BIRKELAND CENTRE
FOR SPACE SCIENCE

Unanswered questions regarding solar wind - magnetosphere interaction

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The University Centre in Svalbard

NTNU
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Unsolved questions……

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Why are the aurora in the cojugate hemispheres asymmetric?

Two topics:

1. Effects of IMF By
2. Transporal arcs

If time:

3. Effects of IMF Bx

IMF By/clock angle and asymmetric footpoints

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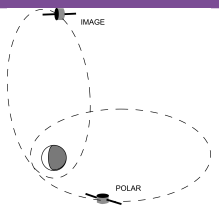
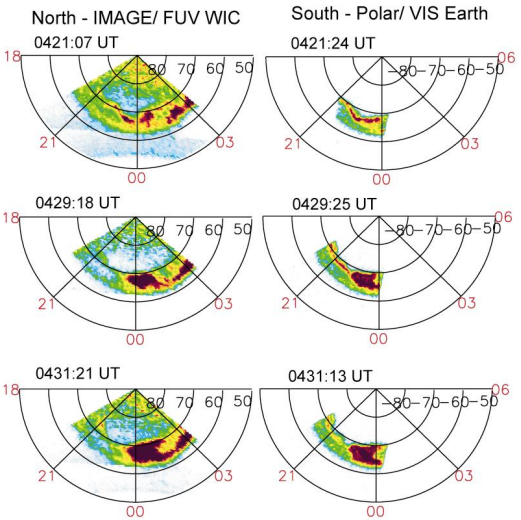
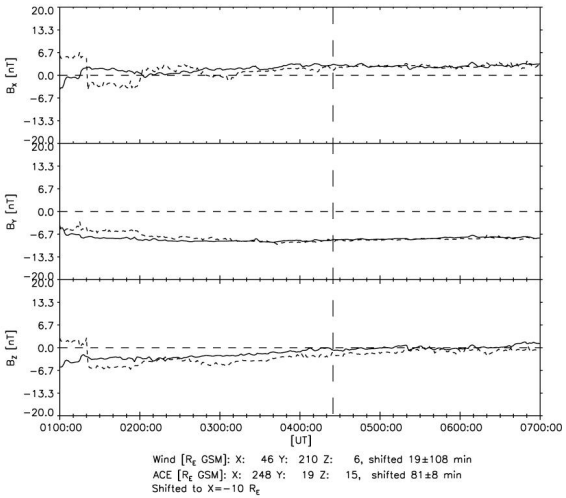


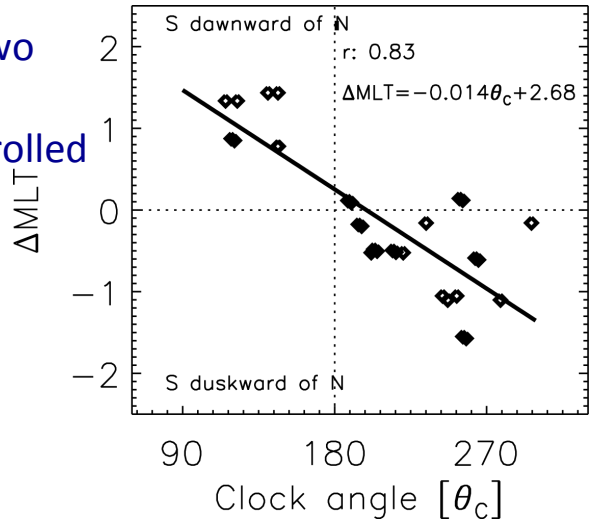
July 02, 2001



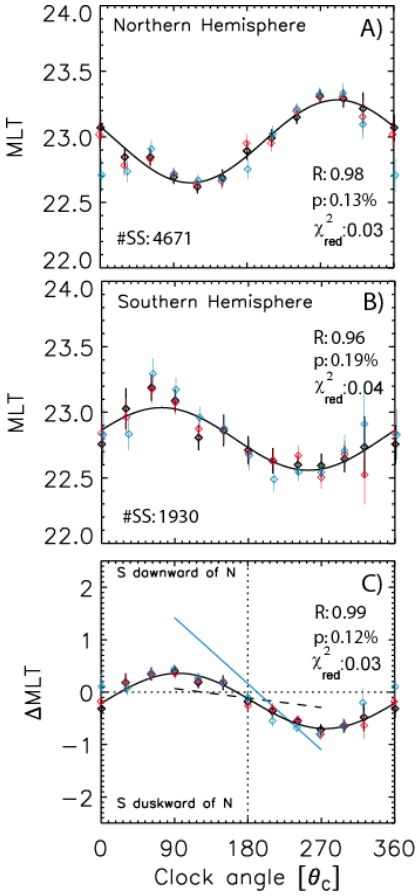


Simultaneous UV aurora in two hemispheres:
Asymmetric foot points controlled by IMF Clock angle

Østgaard et al, JGR, 2005

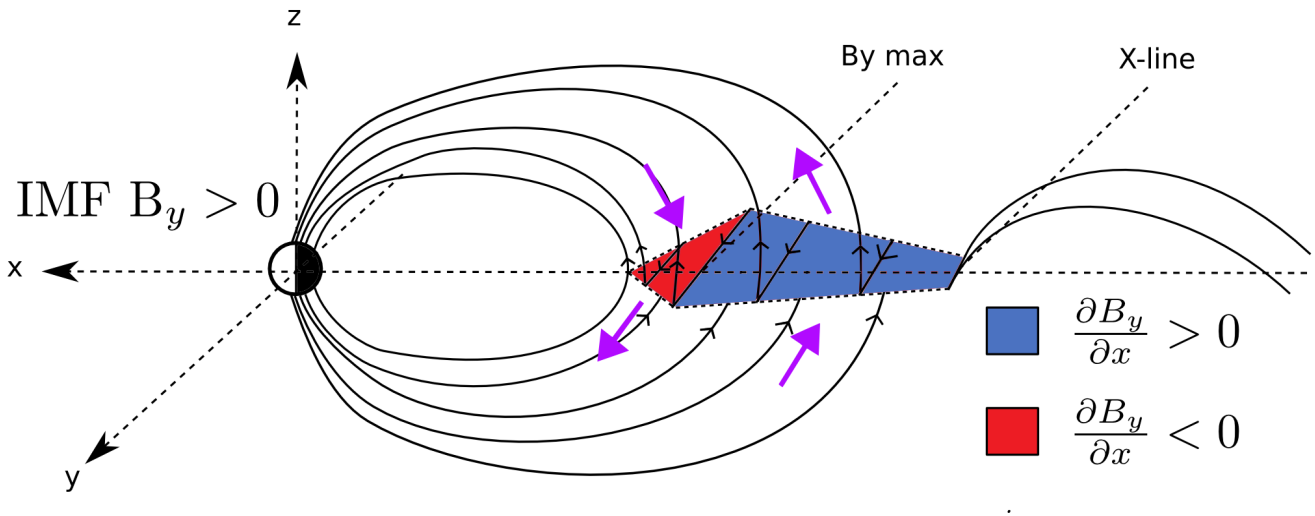


6600 substorm onsets by IMAGE and Polar (4671 NH -1930 SH)



Østgaard et al, GRL, 2012

IMF By ´penetration´: Classical picture



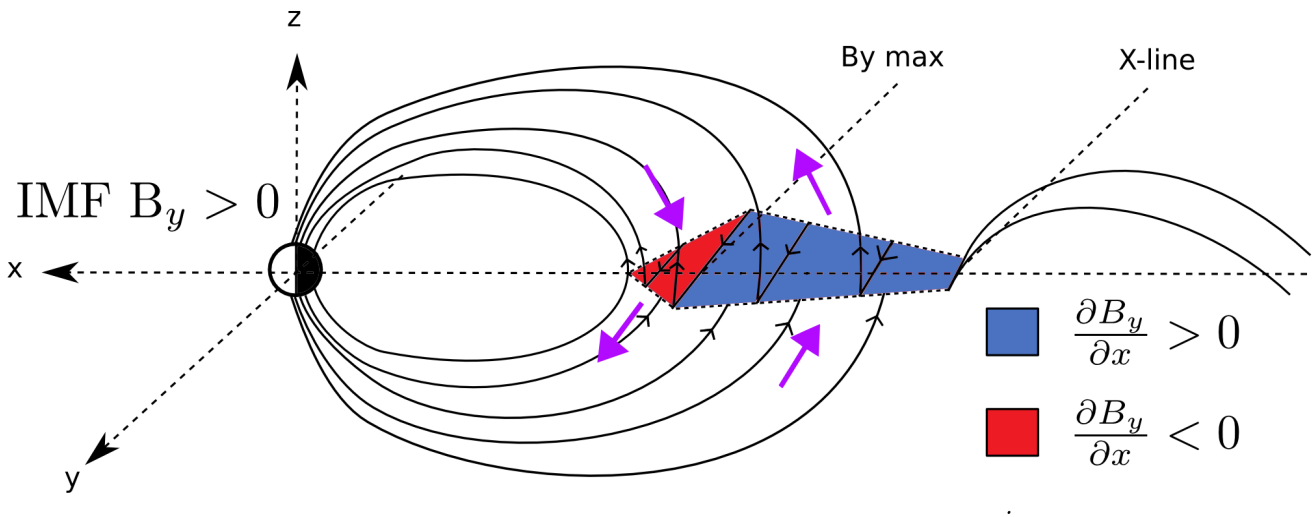
Stenbaek-Nielsen and Otto, 1997

Result of reconnection, By is transported into closed hemisphere

Creates dBy/dx in the tail:

Ampere´s law implies interhemispheric currents

Revised explanation



Stenbaek-Nielsen and Otto, 1997

No interhemispheric currents

Only asymmetric currents

Lobe pressure not reconnection

Magnetospheric By is induced by IMF By

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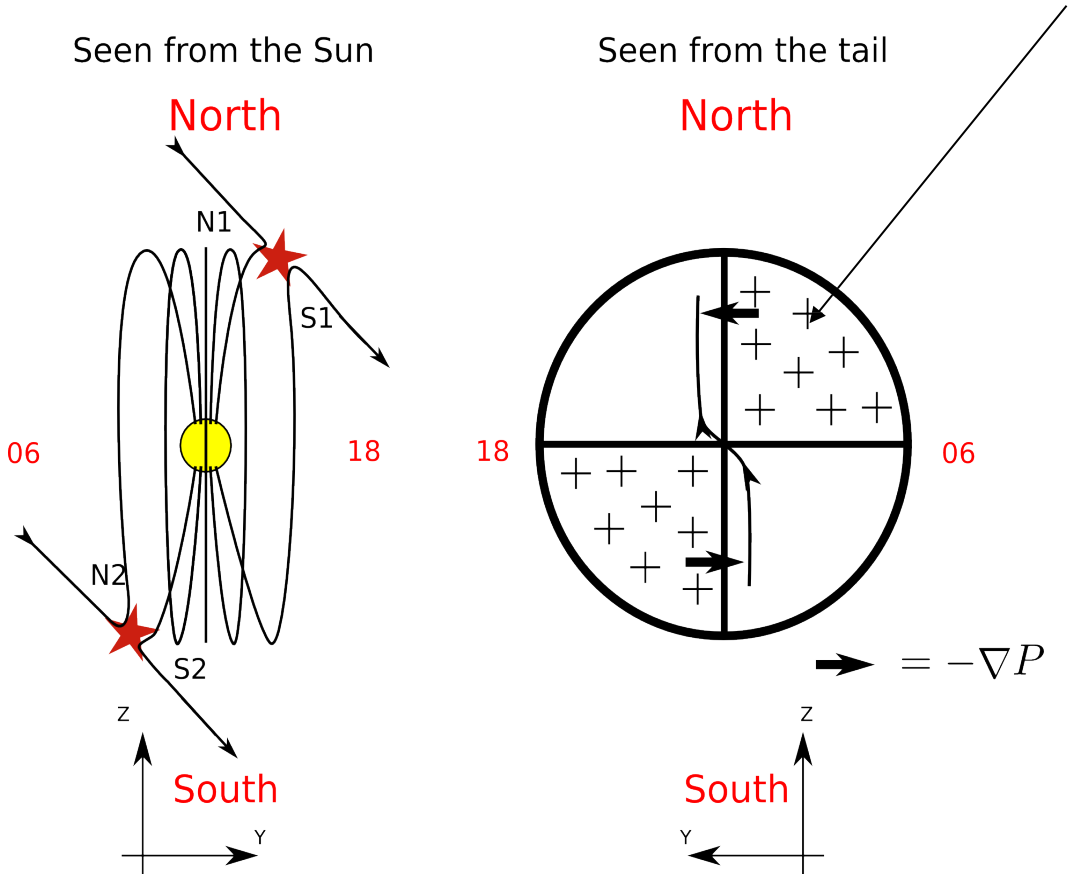
$$\text{IMF } B_y > 0$$



Asymmetric loading of flux and pressure in the lobes

This pressure force affects closed field lines

Result is an induced By

Leads to asymmetric footpoints

No need for reconnection, only lobe pressure

Response time of ~10 minutes

Magnetospheric By is induced by IMF By

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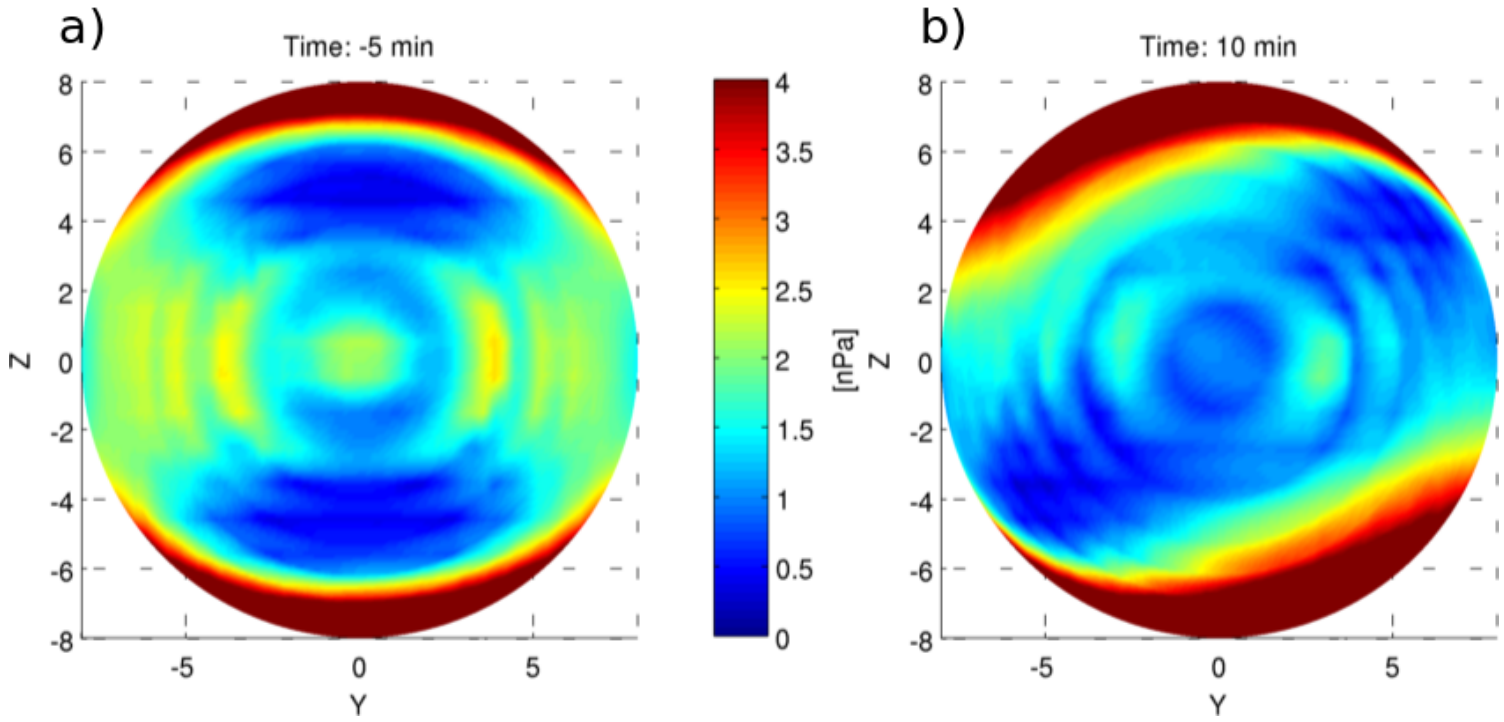
LFM model shows induced By after 10 minutes:

How lobe pressure is added on a half sphere 8 Re seen from sun

IMF By =0

IMF By >0



Induced By and dynamics

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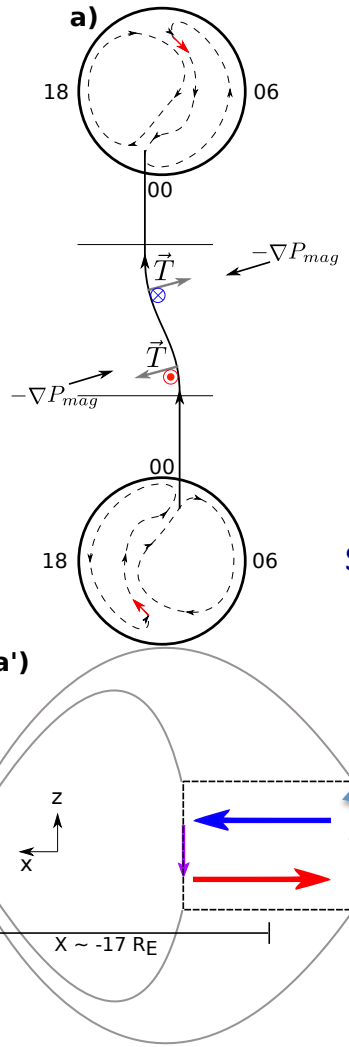
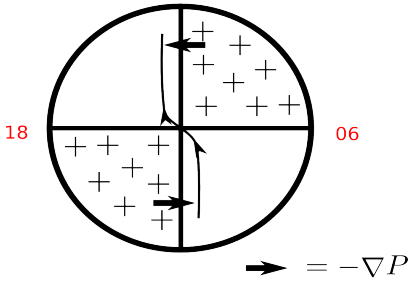
Midtail: 17 Re

- Footpoints in banana and orange cell – dawn cells
- Lobe pressure force
- Tension force
- In ballance
- Finite region of induced By
- No dissipation and currents close locally



north

south



Region of induced By

Induced By and dynamics

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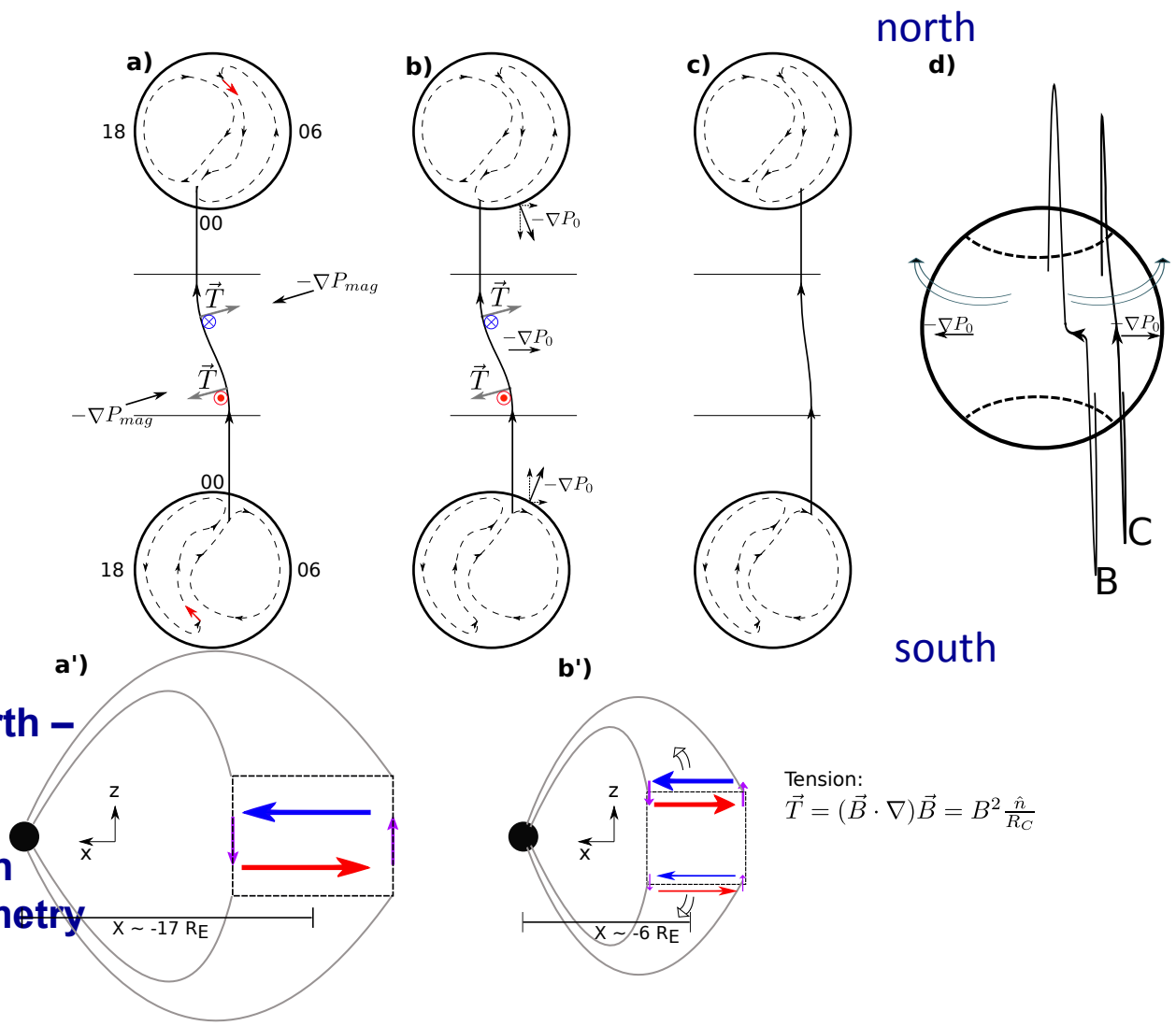
Near Earth: 6 Re

- Less/no lobe pressure
- Tension force
- Pressure from Earth (magnetic and particle)
- Same direction in north
- Opposite in south
- **Stress released into north – up/down currents**
- **Flow in north faster than south – removes asymmetry**



Østgaard et al., 2015 (AGU mon); Tenfjord et al., 2015 (in review process)

Summary – IMF By

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- IMF By does not penetrate the magnetosphere
- By is induced by the asymmetric loading of lobe flux
- Midtail region: forces (tension and lobe pressure) balance and current close locally
- Near Earth: tension and magnetic/particle pressure from Earth: By>0: same direction in north, opposite in south
- Alfven wave/magnetic stress released (up – down current) into north – weaker into south
- No interhemispheric current but asymmetric currents launched from plasma sheet
- Flow faster in north than south – restoring symmetric footpoints.

Questions – IMF By

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What is the time scale of this induction?

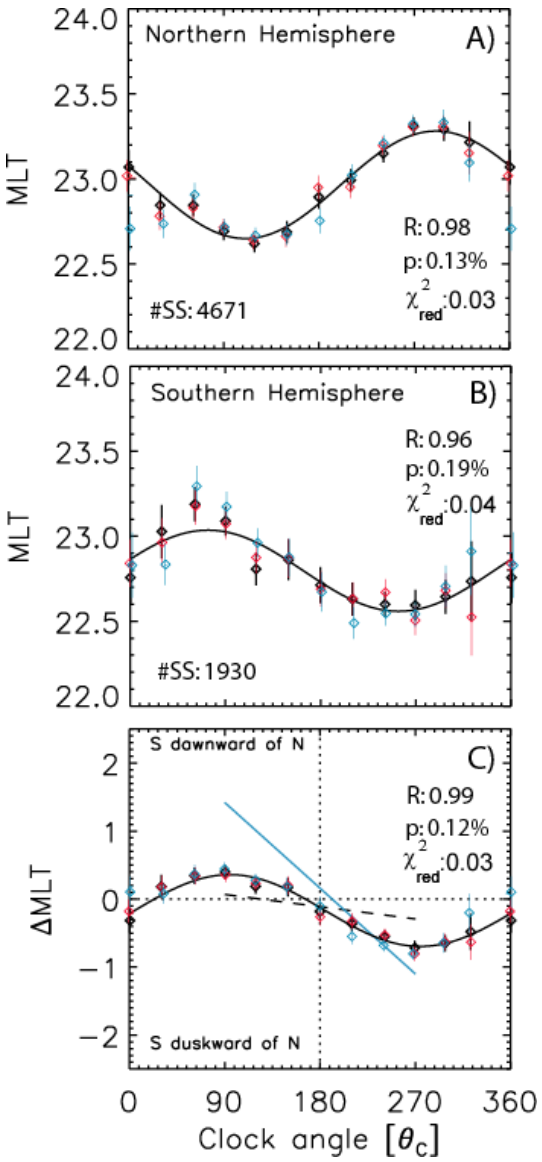
How soon will we see:

- induced By
- asymmetric footpoints
- convection pattern (banana – orange cells)

LFM model and our own results: 10 minutes

Other papers: hours

Time scale of induced By



Østgaard et al.., 2011

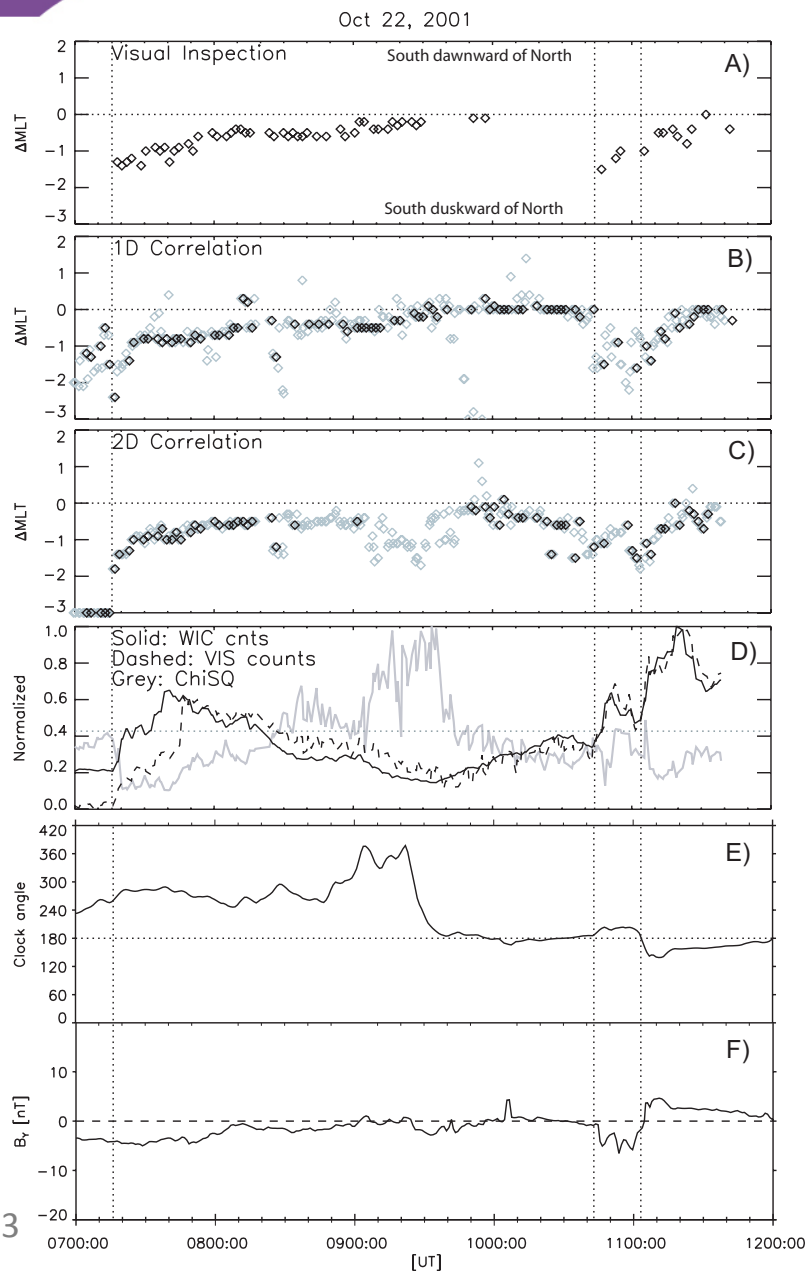
Best ordering of delta MLT

When SW propagated to – 10 Re

Which is about 10 min after subsolar point

Asymmetries established after 10 min.

Time scale of induced By



Østgaard et al.., 2011

Two substorms

SW propagated to – 10 Re which is about 10 min

Delta-MLT follows the By

Asymmetries established after 10 min

Time scale of induced By

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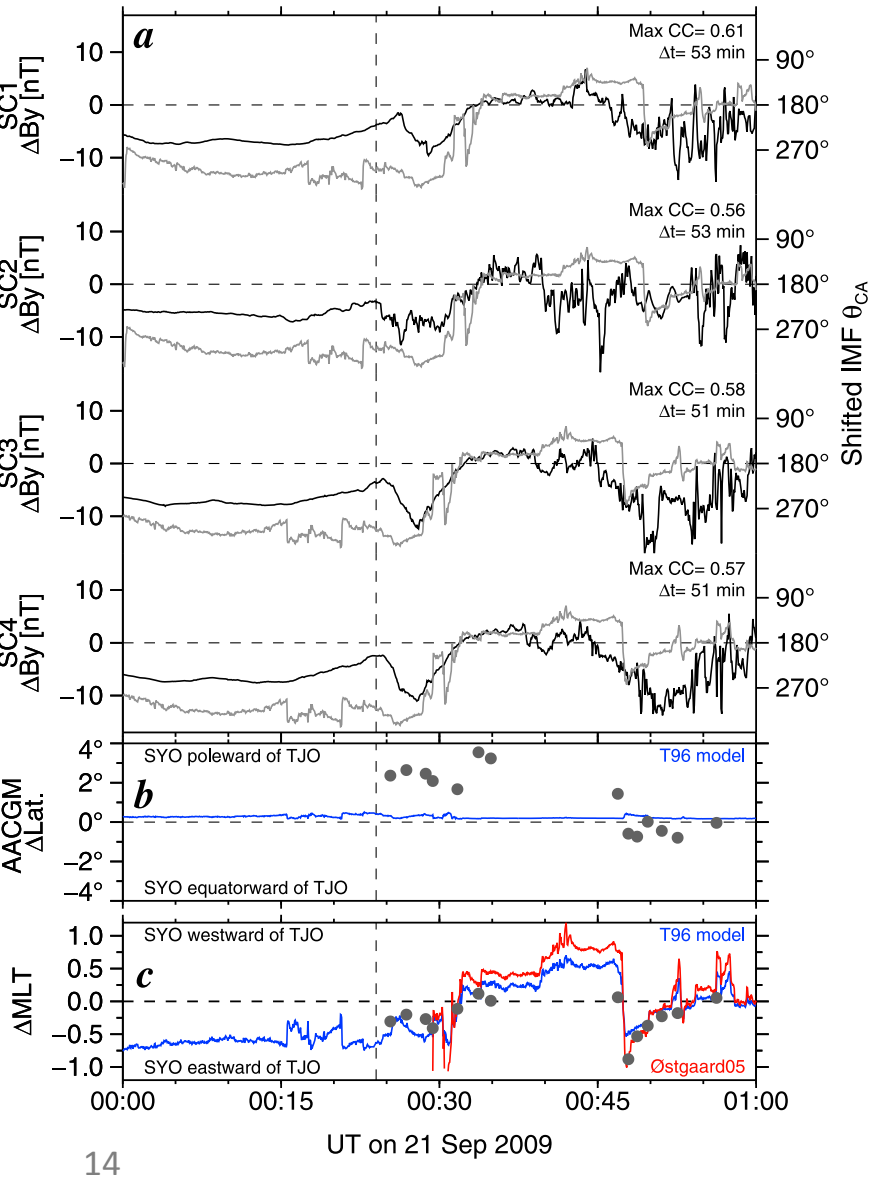
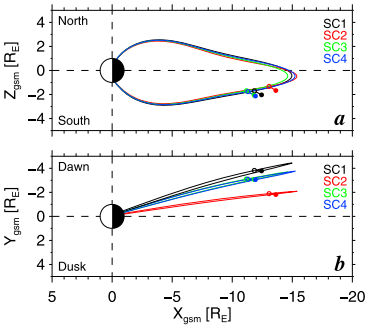
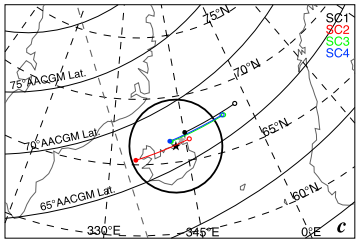


Motoba et al., 2010

ACE - clock angle
Cluster (X:-12,Y:-3) - By



Correlation shows
51-53 min before
By is induced



Auroral all-sky images
Iceland – Antarctica

shows delta-MLT consistent with this time delay

Asymmetries established after 50 minutes

Time scale of induced By

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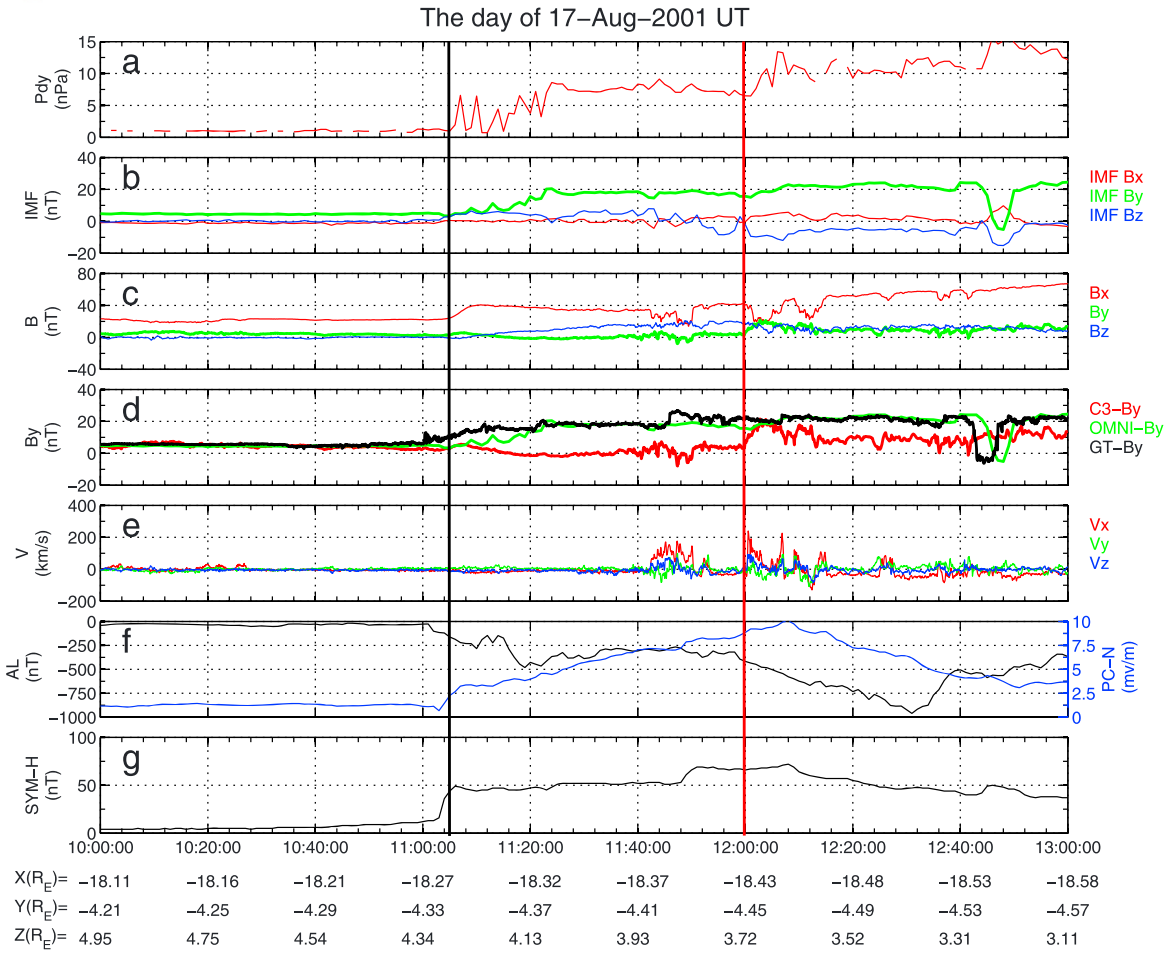

Rong et al., 2015

Cluster sees By at -18.2, -4.4, 3.7

55 minutes after OMNI at sub-solar point.

Asymmetries established after 55 min

Questions – IMF By

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What is the time scale of this induction?

- How soon will we see:
  induced By
  asymmetric footpoints
  convection pattern (banana – orange cells)
- Model (LFM) predicts 10-15 minutes
- Alfven waves also indicate 10-15 minutes
- Our own results indicate 10 min

Some claim it will take hours

- Rong et al., 2015: 55 min for IMF to induce By component
- Motoba et al., 2010: 51 minutes

Polar Arcs

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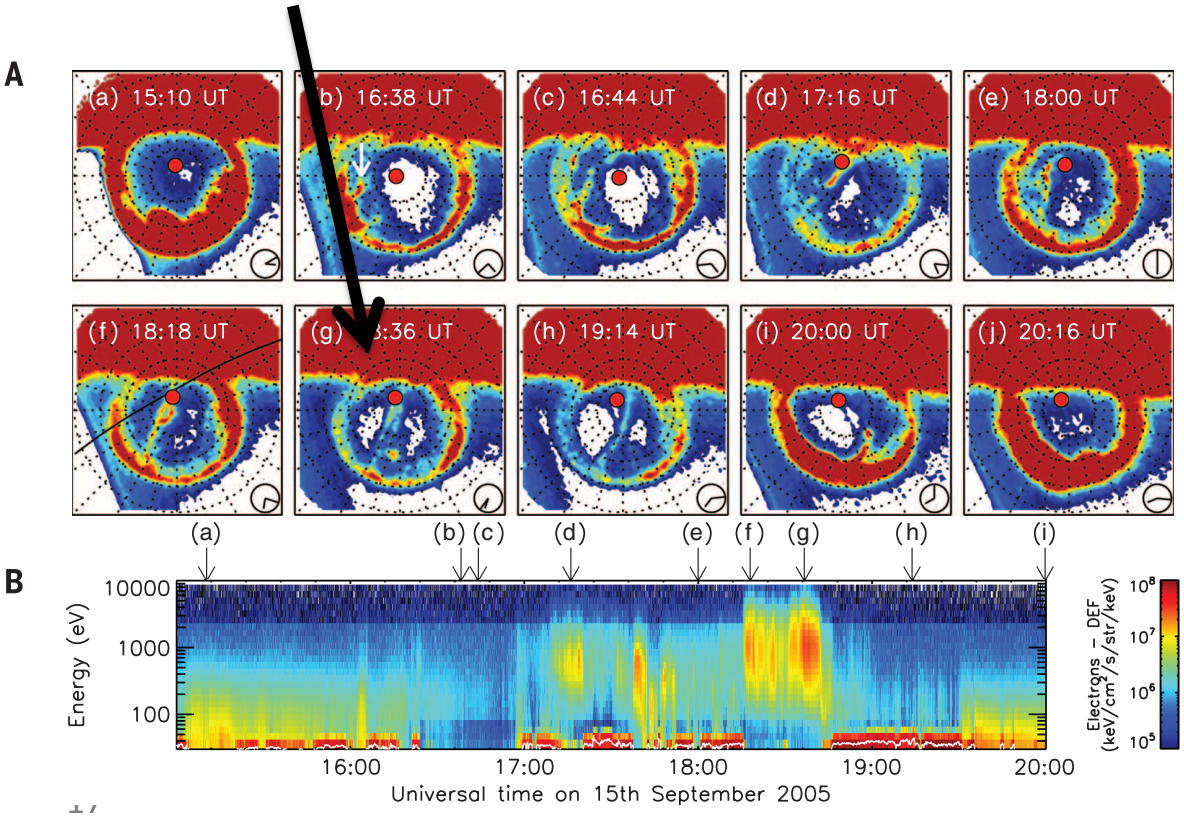
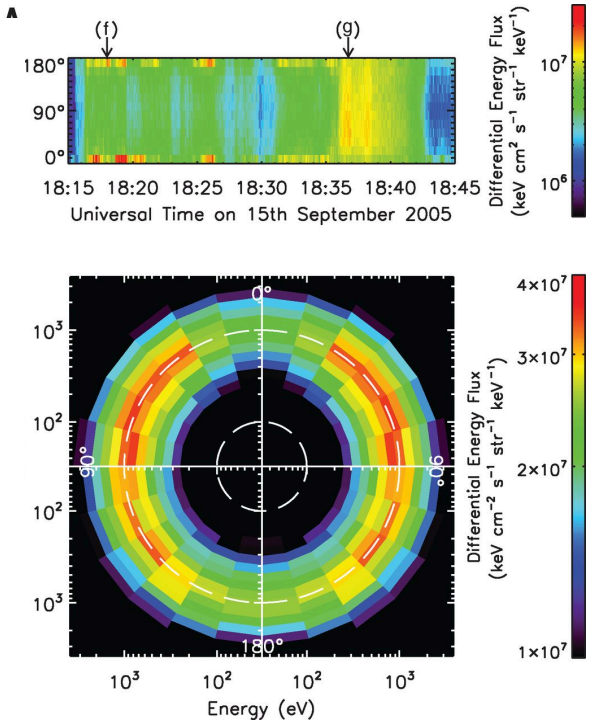
Fear et al., Science, 2014 - Trapped particles in theta aurora

Cluster passed through the polar arc

Time (g): pitch angle distribution and electron energy (phase space) – double loss-cone and trapped particles





Non-conjugate polar Arcs

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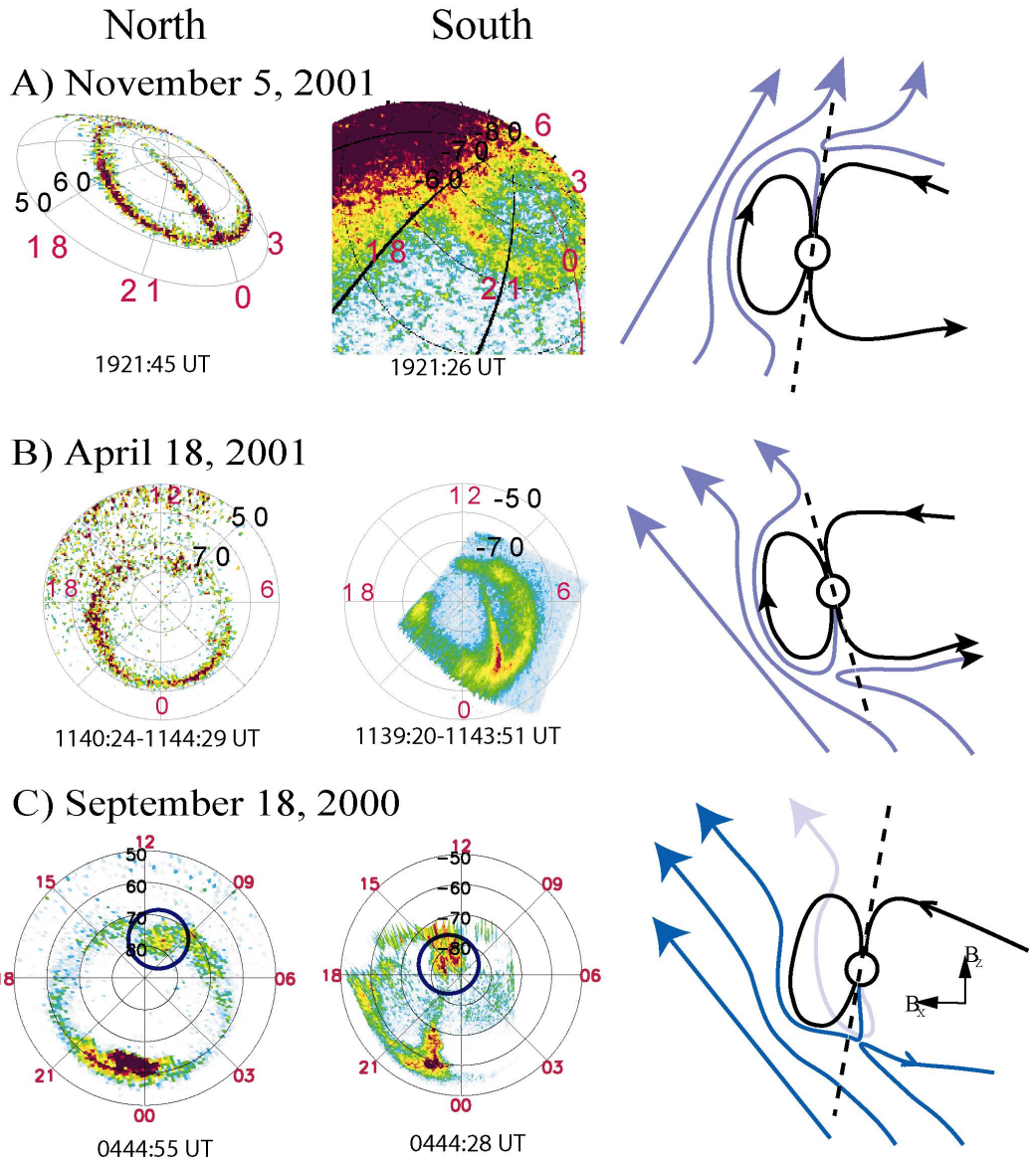
Østgaard et al., 2003, 2007

Conjugate imaging:

three examples of non-conjugate polar arcs

IMF Bx – more efficient lobe reconnection?



Non-conjugate polar Arcs

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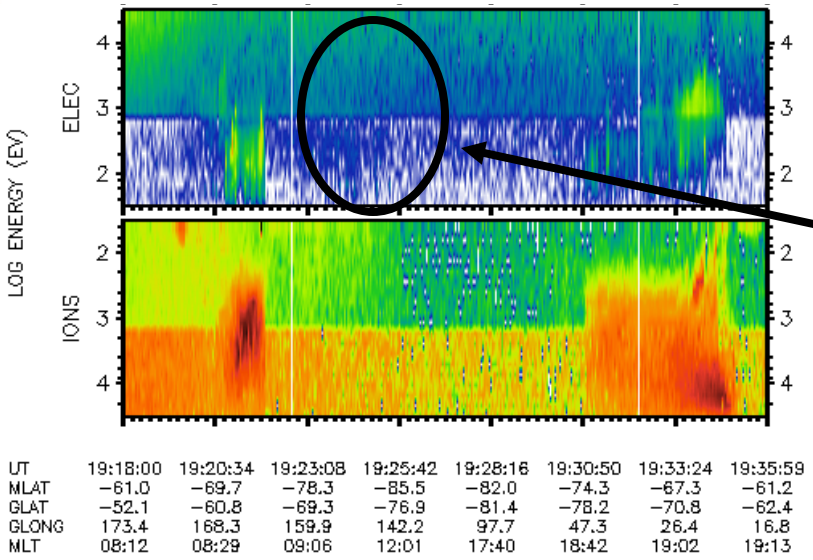
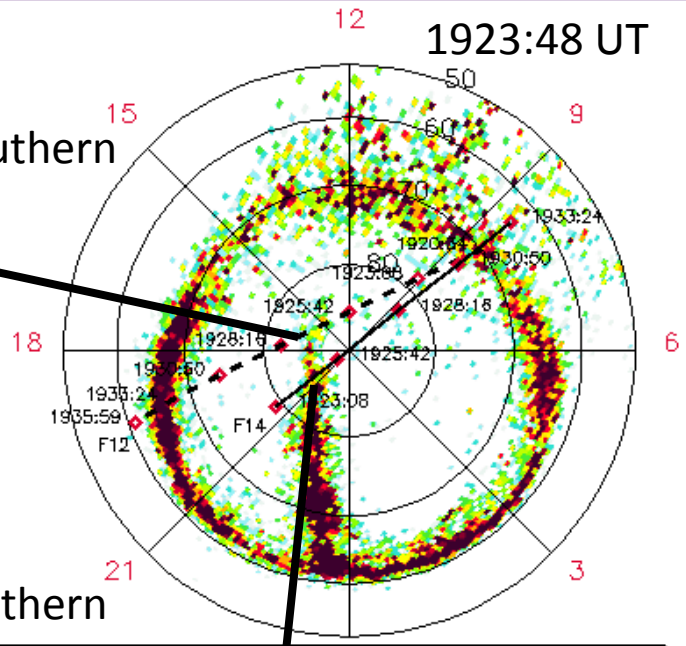
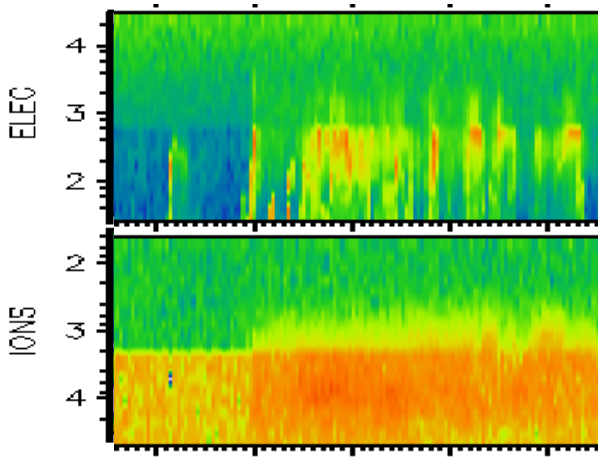


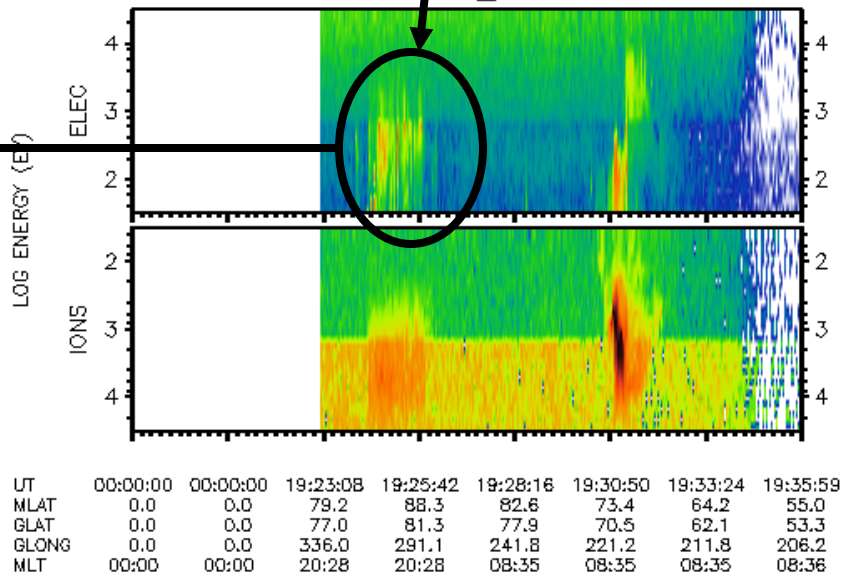
F12 - southern



F14- northern

Particles from Plasma sheet





Non-conjugate polar Arcs

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Are polar arcs on closed or open field lines

Also non-conjugate polar arcs indicate plasma sheet particles

Why then non-conjugate?

Asymmetric mapping?

- into polar arc one hemisphere
- into the auroral arc in the other

IMF Bx – region 1 current and duskside aurora

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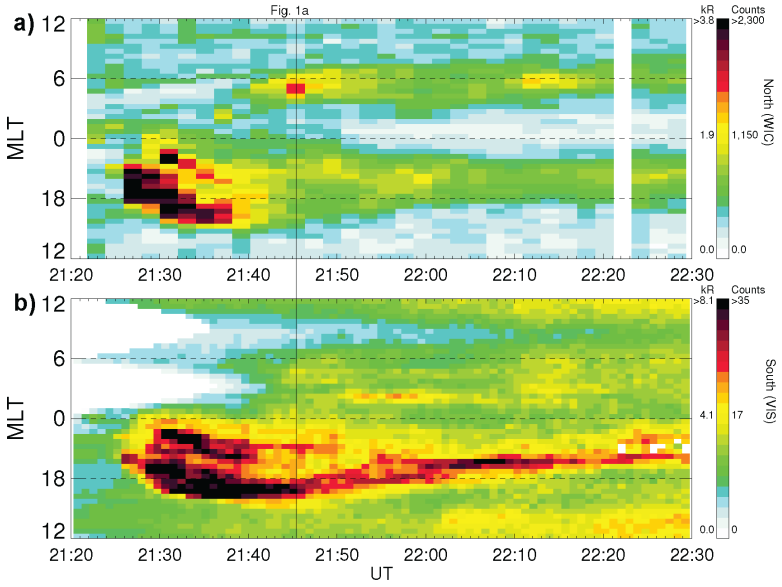
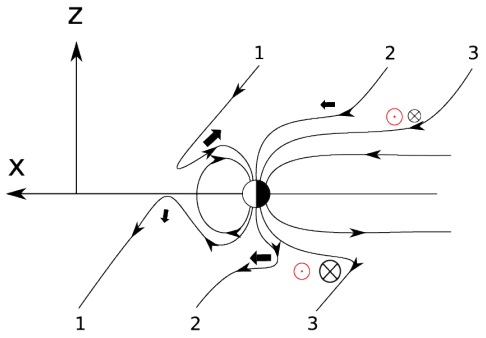
12 May, 2001 2139-2153 UT

Laundal and Østgaard, 2009



$$\text{IMF } B_x > 0 \qquad \odot = \mathbf{E} = -\mathbf{v} \times \mathbf{B}$$

$$\text{IMF } B_z < 0 \qquad \otimes = \delta \mathbf{j}_\perp = \frac{\rho \mathbf{B} \times \frac{d\mathbf{v}}{dt}}{B^2}$$



IMF B_X and dusk side aurora

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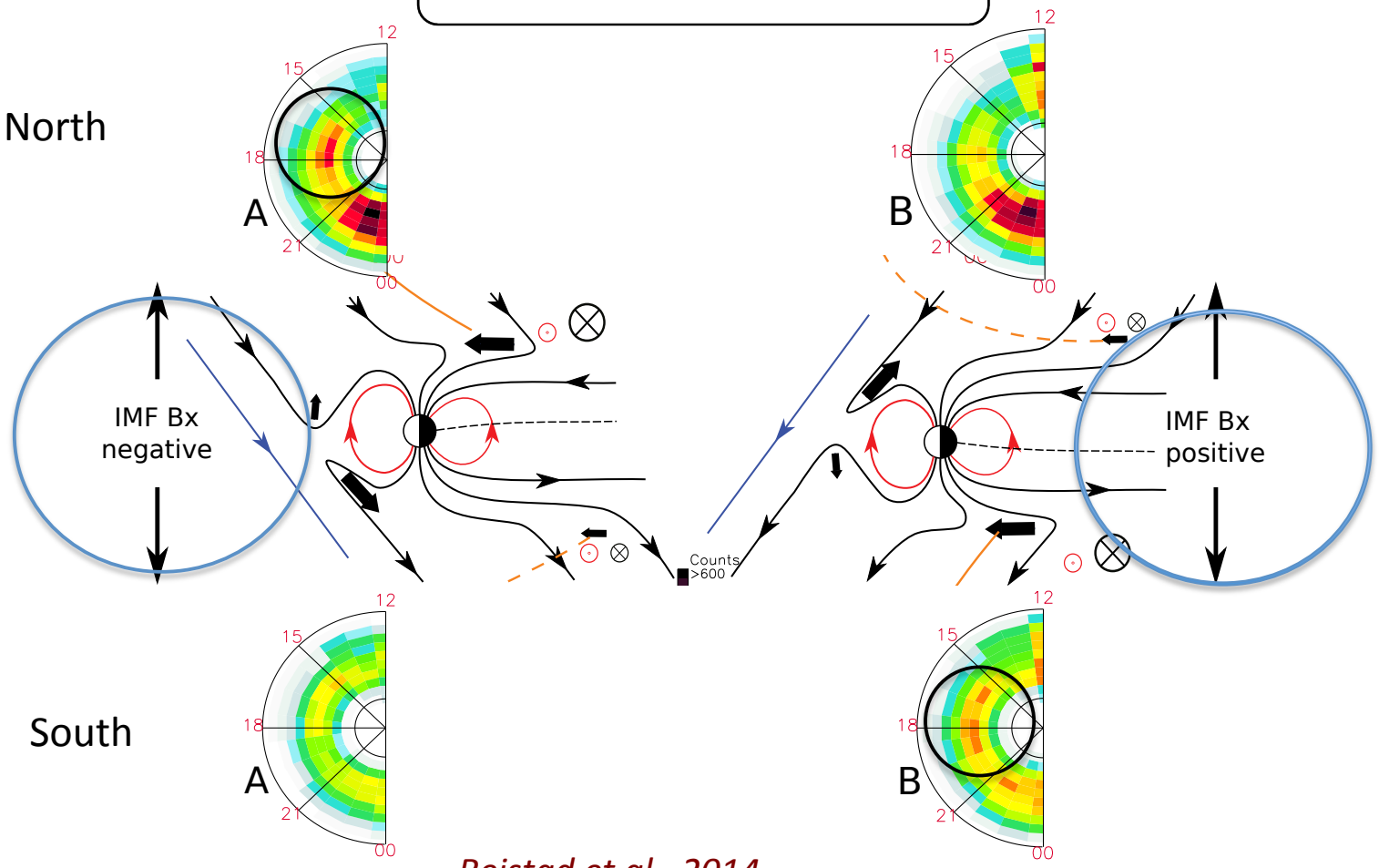
The entire IMAGE data set is used

Selection criteria

|IMF Bx|	>	2 nT
|IMF By|	<	2 nT
IMF Bz	<	0 nT
|Tilt|	∈	[10°, 30°]
	>	10 min between observations

Kolmogorov-Smirnov test: 95% confidence



Reistad et al., 2014

IMF Bx effect

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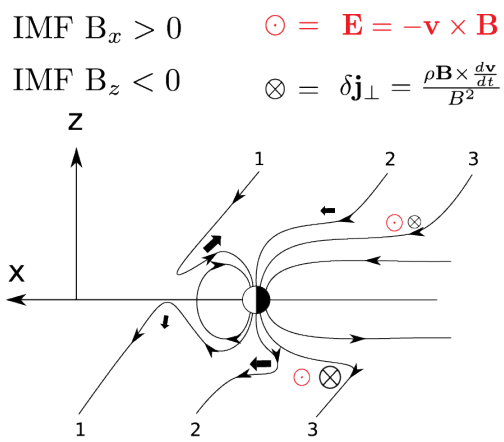
- Small but significant difference in auroral brightness due to IMF Bx
- Consistent with the explanation of difference in solar wind dynamo efficiency
- Even small: |IMF Bx| > 2 nT more than 73% of the time IMF Bz is negative



Question about – IMF Bx

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- One statistical study implies some significance
- Can this result be confirmed by other measurements ?
- AMPERE data should – we looked but have not found ?

Summary of questions

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1. What is the time scale of how IMF By induces a By component in the closed hemisphere?

2. How can polar arcs be non-conjugate and on closed field lines?

3. Does IMF Bx (and tilt) lead to significant differences in energy input into the two hemispheres