Earth's magnetosphere and its interaction with the solar wind

(as seen in auroras, convection, and currents)

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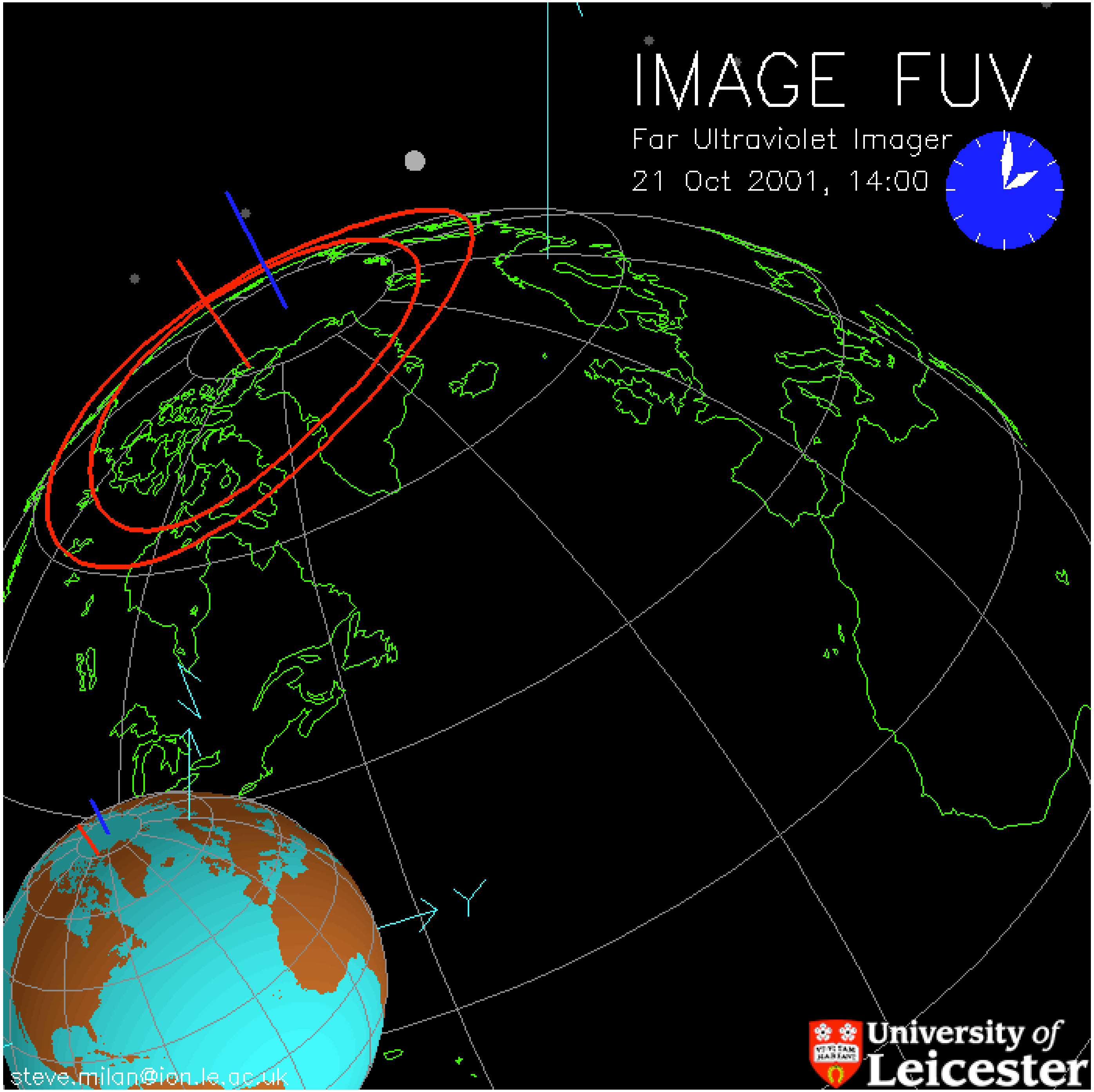
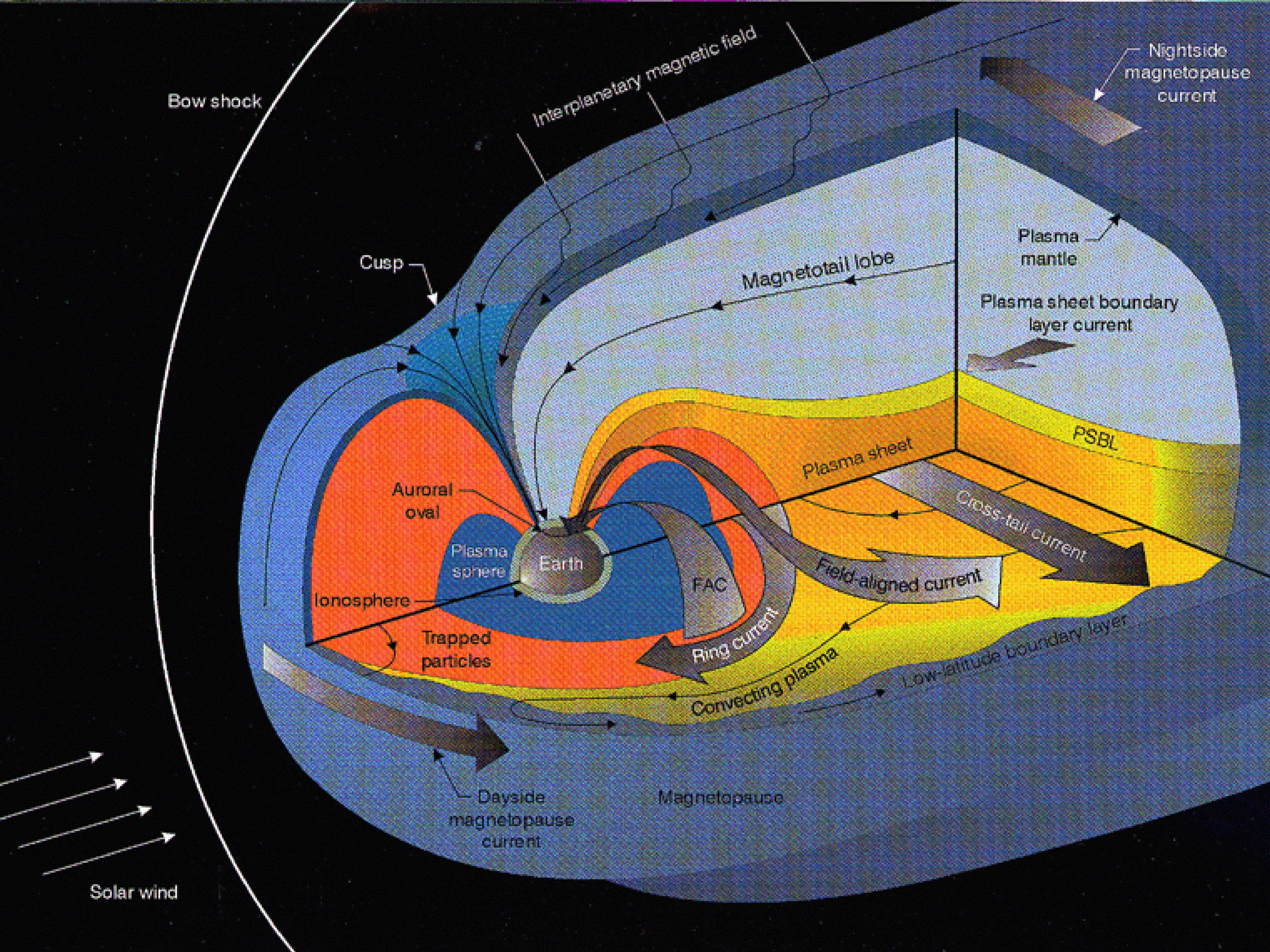
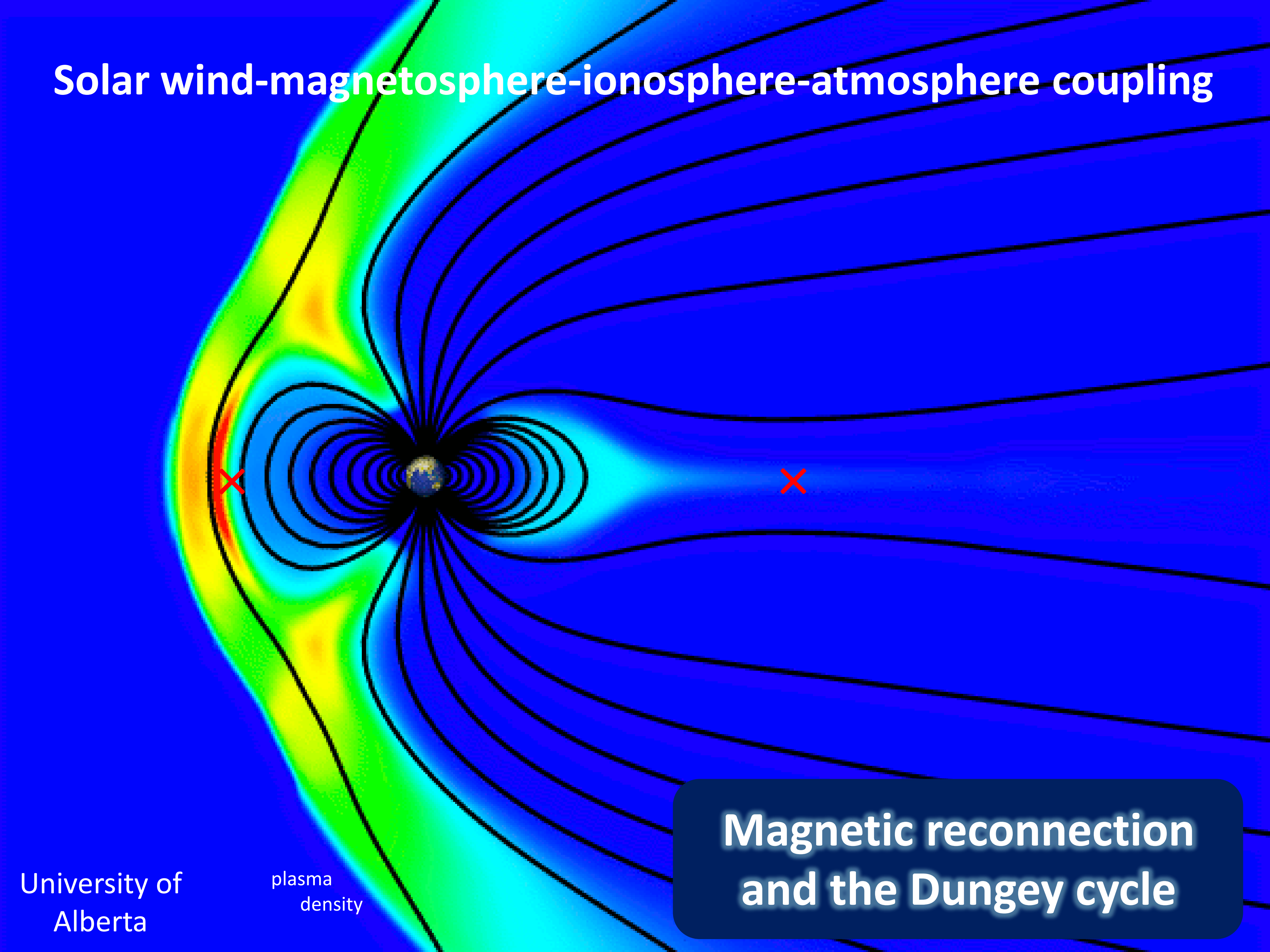


IMAGE FUV

IMAGE data courtesy of Stephen Mende, Harald Frey and the IMAGE FUV team

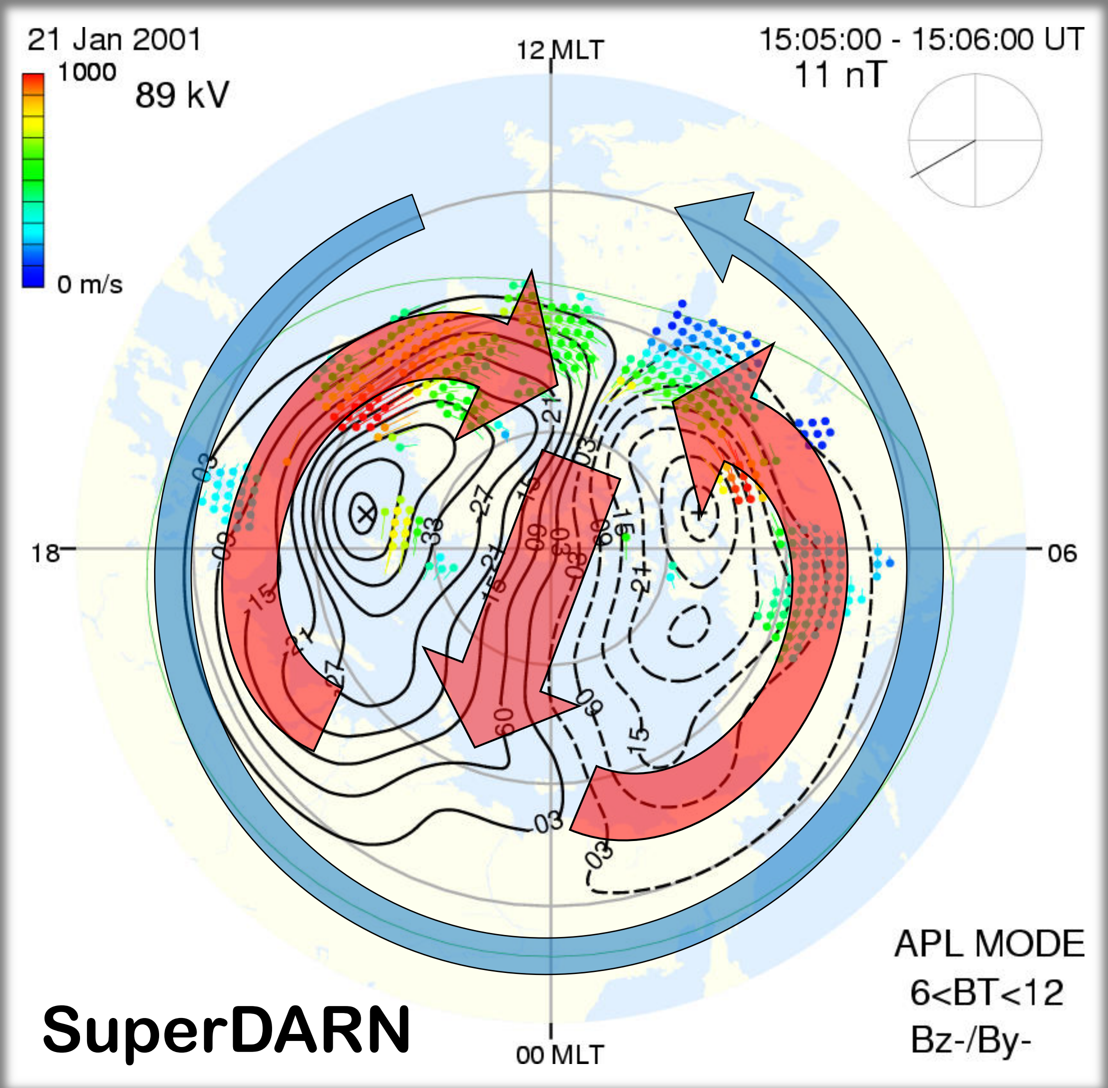


Bow shock
Interplanetary magnetic field
Nightside magnetopause current
Plasma mantle
Magnetotail lobe
Plasma sheet boundary layer current
Cusp
PSBL
Plasma sheet
Auroral oval
Cross-tail current
Plasma sphere
Earth
FAC
Field-aligned current
Ionosphere
Trapped particles
Ring current
Low-latitude boundary layer
Convecting plasma
Dayside magnetopause current
Magnetopause
Solar wind



Solar wind-magnetosphere-ionosphere-atmosphere coupling
Magnetic reconnection and the Dungey cycle
University of Alberta
plasma density

Ionospheric convection

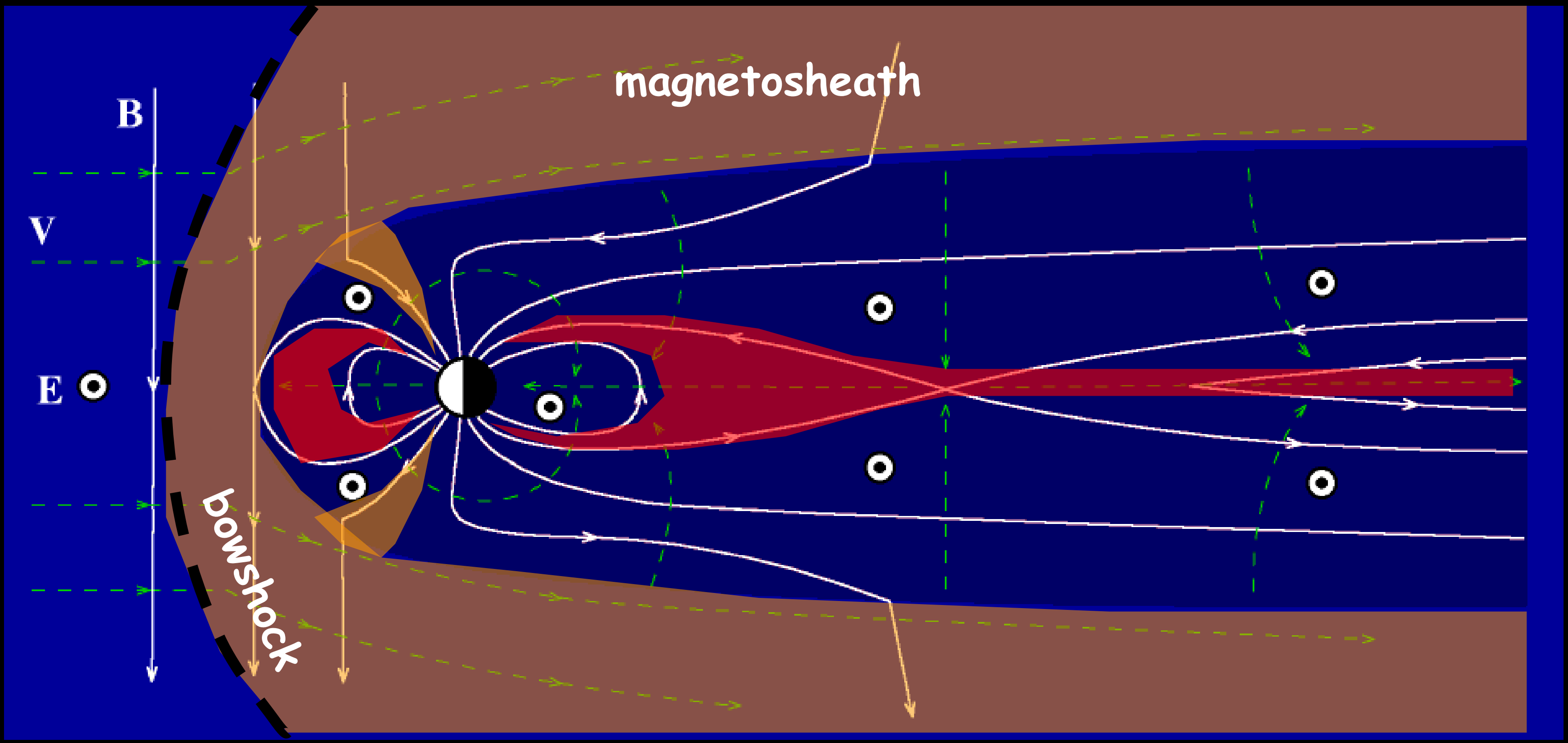


It takes 4 hours for the ionosphere to convect across the polar cap and 8 hours to return

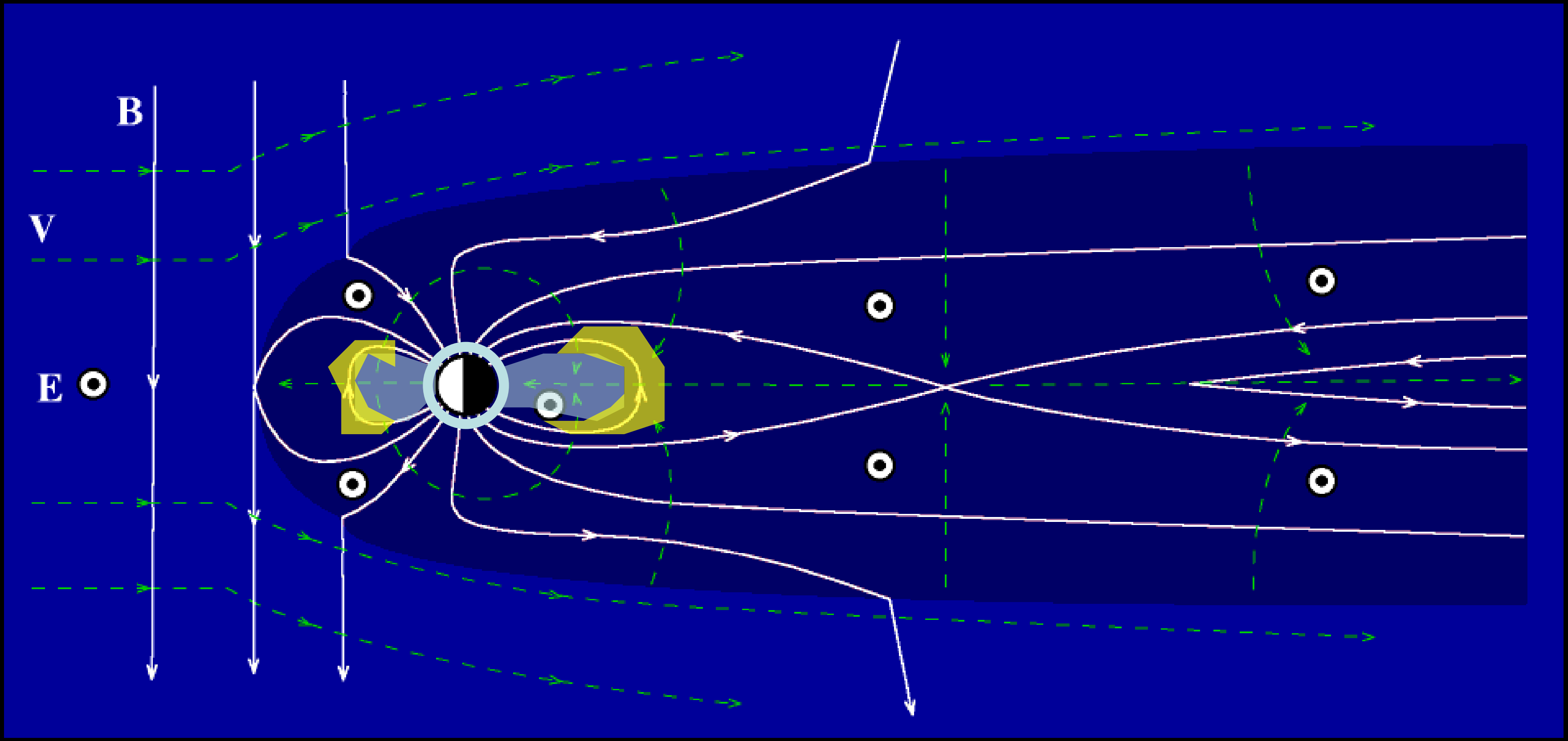
We can calculate that the magneto-tail is 1000 R_E long

Corotation in the inner magnetosphere

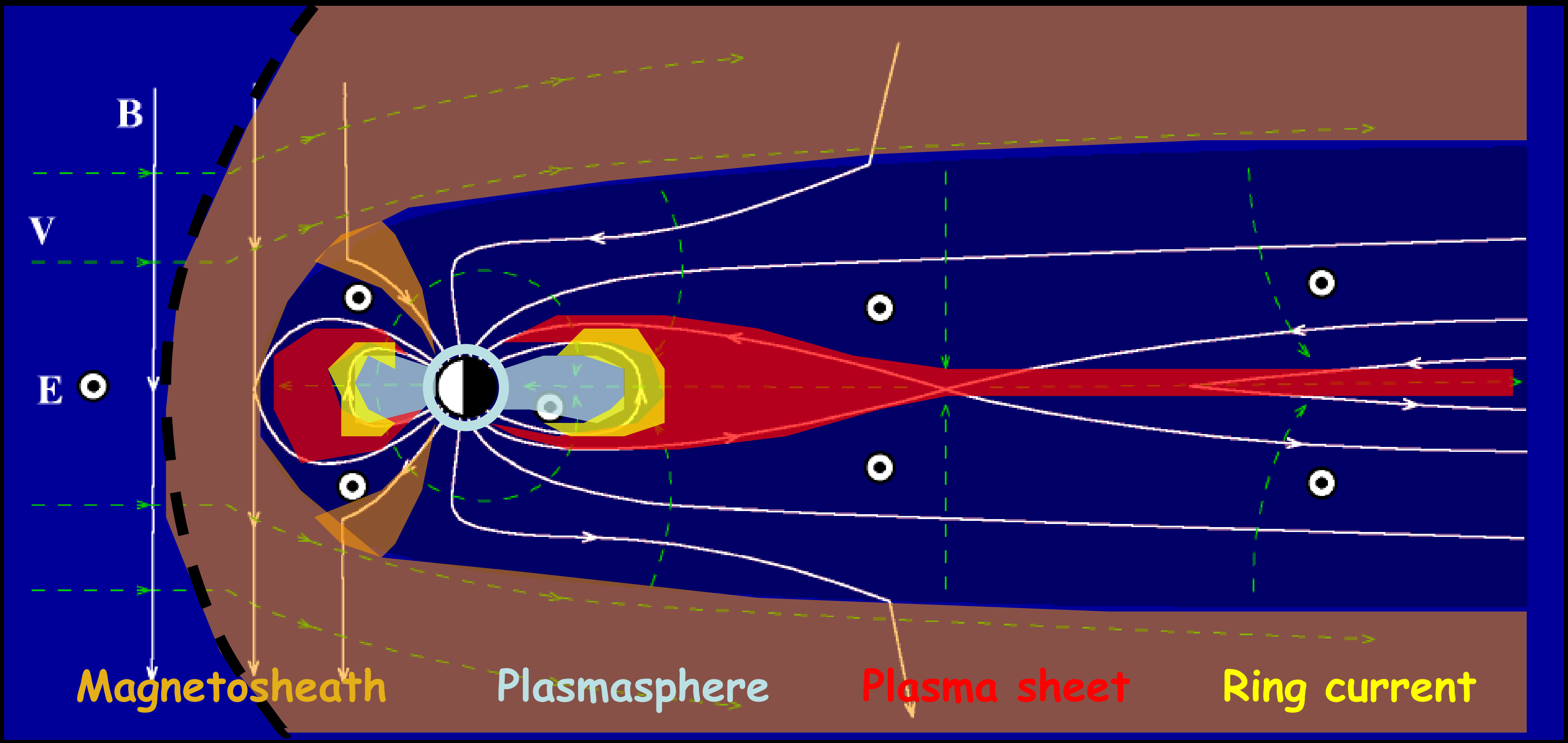
Plasma populations in the magnetosphere

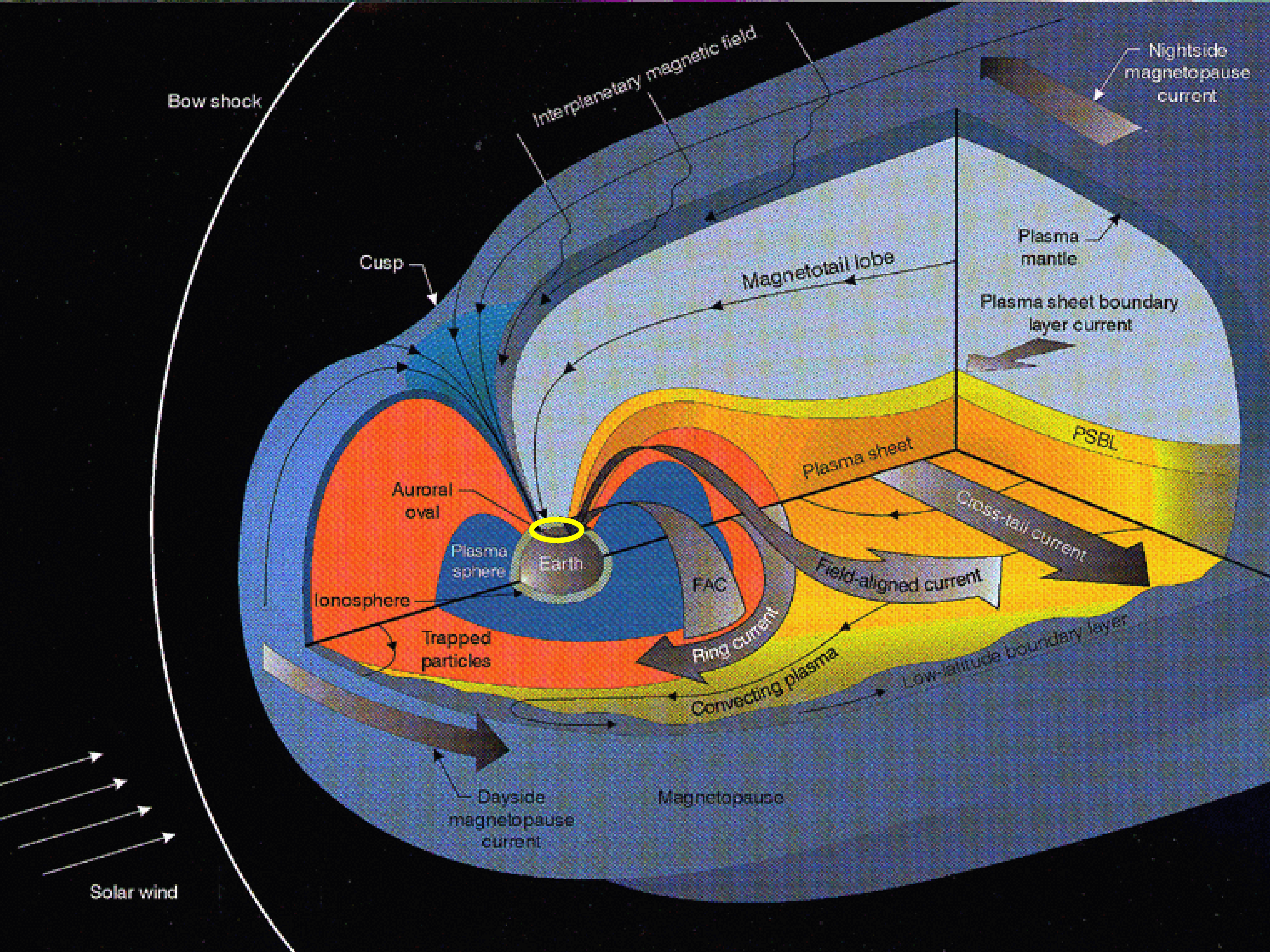


Plasma populations in the magnetosphere



Plasma populations in the magnetosphere





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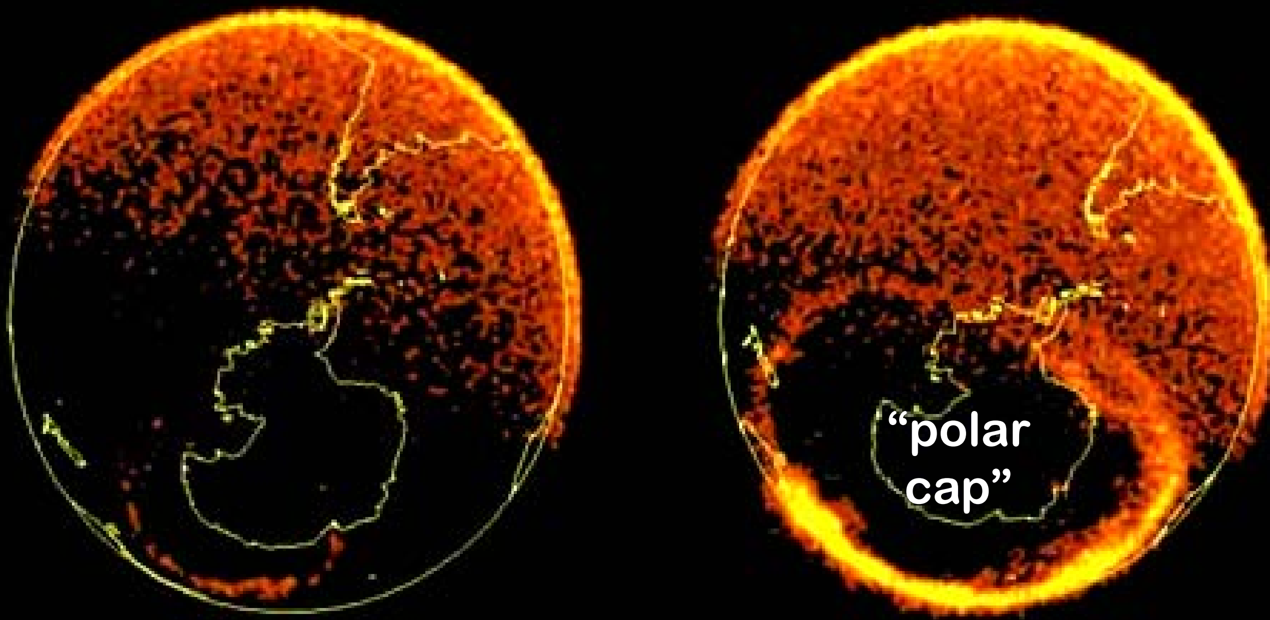
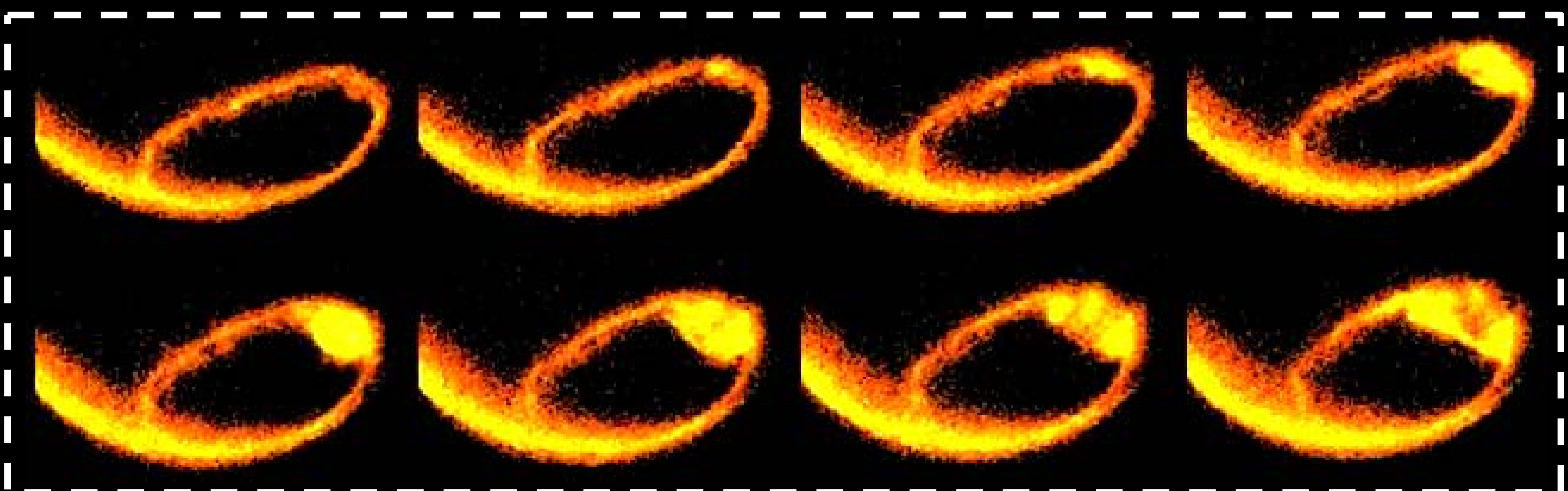


The auroral oval is highly variable in brightness and size

The "substorm"

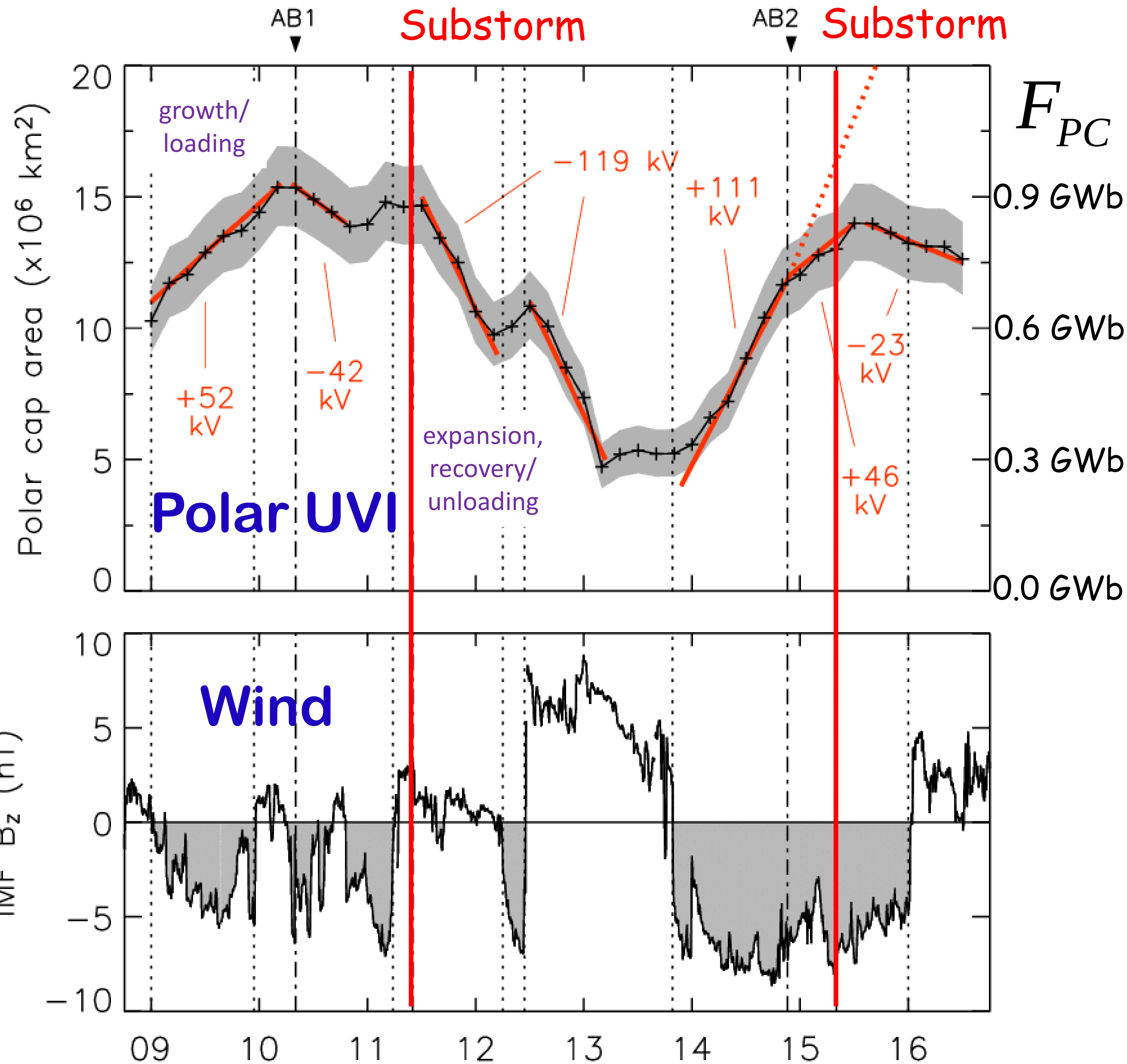


5 June 1998

Open flux

IMF B_Z

Milan et al. (2003)

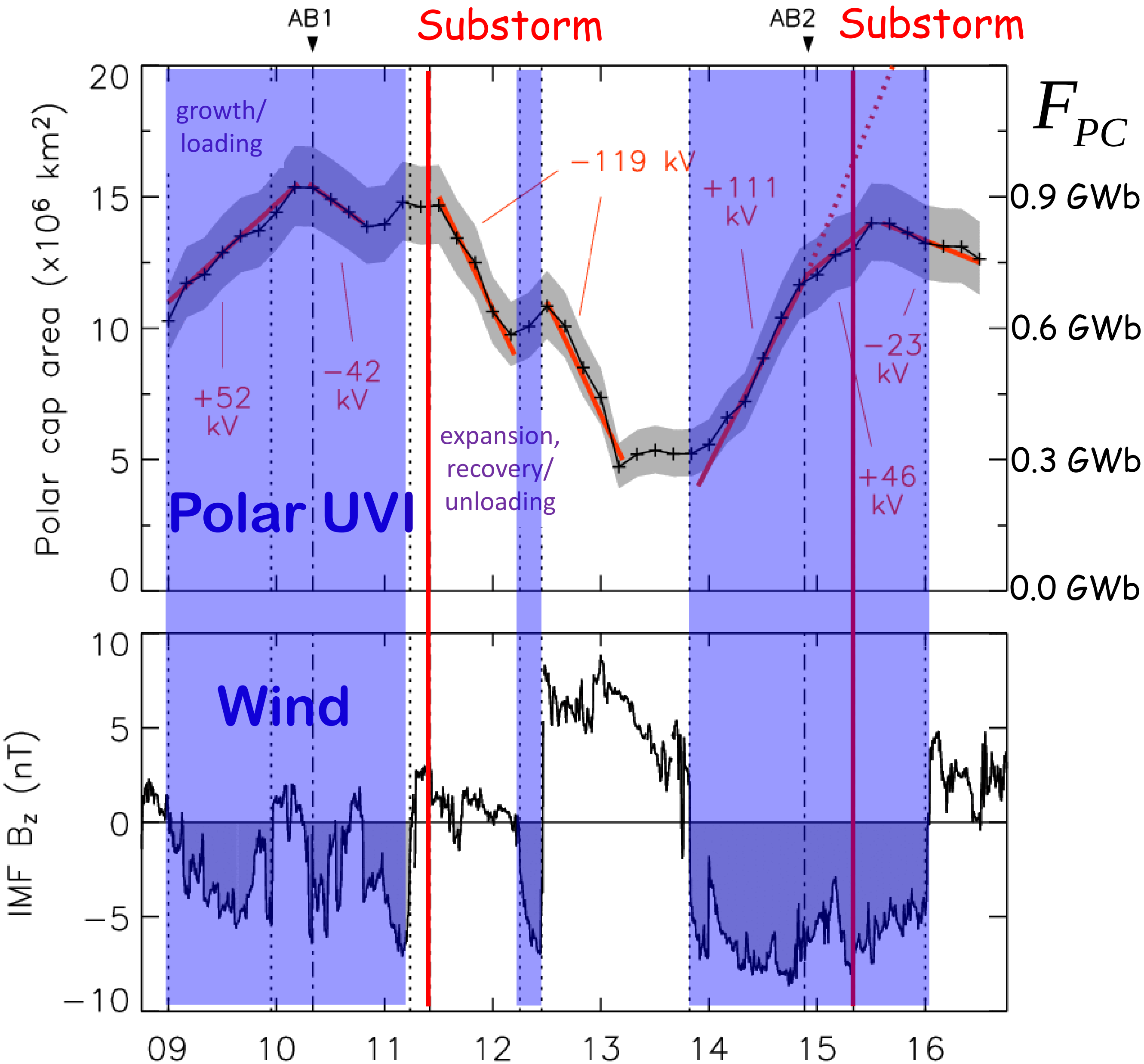


steve.milan@le.ac.uk

5 June 1998

Open flux

IMF B_Z



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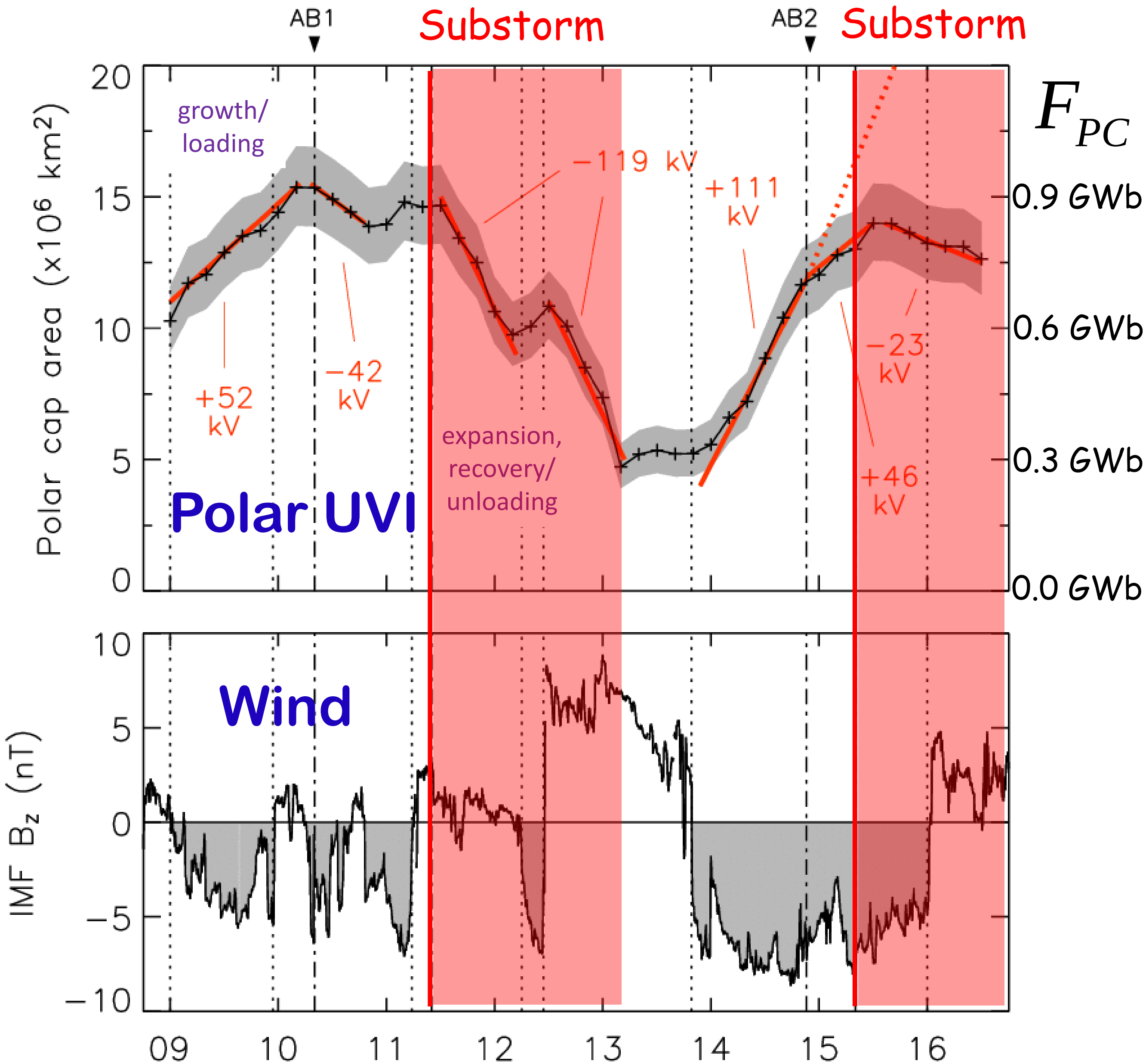

Milan et al. (2003)

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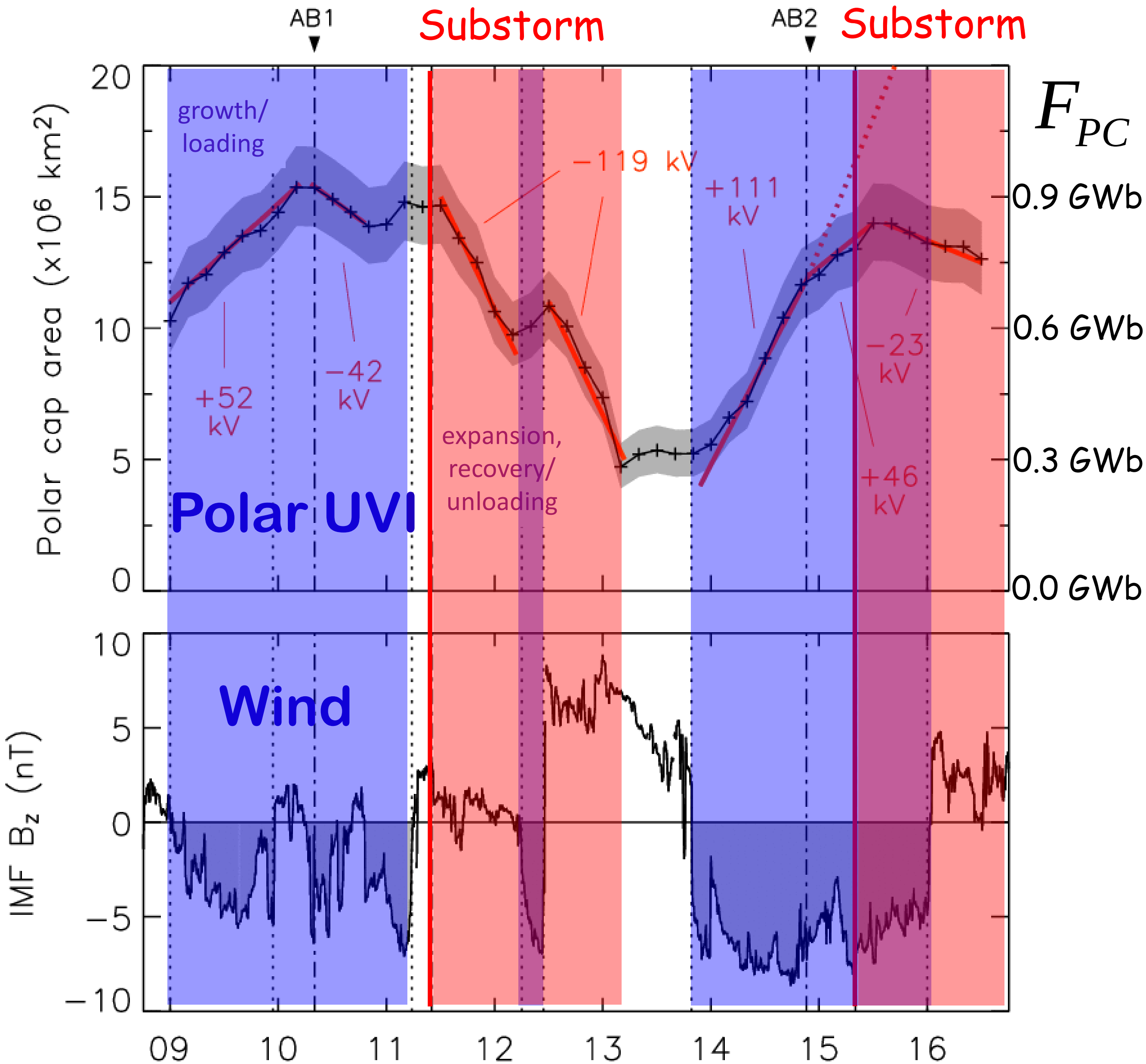

Milan et al. (2003)

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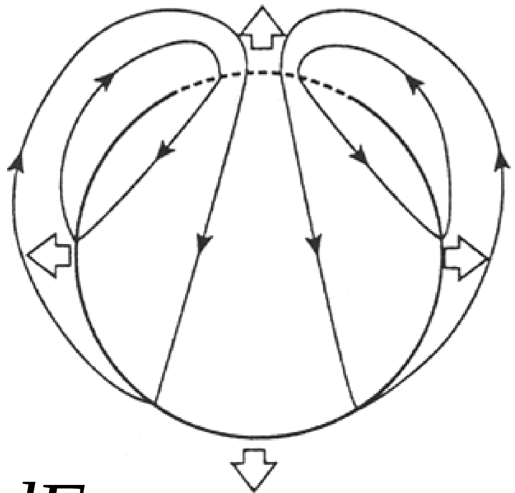
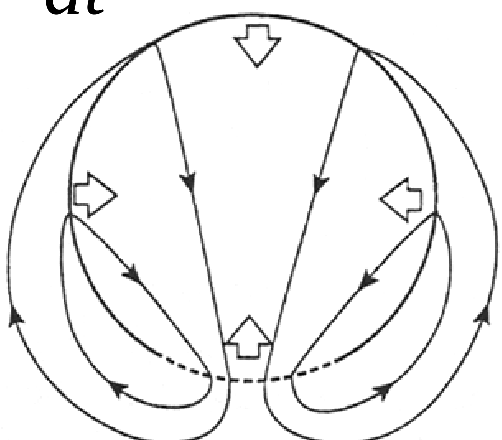
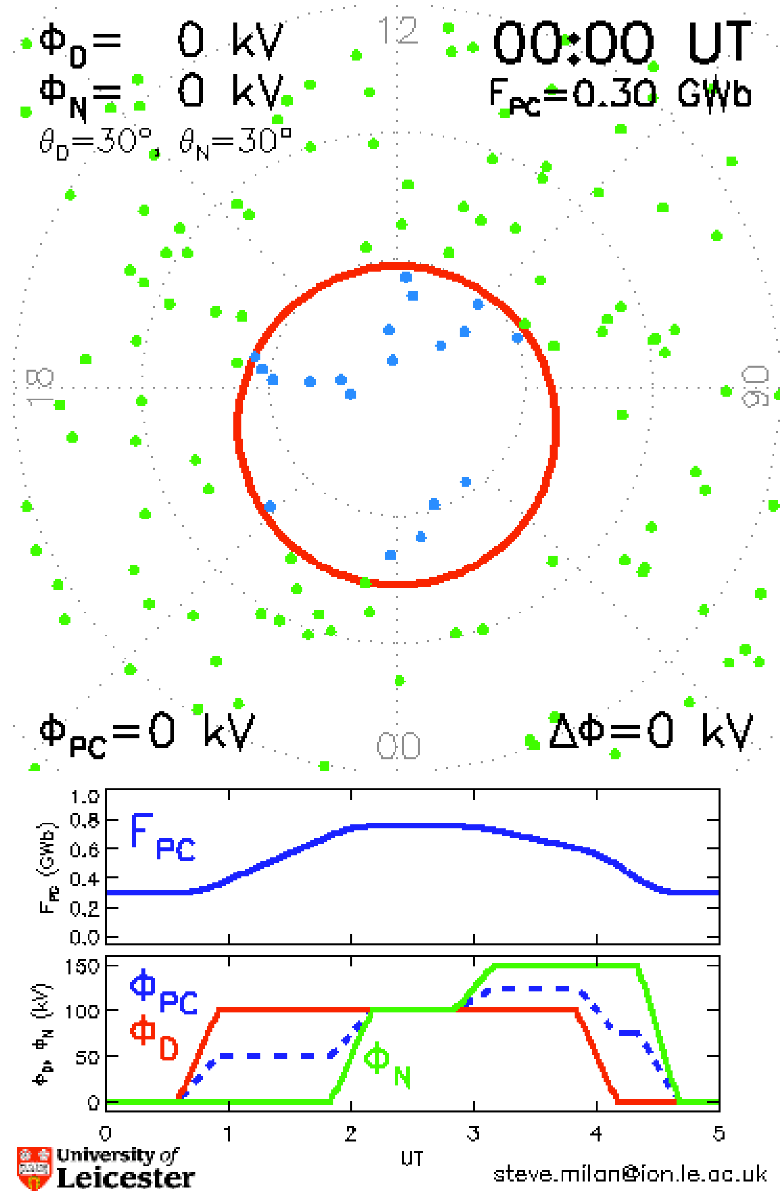
The expanding/contracting polar cap



$$\frac{dF_{PC}}{dt} = \Phi_D - \Phi_N$$





Faraday (1831)
Siscoe and Huang (1985)
Cowley and Lockwood (1992)
Milan (2013)

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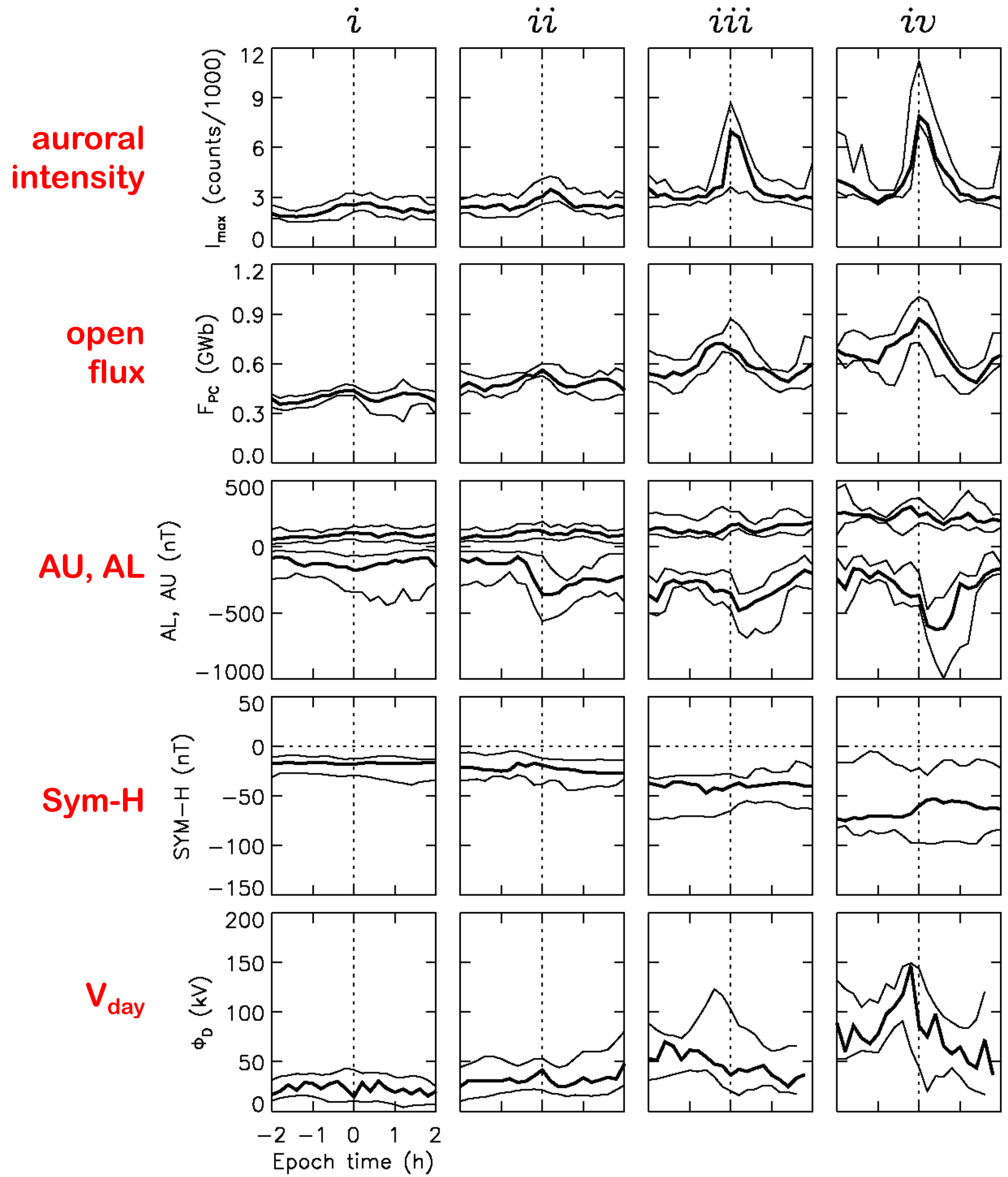
Open flux control of intensity

Superposed epoch analyses of auroral intensity, open flux, AU and AL, Sym-H, and SW-coupling during 40 substorms

Substorms binned by open flux at onset



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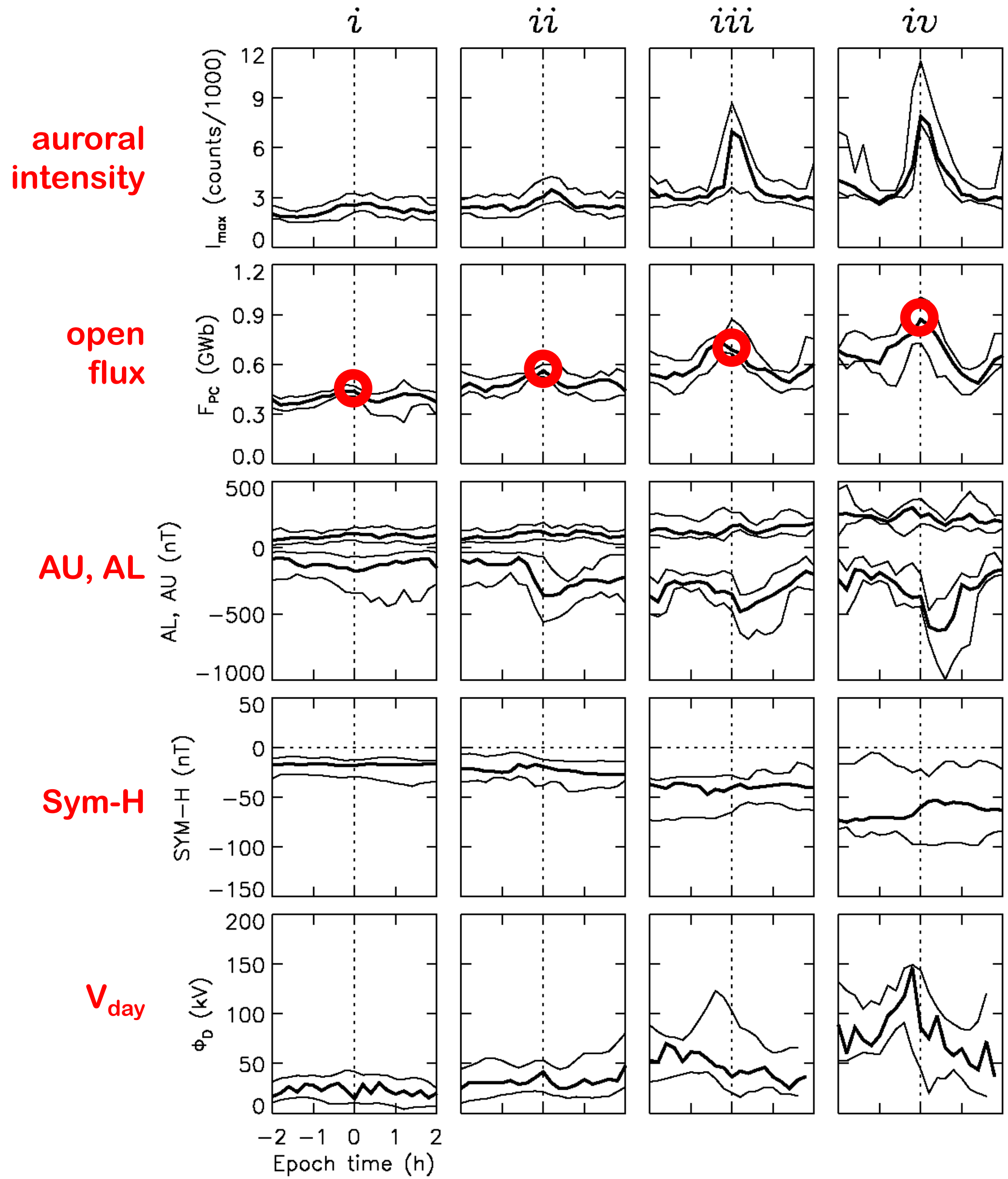

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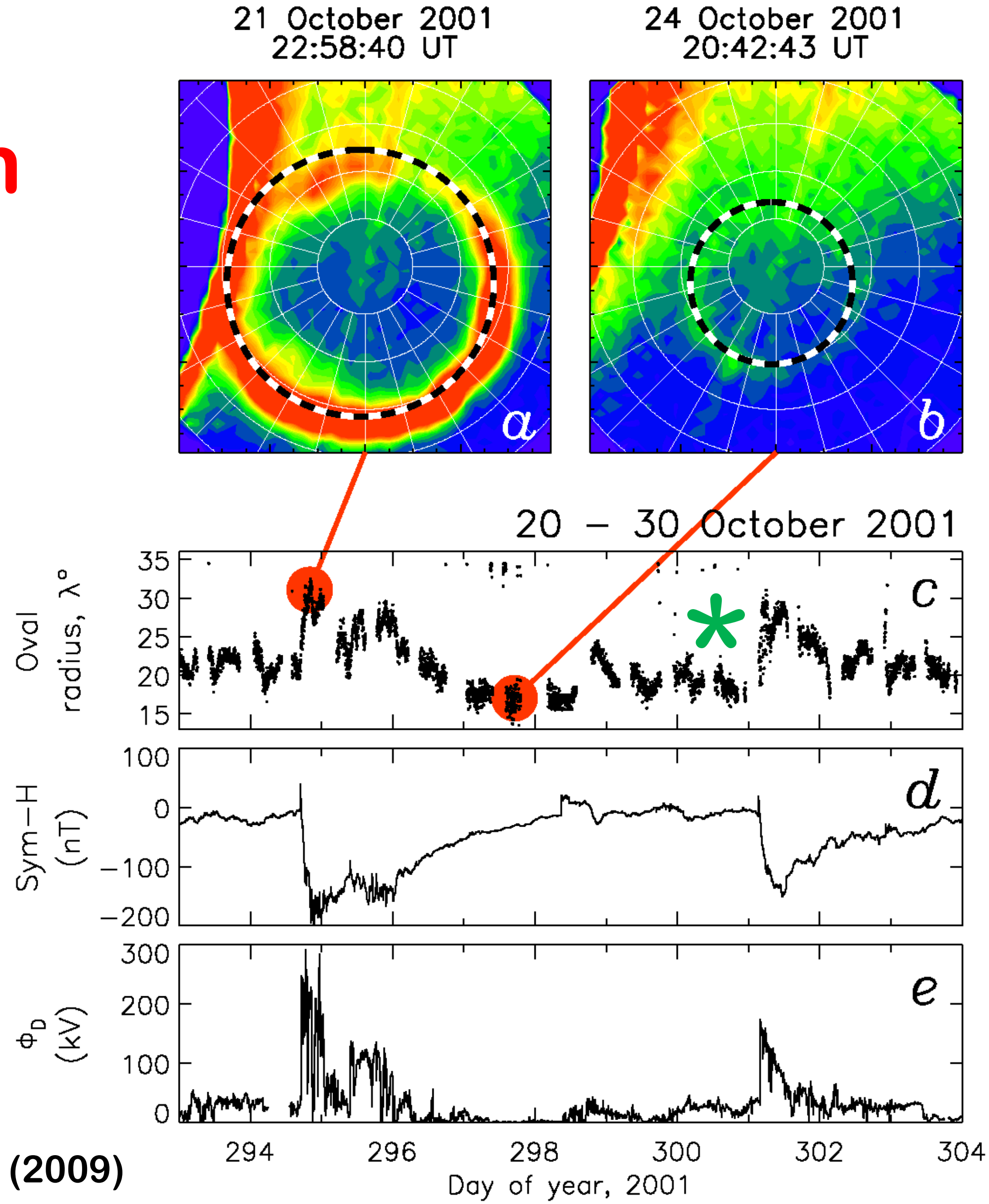
Open flux variations on substorm and storm time-scales



Proxy for open flux content

Proxy for ring current intensity

* data gaps due to orbit of IMAGE

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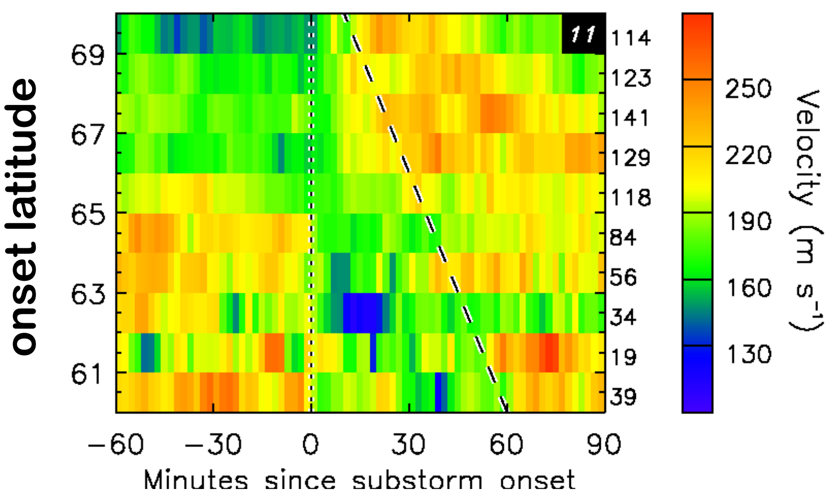
Milan (2009)

Superposed epoch analysis of convection

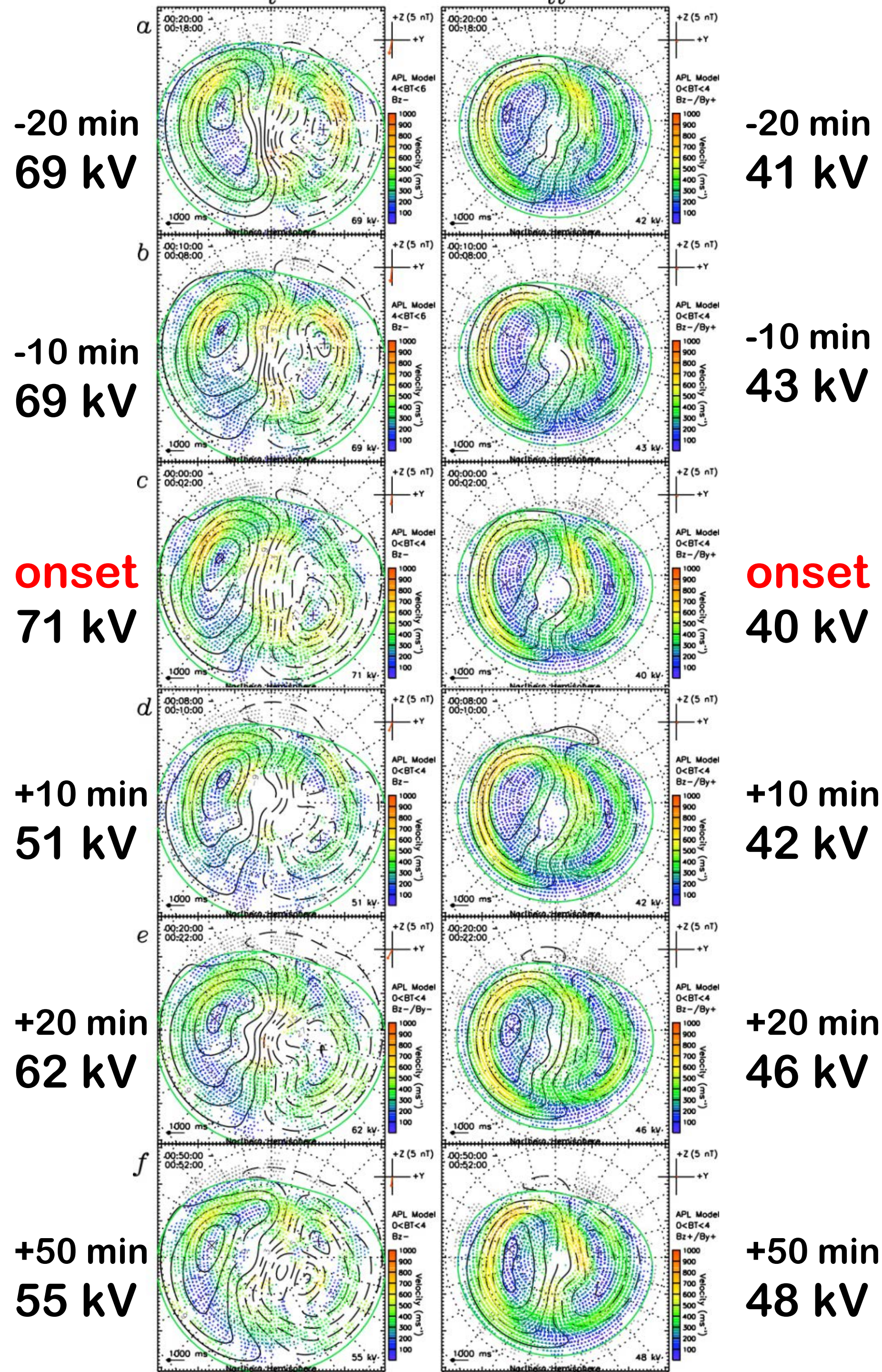
- High latitude substorms have prompt convection response
- Low latitude substorms have convection decrease at onset

Substorm electrodynamics influenced by auroral bulge conductivity

Convection velocity in onset region

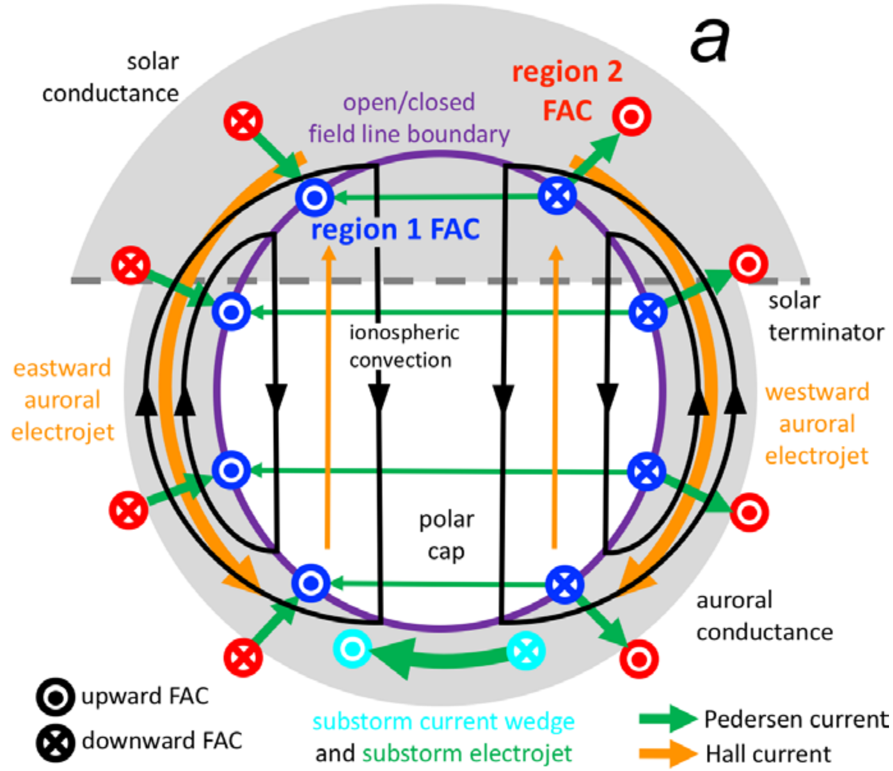


Grocott et al. (2009)

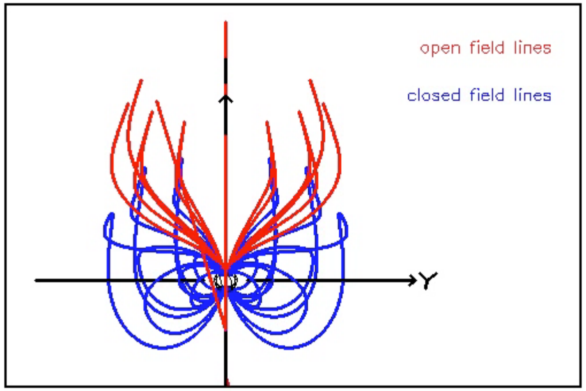


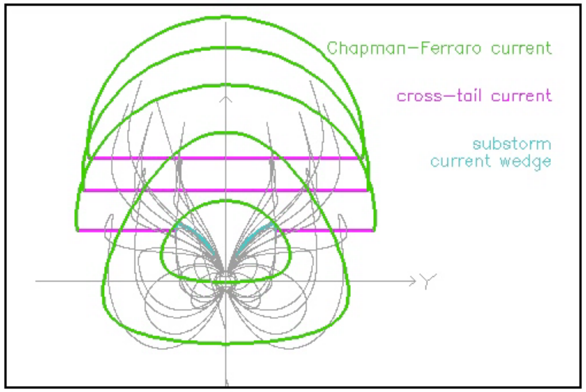
Solar wind-magnetosphere-ionosphere-atmosphere coupling

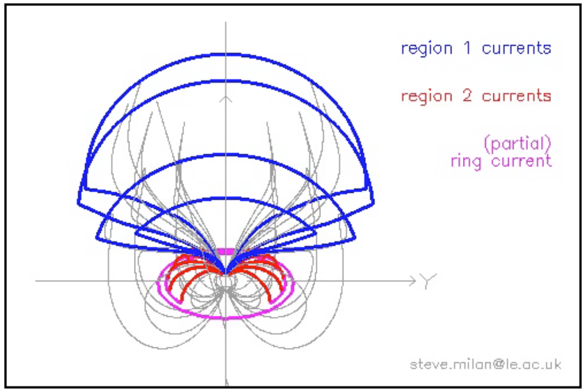
- The solar wind-magnetosphere interaction distorts the dipolar field of the Earth resulting in currents at the magnetopause and in the magnetotail
- This interaction also leads to dynamics which are communicated to the ionosphere by further current systems



Milan et al. (2016)

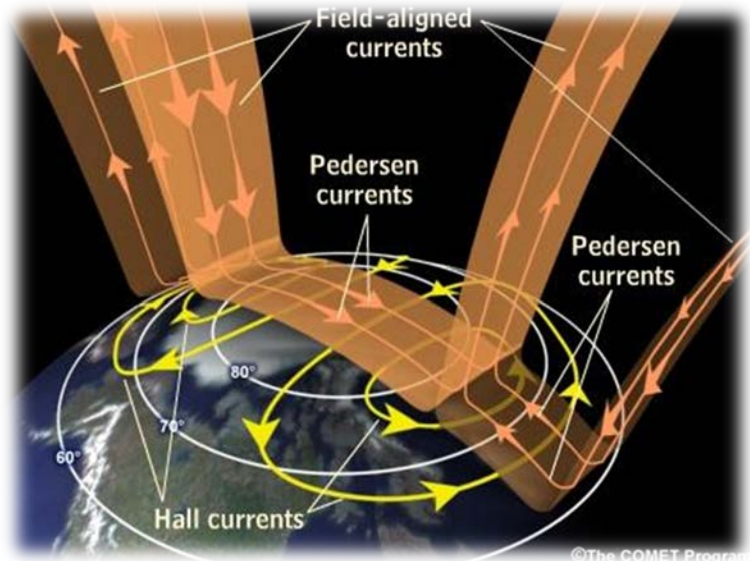


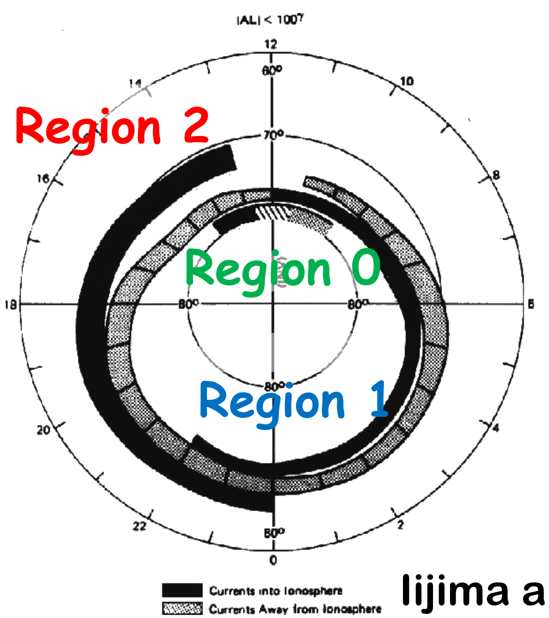




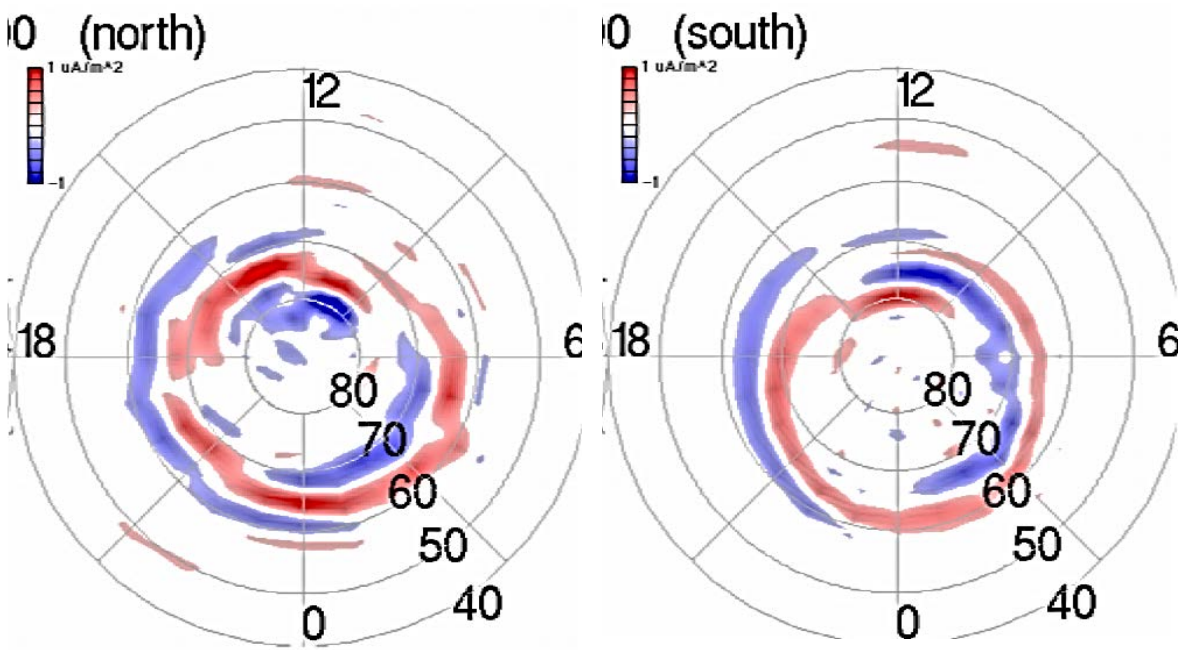
Birkeland currents from AMPERE

(Active Magnetosphere and Planetary Electrodynamics Response Experiment)



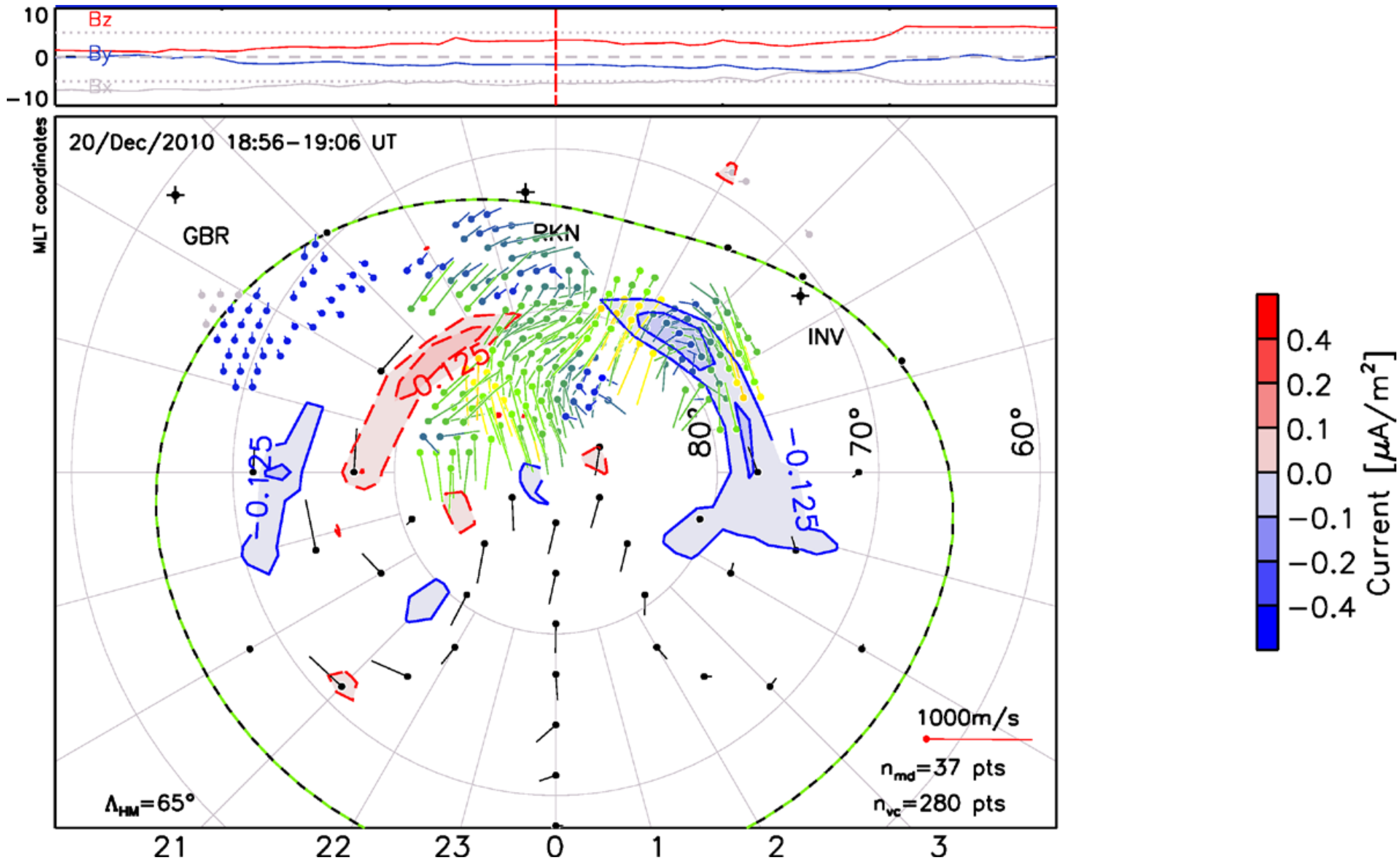


Iijima and Potemra (1978)



After Anderson et al. (2000), Waters et al. (2001)

AMPERE and SuperDARN



Courtesy Lasse Clausen

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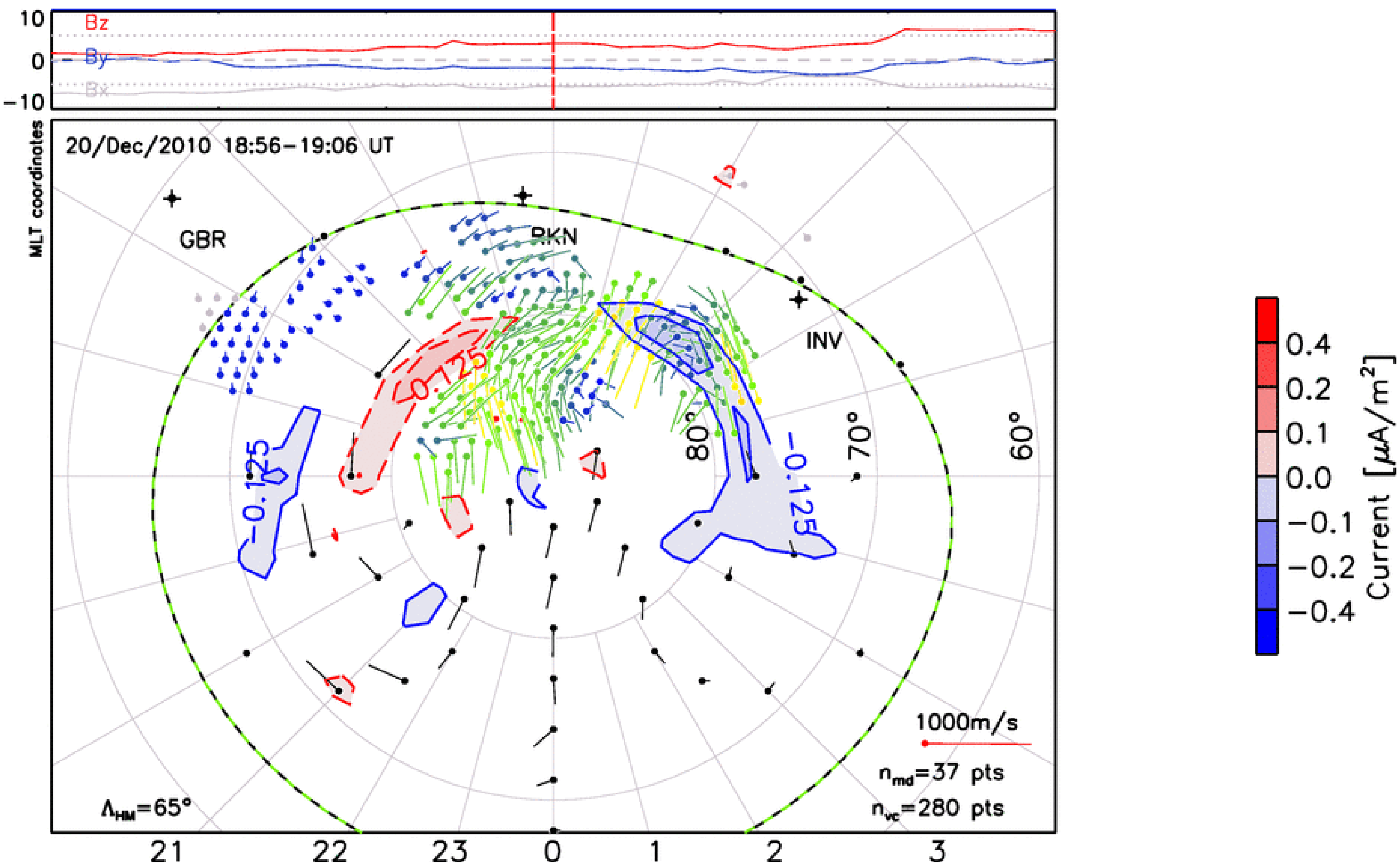
AMPERE and SuperDARN



Courtesy Lasse Clausen

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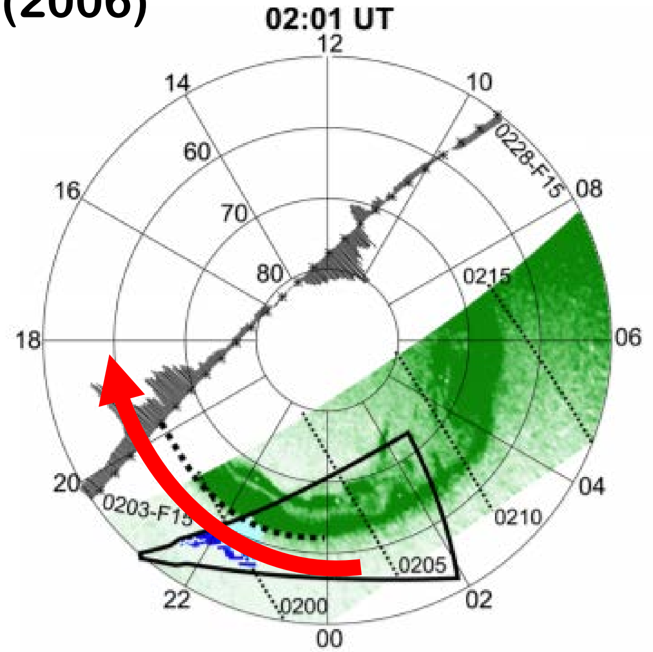
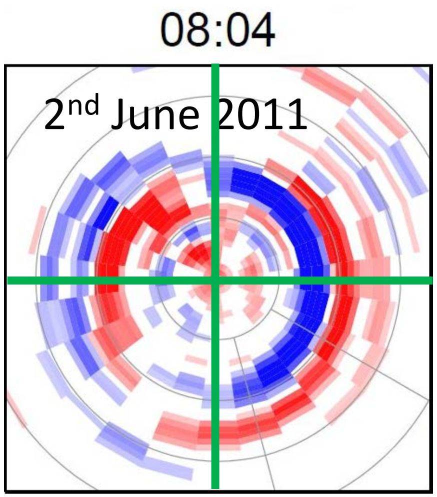
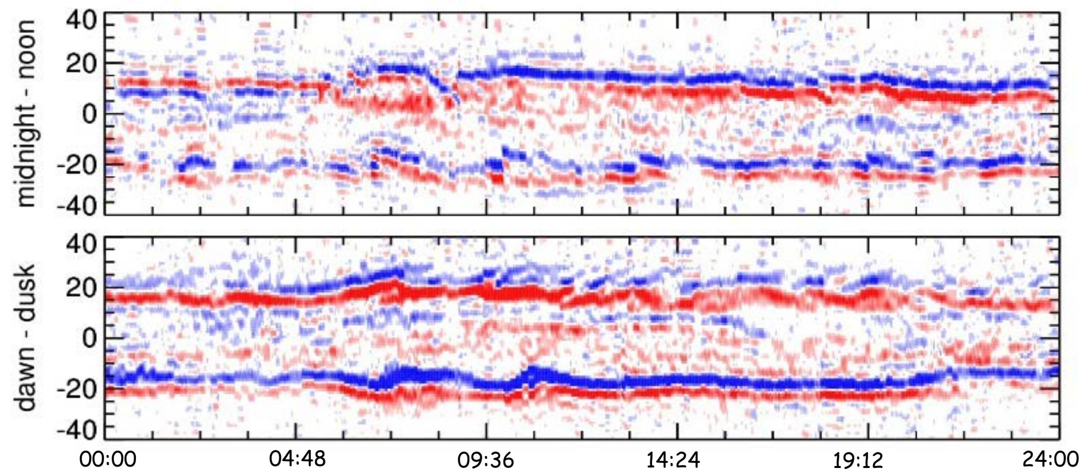
Oksavik et al.
(2006)



Sub-Auroral Polarization Streams (SAPS)

- Fast westward convection flows in the mid-latitude ionosphere, associated with storm processes – inner magnetosphere dynamics
- AMPERE observes bifurcations of the region 2 currents, esp. at dusk, associated with substorms
- In the pre-midnight sector this forms an up/down current pair, consistent with a flow channel





Sangha et al. (in prep.)

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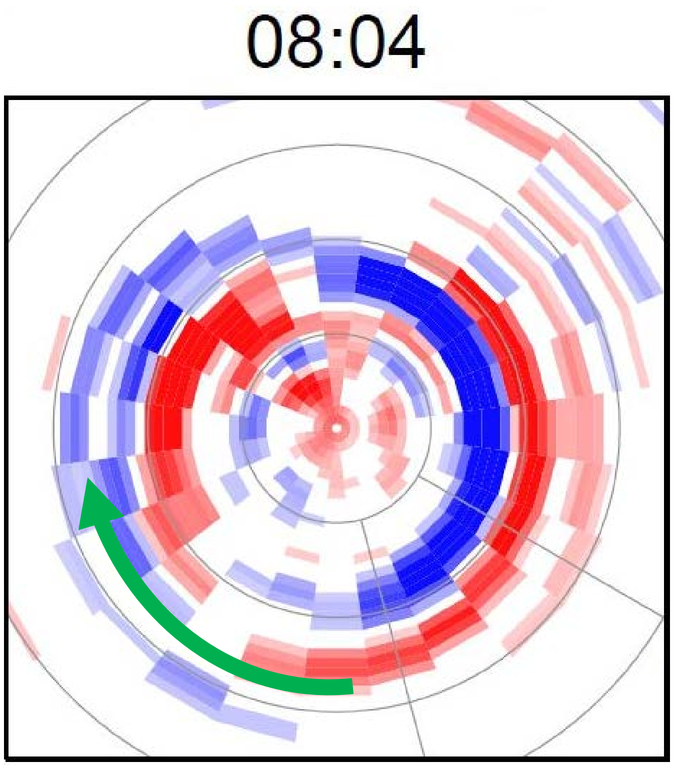
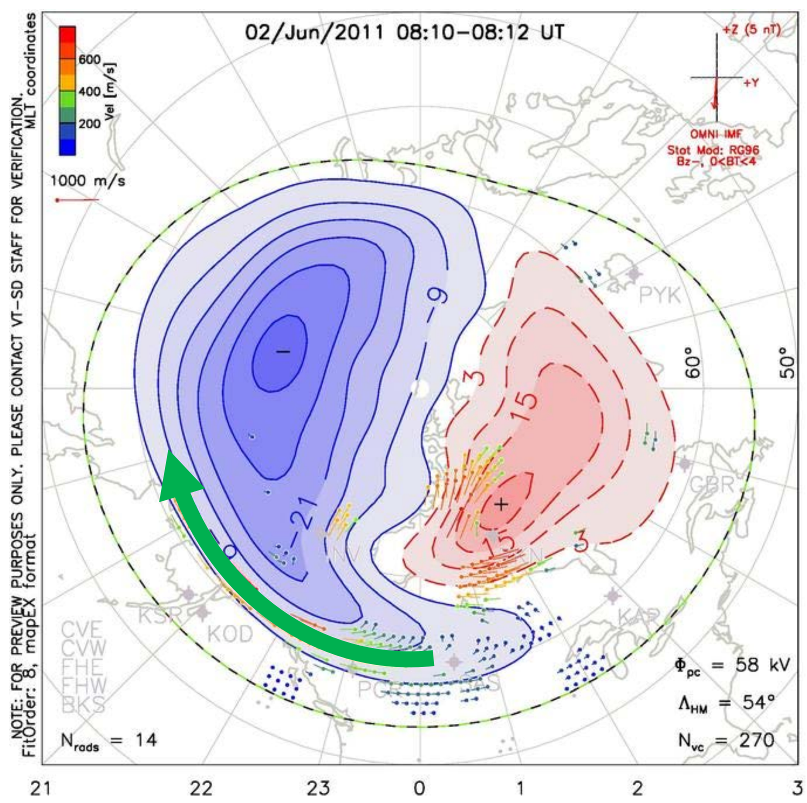
Sub-Auroral Polarization Streams (SAPS)

- Association of fast westwards flow stream in the pre-midnight sector with bifurcated (downward) region 2 current
- Auroras collocated with upwards current regions
- Ionospheric conductance (or lack thereof) and inner magnetosphere dynamics (partial ring current) both play a role in the generation of fast flow

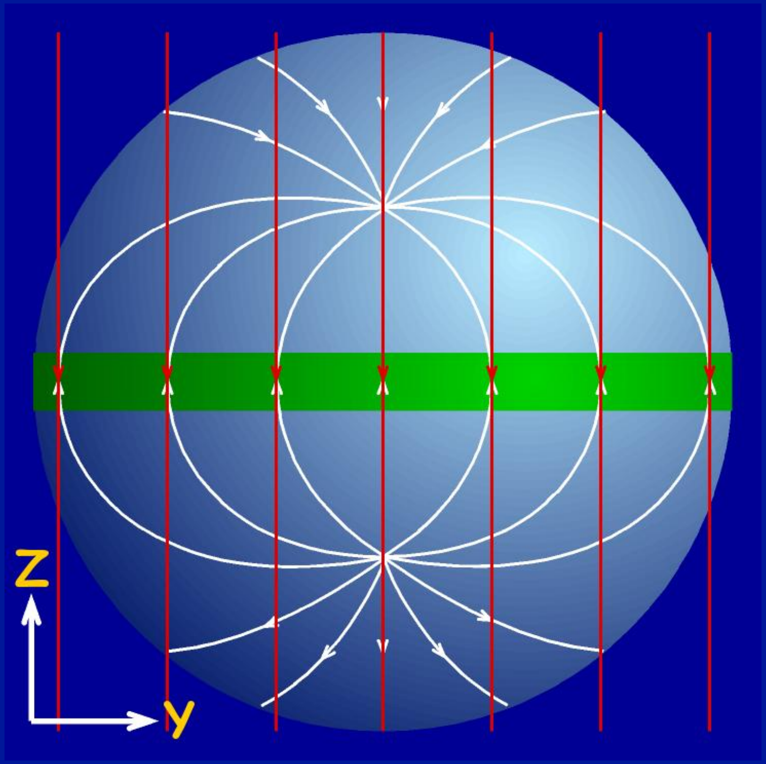




Solar wind-magnetosphere coupling

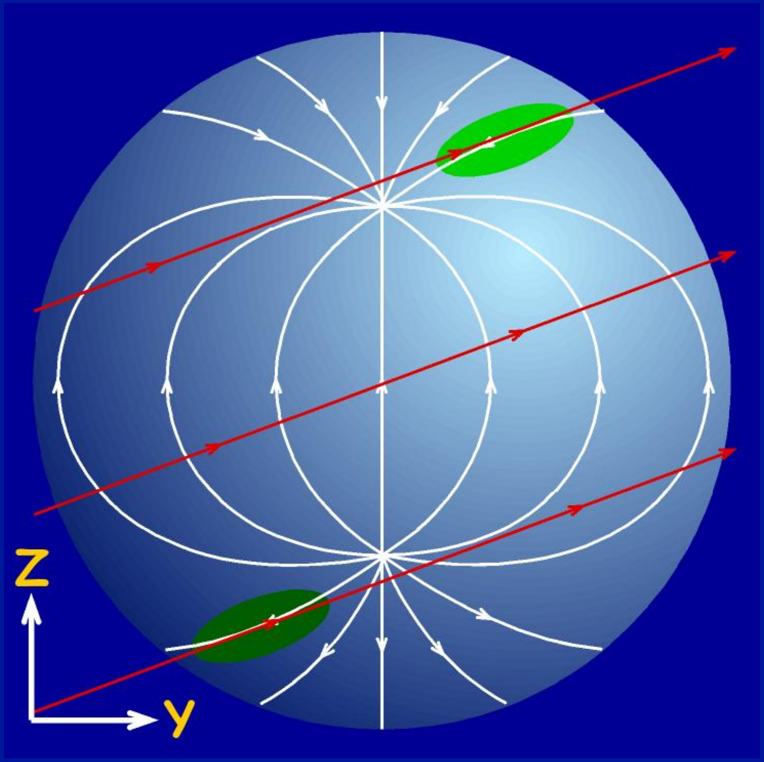
Reconnection location

IMF $B_z < 0$, $B_y = 0$



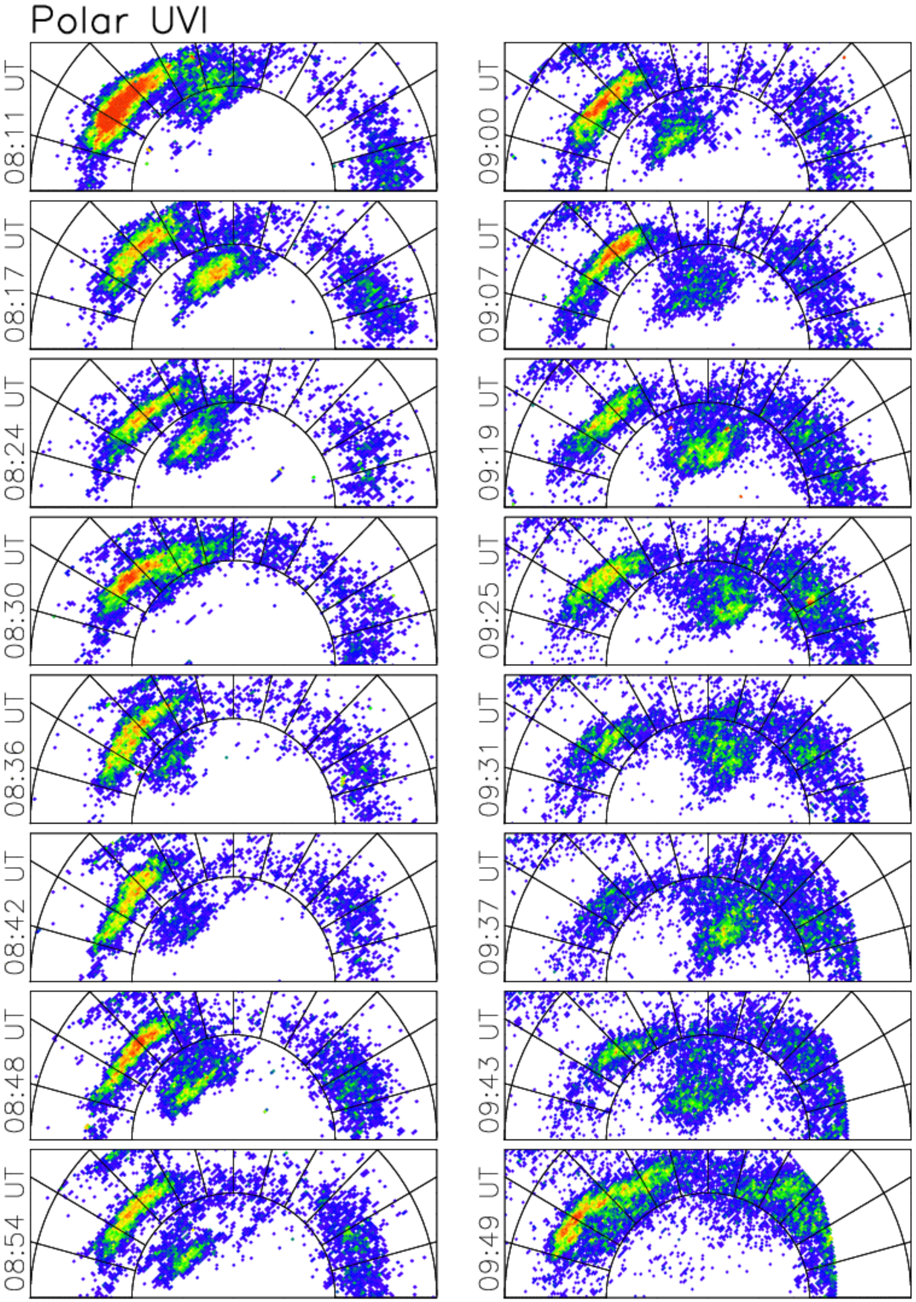
Reconnection with closed field lines

IMF $B_z > 0$, $B_y > 0$

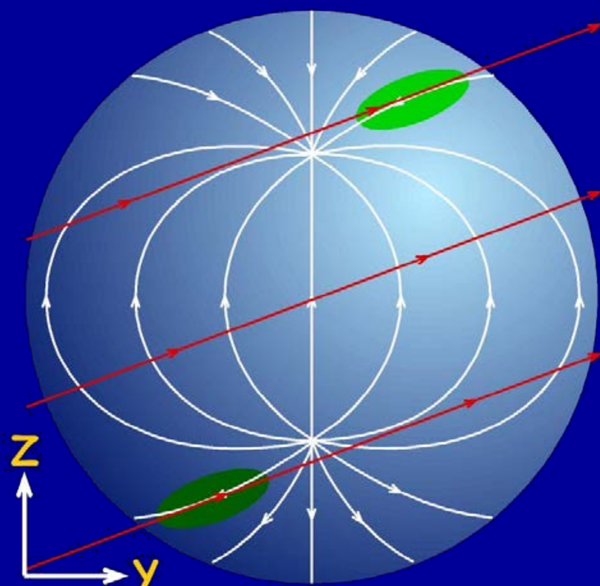


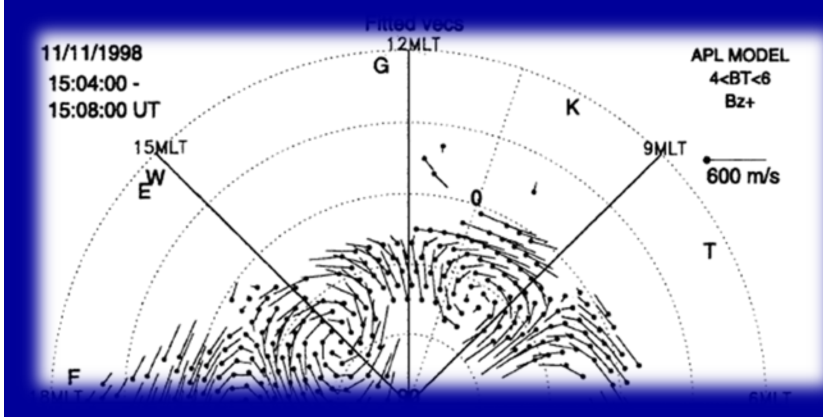
Reconnection with open field lines

Northwards IMF "cusp spot"



Milan et al. (2000)





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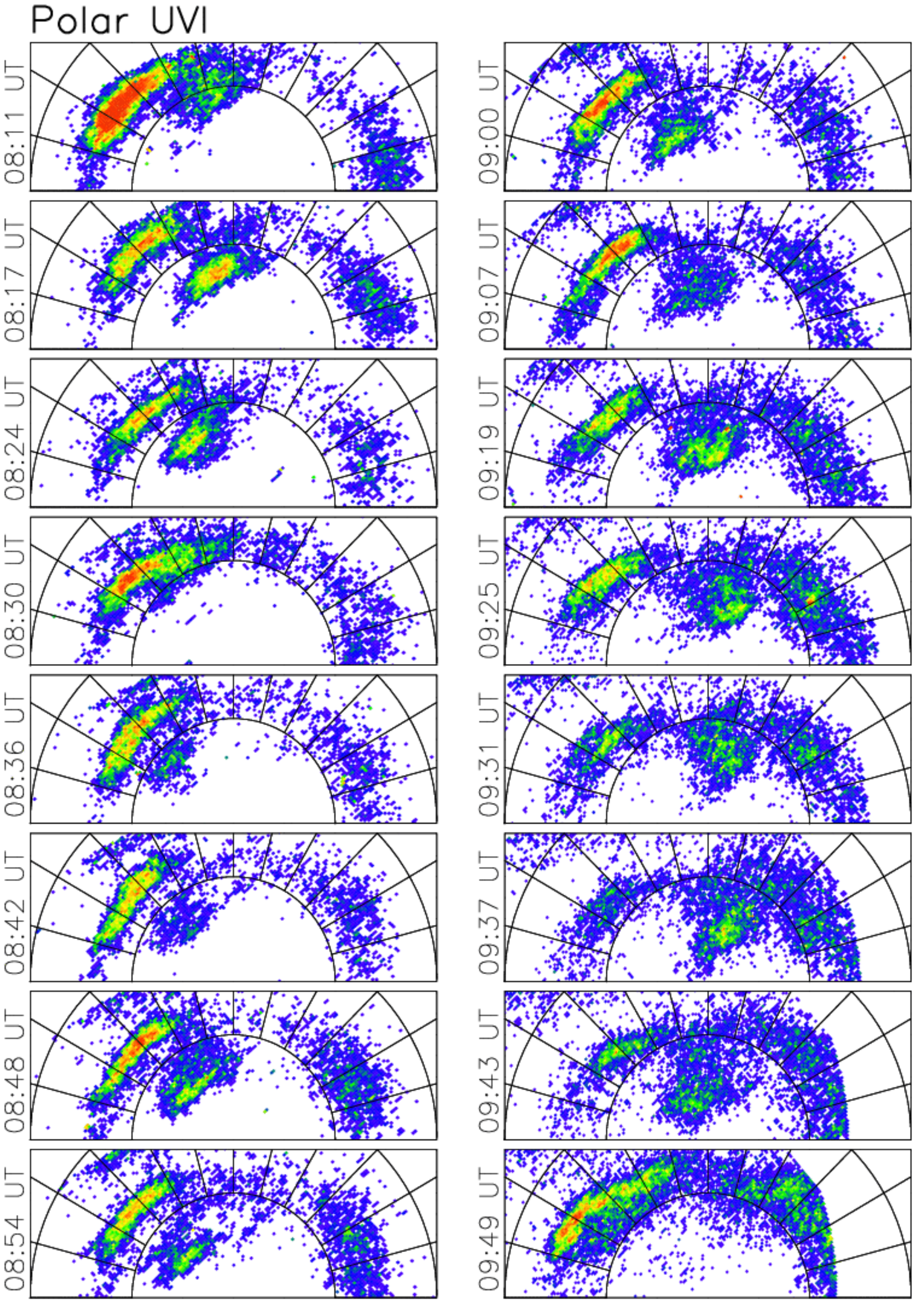
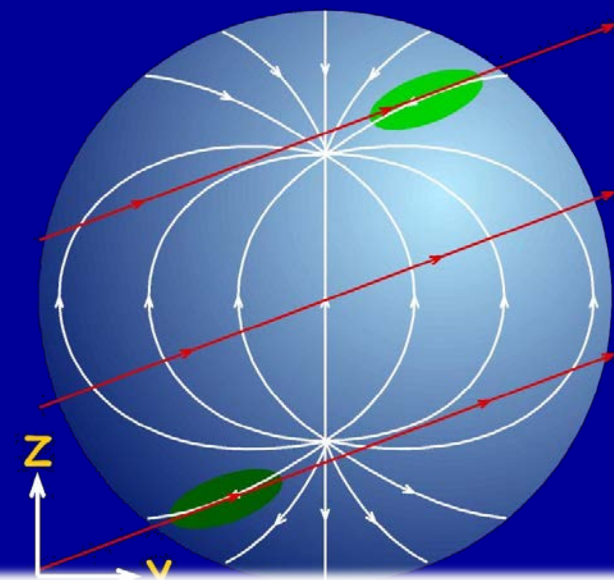
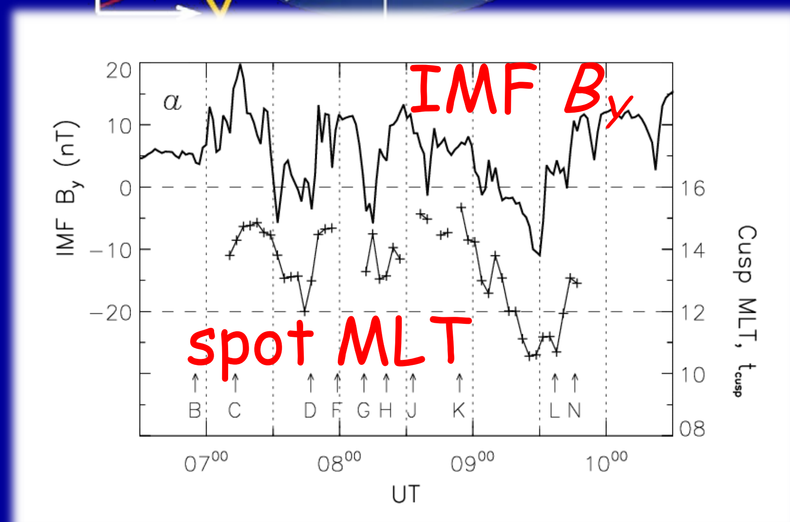
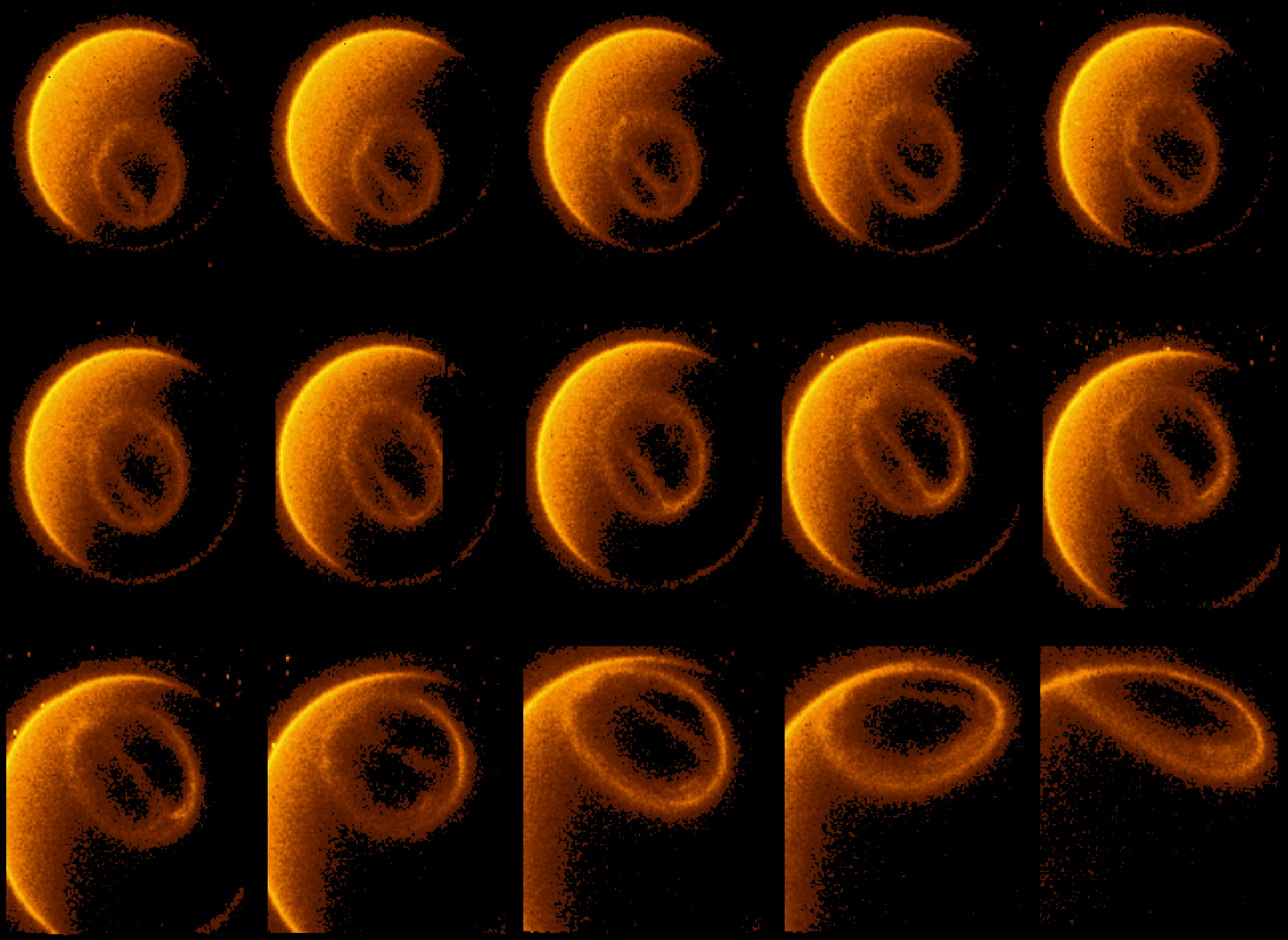






Milan et al. (2000)

Transpolar arcs - theta aurora

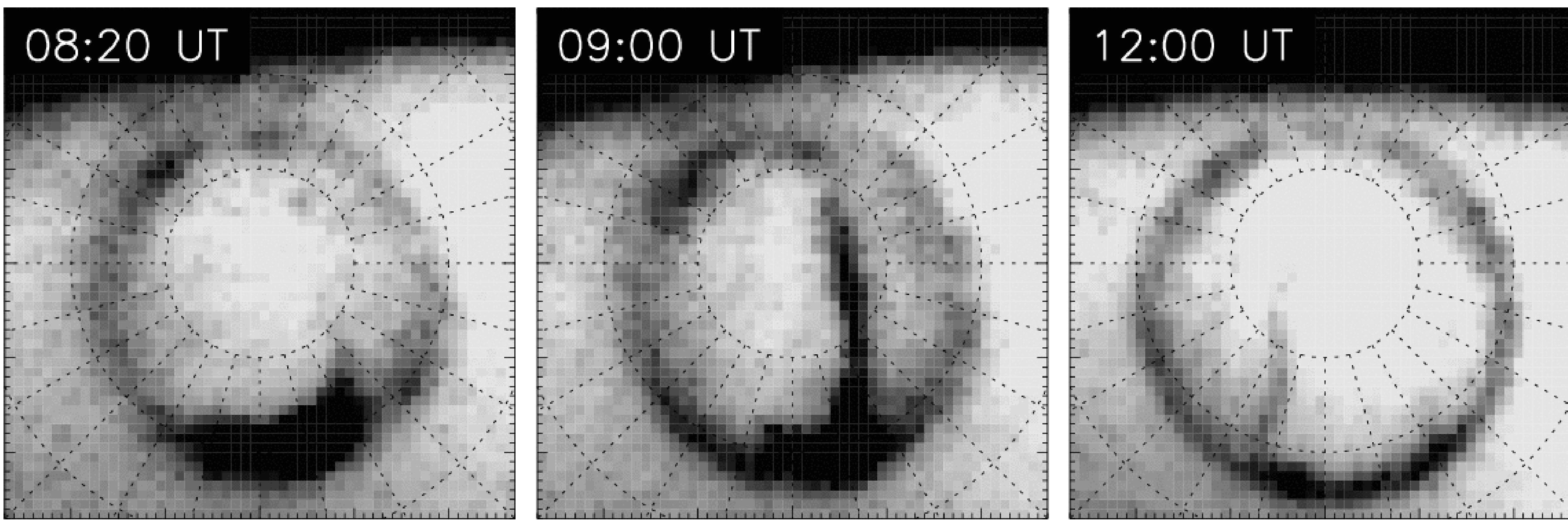


Transpolar arcs - theta aurora

The arc grows across the polar cap from a brightening of the nightside auroral oval

It moves across the polar cap as IMF B_Y switches

It fades into the nightside aurora as the IMF turns southwards once again



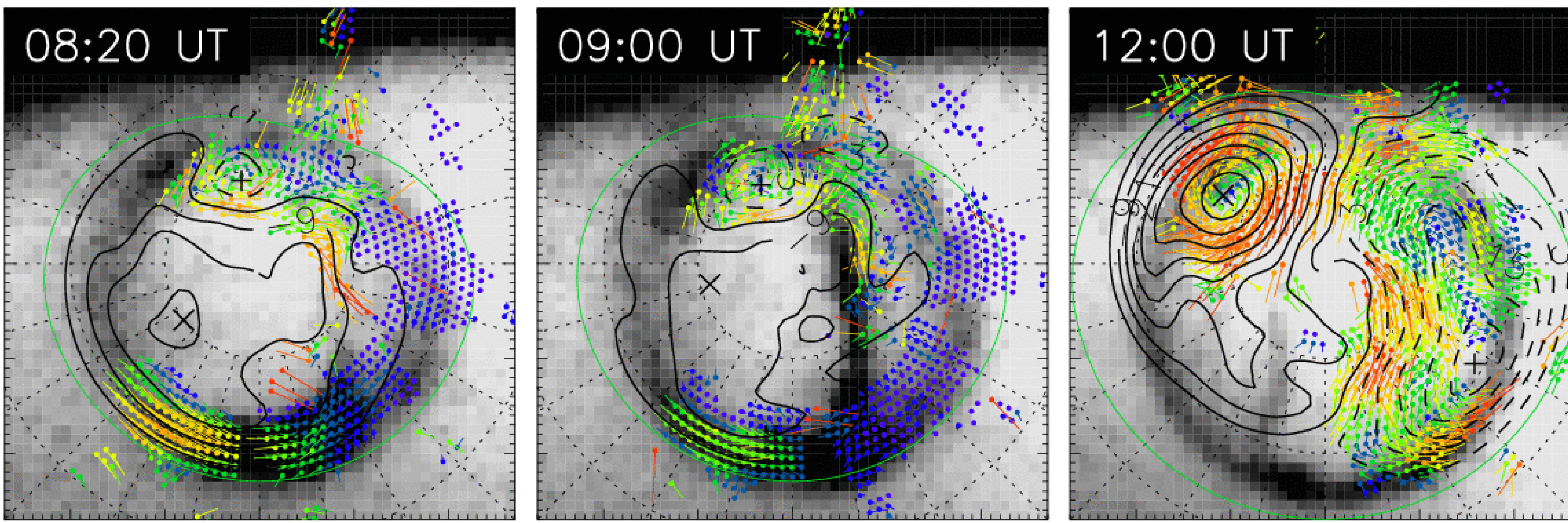
Milan et al. (2005)

Transpolar arcs - theta aurora

Azimuthal flows indicate magnetic reconnection in a twisted magnetotail

Dayside vortical flows indicate that the TPA moves under the influence of “lobe stirring”

The TPA is pushed towards the night-side as standard Dungey cycle flows add new open flux



Milan et al. (2005)

Conclusions

- The open magnetosphere model provides a holistic picture which explains not only the magnetic and plasma **structure** of the magnetosphere, but also the **dynamics**
- Many, originally unsuspected, magnetospheric phenomena fit naturally into the open magnetosphere picture
- The inner magnetosphere and ionospheric conductance are also important for understanding the dynamics of the magnetosphere

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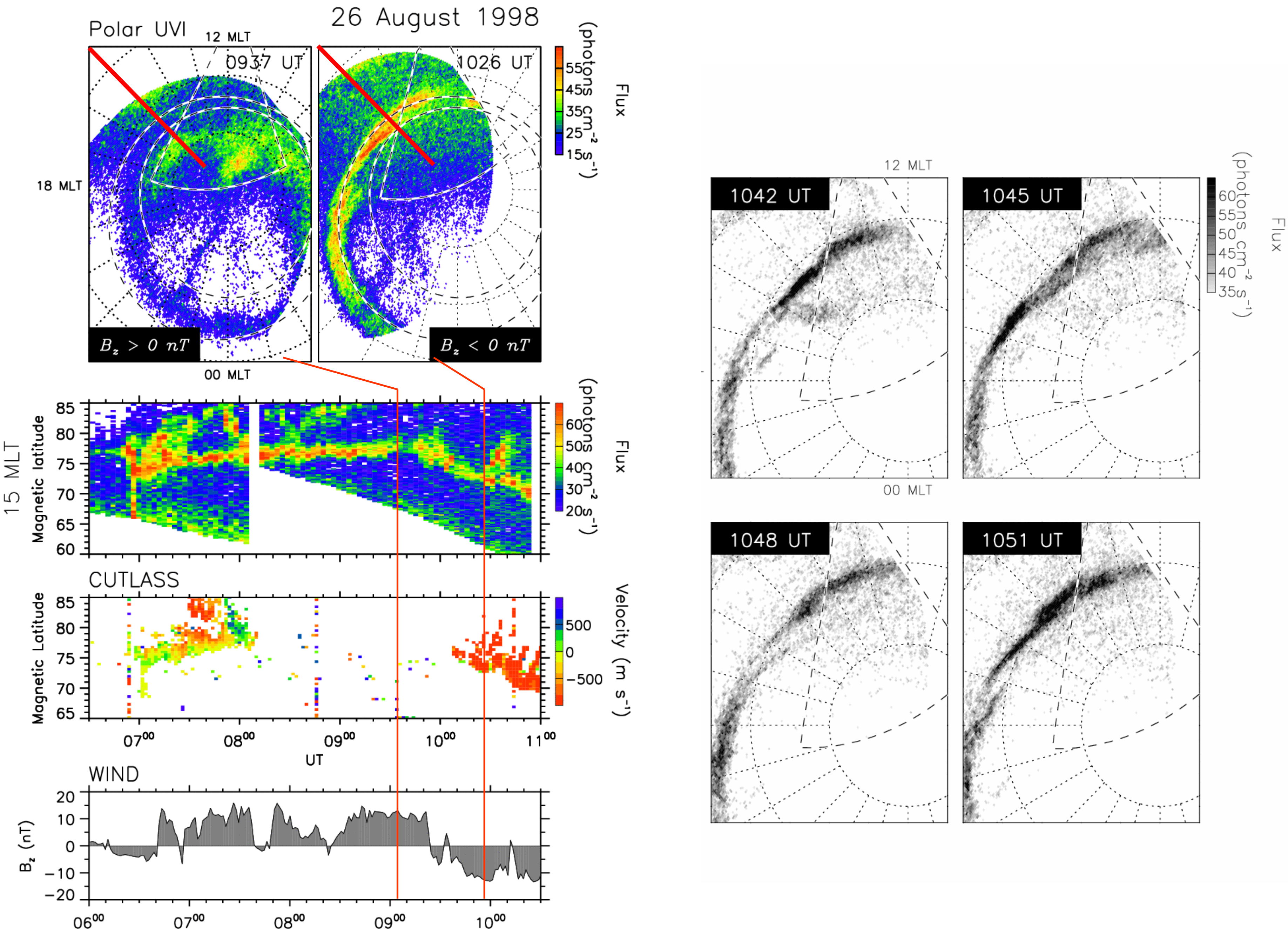
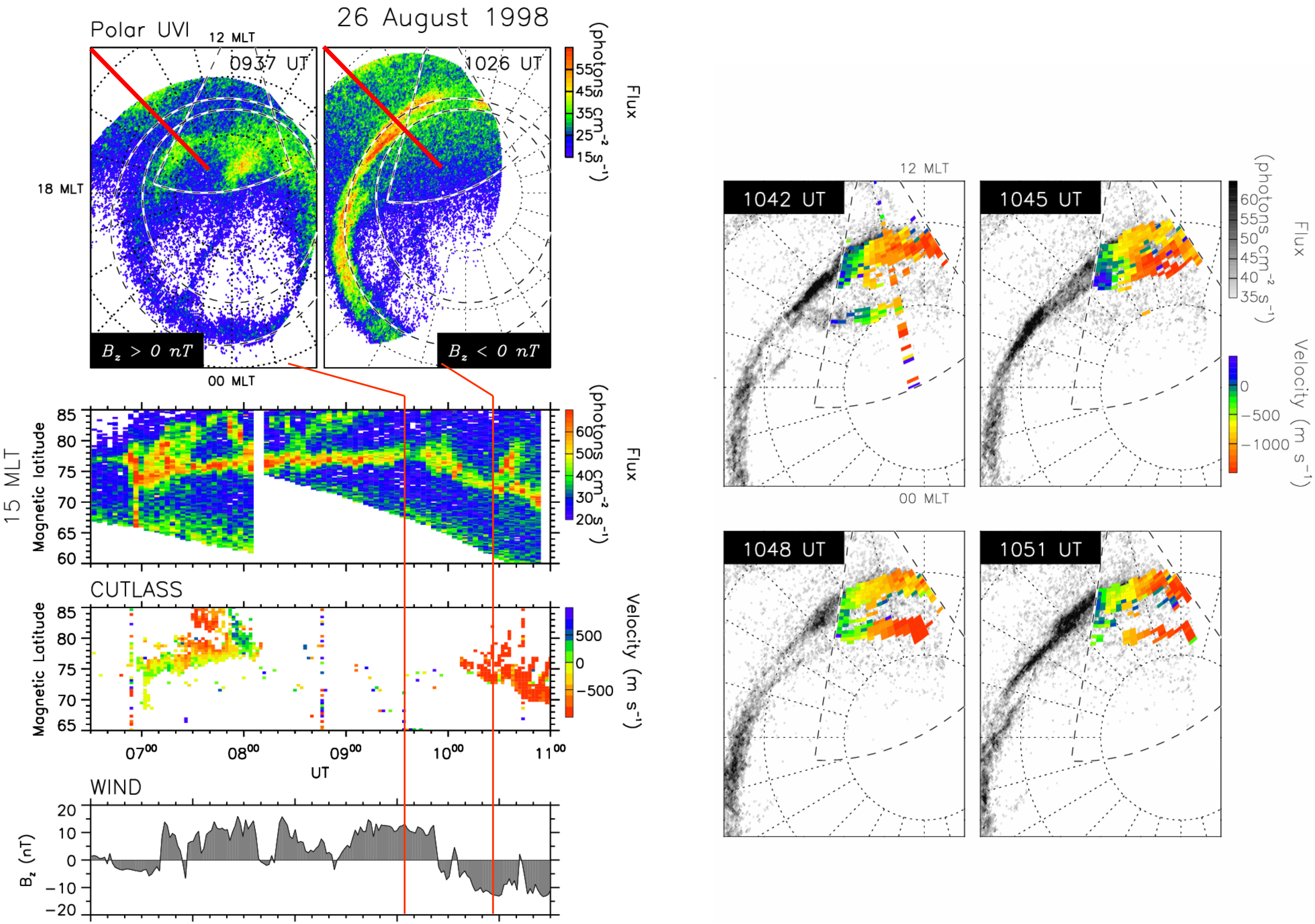
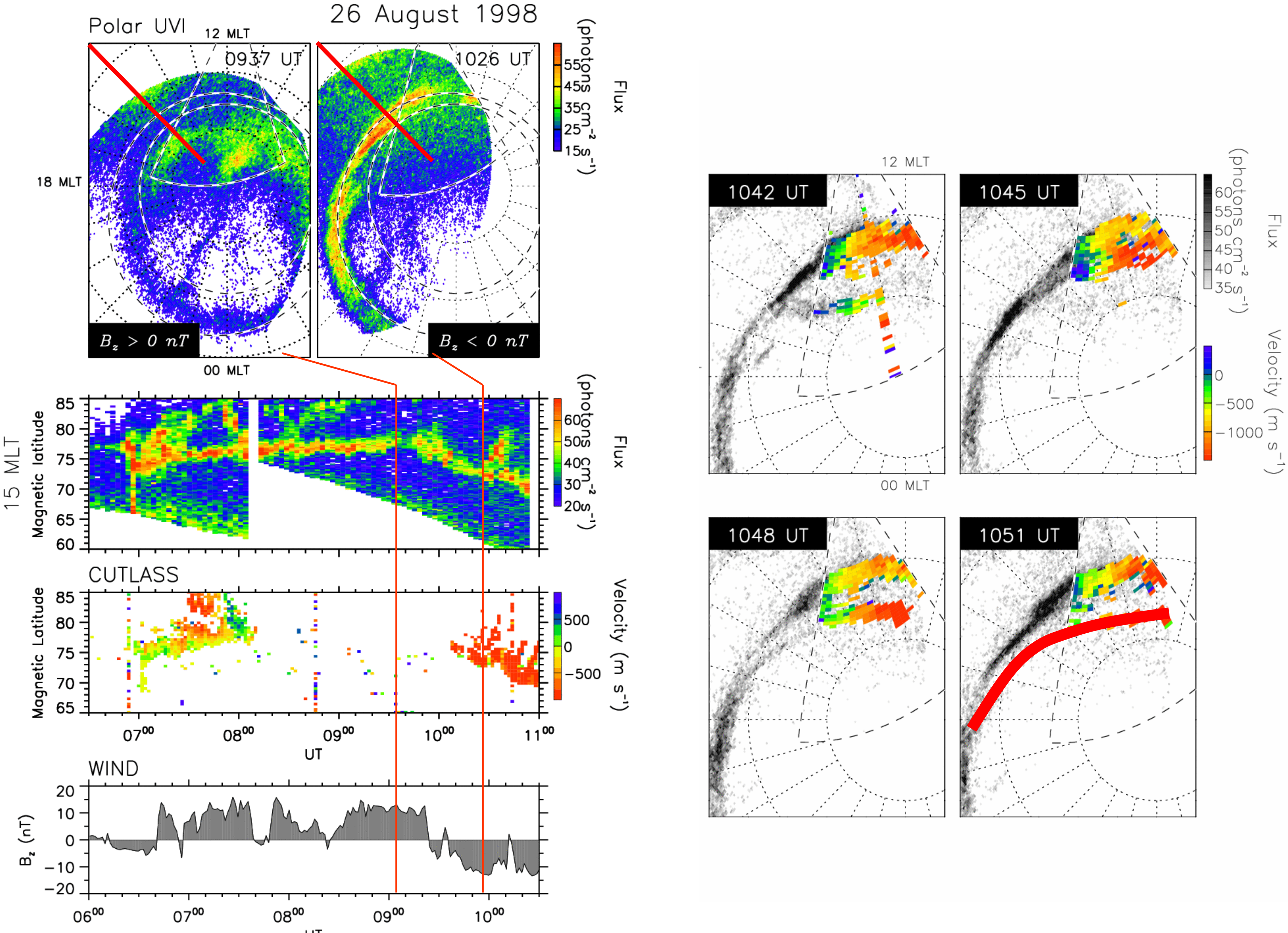


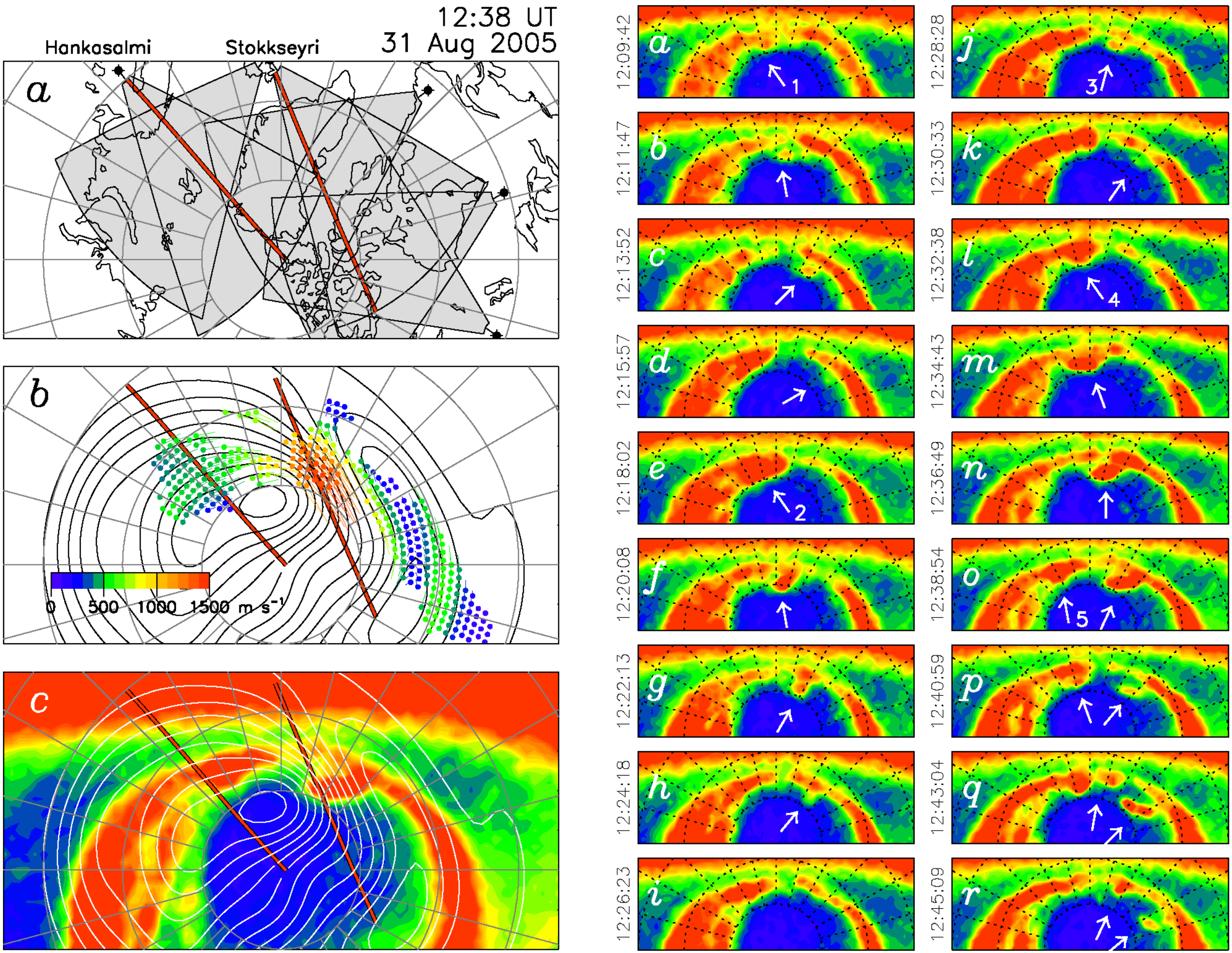
Milan et al. (2000b)



Milan et al. (2000b)



Milan et al. (2000b)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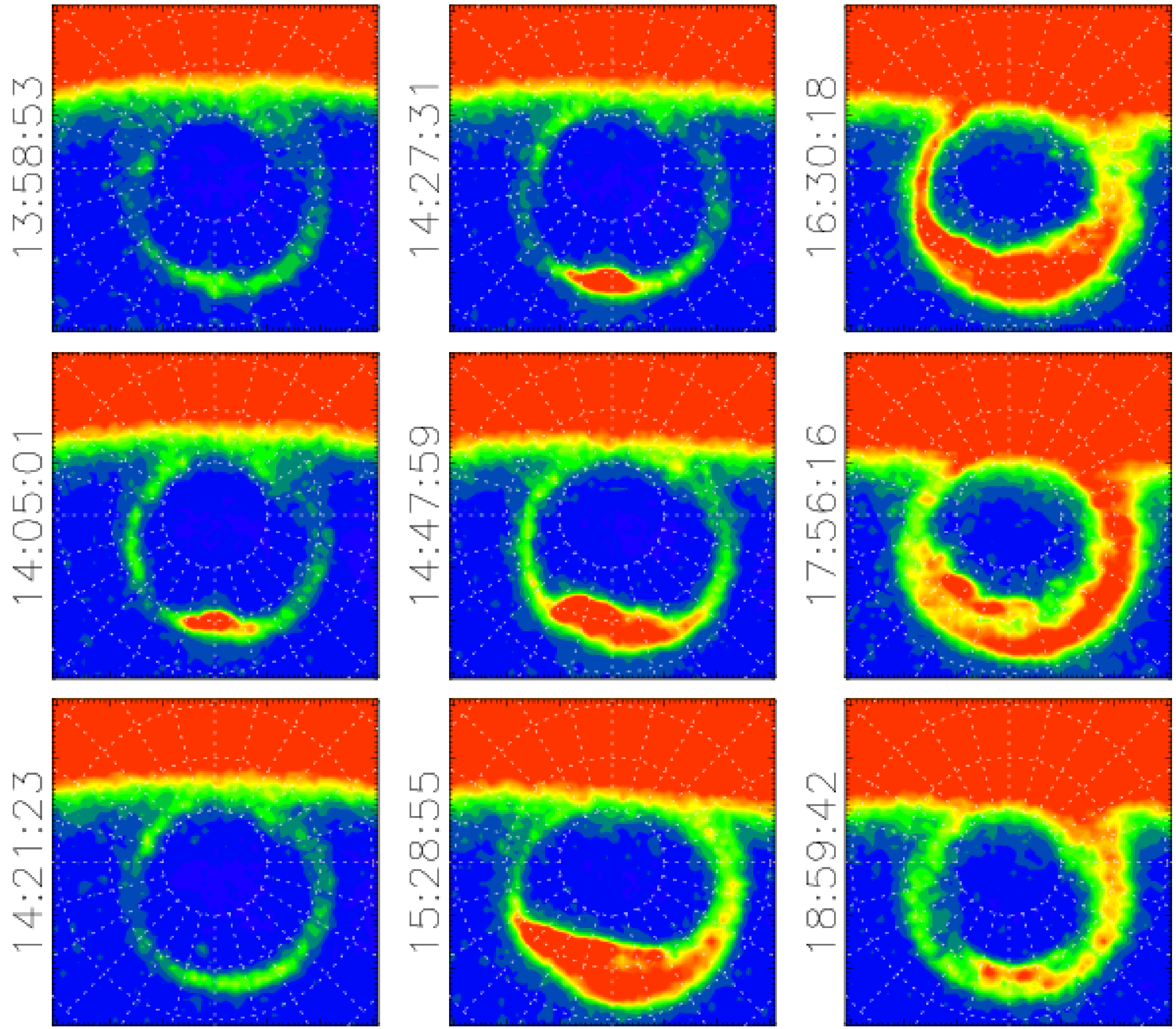
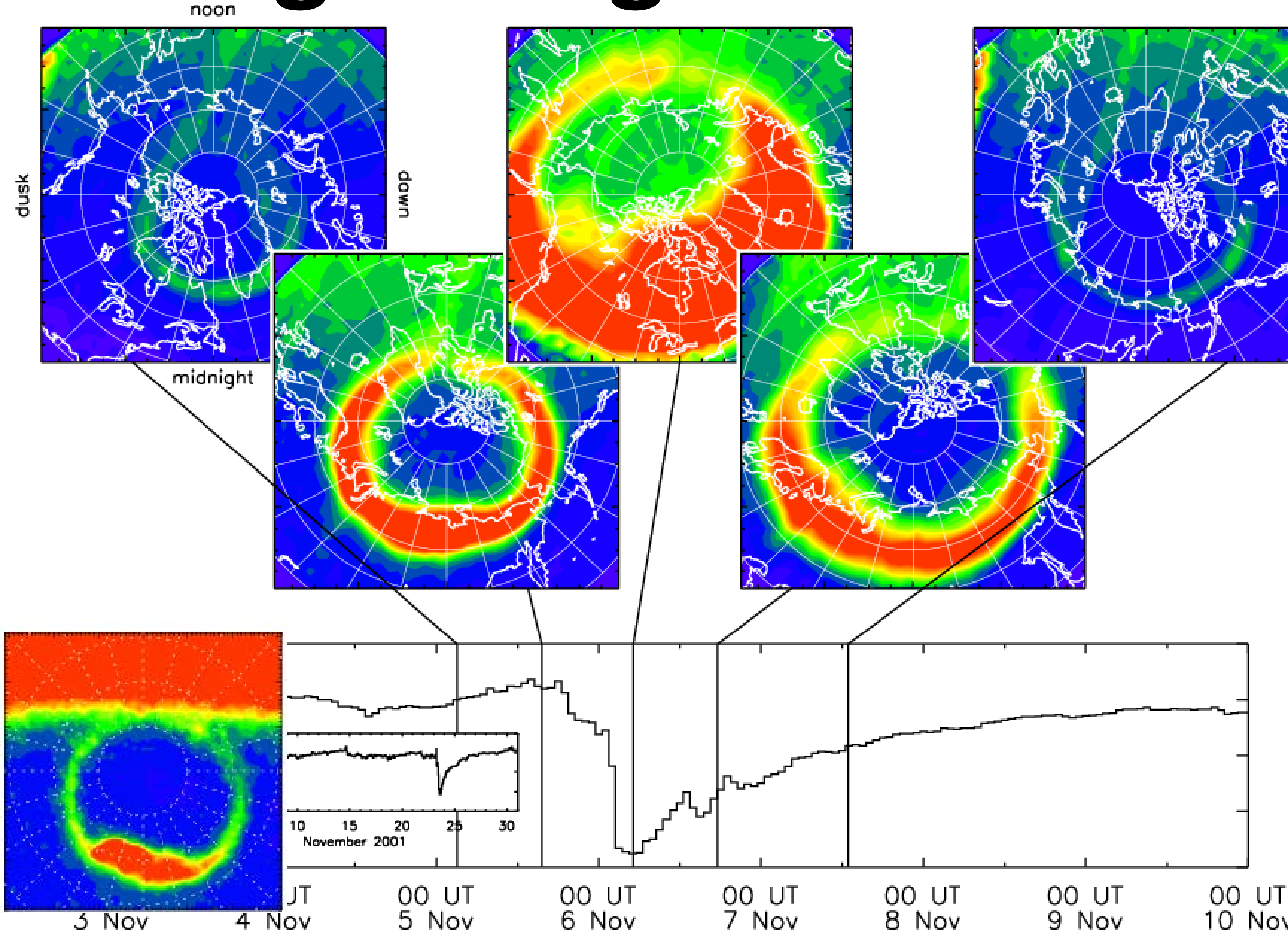
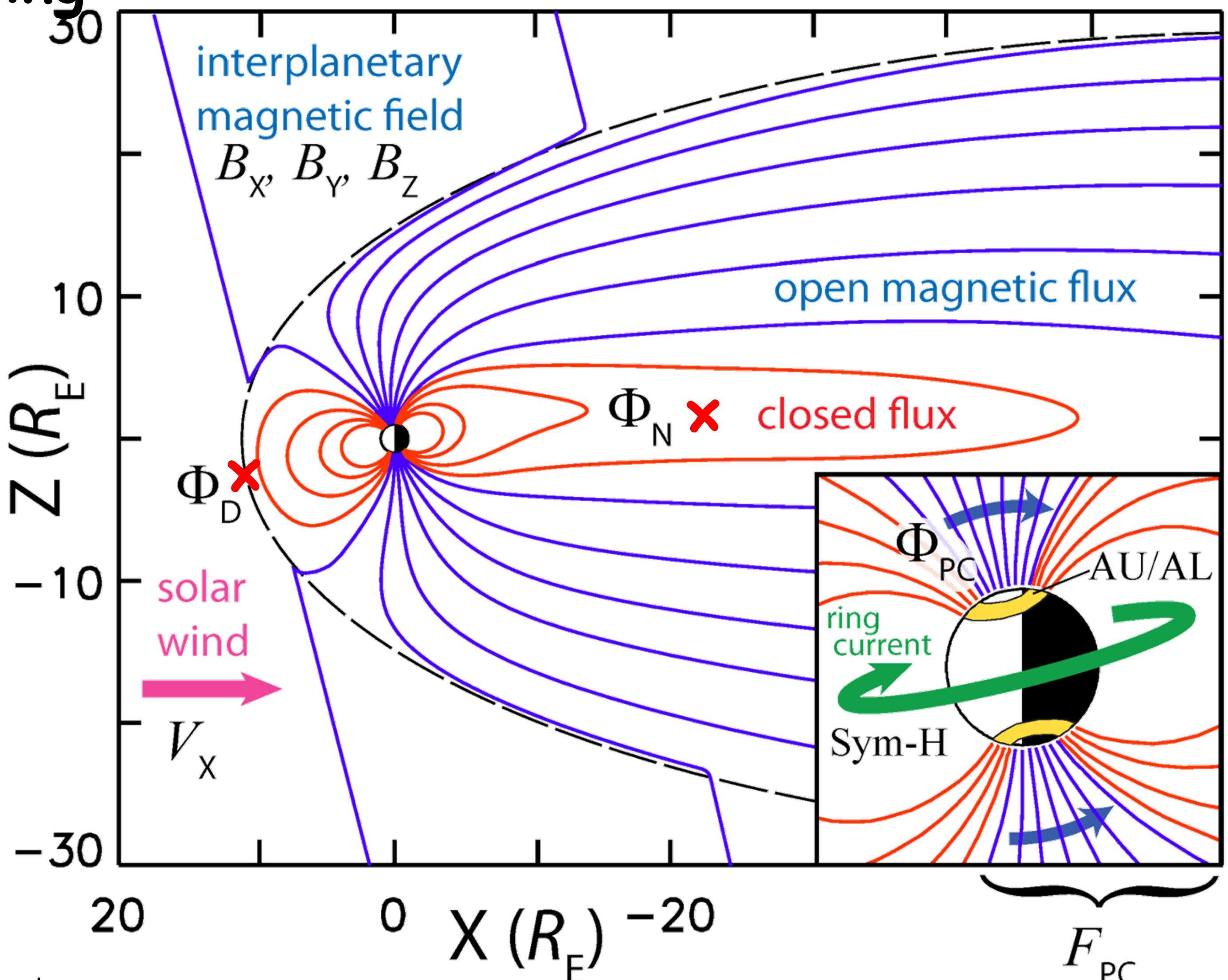
The auroral substorm



The geomagnetic storm



Solar wind-magnetosphere-ionosphere-atmosphere coupling



Milan et al. (2009)

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