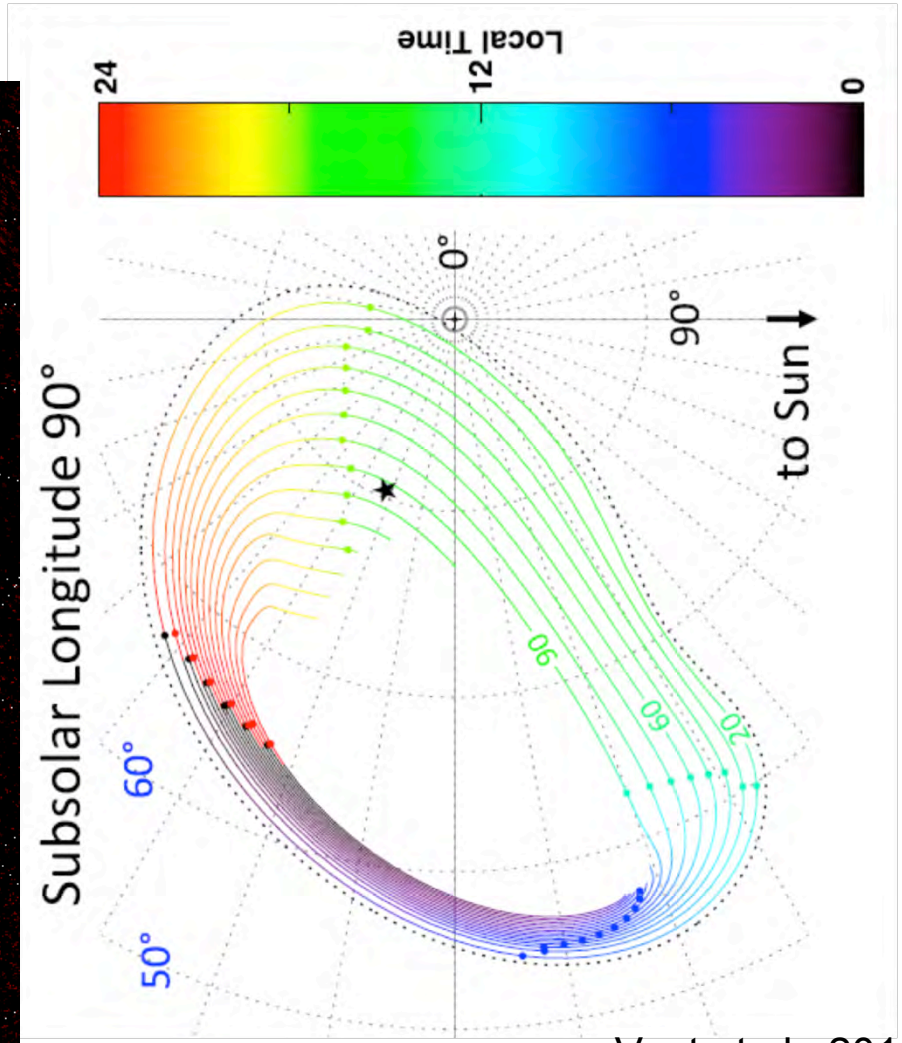


Bonfond et al., 2011

Quasi-periodic polar flares

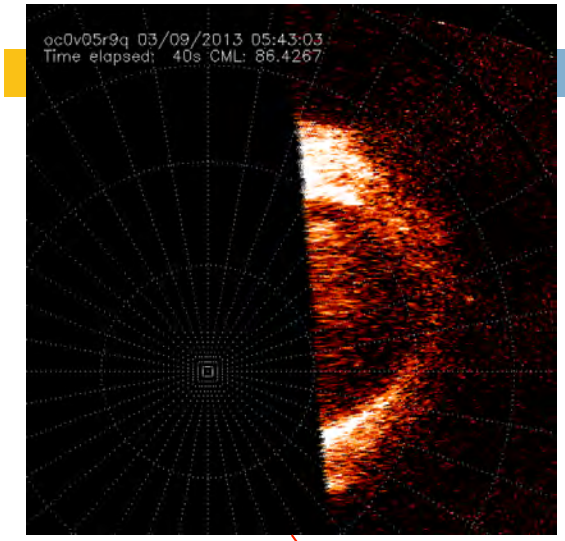
Bonfond et al., in preparation

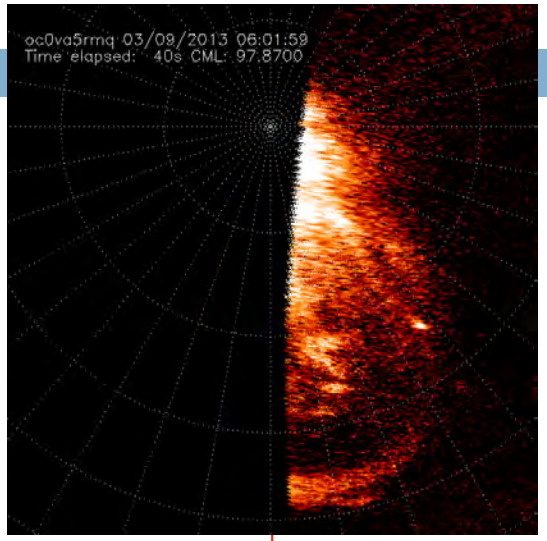


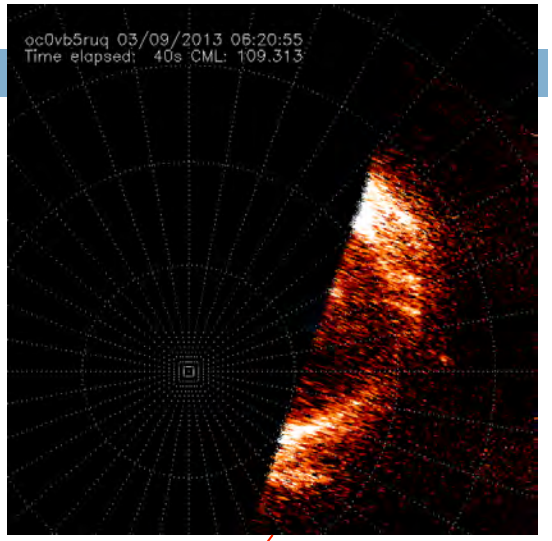


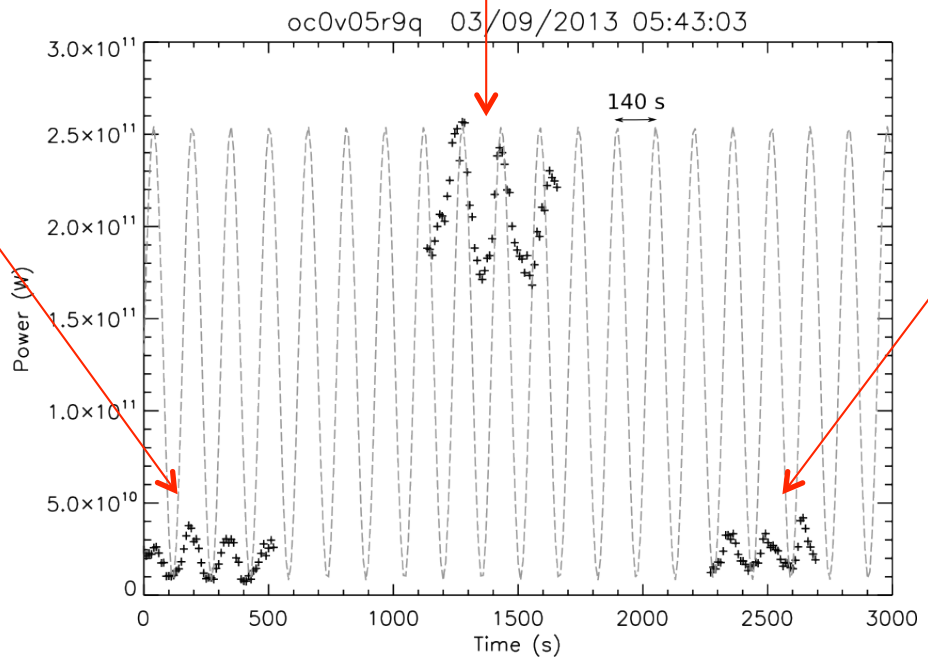
Vogt et al., 2011

Opposite hemispheres





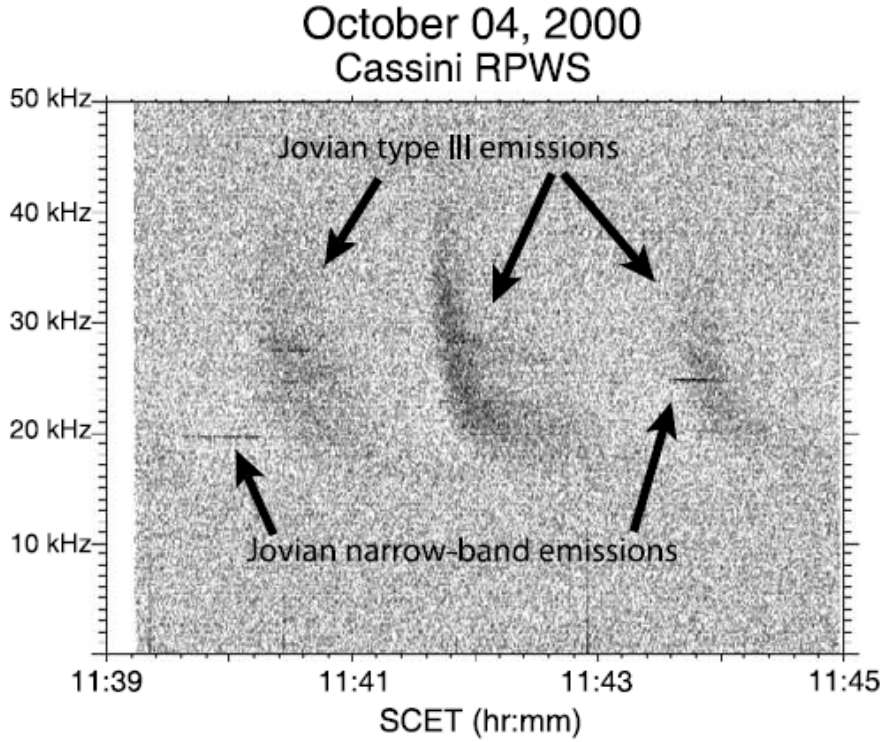




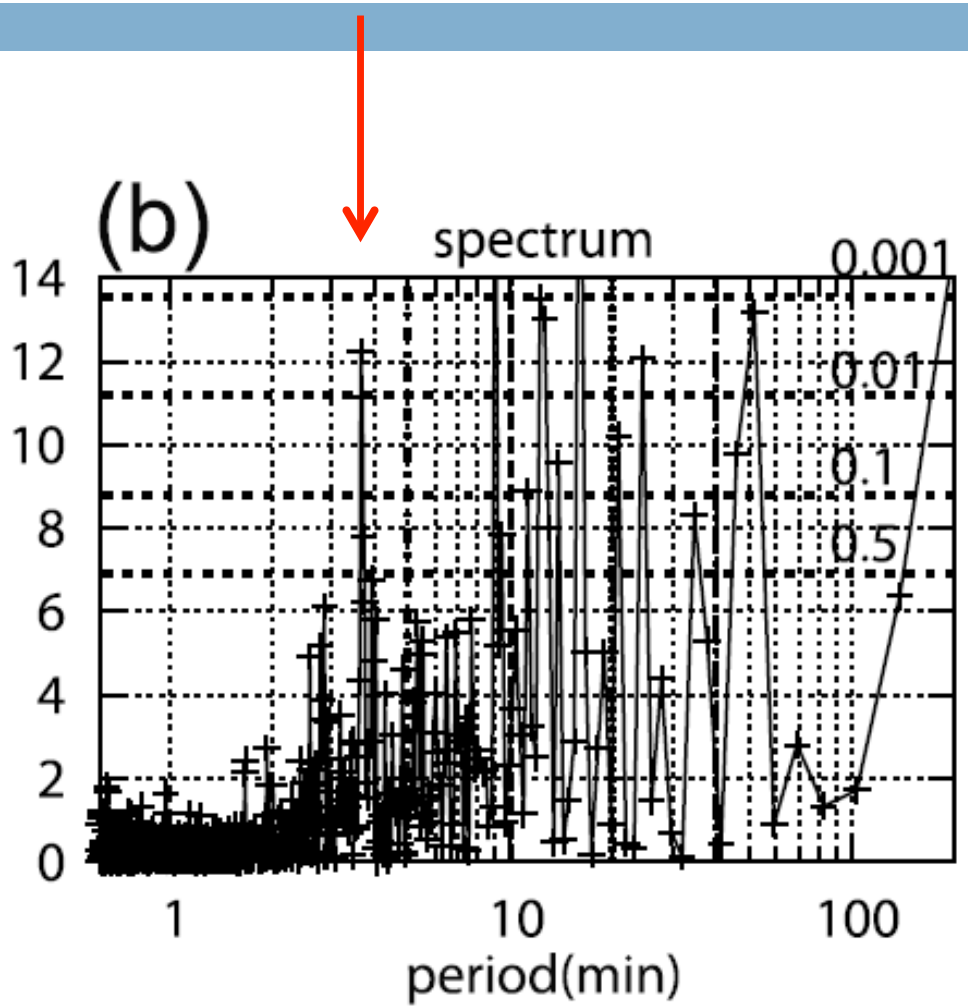
North and South flare in phase

Bonfond et al., in preparation

Radio

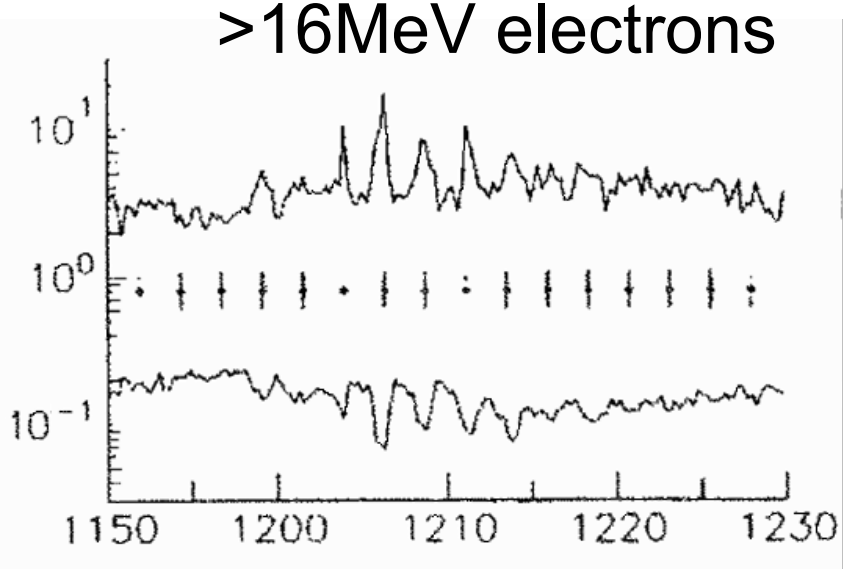


Hospodarsky et al., 2004

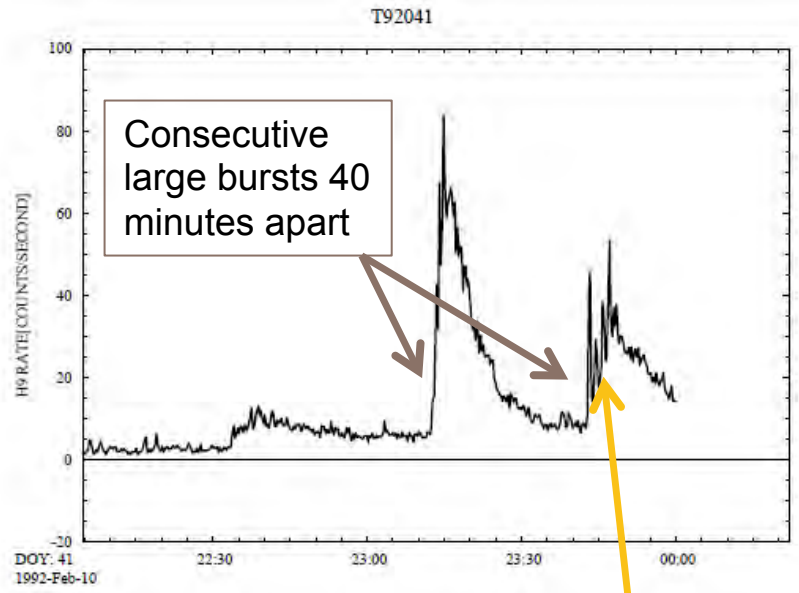


Kimura et al., 2012

Ulysses/COSPIN/HET, Channel H9 (e^- >16MeV)



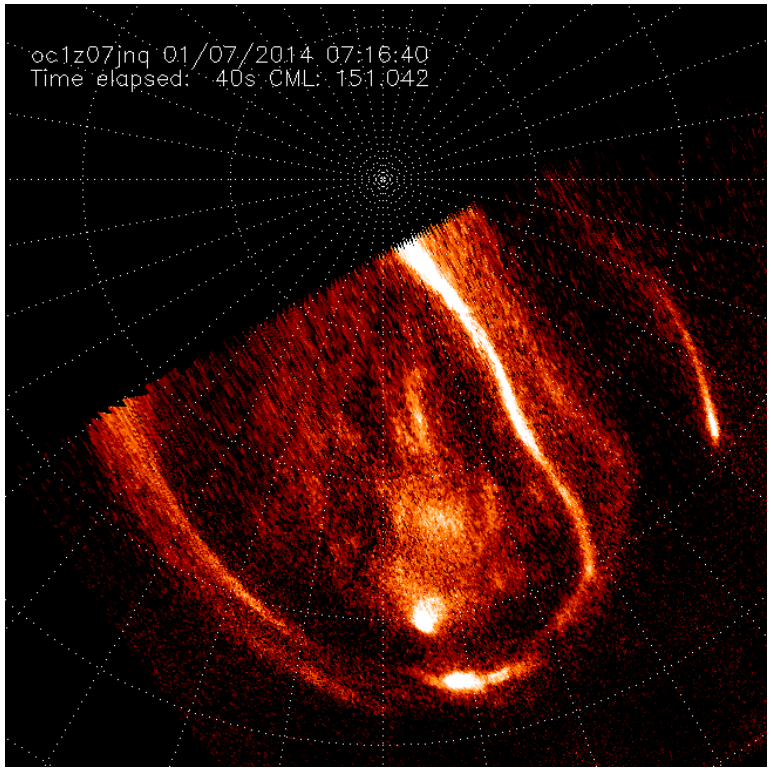
Electron bursts (Ulysses): 144s
McKibben et al., 1993



2-3 minutes long sub-structures in the 40-minutes bursts

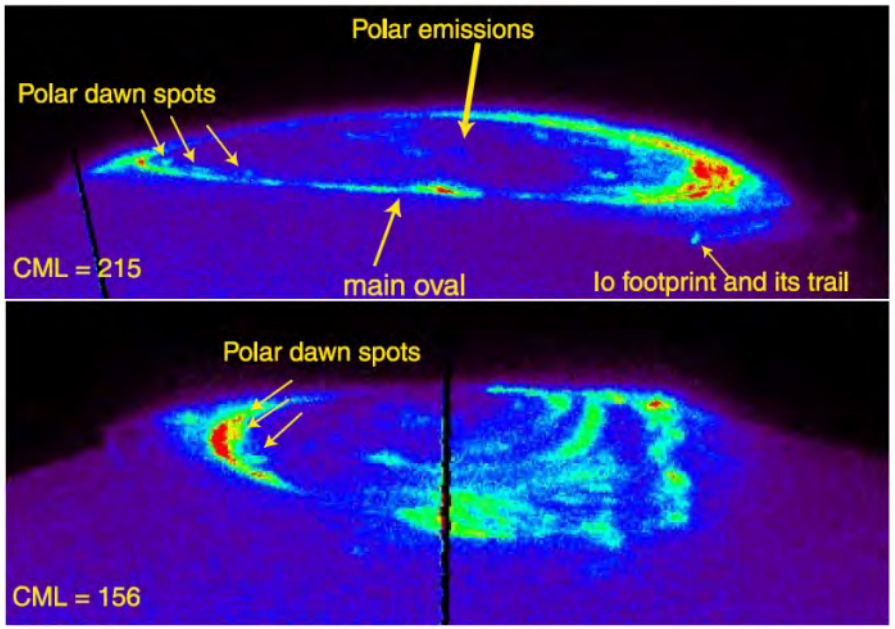
Polar aurora: Different types of flares?

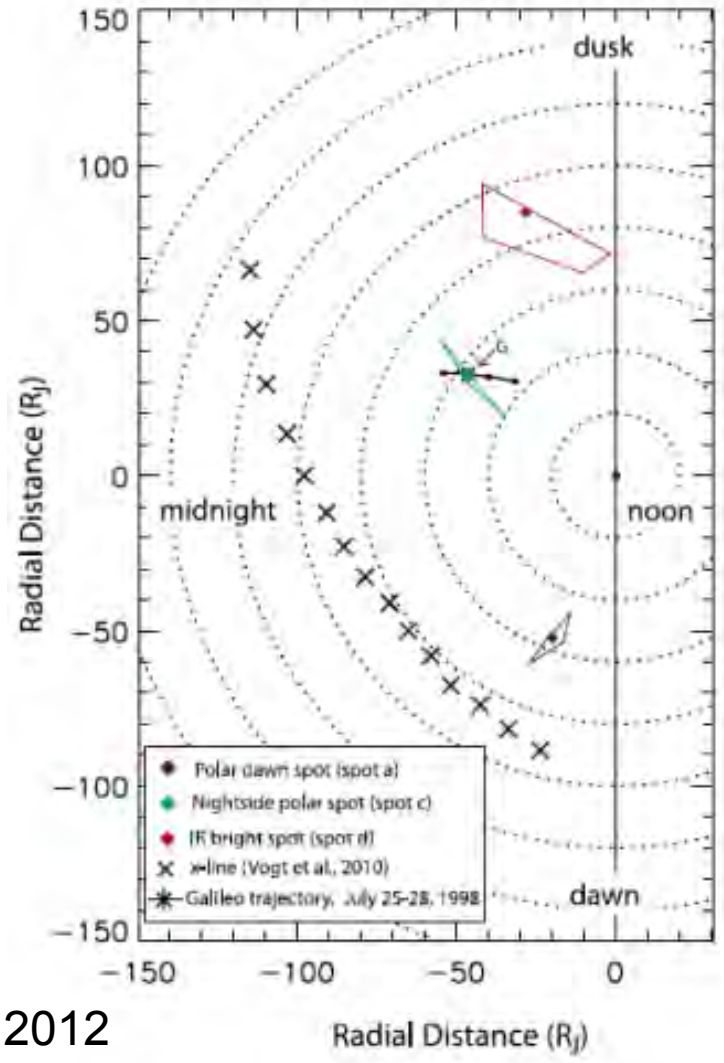
- Quasi-periodic flares: only obvious in 6 cases out of 14 in the HST/Exceed campaign
- Unique big flares: Are they part of a sequence?



Bonfond et al., in preparation

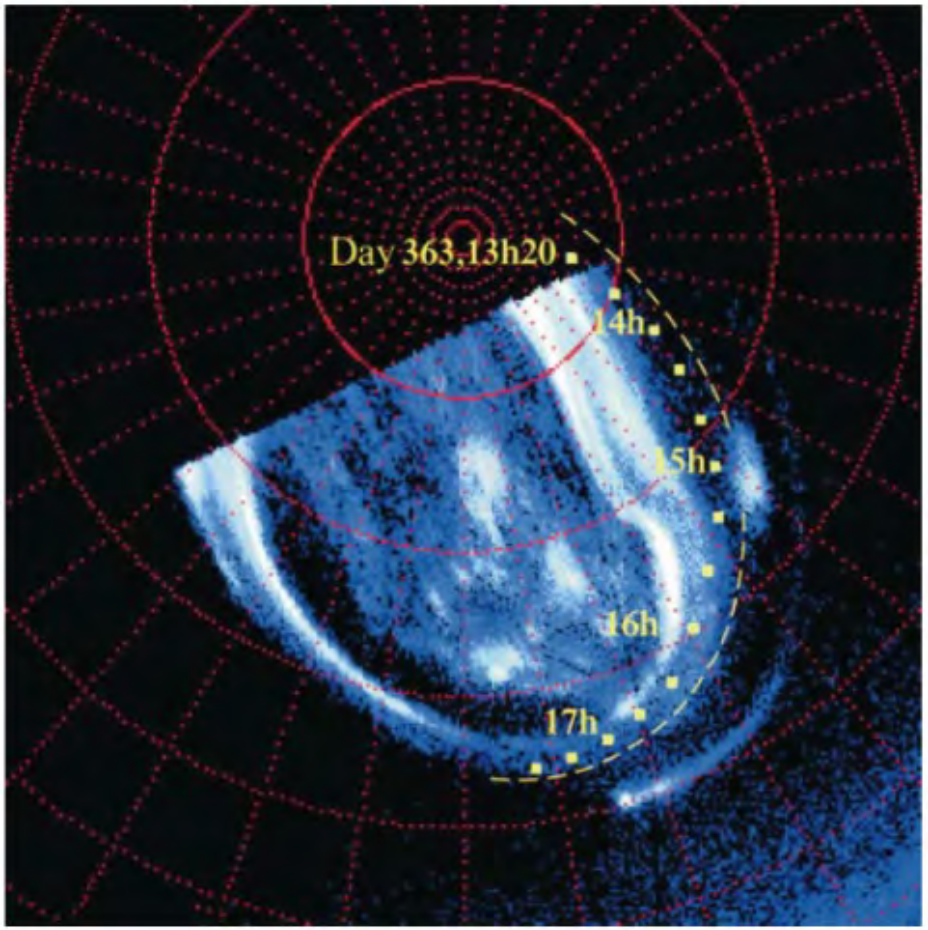
Polar dawn spots



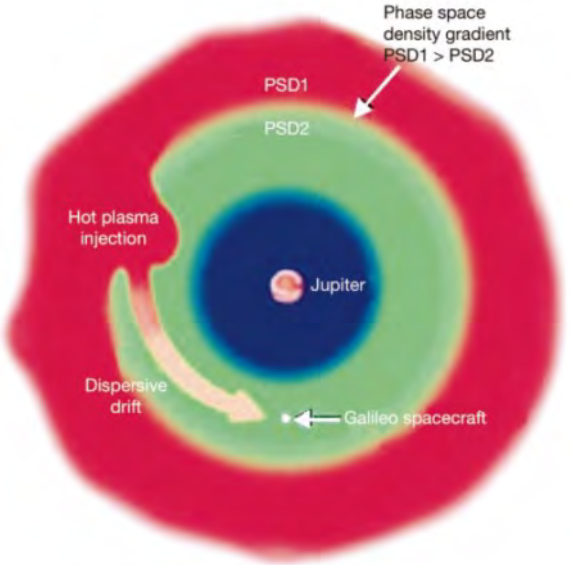


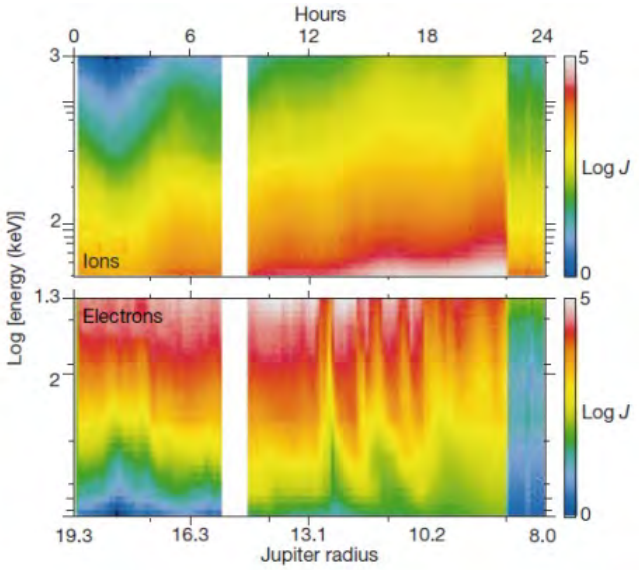
Radioti et al.2008, 2012

Plasma injection signatures

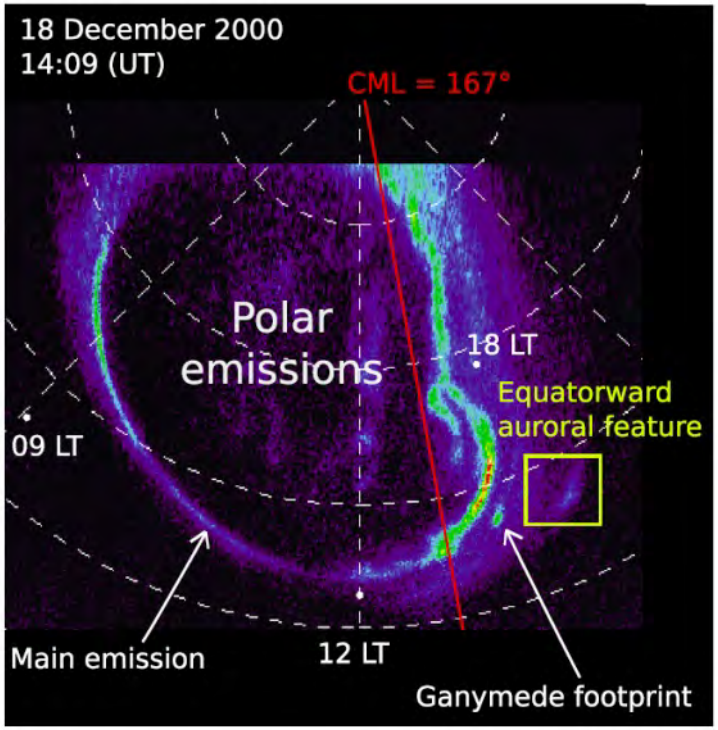


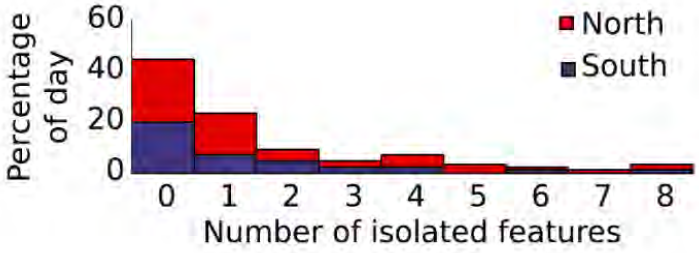
Mauk et al. 2002

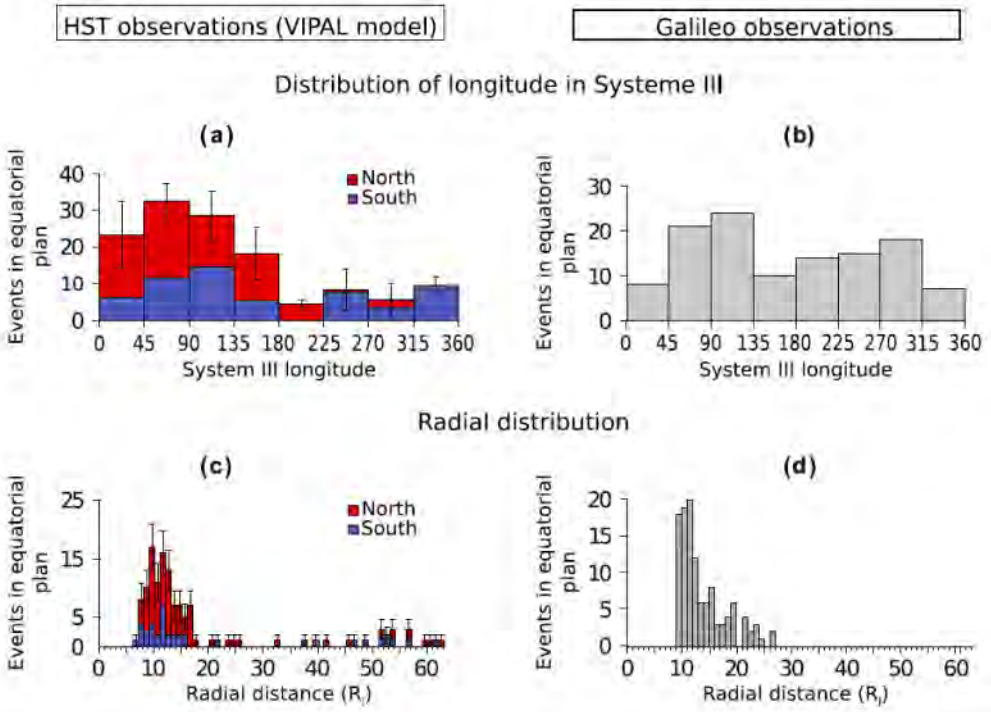




Statistics of injection signatures

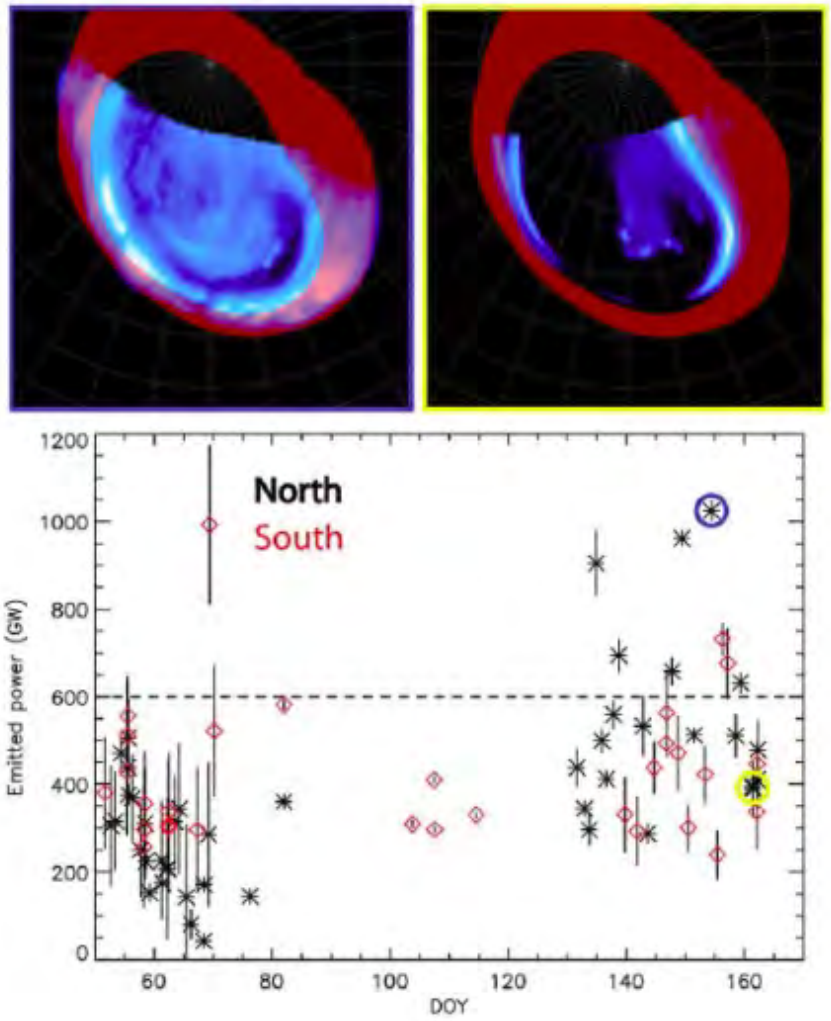


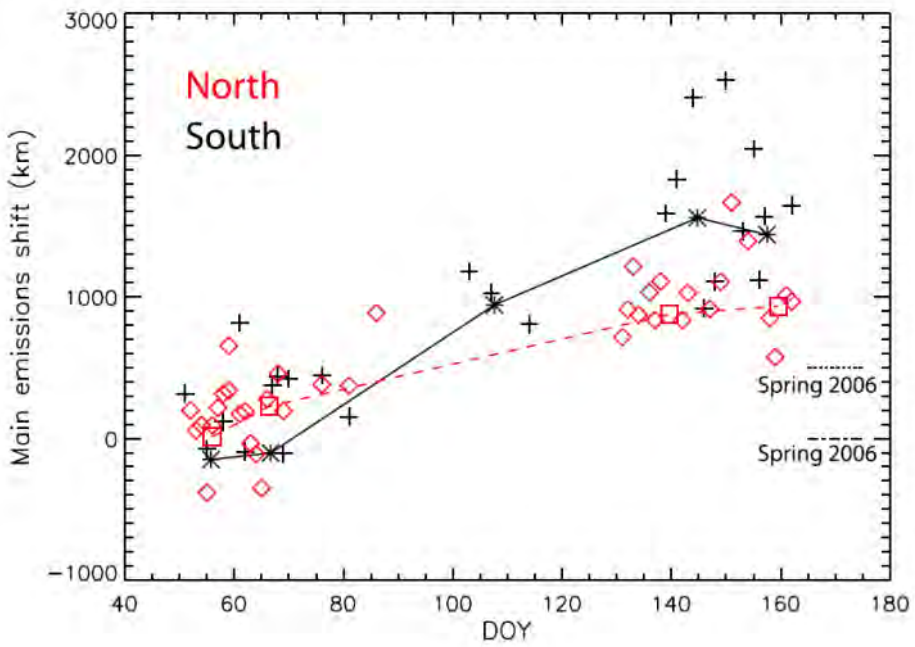




Dumont et al. 2014

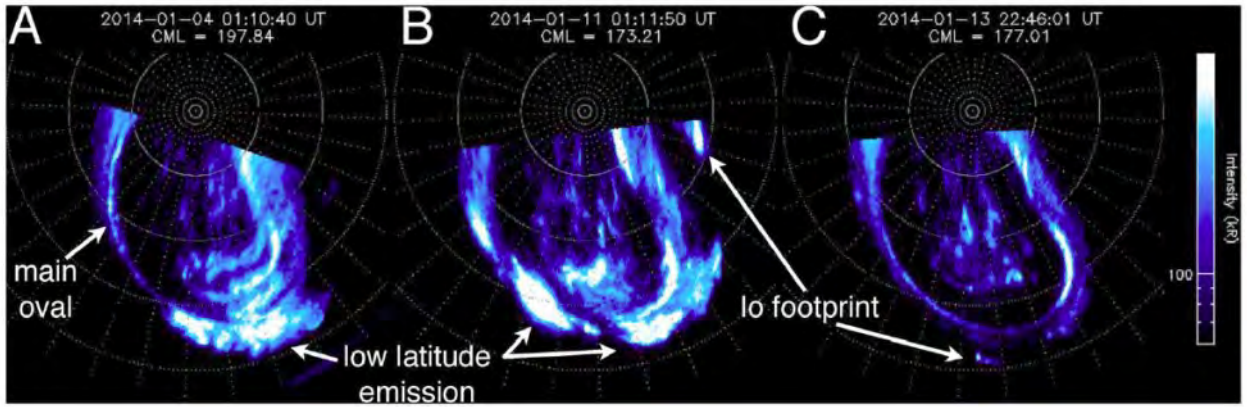
A major component of the aurorae

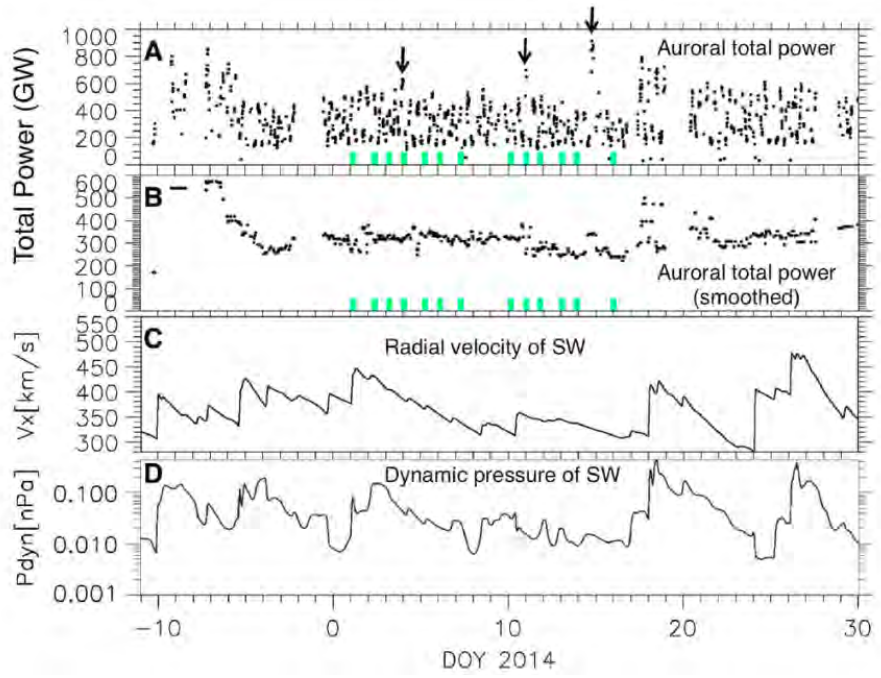




Bonfond et al. 2012

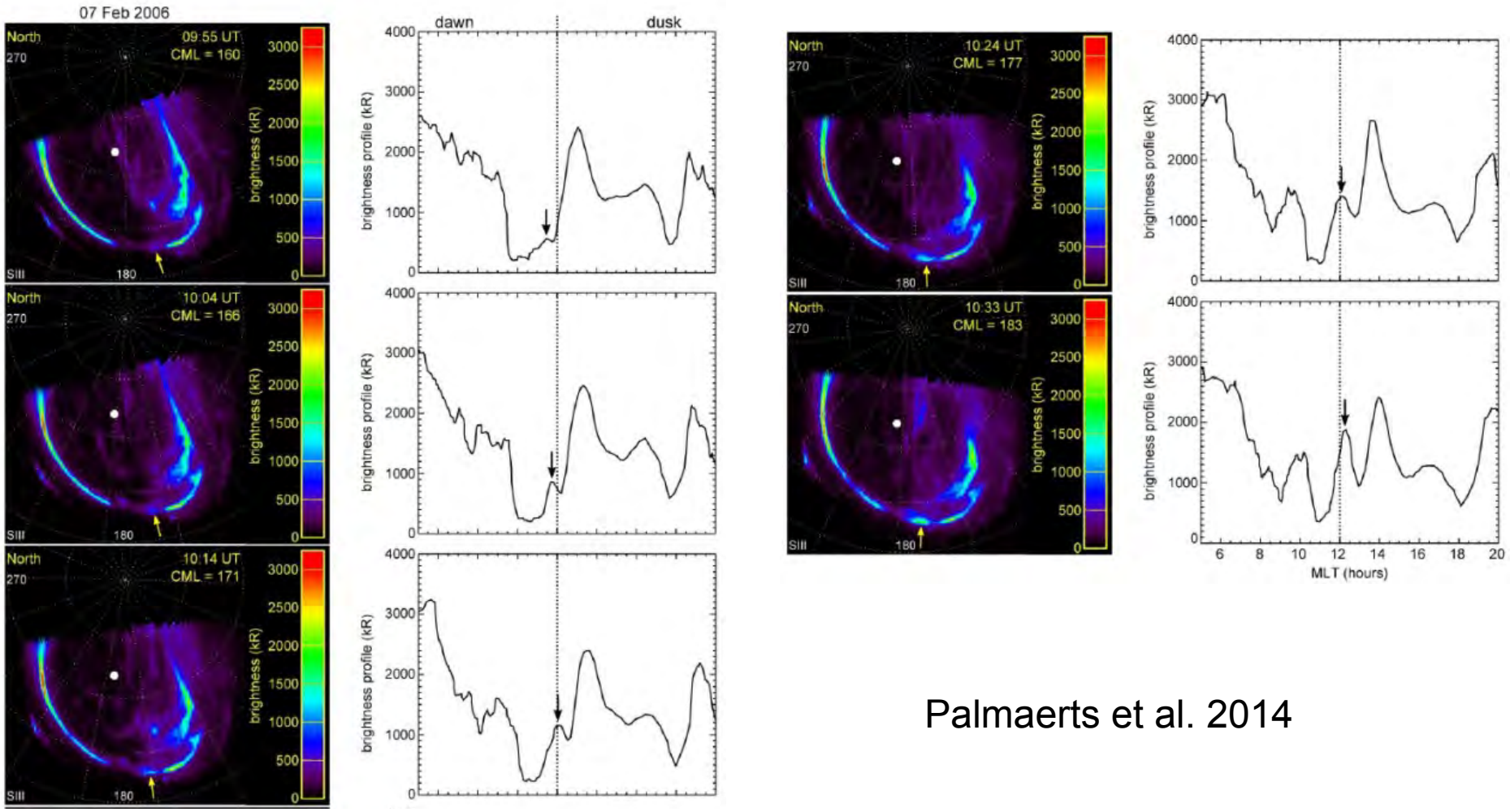
A major component of the aurorae





Kimura et al. 2015

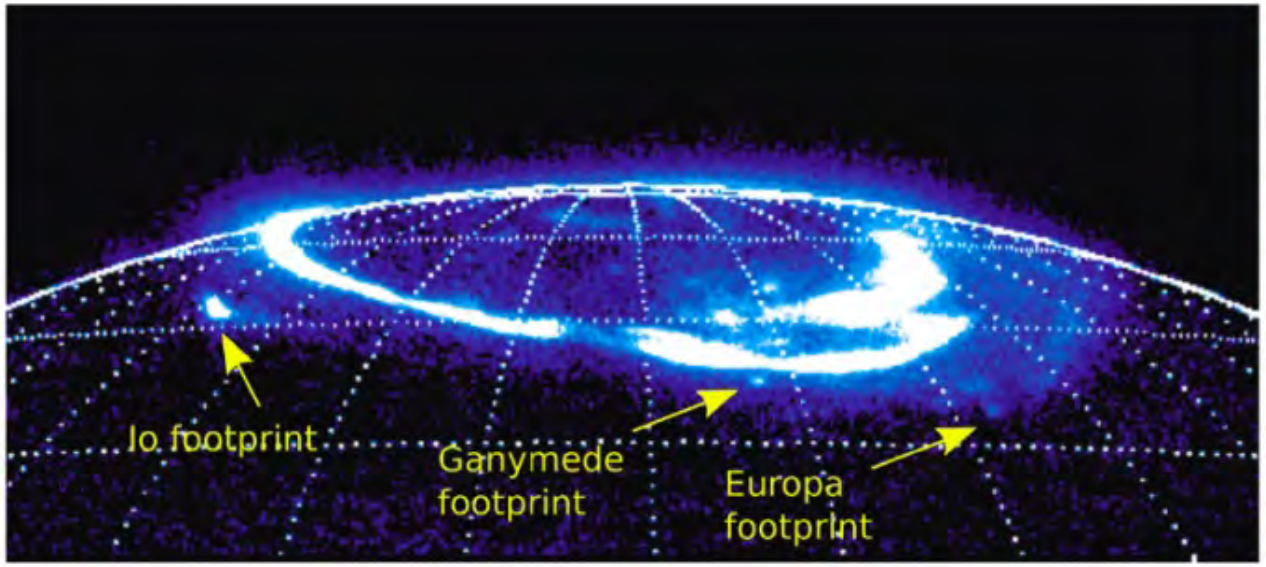
Transient small scale feature

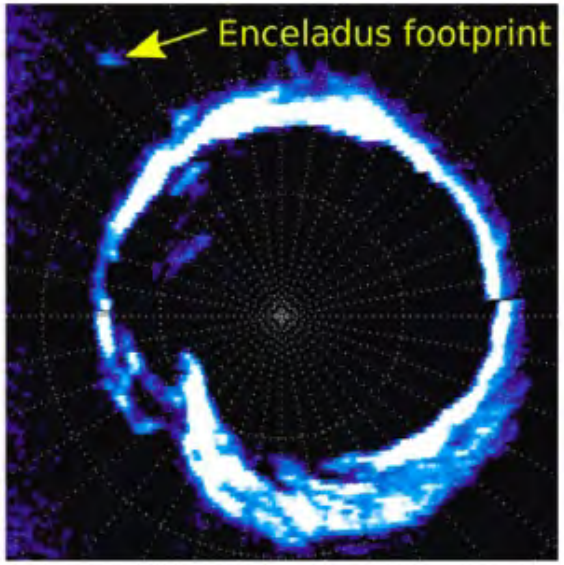


Palmaerts et al. 2014

Widespread phenomenon on giant planets

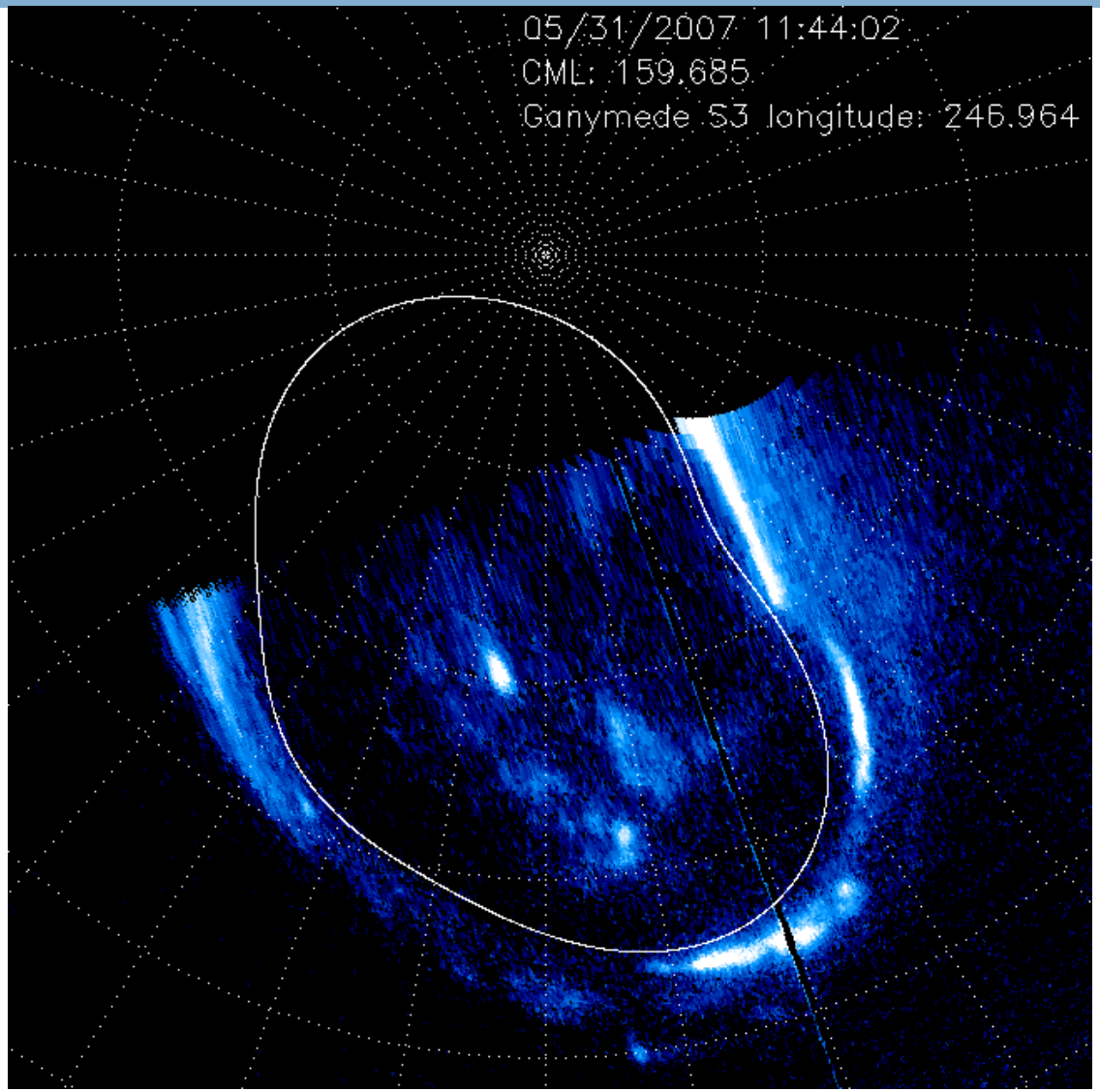
- Io, Europa and Ganymede footprints
- Saturn: Enceladus footprint





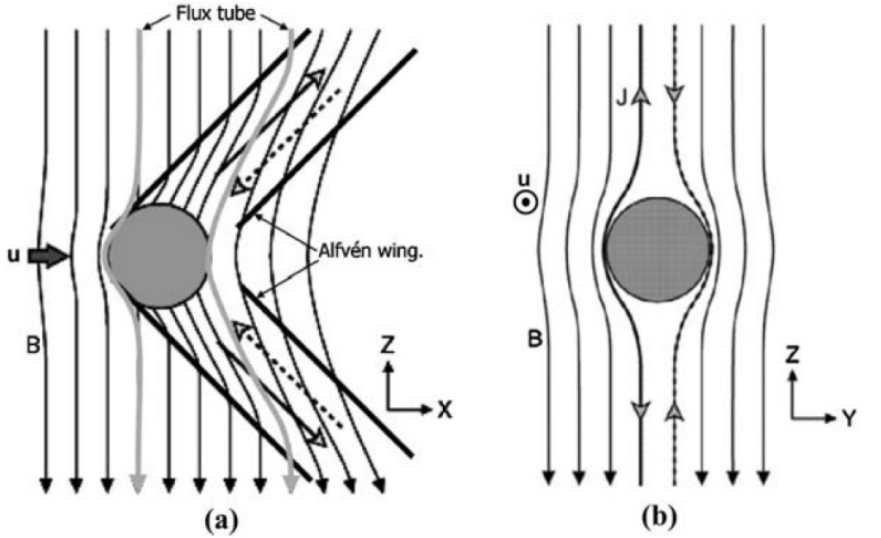
Cf. Clarke et al. 2002, Pryor et al., 2011

GFP as a landmark in the magnetosphere

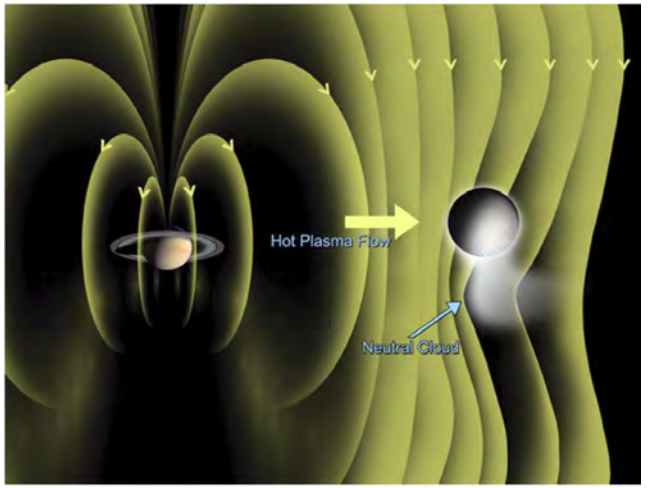


Bonfond et al., 2012

Local satellite-magnetosphere interaction

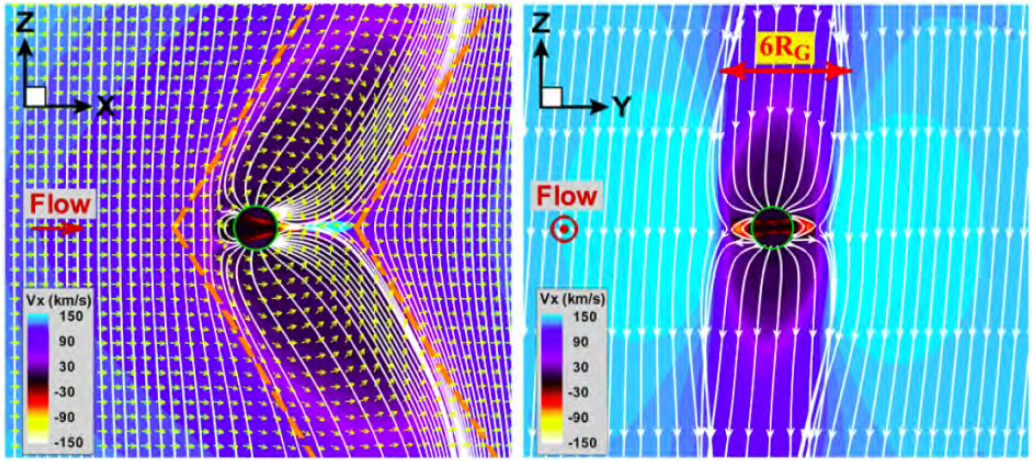


Kivelson et al., 2004

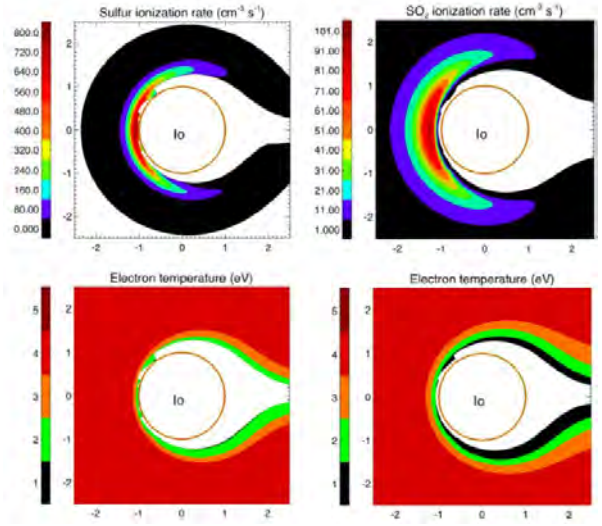


Dougherty et al. 2006

See Jia et al., 2009b and references therein

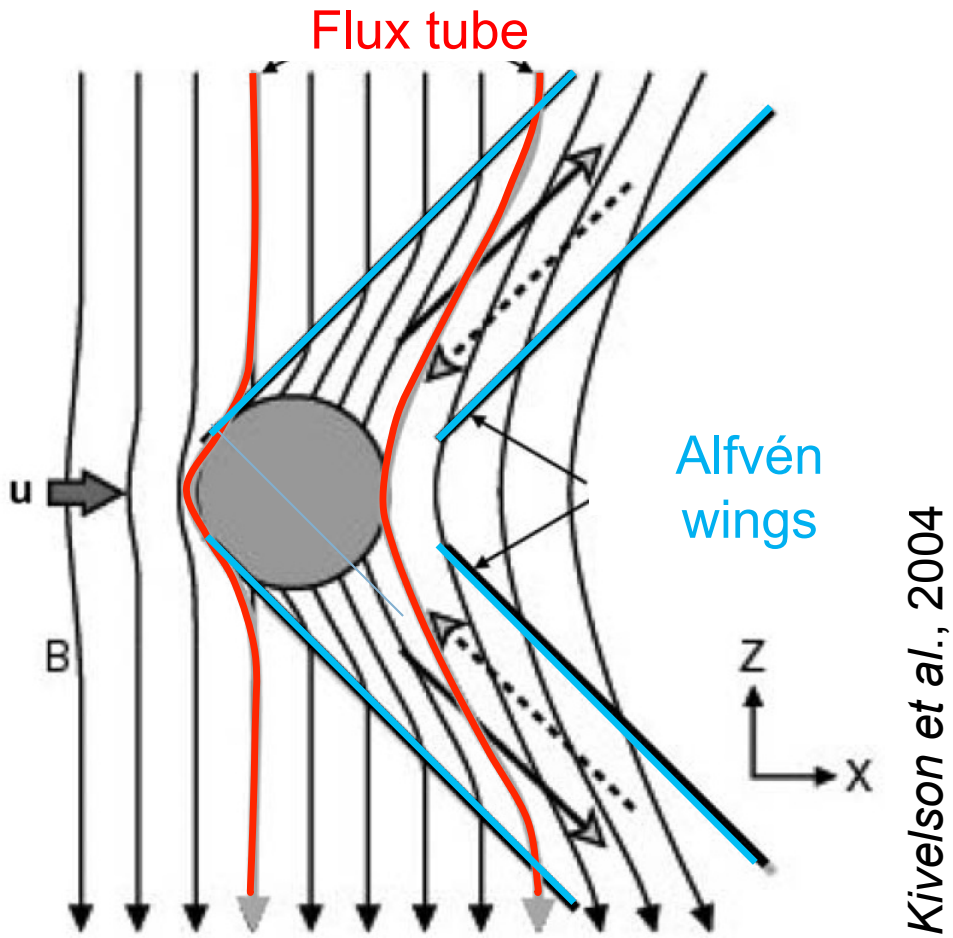


Jia et al. 2009a



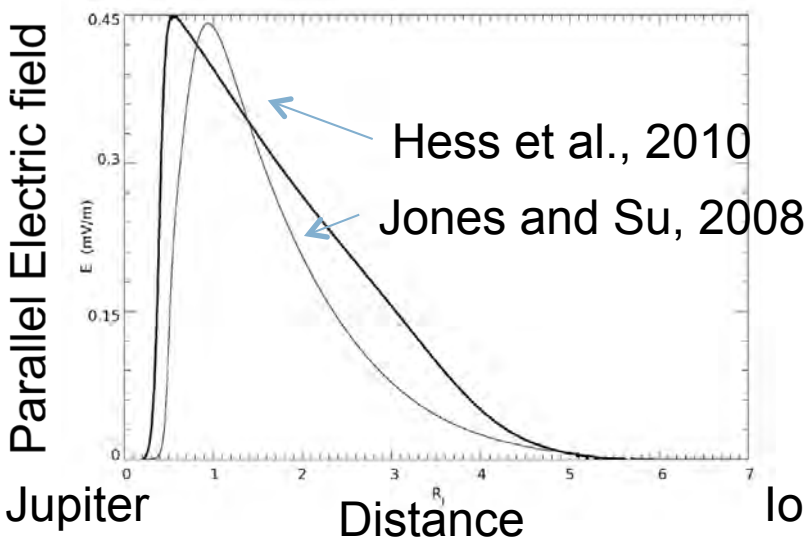
Dols et al., 2012

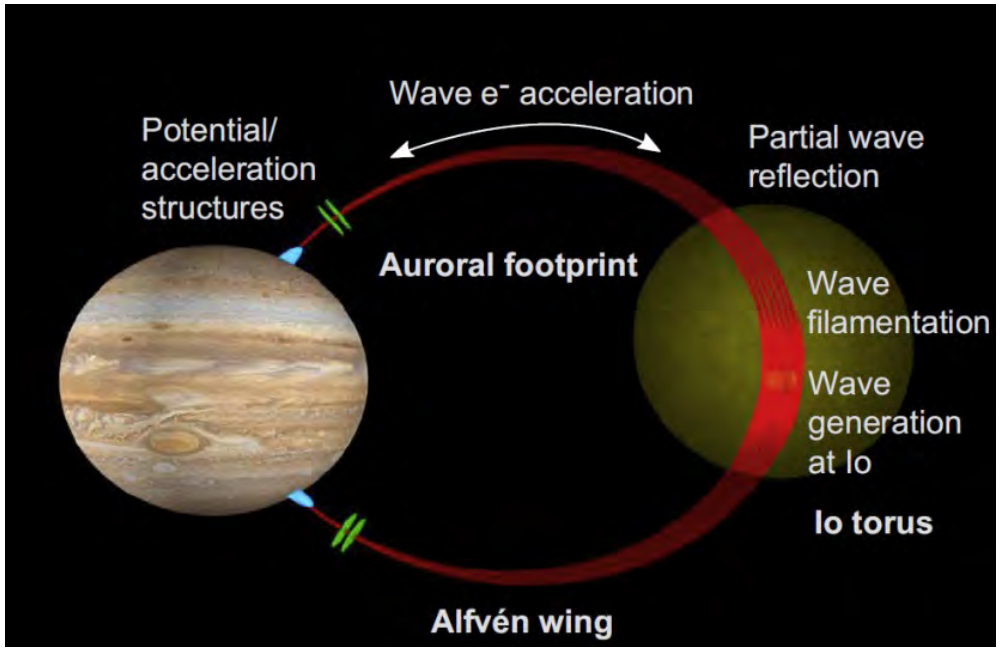
Interaction model



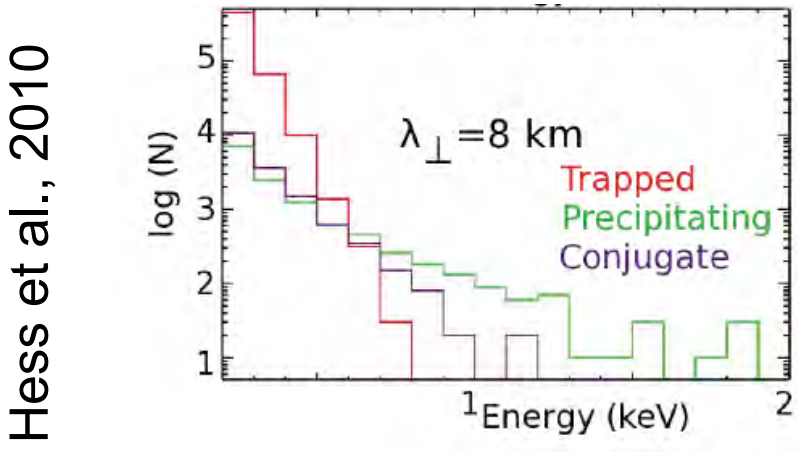
Kivelson et al., 2004

Inertial Alfvén waves + filamentation

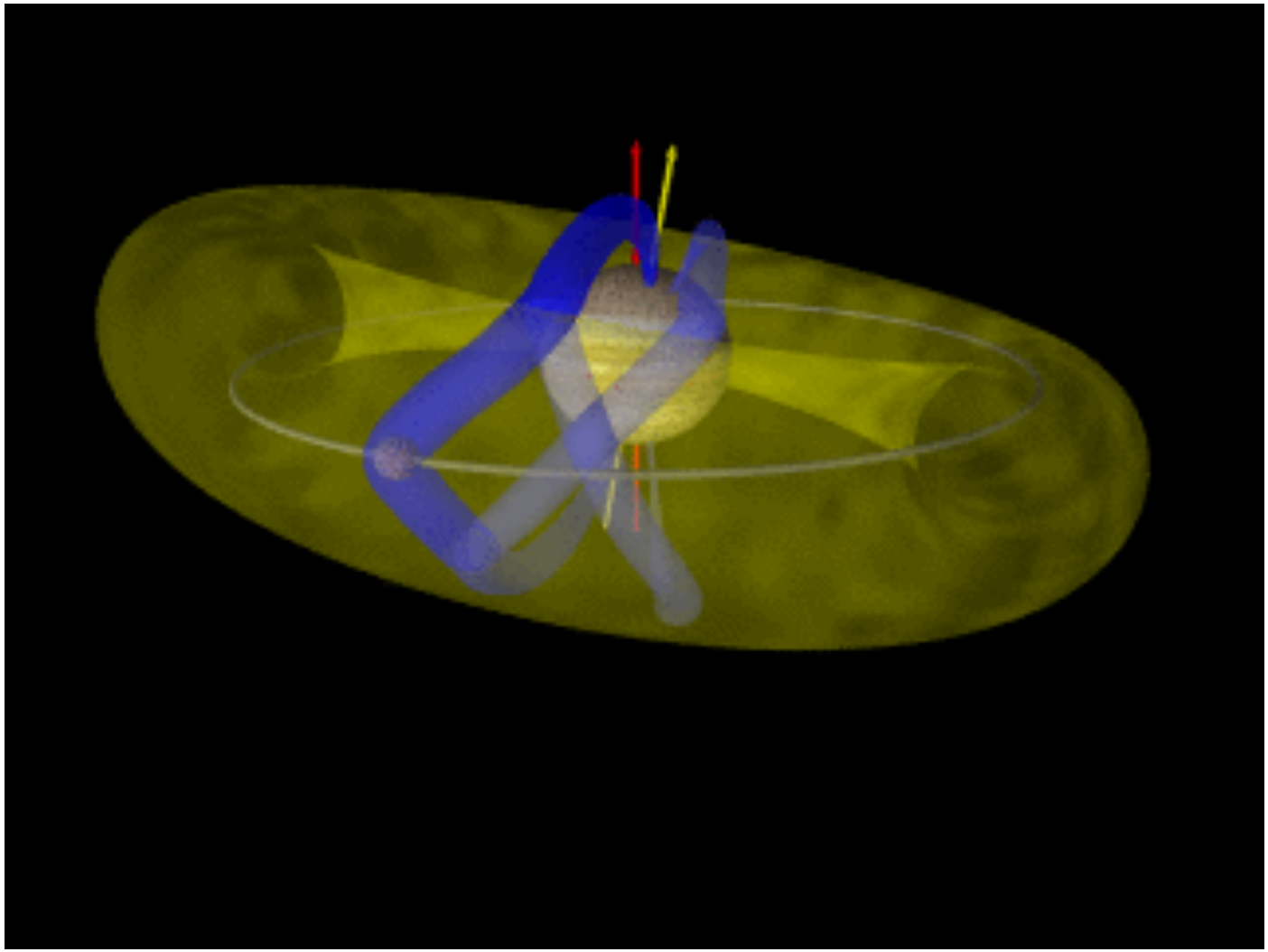




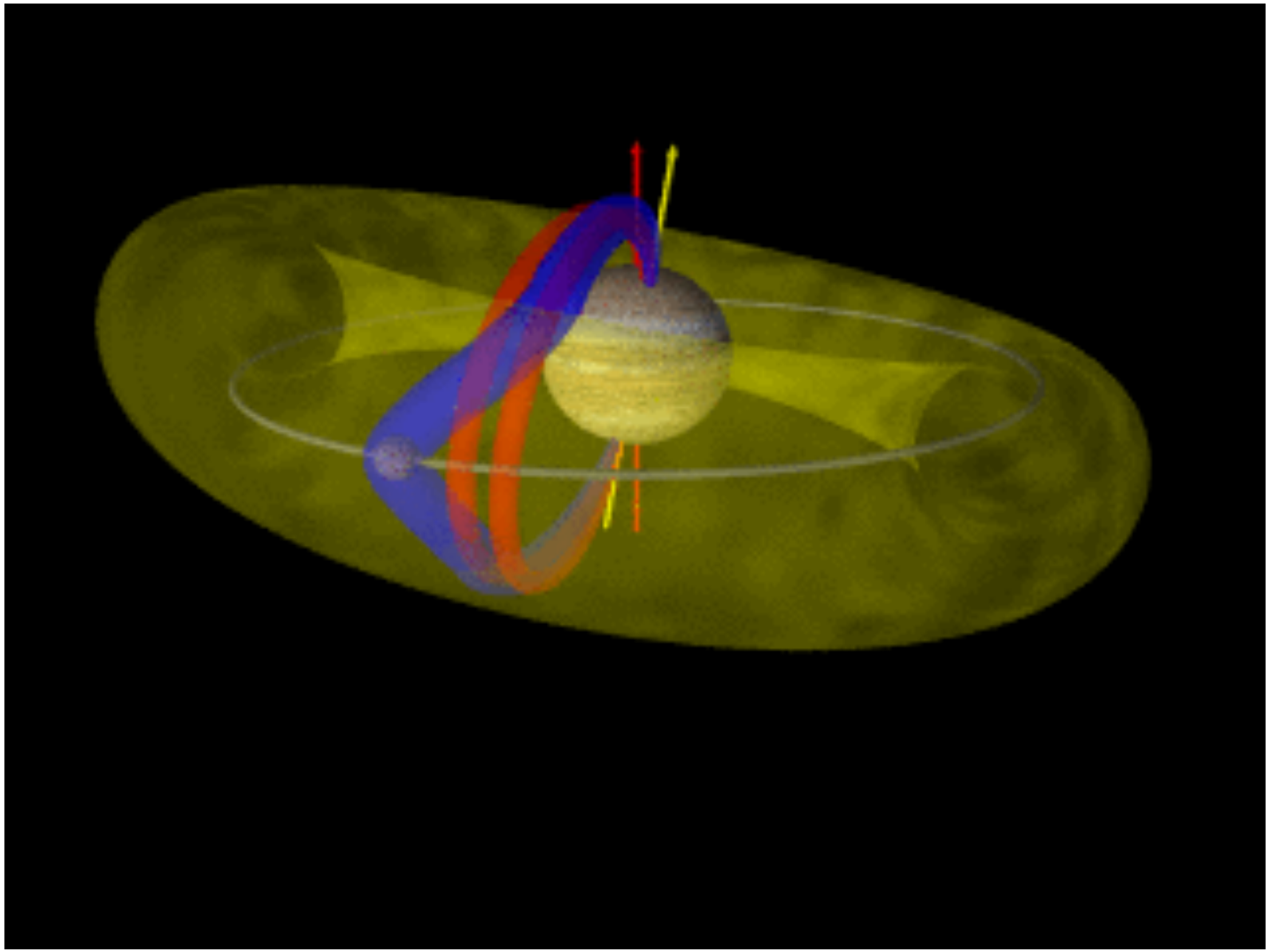
Bonfond et al., 2013



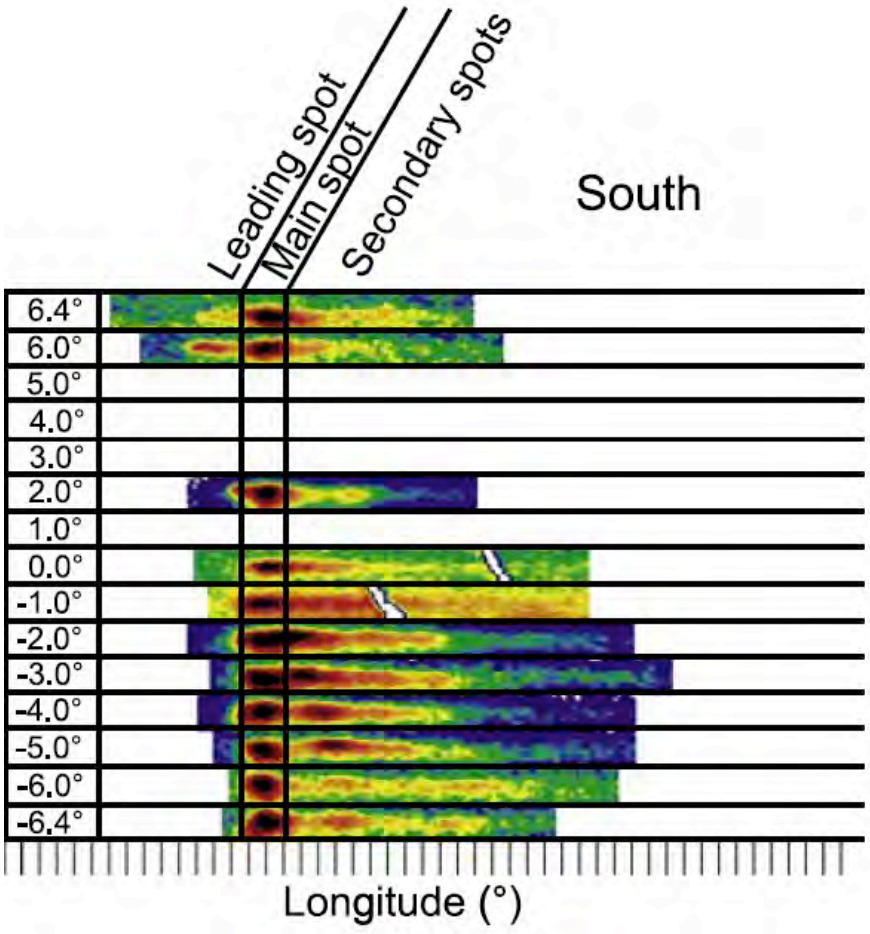
Reflected Alfvén waves



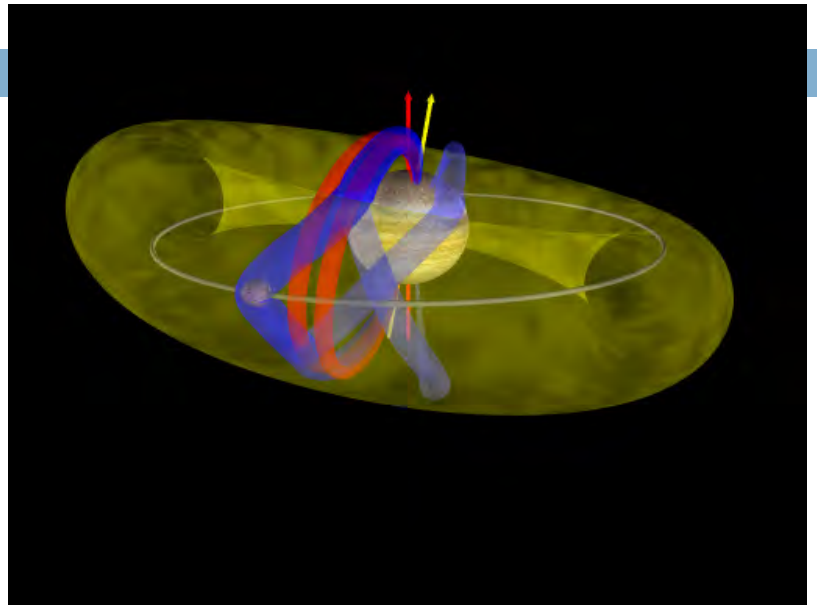
Trans-hemispheric electron beams

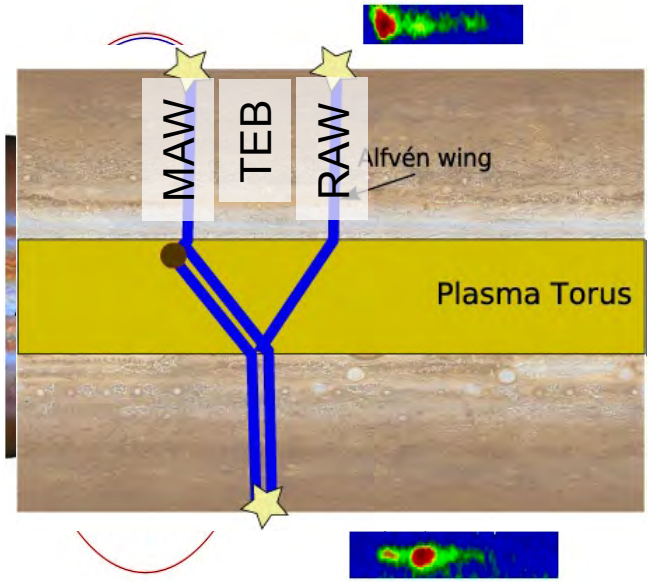


Spots multiplicity evolution

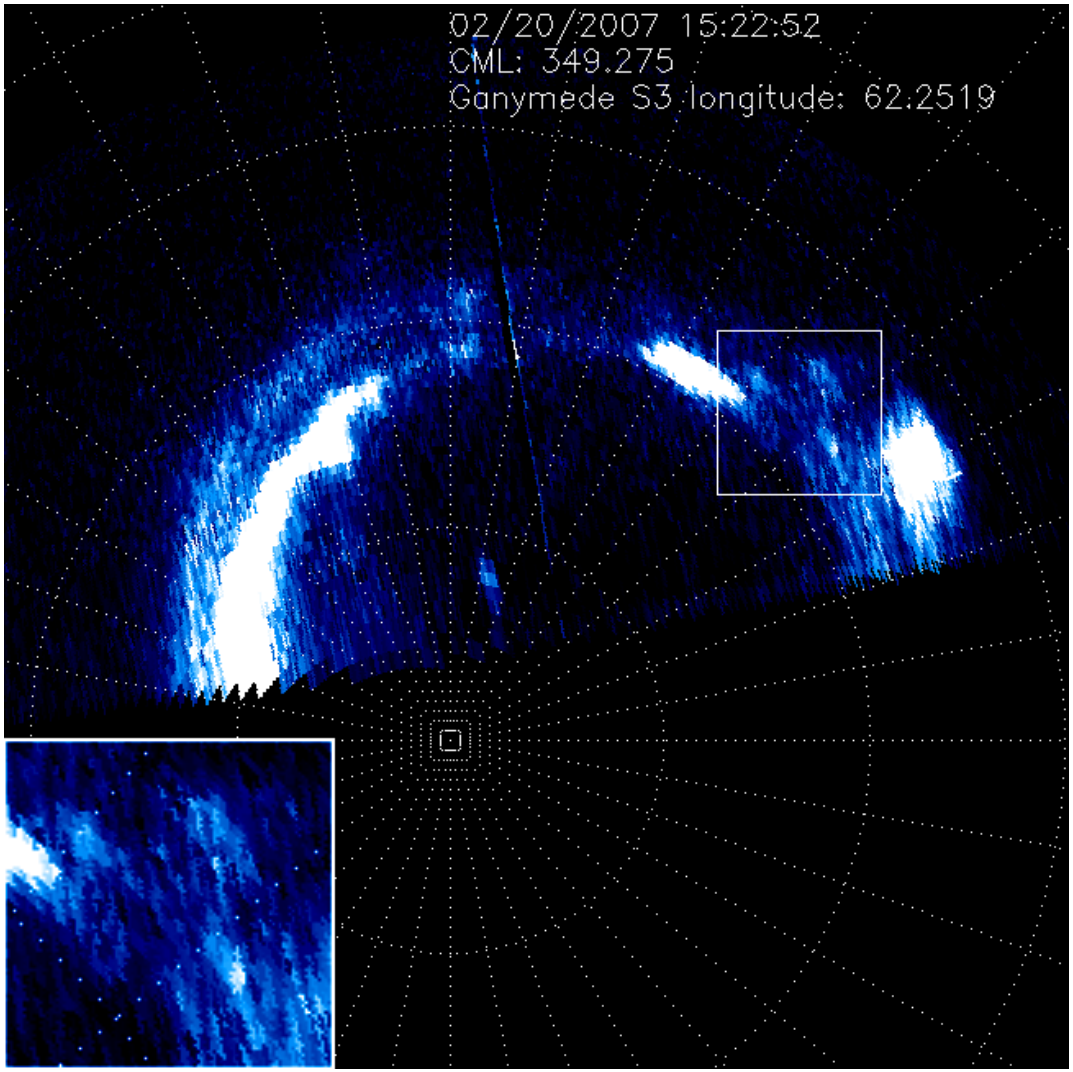


Bonfond et al., 2008



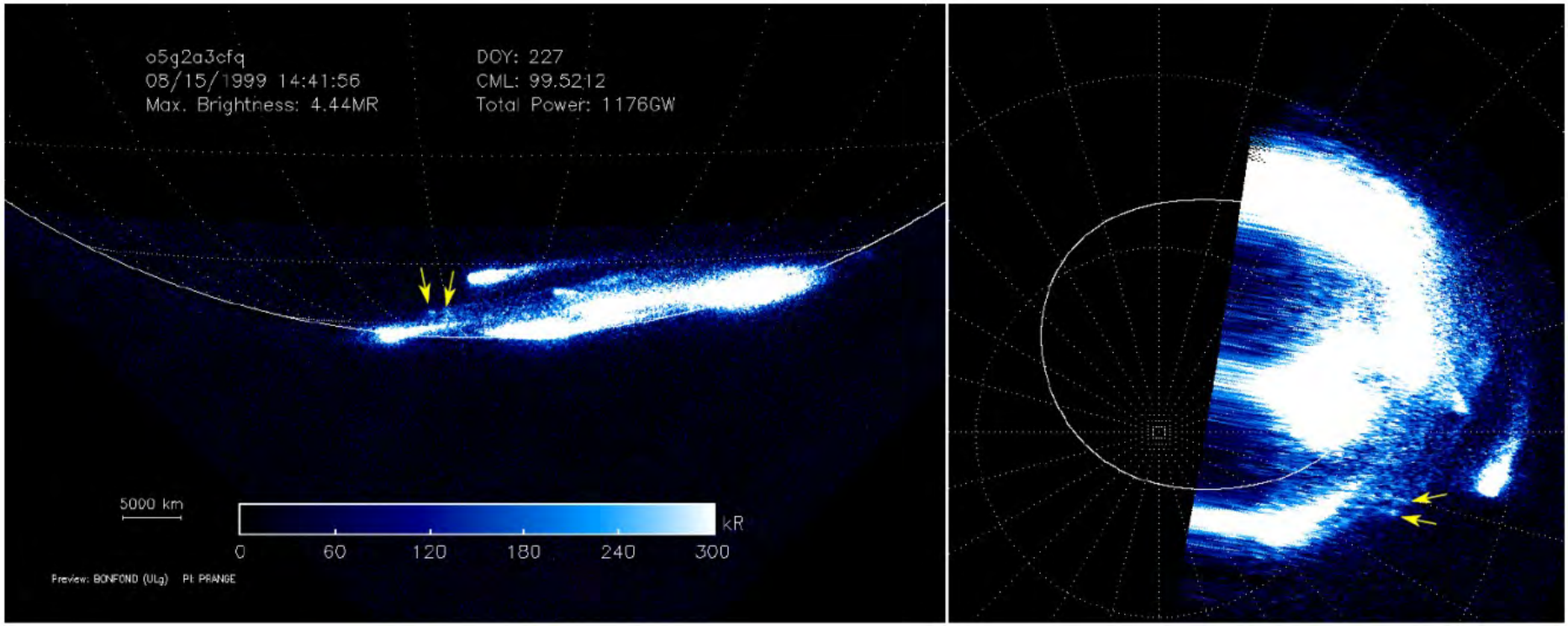


The multiple spots of the Ganymede footprint



Bonfond et al., 2013

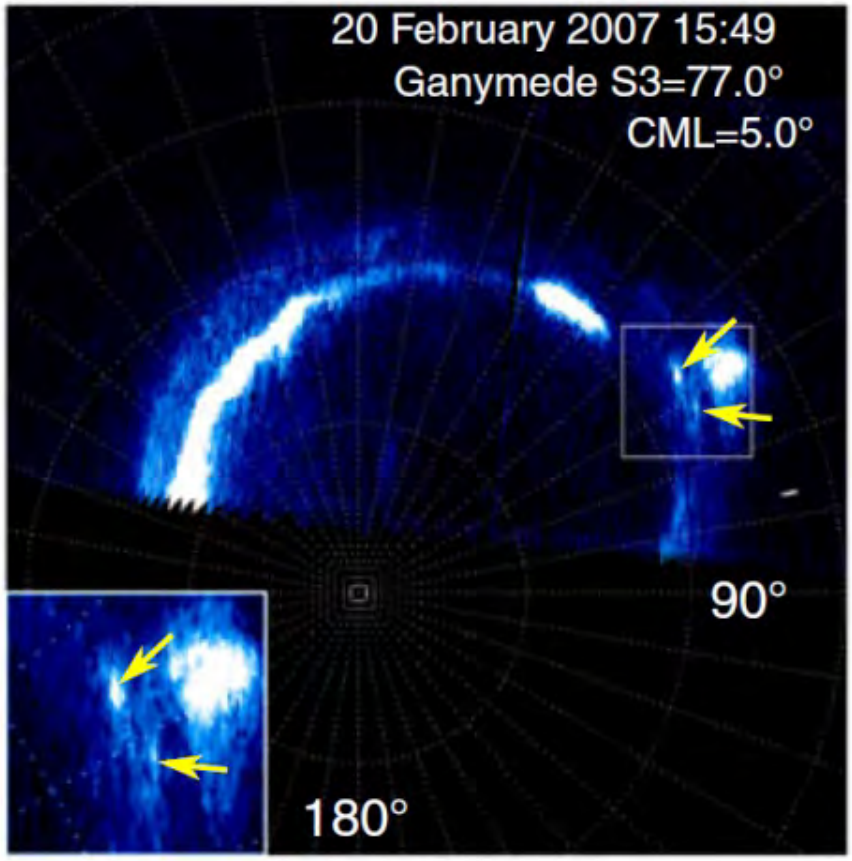
The multiple spots of the Europa footprint

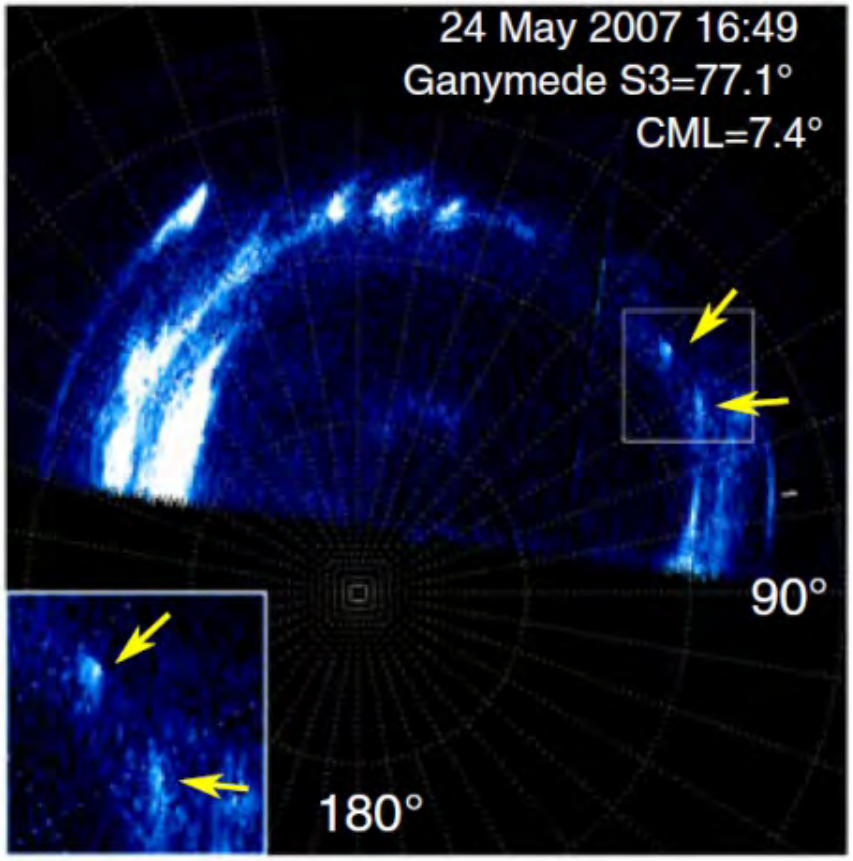


Bonfond et al., in preparation

Interspot distance variations

- For a same S3 longitude, the distance can vary

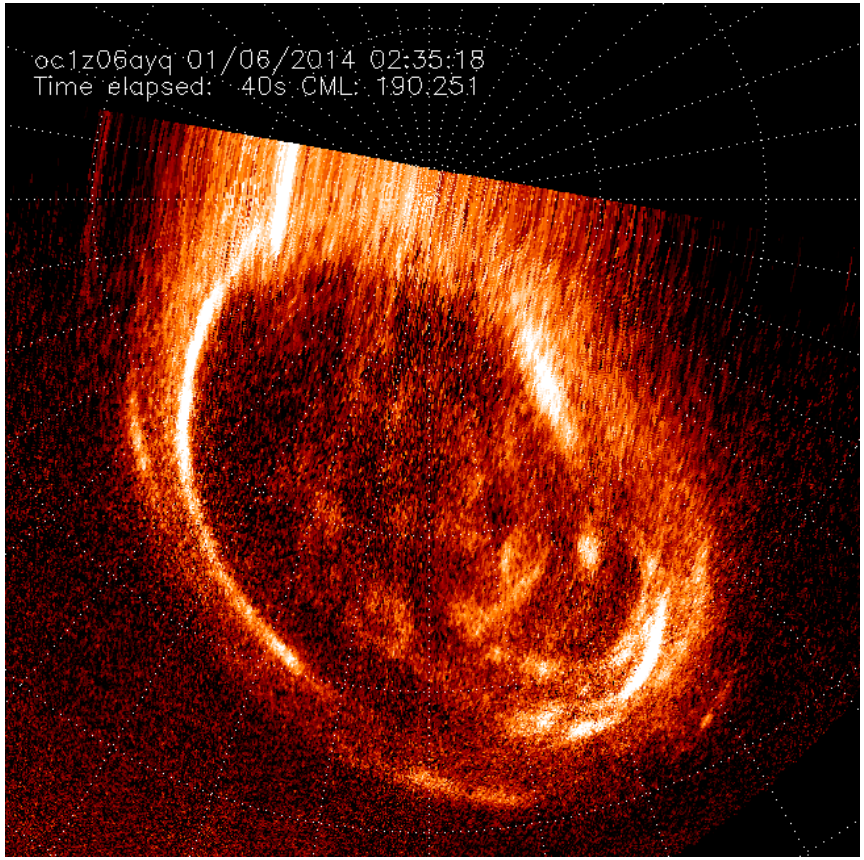




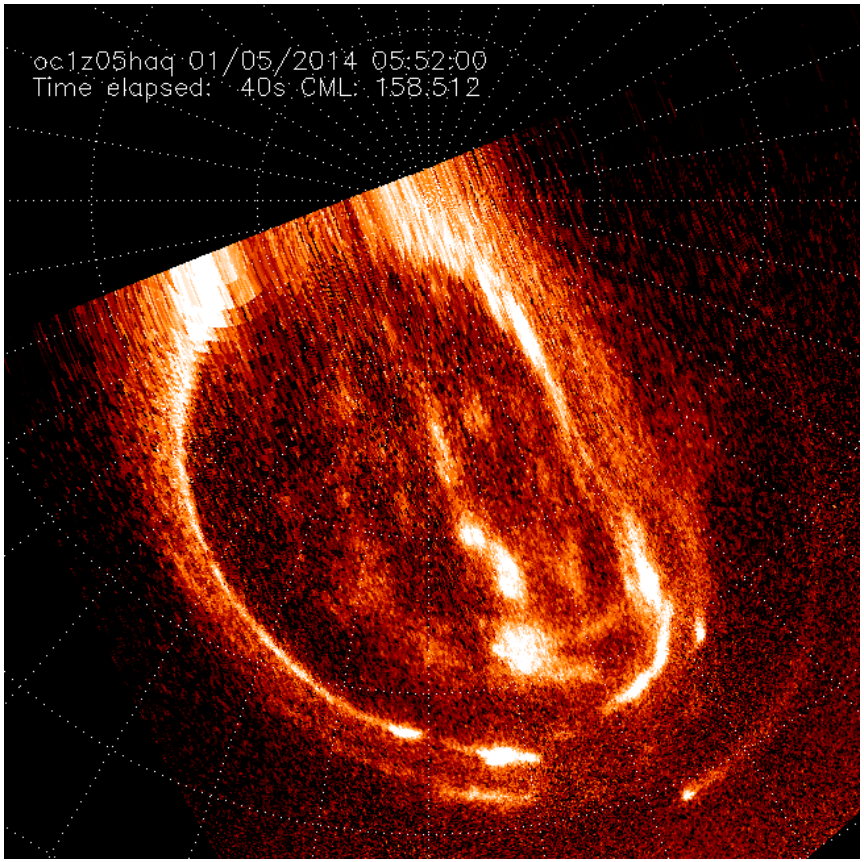
Bonfond et al., 2013

Tails for the Europa and Ganymede footprints

Europa footprint

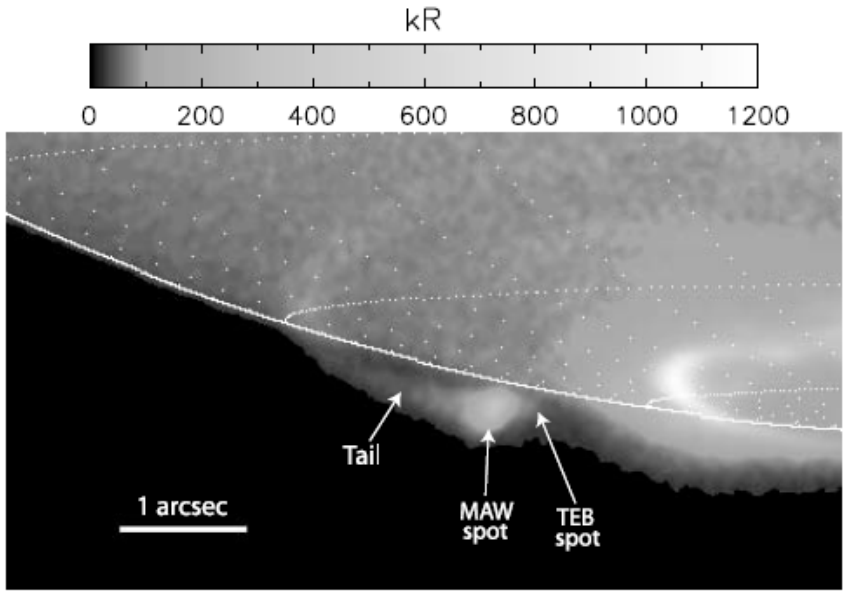


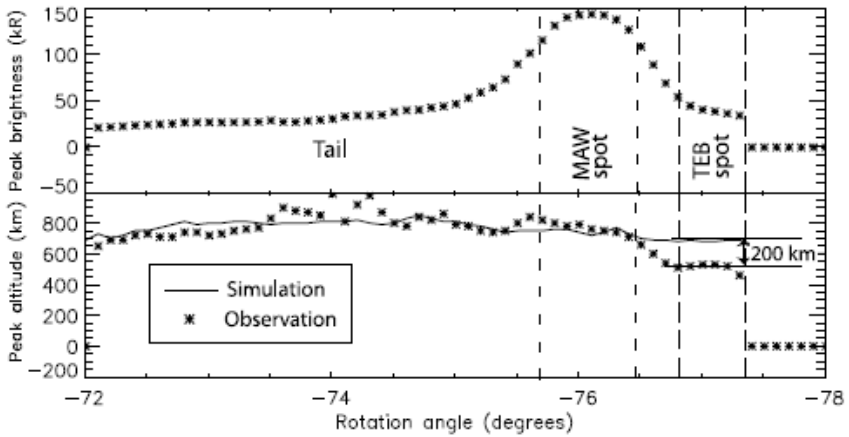
Ganymede footprint



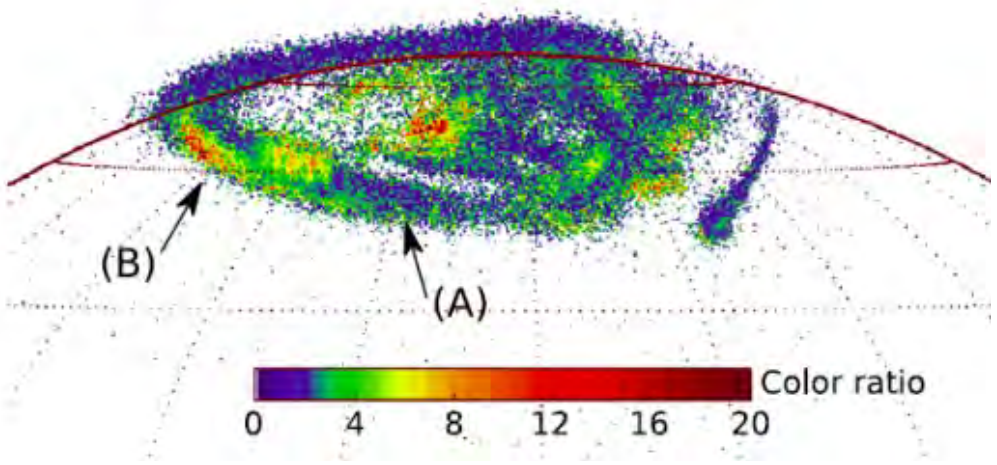
Bonfond et al., in preparation

IFP features' altitude





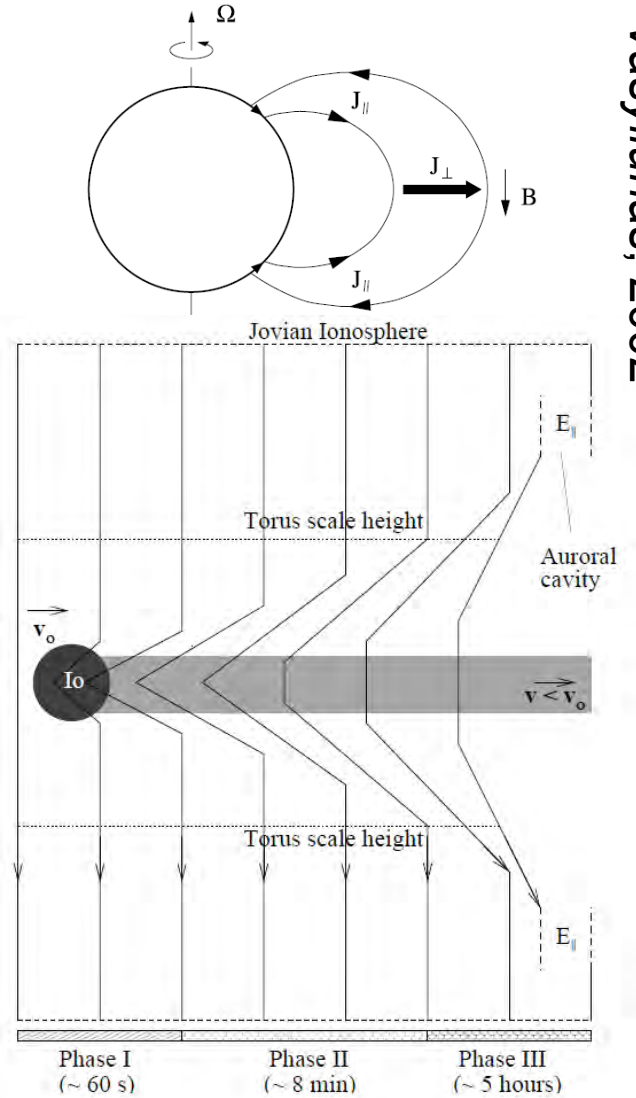
- Peak altitudes:
  - Main spot: 900 km
  - TEB spot: 700 km
  - Tail: 900 km



Bonfond , 2010

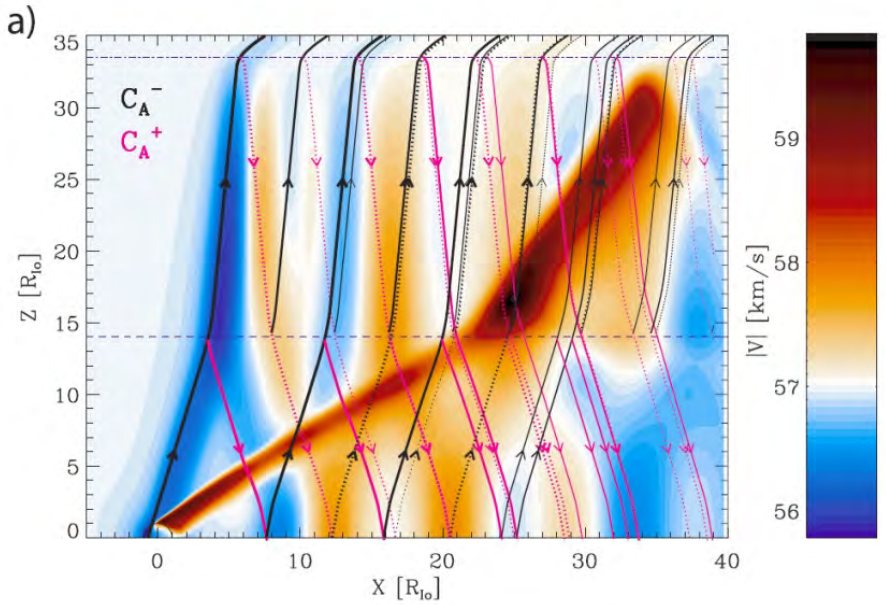
Gérard et al. , 2014

Trailing tail models: steady state vs. Alfvén waves' multiple reflections



Hill and Vasyliunas, 2002

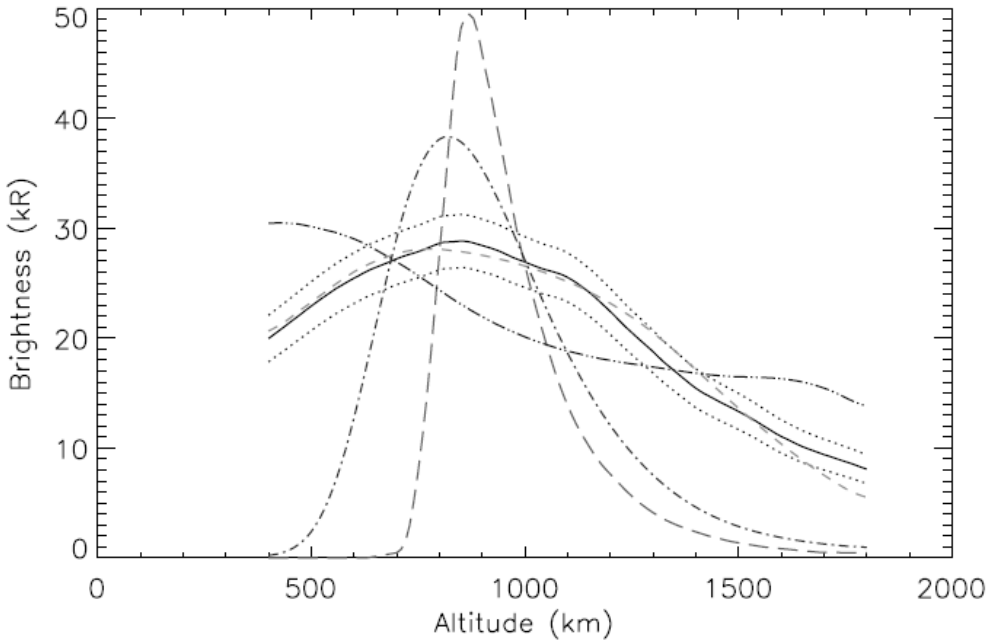
Delamere et al., 2003



Jacobsen et al., 2007

Estimate of the electrons energy

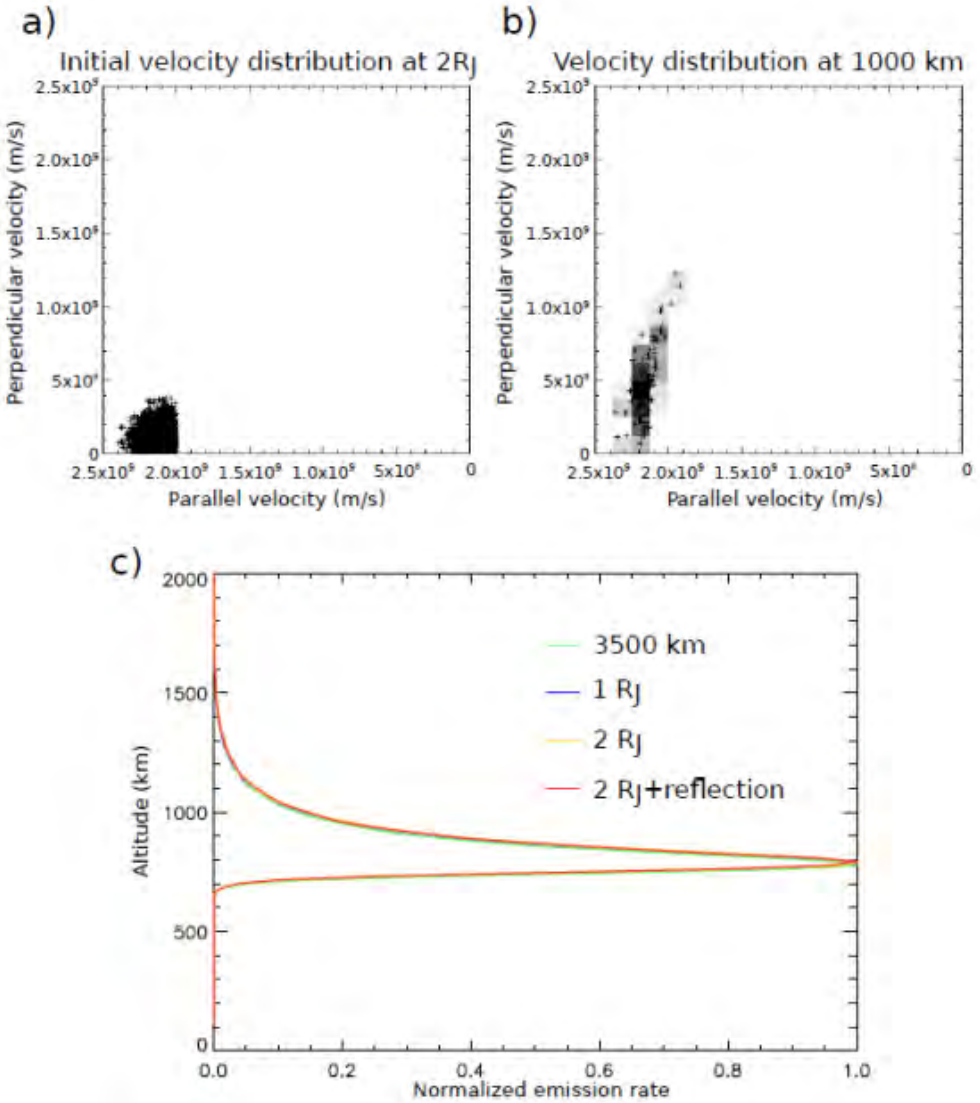
- Monte-Carlo electron energy degradation model for theoretical distributions
- Only the Kappa distribution reproduces the observations
- Mean electrons energy: ~1keV (in lieu of 55 keV)
- Contradicts models based on quasi-static electric fields



Bonfond et al., 2009

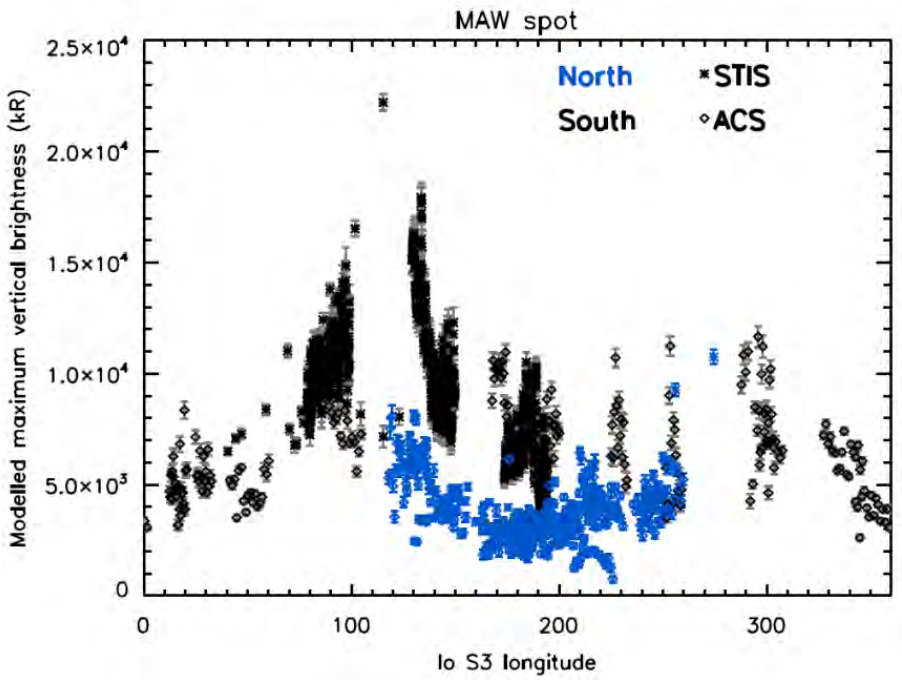
Distribution	Characteristic energy (E_0)	Spectral index (γ or κ)	Mean energy
Mono-energetic	2 keV (1.3 keV)	-	2 keV (1.3 keV)
Maxwellian	960 eV (540 eV)	-	1.9 keV (1.1 keV)
Kappa	70 eV (75 eV)	2.3 (2.4)	1.1 keV (0.8 keV)
Power-law	-	1.9 (1.8)	-

Vertical distribution of the IFP tail

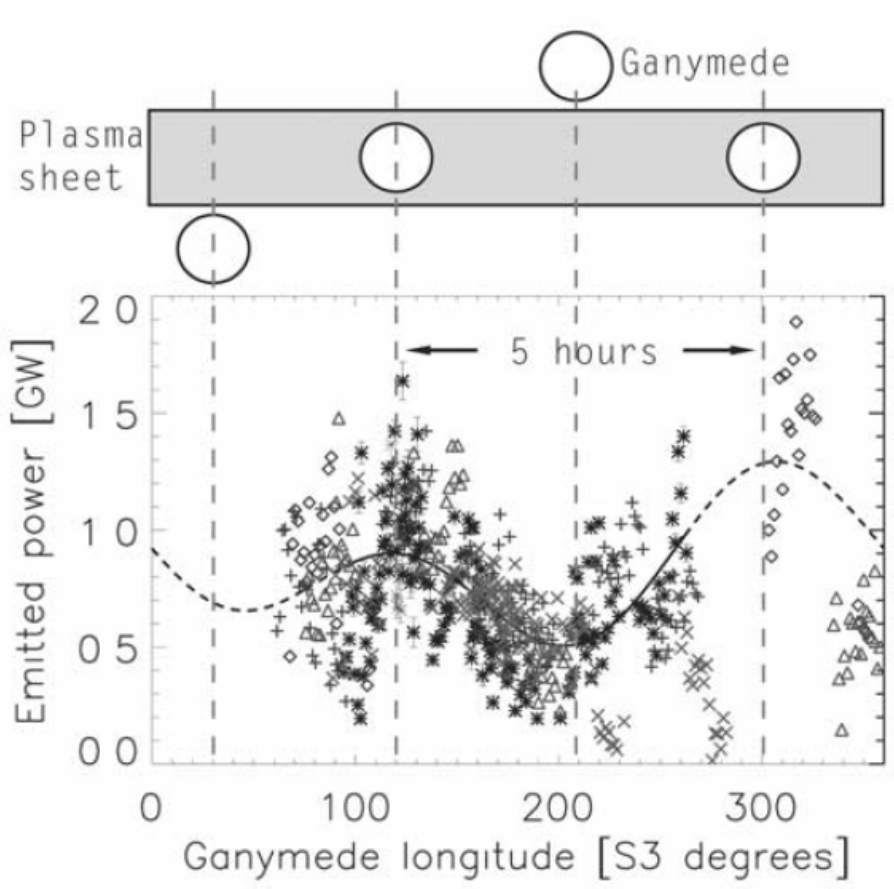


Bonfond et al., in preparation

System III spots brightness variations

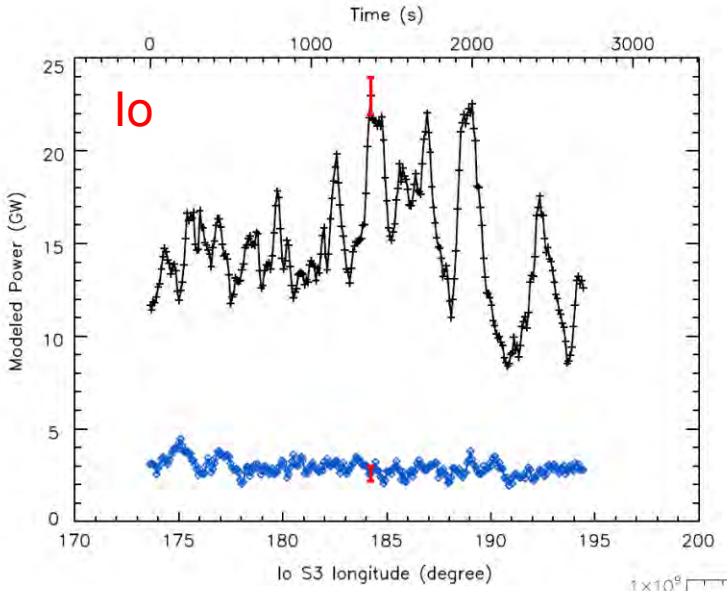


Bonfond et al., 2013



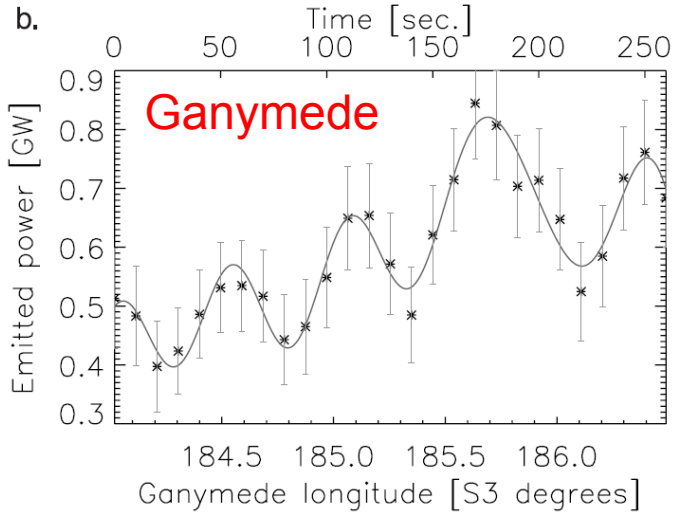
Grodent et al., 2009

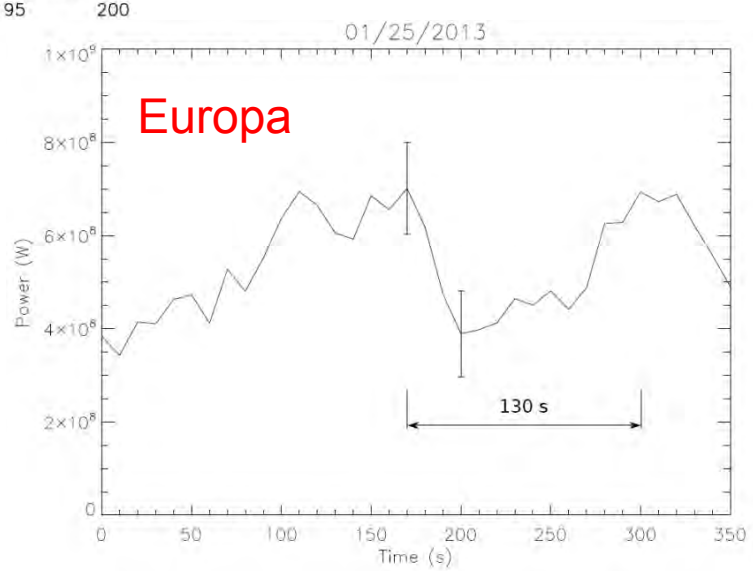
Short timescale variations



Bonfond et al., 2013

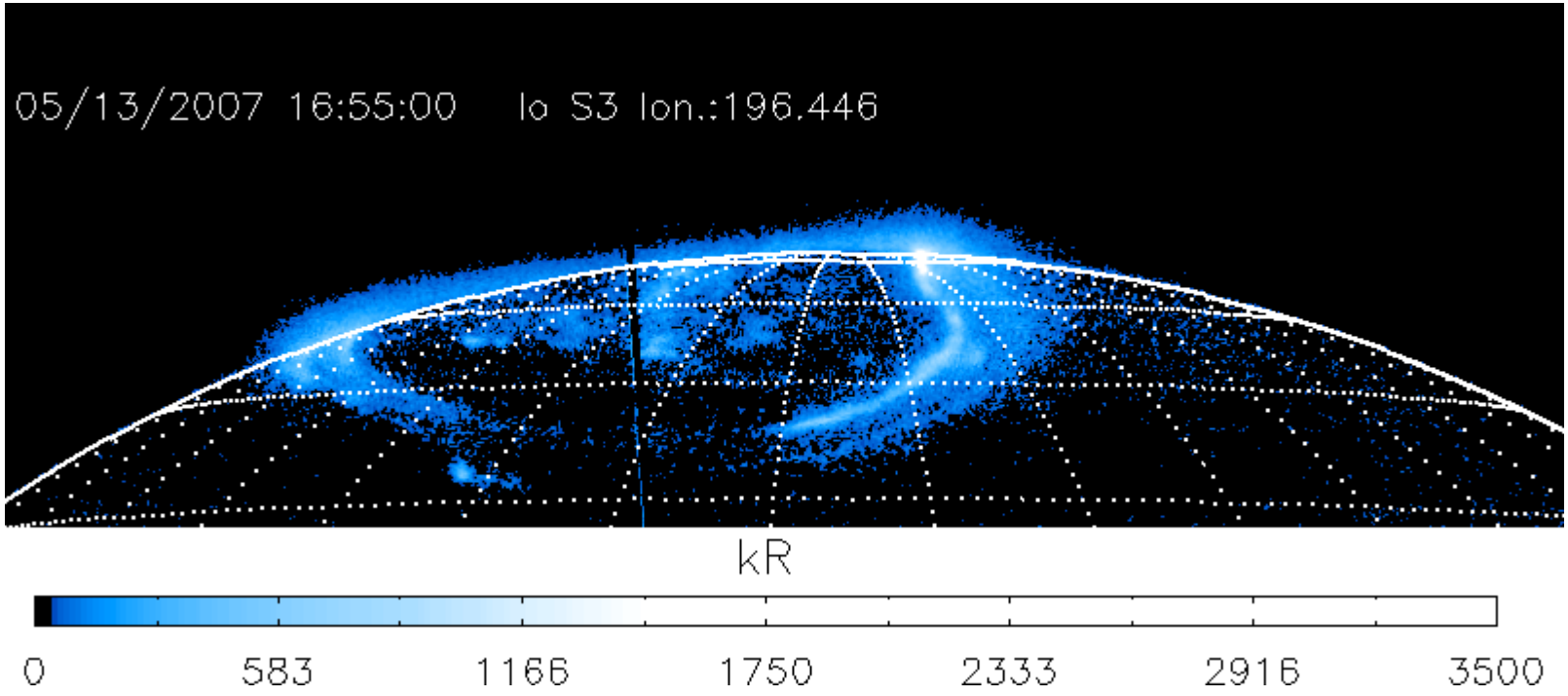
Grodent et al., 2009





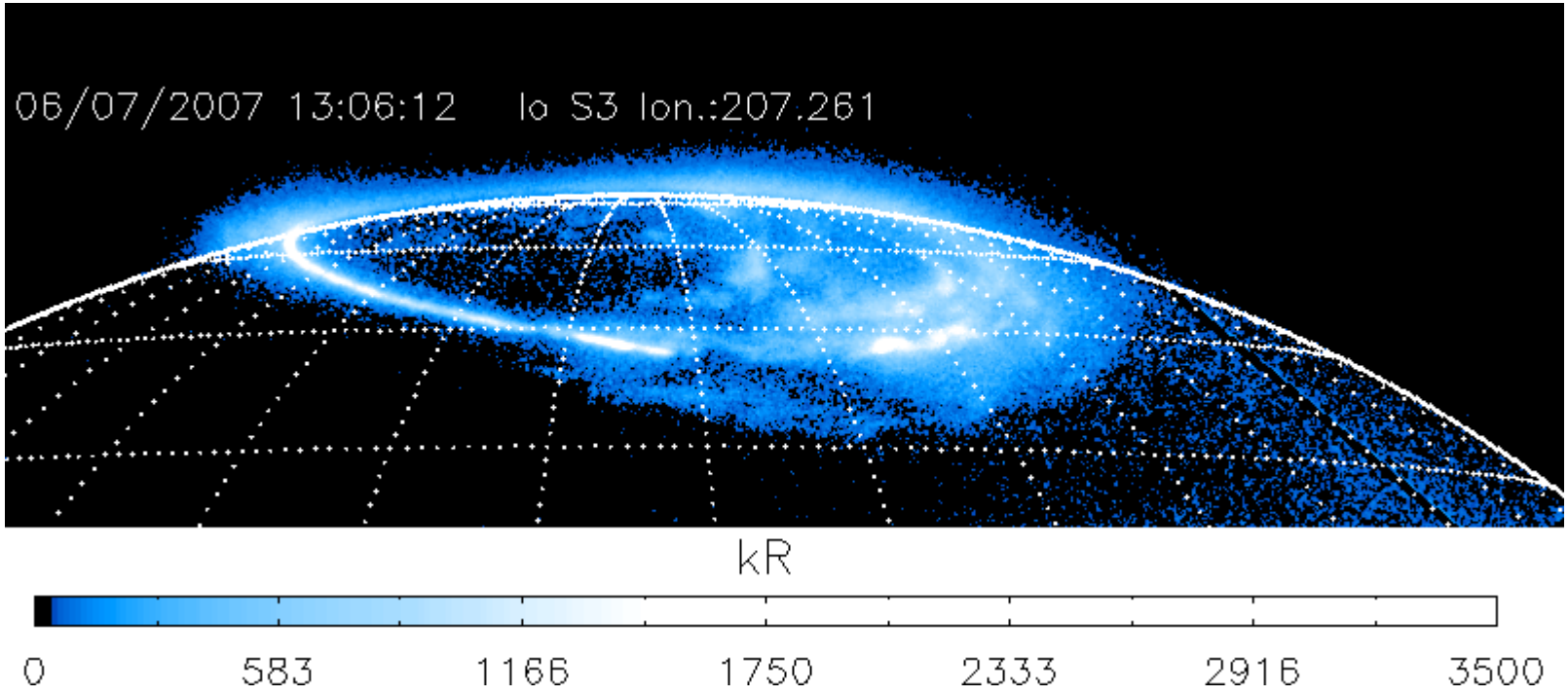
Bonfond et al., in preparation

The usual case



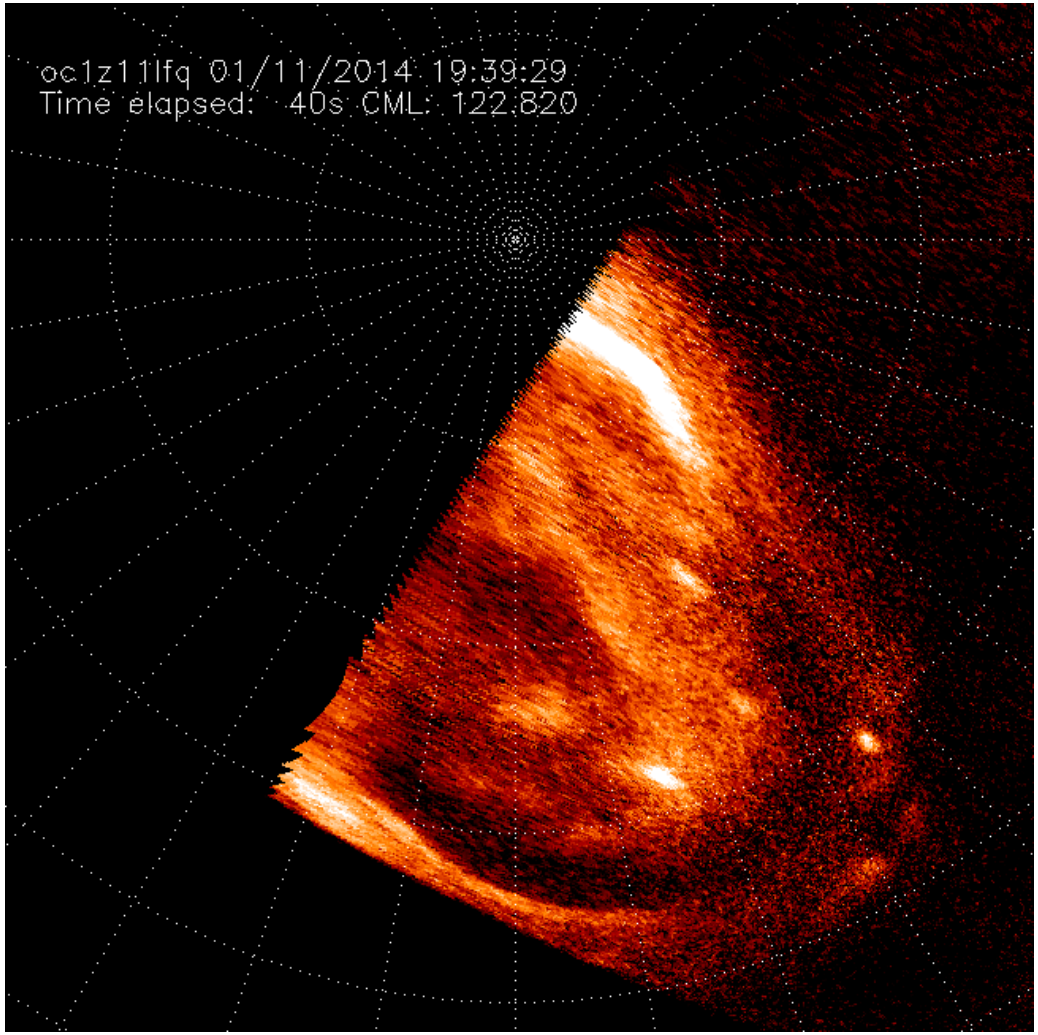
Bonfond et al., 2012

An unusual case



Bonfond et al., 2012

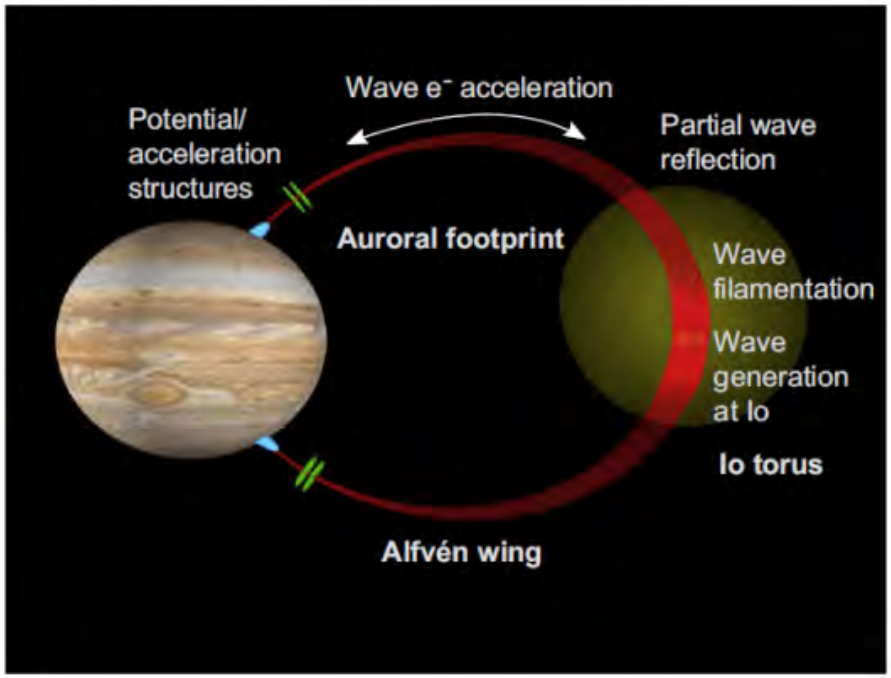
Temporary dimming of the GFP

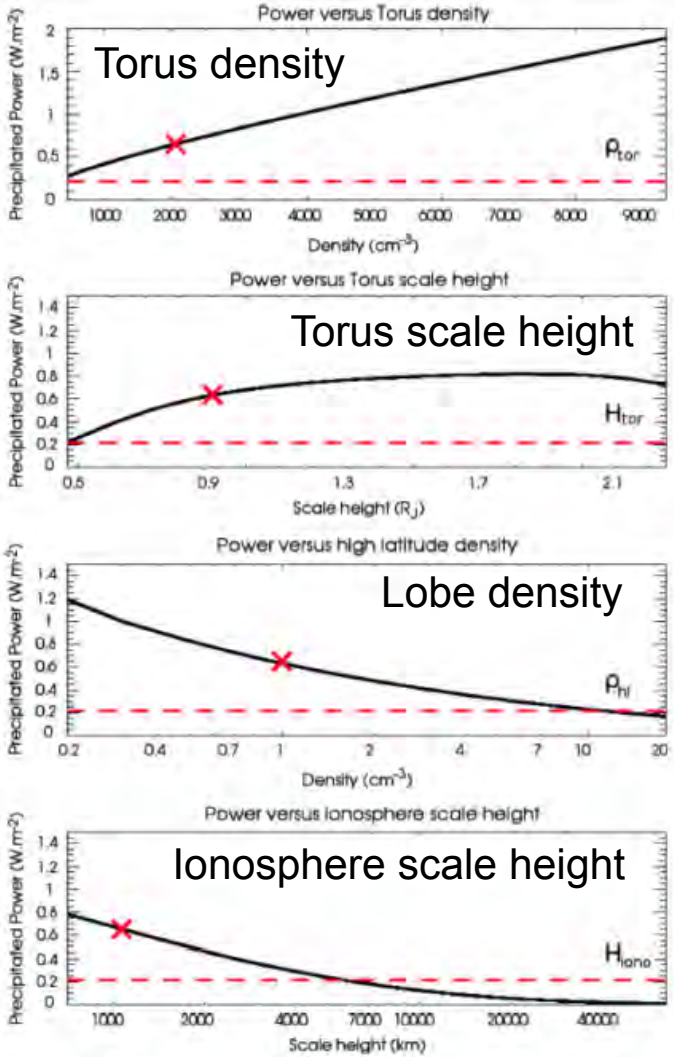


Bonfond et al., in preparation

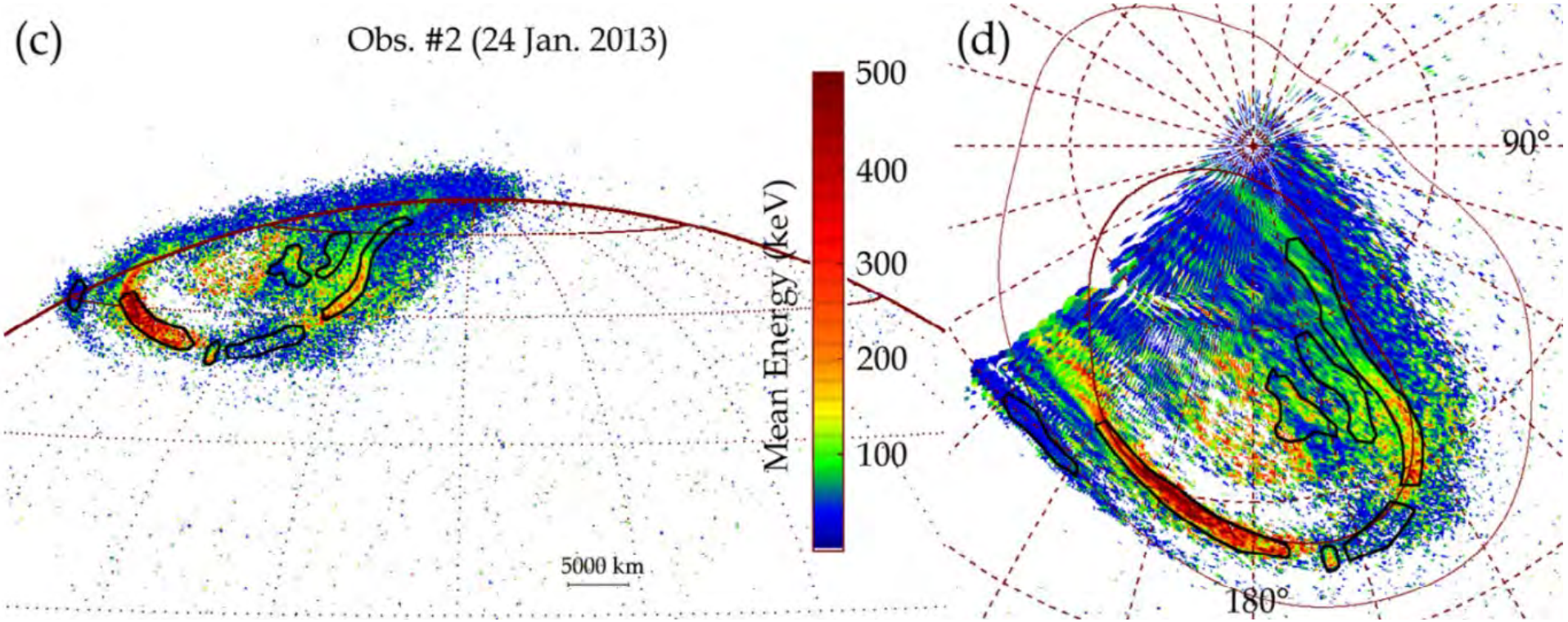
Which parameter is the more likely to operate?

- Hess et al., 2013



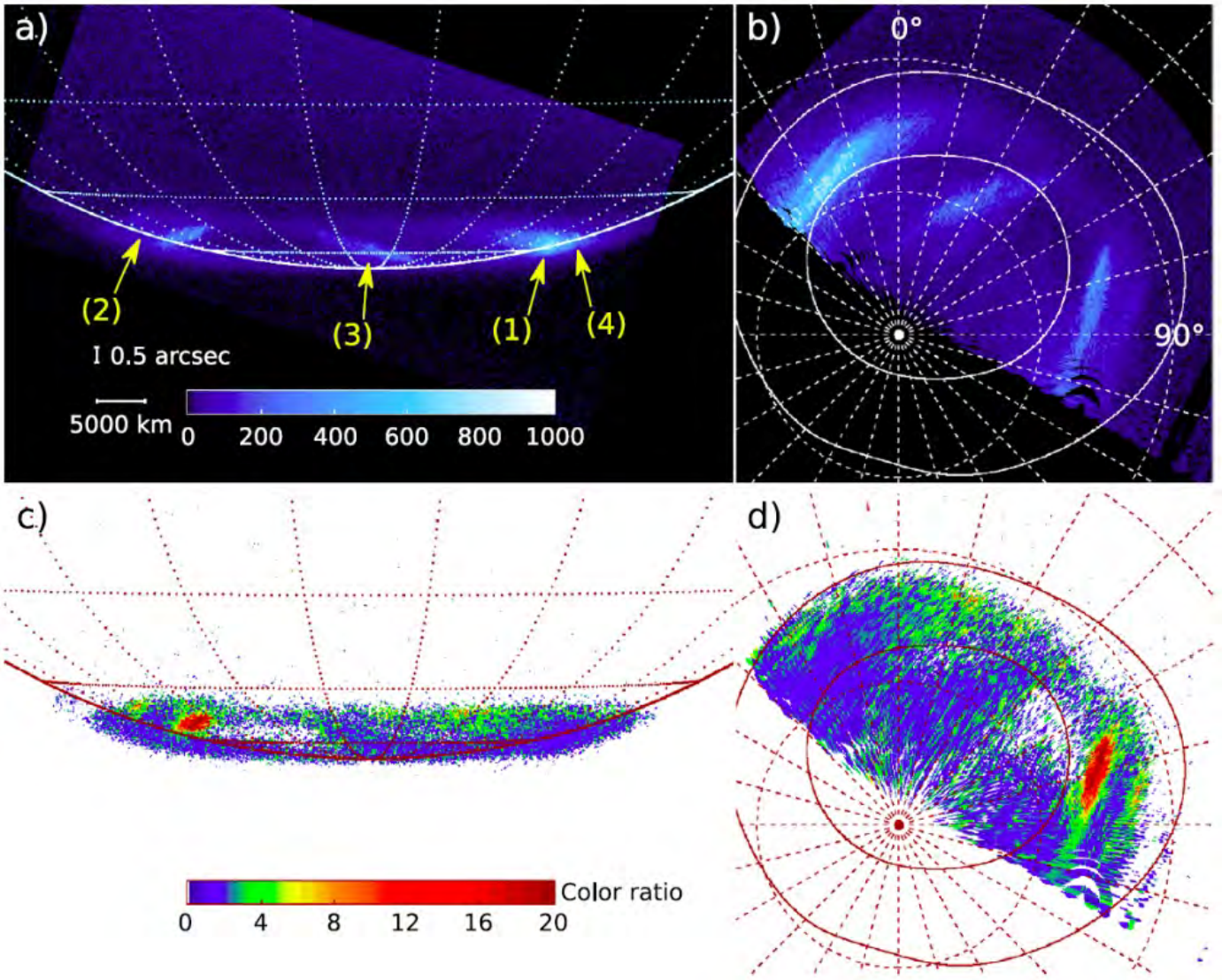


Color ratio of the GFP



Gustin et al., 2016

Color ratio of the GFP



Gérard et al., 2014

Take home messages

- The aurorae are made of many components
- The polar region is still poorly understood
- All footprints are made of at least 2 spots and a tail
- Footprints interact with injections