Inter-hemispheric Similarities and Asymmetries of the Afternoon Aurora: An Indicator of Solar Wind-Magnetosphere Energy Transfer

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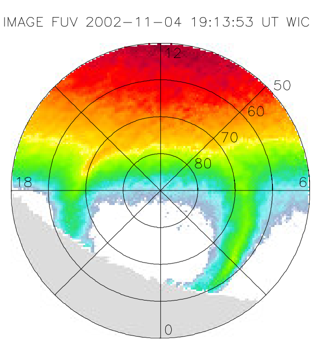
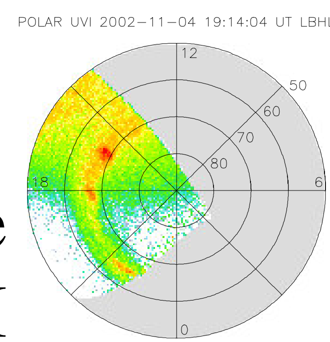


Northern Hemisphere
IMAGE WIC

Southern Hemisphere
Polar UVI



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Outline

1. **Introduction:**
   Background/
   Previous Work/
   Motivation

2. **Recent Results and Interpretation**

3. **Current Progress**

Introduction (part 1)

- The dayside magnetosphere responds directly to incident interplanetary magnetic field (IMF) and solar wind energy

- Changes in the IMF and solar wind drive changes in magnetospheric and ionospheric convection

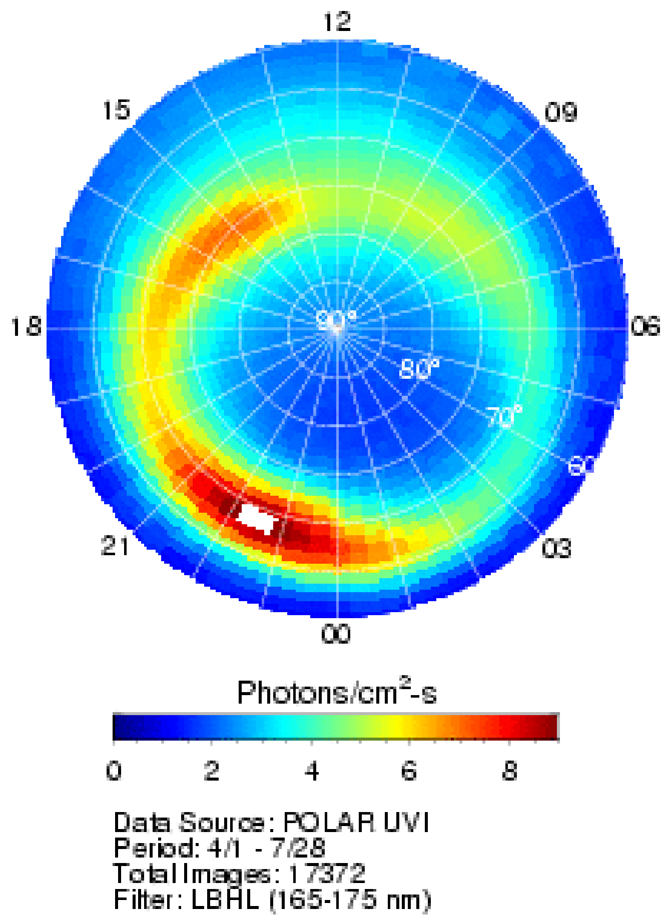
- Currents and (in the case of upward currents) aurora respond to these changes

⇒ Dayside aurora is a direct indicator of how the magnetosphere-ionosphere system responds to IMF and solar wind energy input

Introduction (part 2)

- Focus on afternoon sector – 15 MLT bright spot
- Region of persistent auroral emission centered near 15 MLT and 75 degrees latitude [*Cogger et al.*, 1977; *Liou et al.*, 1997]
- Caused by low energy (< ~ 1 keV) electron precipitation [*McDiarmid et al.*; 1975, *Evans*, 1985; *Newell et al.*, 1996]
- Co-located with maximum in Region 1 current [*Iijima and Potemra*, 1987] and Poynting flux [*Keiling et al.*, 2003]
- Appearance and behavior influenced by solar wind and IMF [*Murphree et al.*, 1981; *Vo and Murphree*, 1995]
- Can be structured and dynamic (string of pearls configuration) [*Lui et al.*, 1987; *Potemra et al.*, 1990, *Rostoker et al.*, 1992]
- Varies with season: more likely in summer [*Liou et al.*, 2001] ⇒ **hemispheric differences**

The afternoon auroral bright spot is persistent in image data



(from *Liou et al.* [1997])

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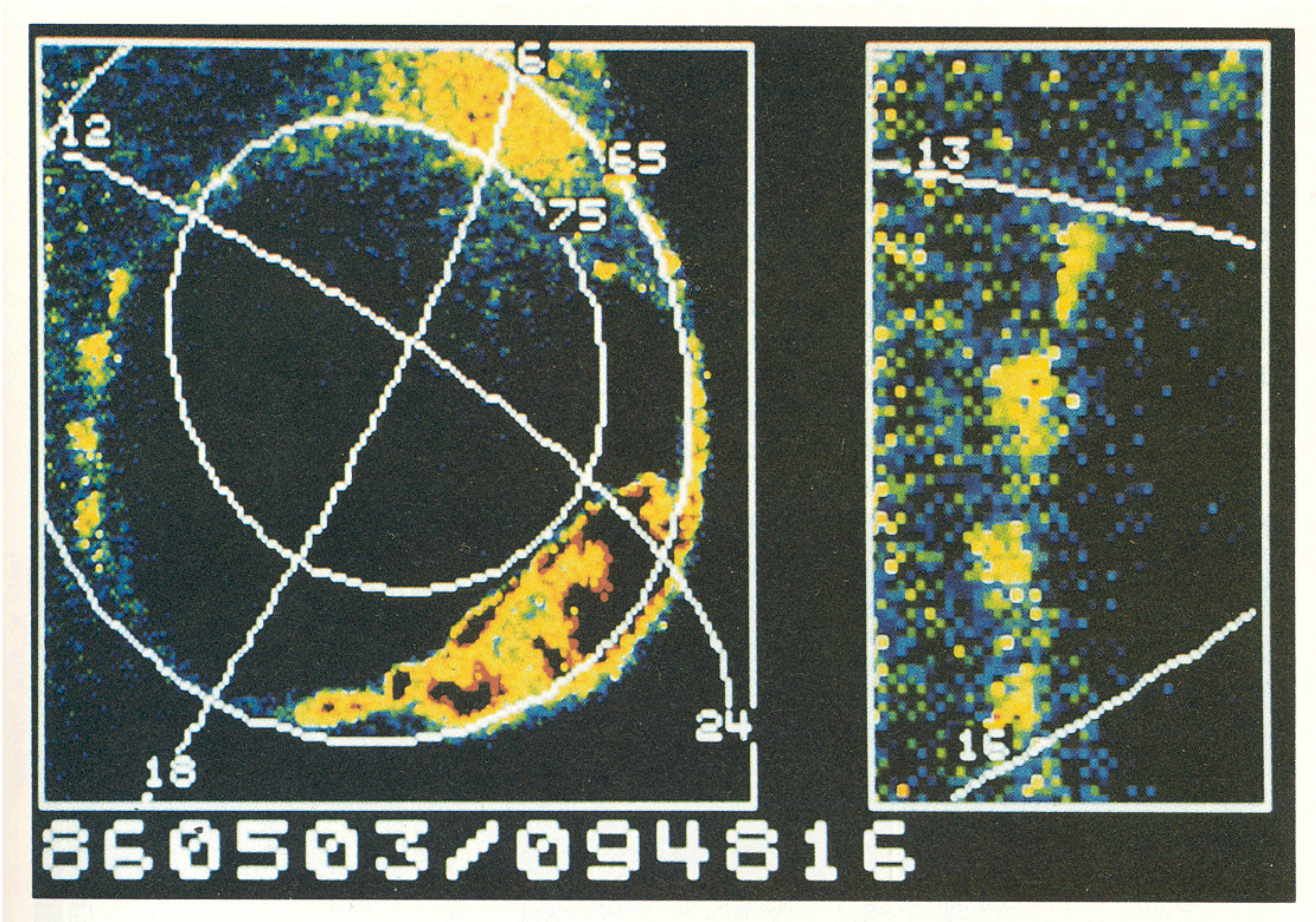
The afternoon auroral bright spot can be structured and dynamic



"String of pearls" configuration
(from *Lui et al.* [1989])

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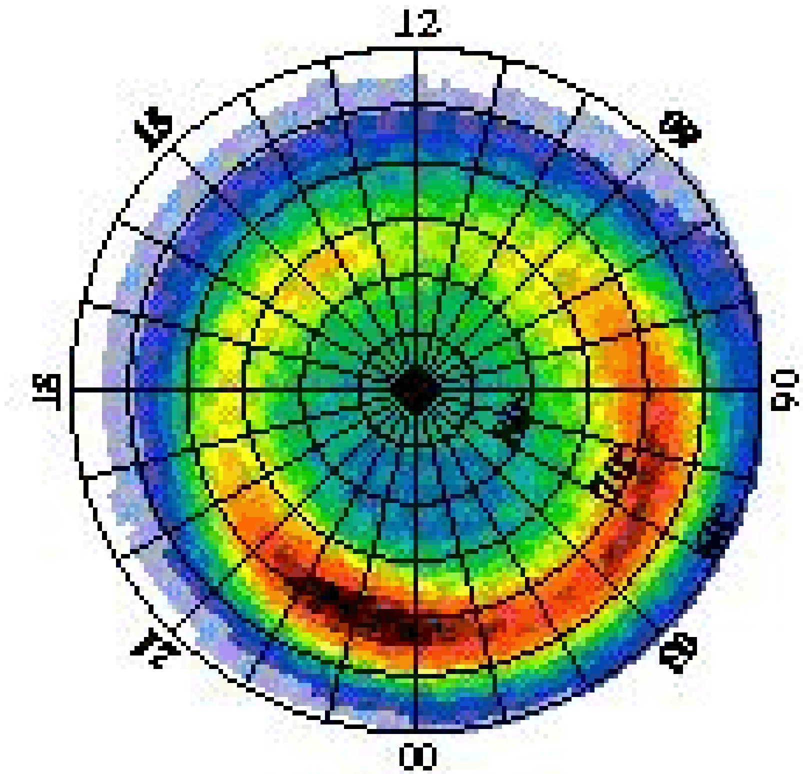
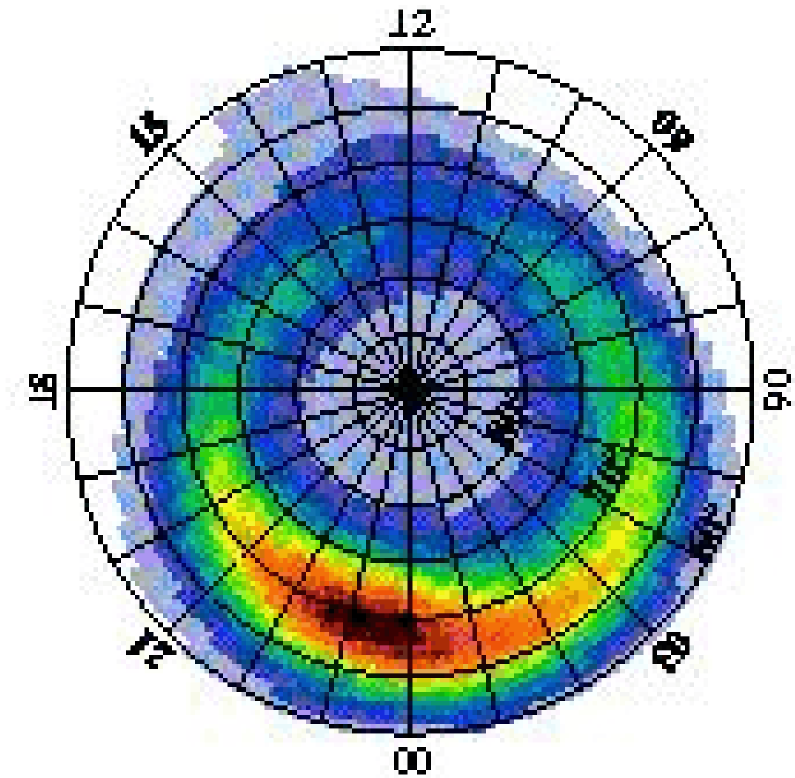
  ⇒ **hemispheric differences**

The afternoon auroral bright spot varies with season

Summer



Winter



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- Previous conjugate observations limited to small scales (in situ point measurements or ground based instruments) in at least one hemisphere [*Dickinson et al.*, 1986; *Mende et al.*, 1990; *Burns et al.*, 1990, 1992; *Vo et al.*, 1995]

- *Fillingim et al.* [2005] presented the first simultaneous images of dayside aurora from two global auroral imagers in opposite hemispheres (IMAGE WIC in northern hemisphere and Polar UVI in south)
- Addressed the issue of conjugacy of the dayside aurora on a synoptic scale for the first time
- Related differences in aurora to solar wind and IMF conditions

- Continuation of the work of *Fillingim et al.* [2005]

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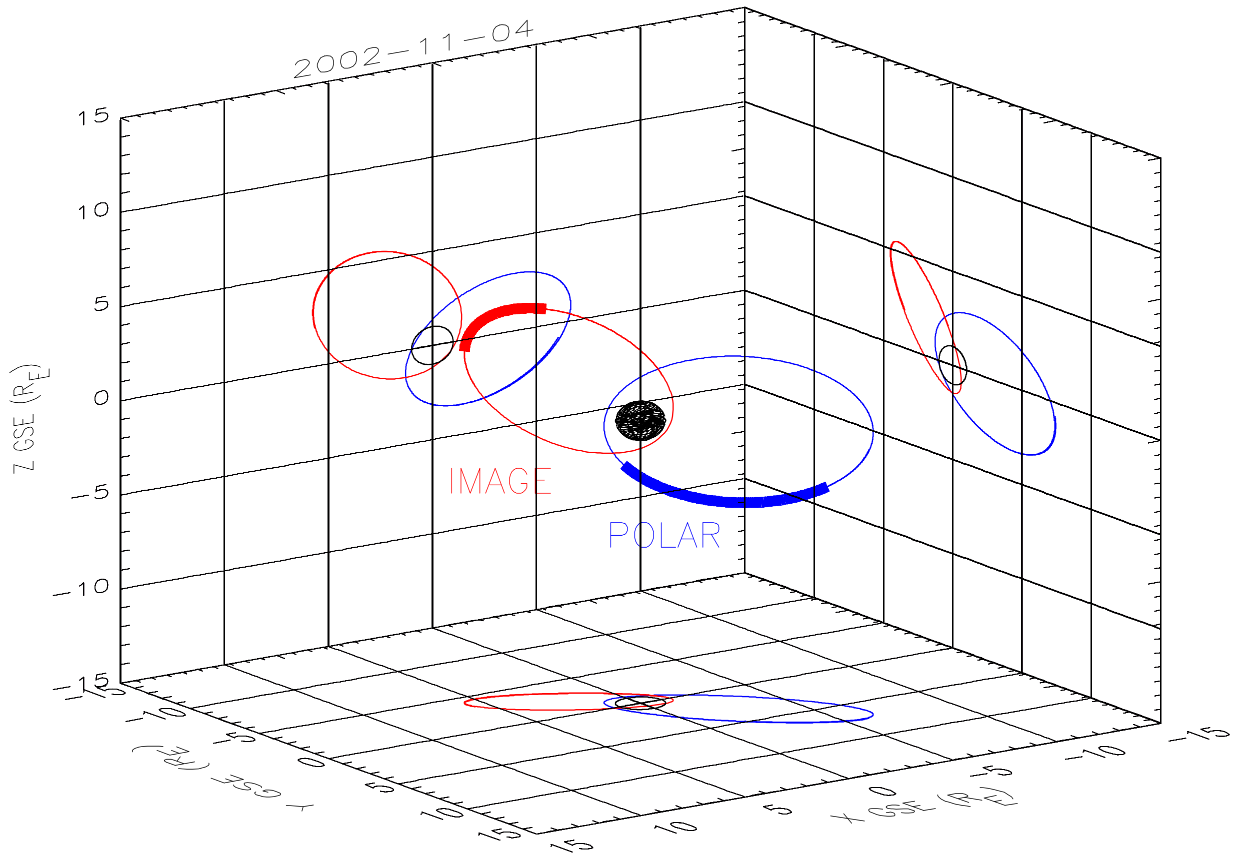
Spacecraft Orbits

From October 2002 to March 2003 IMAGE WIC and Polar UVI were in ideal positions and orientations for dayside conjugate observations



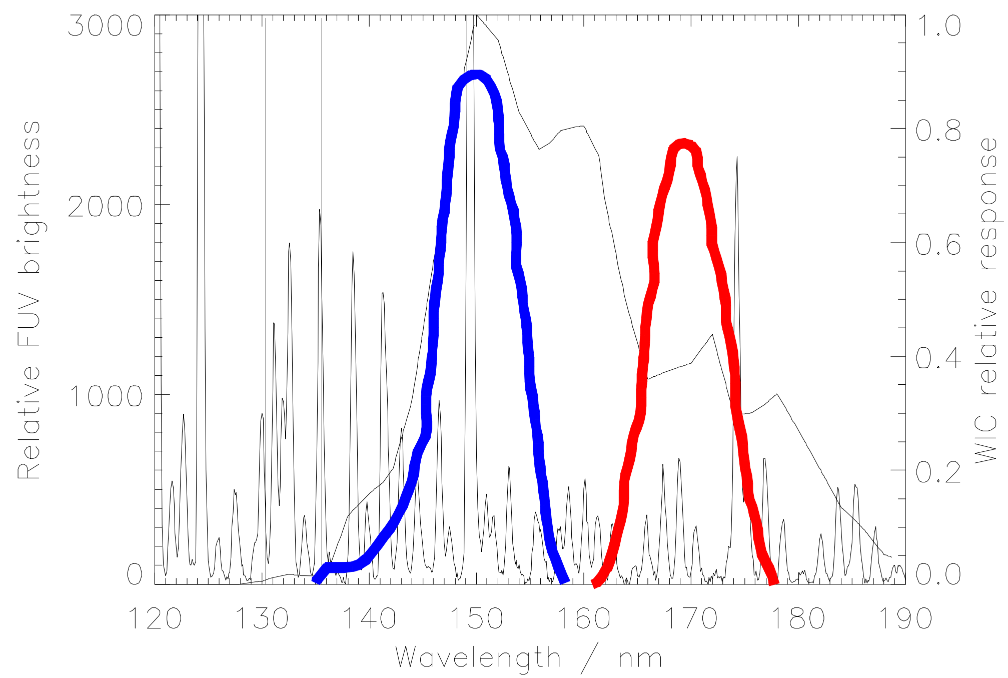
Instrumentation

IMAGE Wideband Imaging Camera (WIC) &
Polar Ultraviolet Imager (UVI) LBHS & LBHL

Temporal resolution
WIC: 10 second integration every 2 minutes
UVI: 18 & 36 second integration, cyclic

Spatial resolution
WIC: ~ 50 km
UVI: ~ 30 km

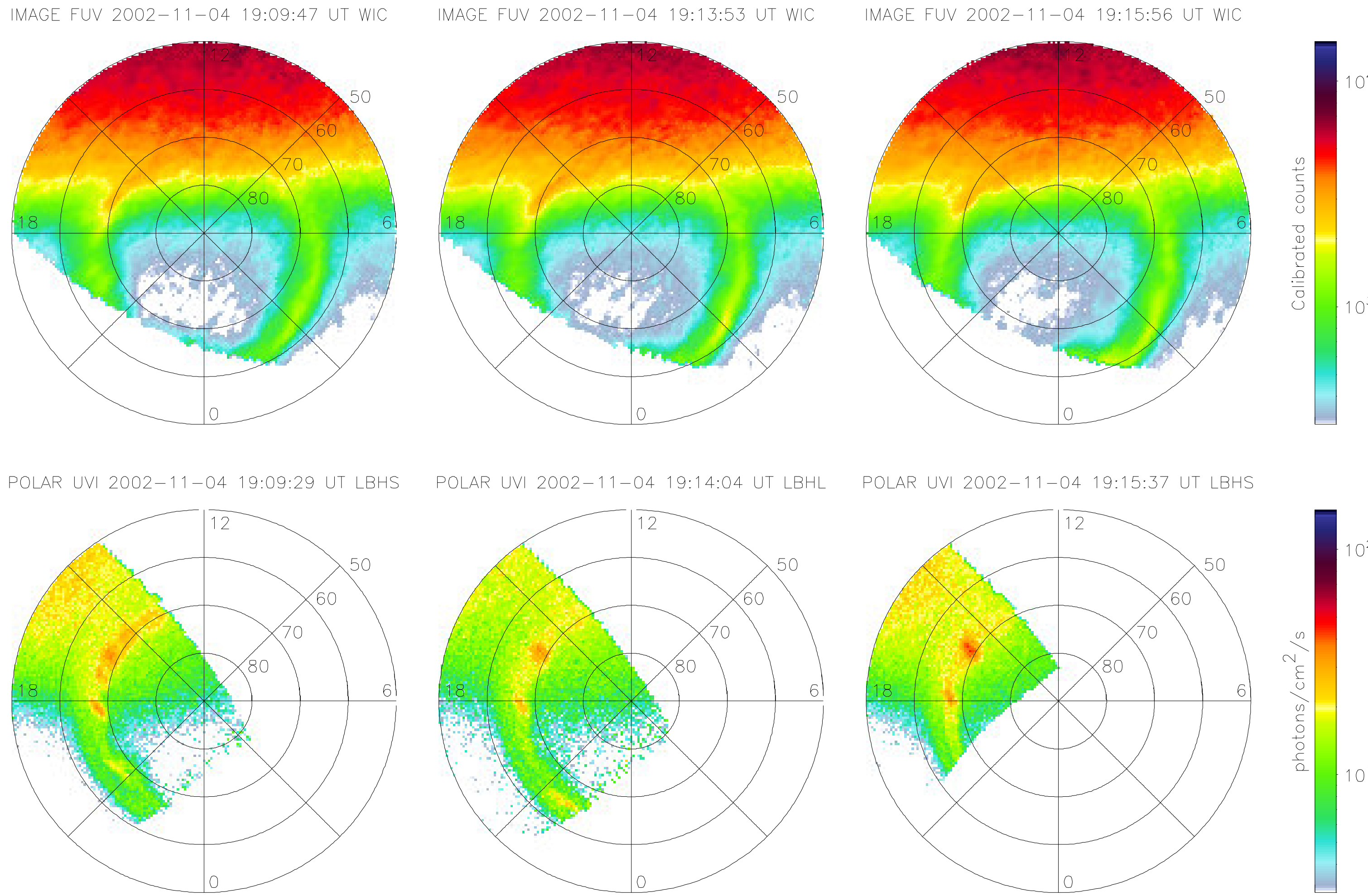
Spectral resolution
WIC: 140 to 190 nm –
LBHS: 140 to 160 nm –
LBHL: 160 to 180 nm –



4 November 2002

Northern Hemisphere

Southern Hemisphere



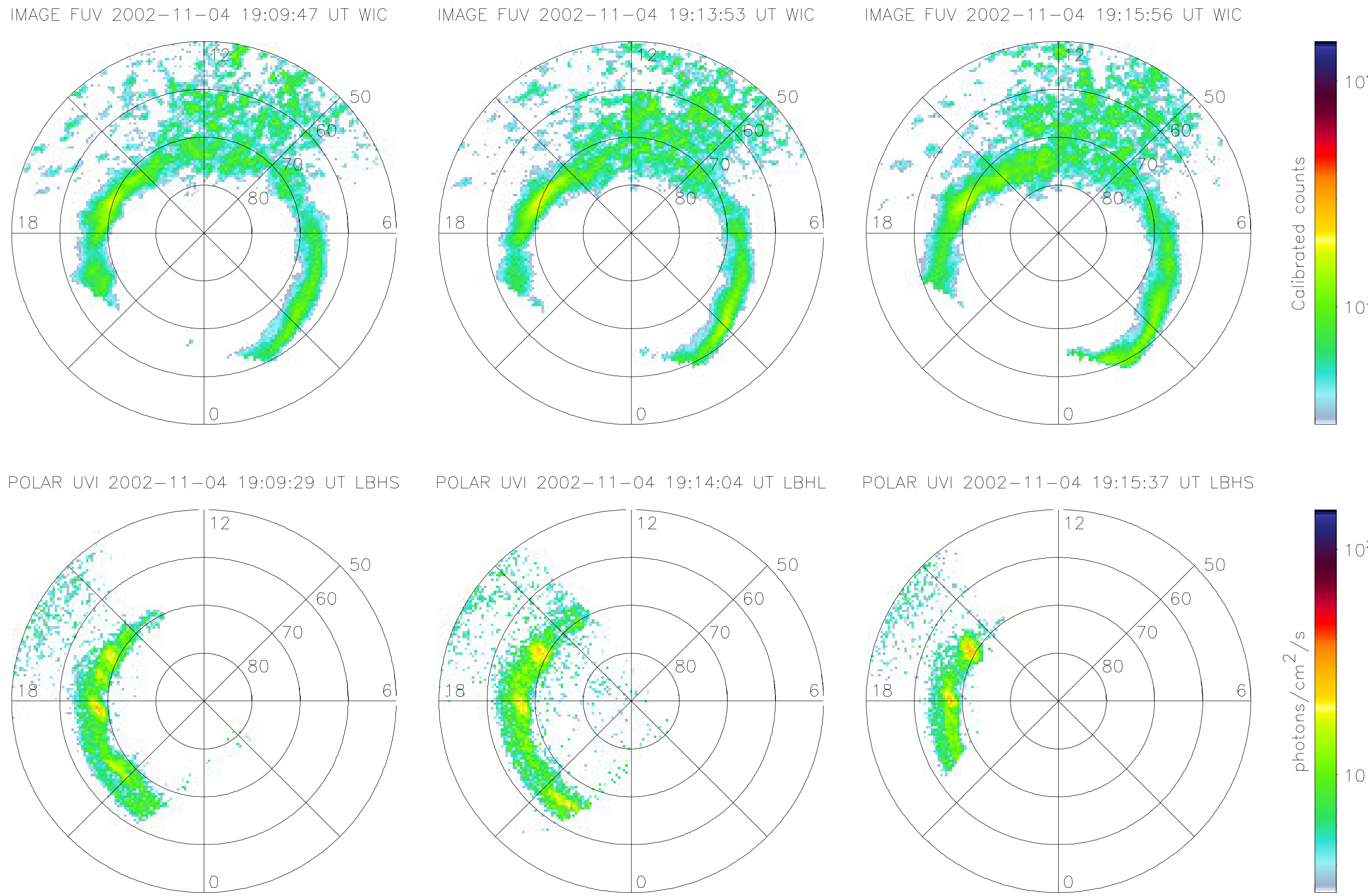
NH: enhanced, unstructured emission in afternoon

SH: multiple spots; number, location, and intensity change

4 November 2002

Northern Hemisphere

Southern Hemisphere



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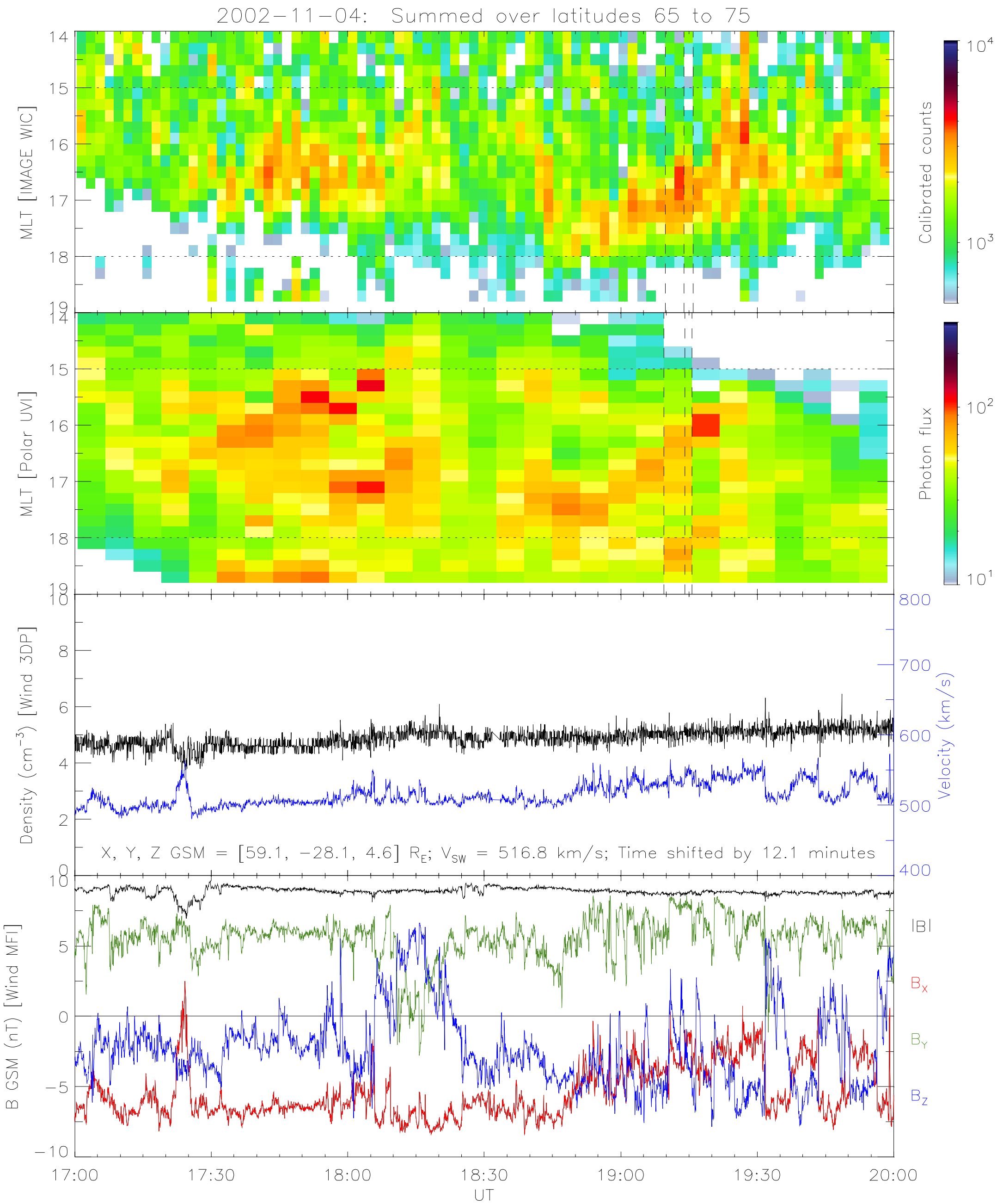


NH: enhanced emission; variable intensity and location; single region

SH: multiple regions of emission; vary in intensity and location; different regions behave differently

Steady solar wind density and velocity

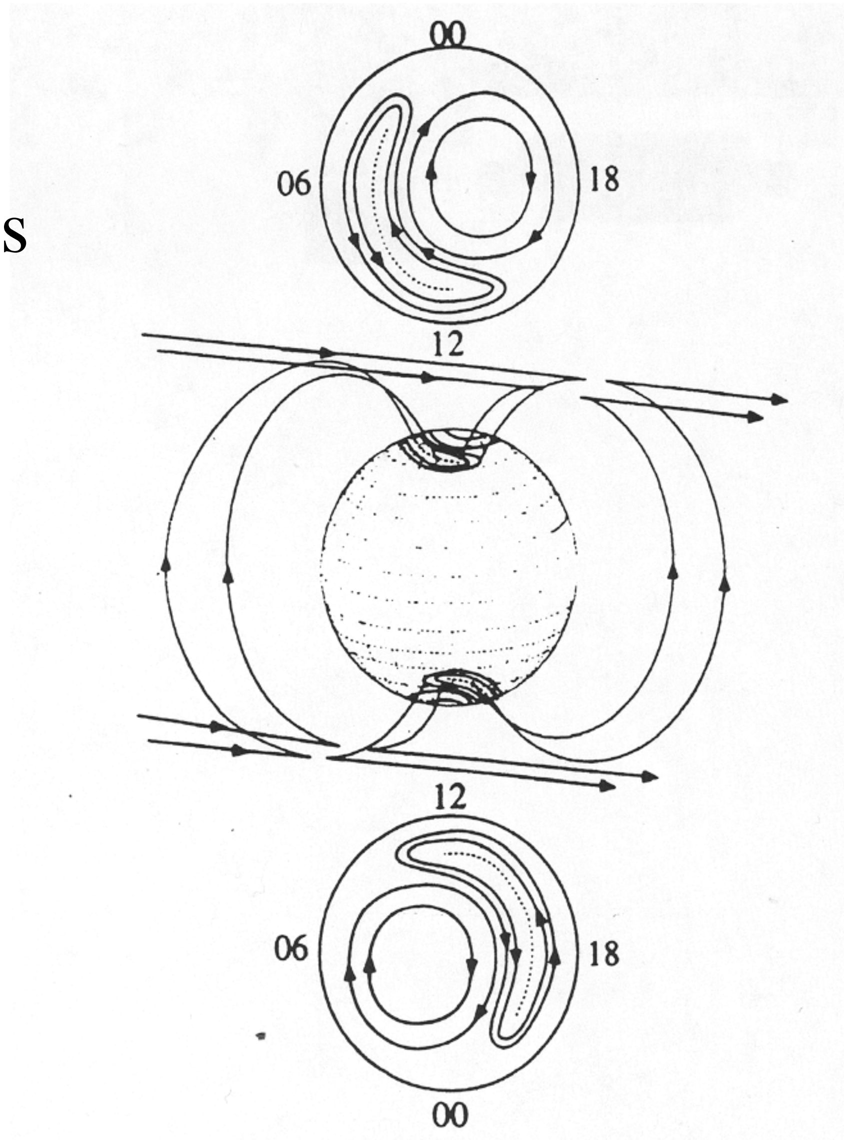
IMF: $B_X < 0$
$B_Y > 0$
$B_Z < 0$ (with some positive exursions)

Interpretation

For $B_Z < 0$ and strong B_Y
⇒ mirror image convection patterns

For $B_Y > 0$ (shown),
- In northern hemisphere crescent shaped cell at dawn, circularly shaped cell at dusk

- In southern hemisphere circularly shaped cell at dawn, crescent shaped cell at dusk



(from *Clauer et al.* [1997])

Interpretation (cont'd)

- Crescent shaped cell ⇒ large velocity shear ⇒ strongly con/diverging $E_{\perp}$, $J_{\perp}$ ⇒ intense $J_{//}$
- $J_{//}$ is upward on duskside ⇒ enhanced auroral precipitation in southern hemisphere ⇒ **hemispheric asymmetry** (consistent with *Robinson et al.* [1986] – B_Y control of $J_{//}$ & *Kozlovsky et al.* [2003] – inter-hemispheric current)

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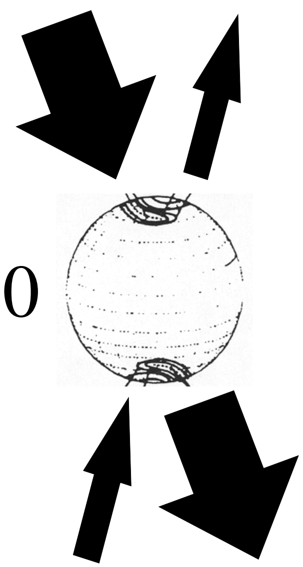
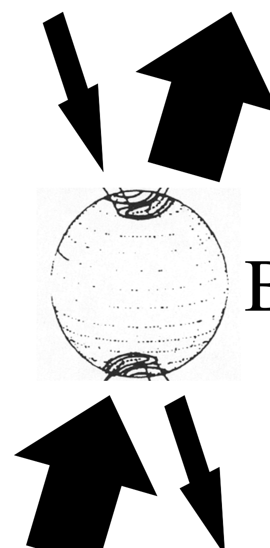
$B_Y > 0$



Prediction:
For $B_Y > 0$, afternoon aurora enhanced in south;
for $B_Y < 0$, afternoon aurora enchanced in north.



$B_Y < 0$

Why Multiple Spots?

- "String of pearls" configuration is consistent with KHI [*Lui et al.*, 1989; *Rostoker et al.*, 1992; *Wei and Lee*, 1993]
- KHI occurs at velocity shear; assumed to occur at equator

Problems:

- Observed v_{phase} ~ 0.5 km/s sunward (also anti-sunward)

$$v_{phase} = (\rho_1 v_1 + \rho_2 v_2)/(\rho_1 + \rho_2)$$

  for 1: BL & 2: PS, $\rho_1 \approx \rho_2$, $|v_1| > |v_2|$; v_{phase} anti-sunward
- Multiple spots only in one hemisphere, not both as expected

KHI occurs near the ionosphere (low altitude – crescent cell)
Depends on $|B_Y/B_Z|$ [cf. *Ridley and Clauer*, 1996]
Imbalance in $J_{//}$ decouples hemispheres [*Kozlovsky et al.*, 2003]

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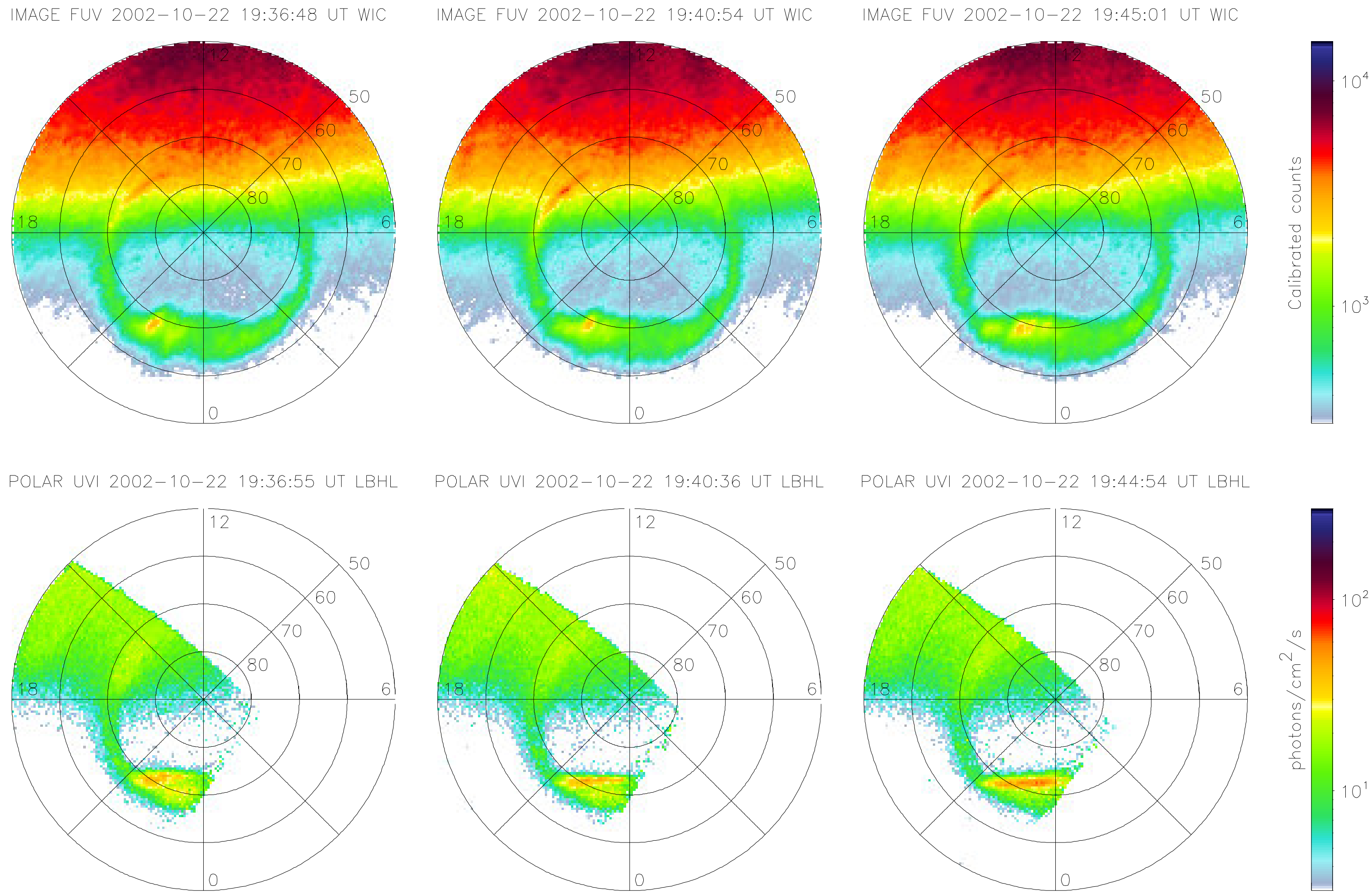
22 October 2002

Northern Hemisphere

Southern Hemisphere



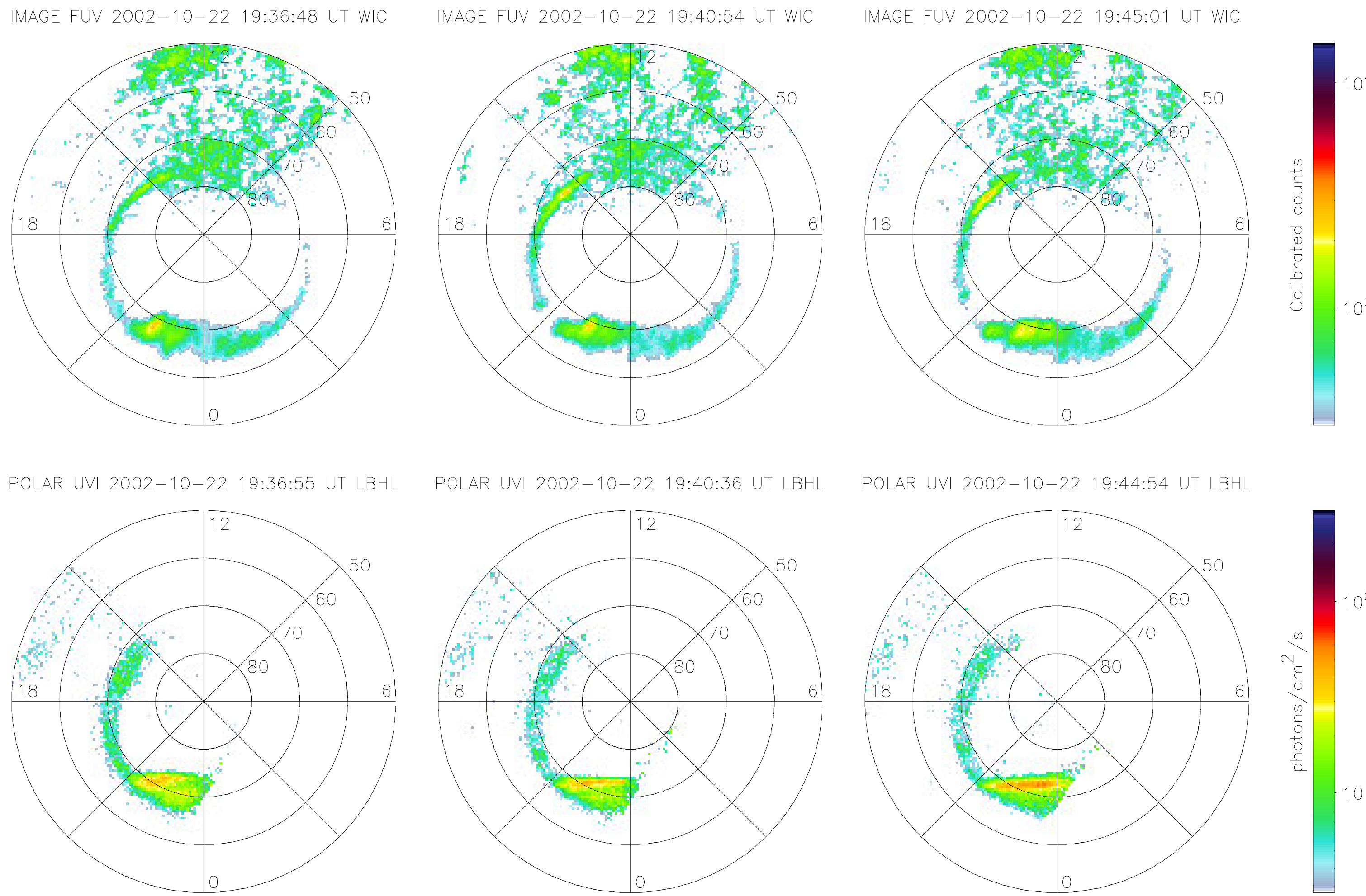
NH: latitudinally narrow emission; brightens near 19:40 UT

SH: broader, more diffuse emission; no noticeable change

22 October 2002

Northern Hemisphere

Southern Hemisphere



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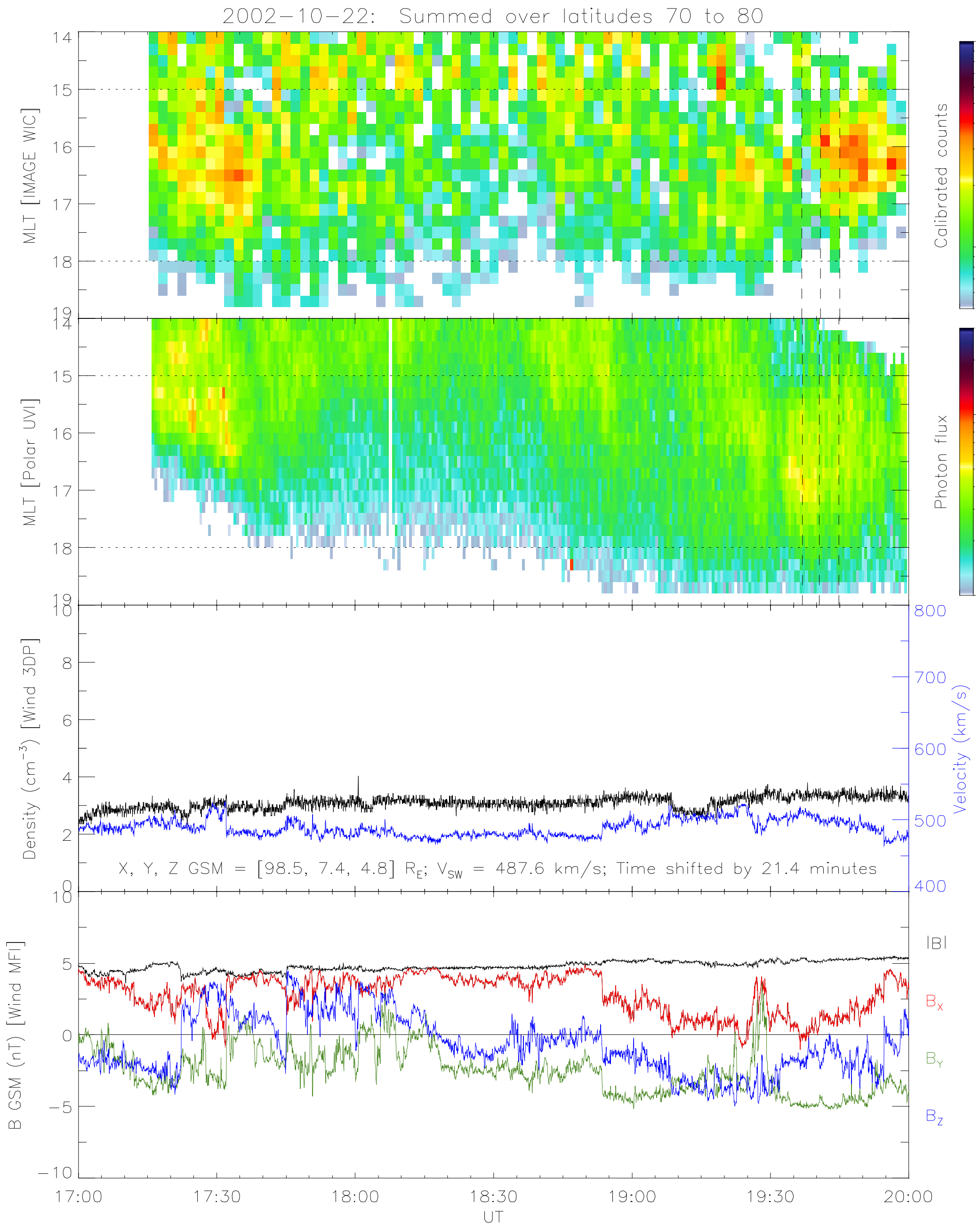


NH: very quiet from 17:45 to 19:15 UT; brightening near 19:40 UT; narrow MLT range (peaked)

SH: aurora brightens near 19:30 UT; diffuse in latitude and MLT

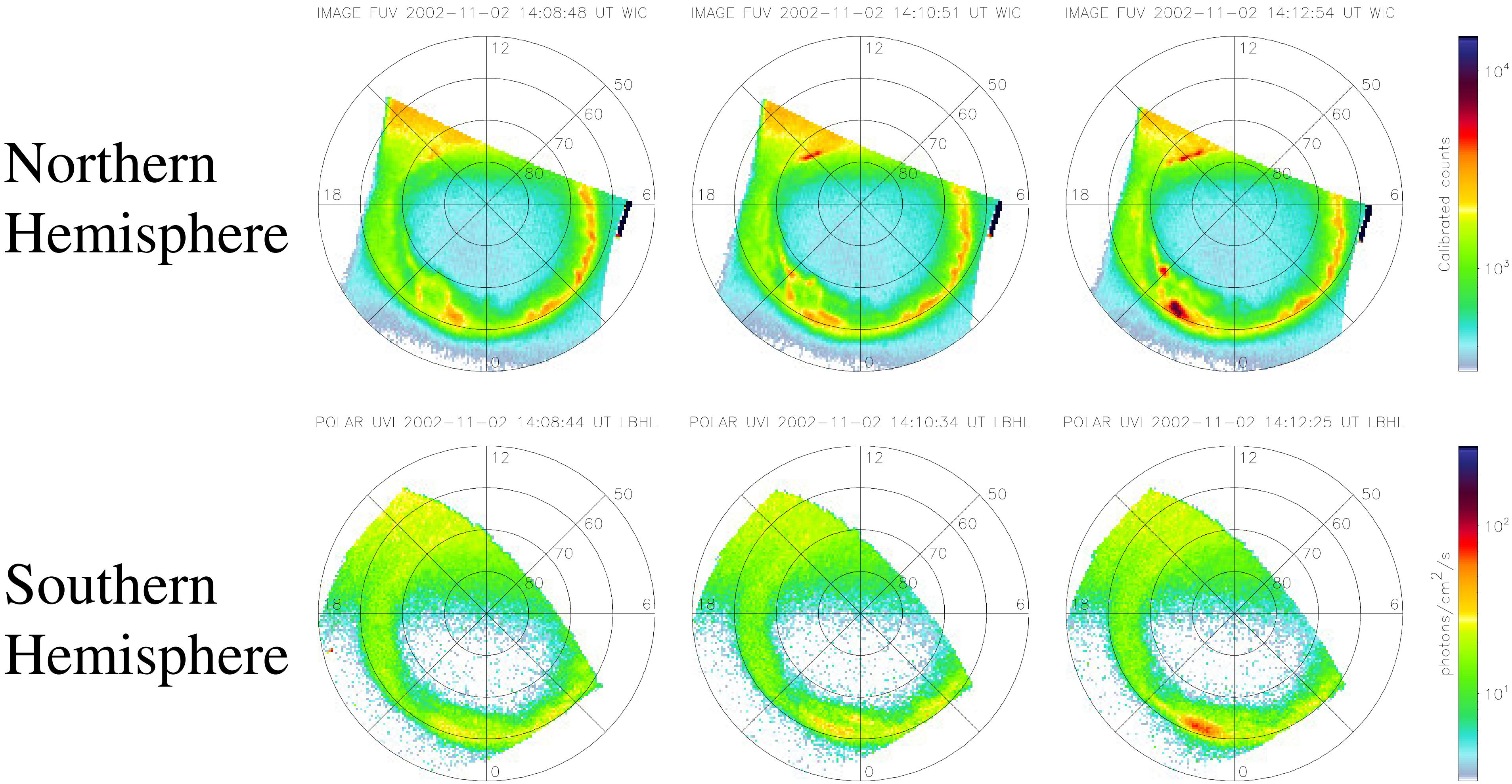
Steady solar wind density and velocity

IMF $B_X > 0$

$B_Y < 0$

$B_Z < 0, > 0, < 0$

2 November 2002

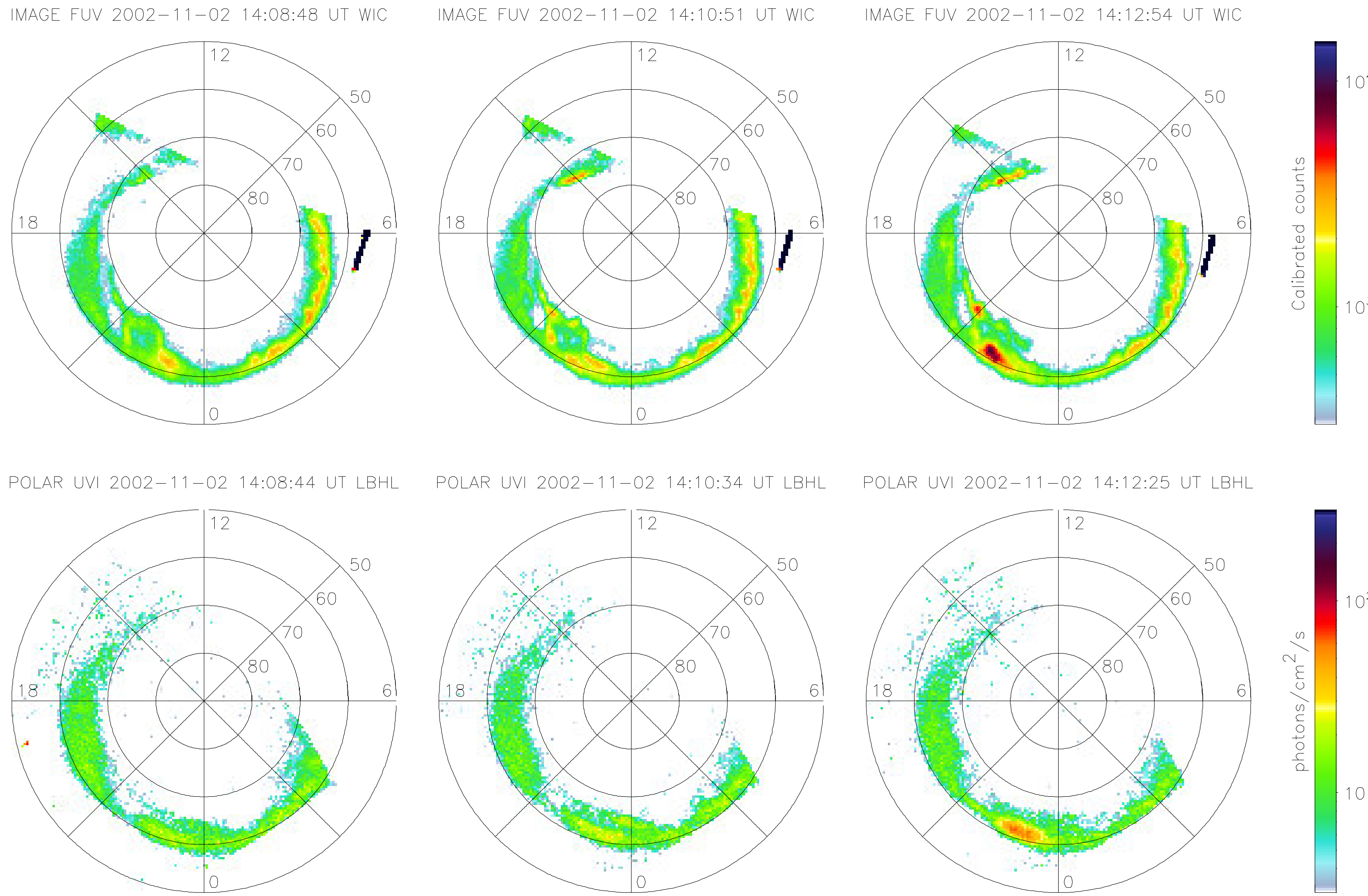


NH: sudden brightening at 14:10 UT; SH: no change

2 November 2002

Northern Hemisphere

Southern Hemisphere



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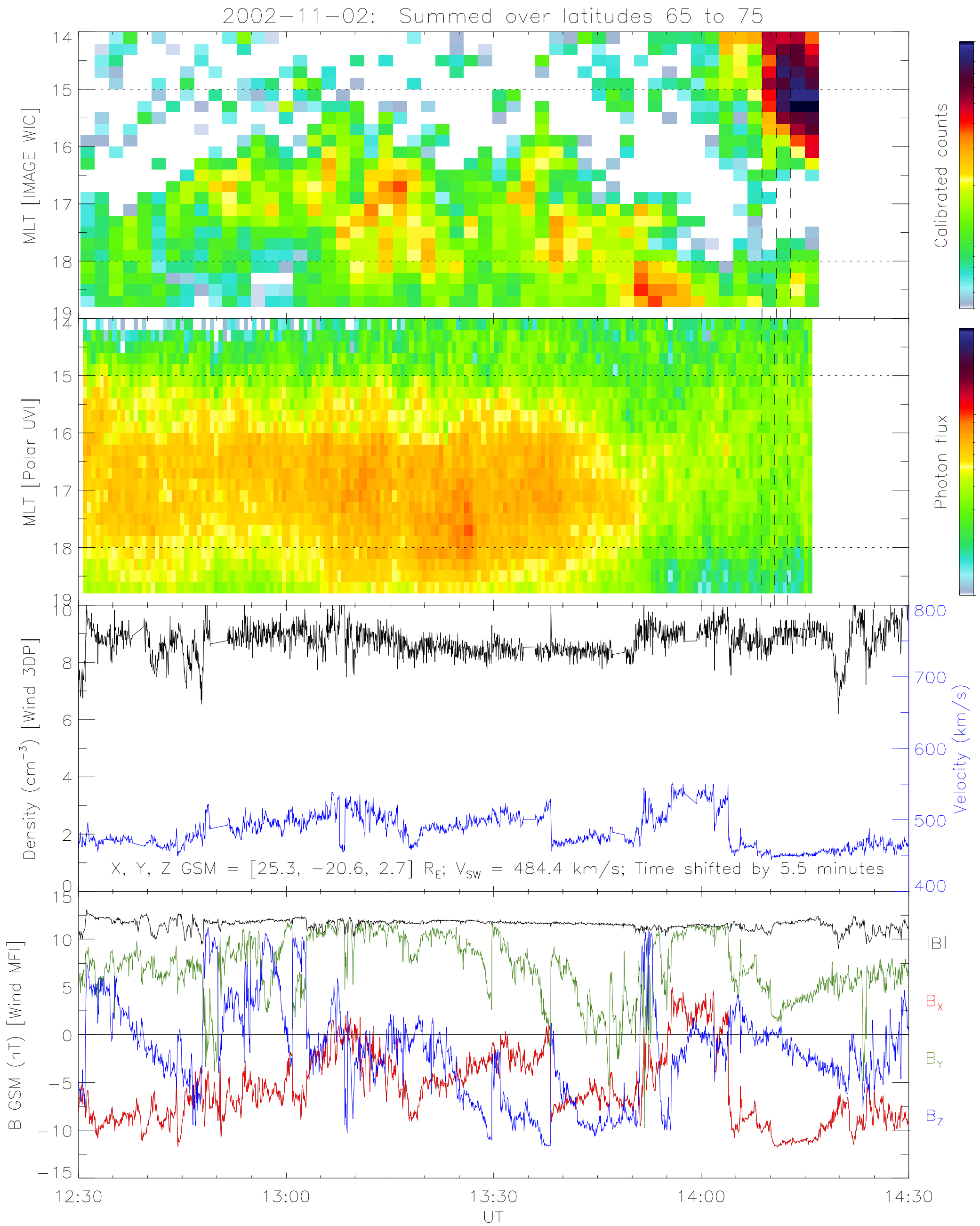


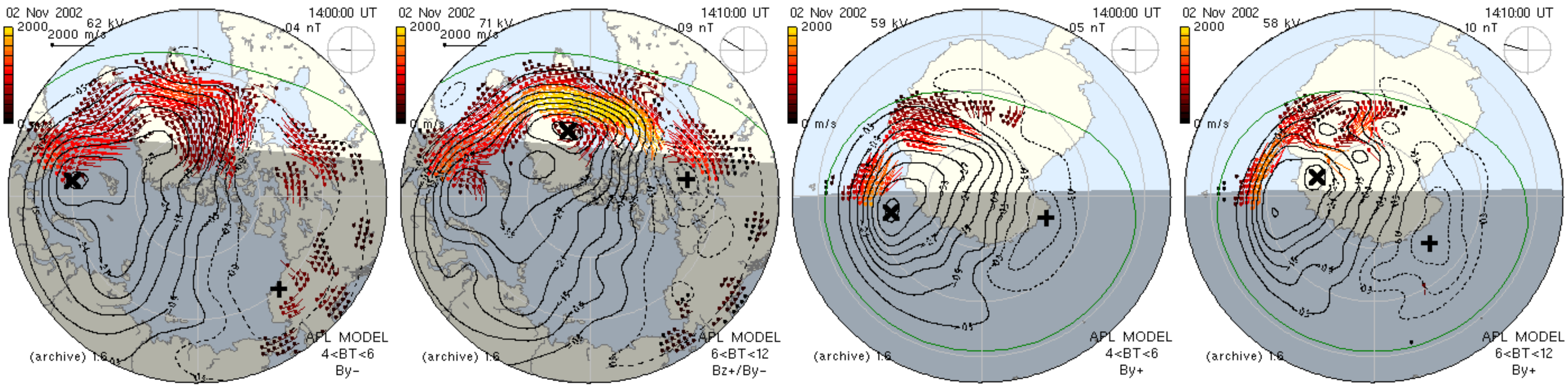
NH: intermittent spots before 14 UT; sudden brightening at 14:10 UT

SH: wide, diffuse emission; fades before 14 UT; no change at 14:10 UT

SW density high; > 30% drop in P_{dyn} at 14:05 UT

Large IMF |**B**|; rapid rotation from Y dominated to – X dominated (radial) IMF at 14:05 UT

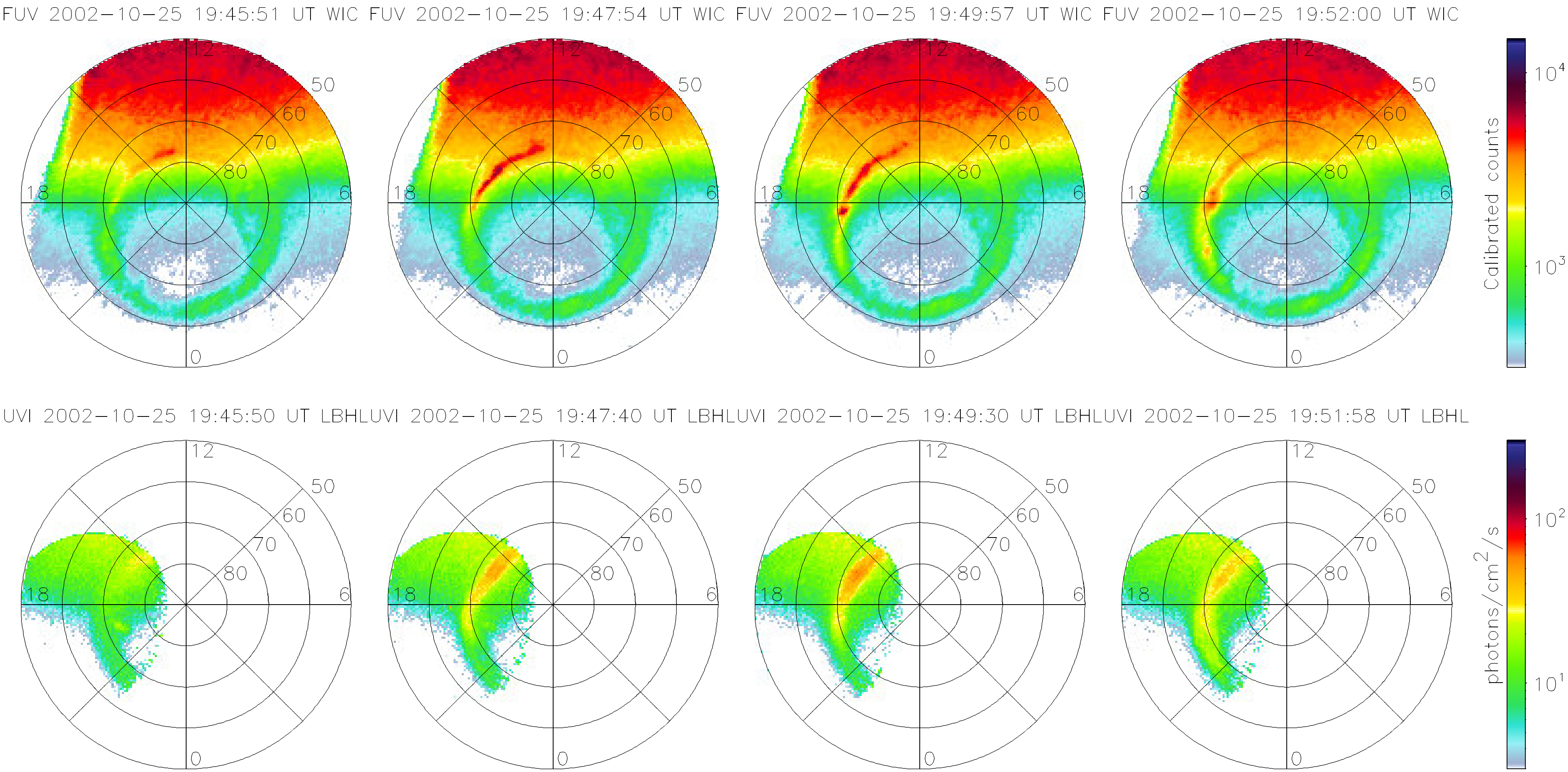
<u>SuperDARN Data</u>



NH: Large increase in dayside velocities in eastward direction
Large increase in velocity shear ⇒ could increase FAC
Response to solar wind/IMF change?

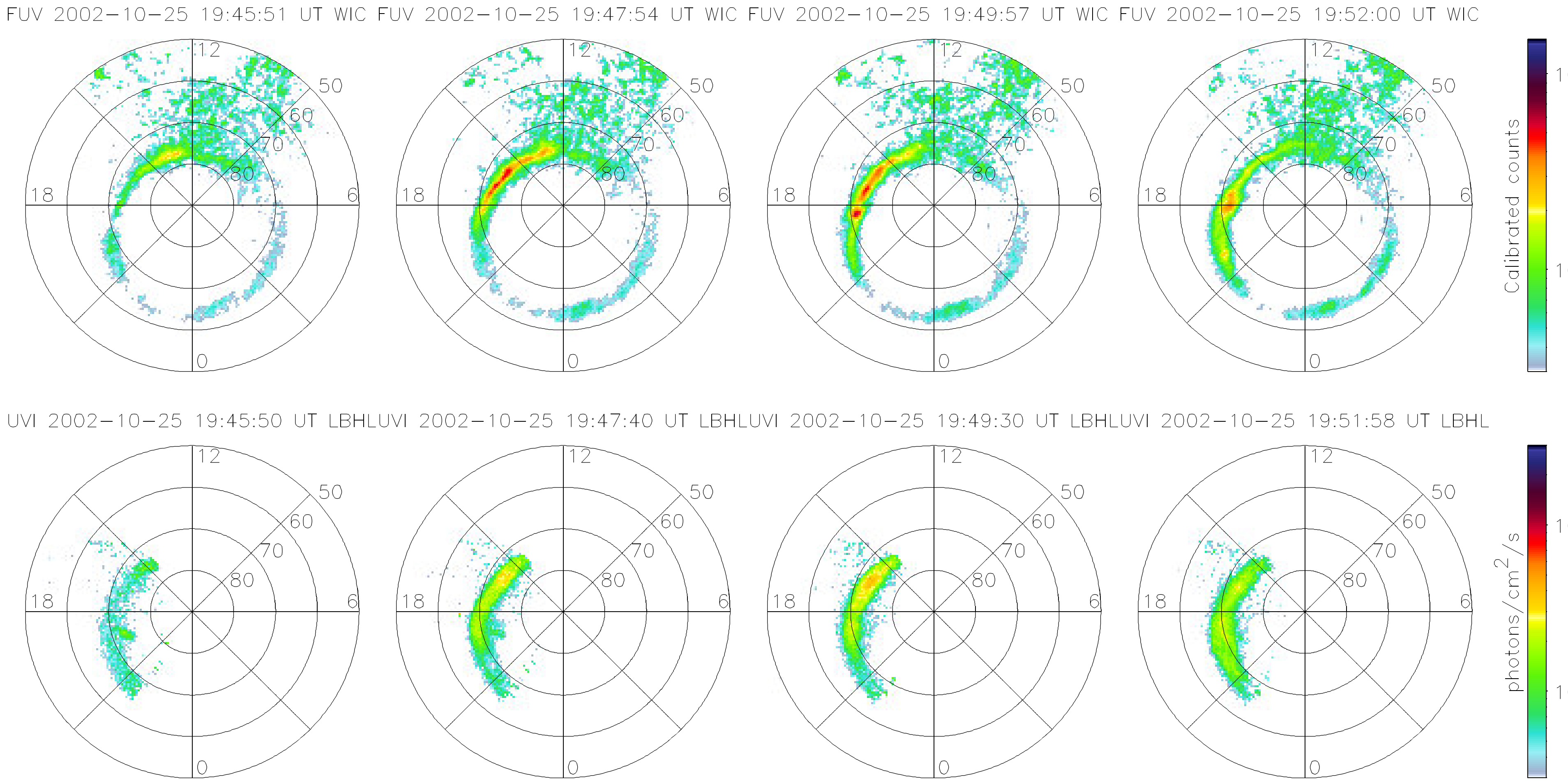
SH: Good data coverage; no increase in dayside velocities
Complex change in convection pattern; stagnation point?
No auroral signature

25 October 2002



Simultaneous widespread brightening (< 15 MLT to 18 MLT) in both hemispheres at 19:47 UT (relatively conjugate)

25 October 2002



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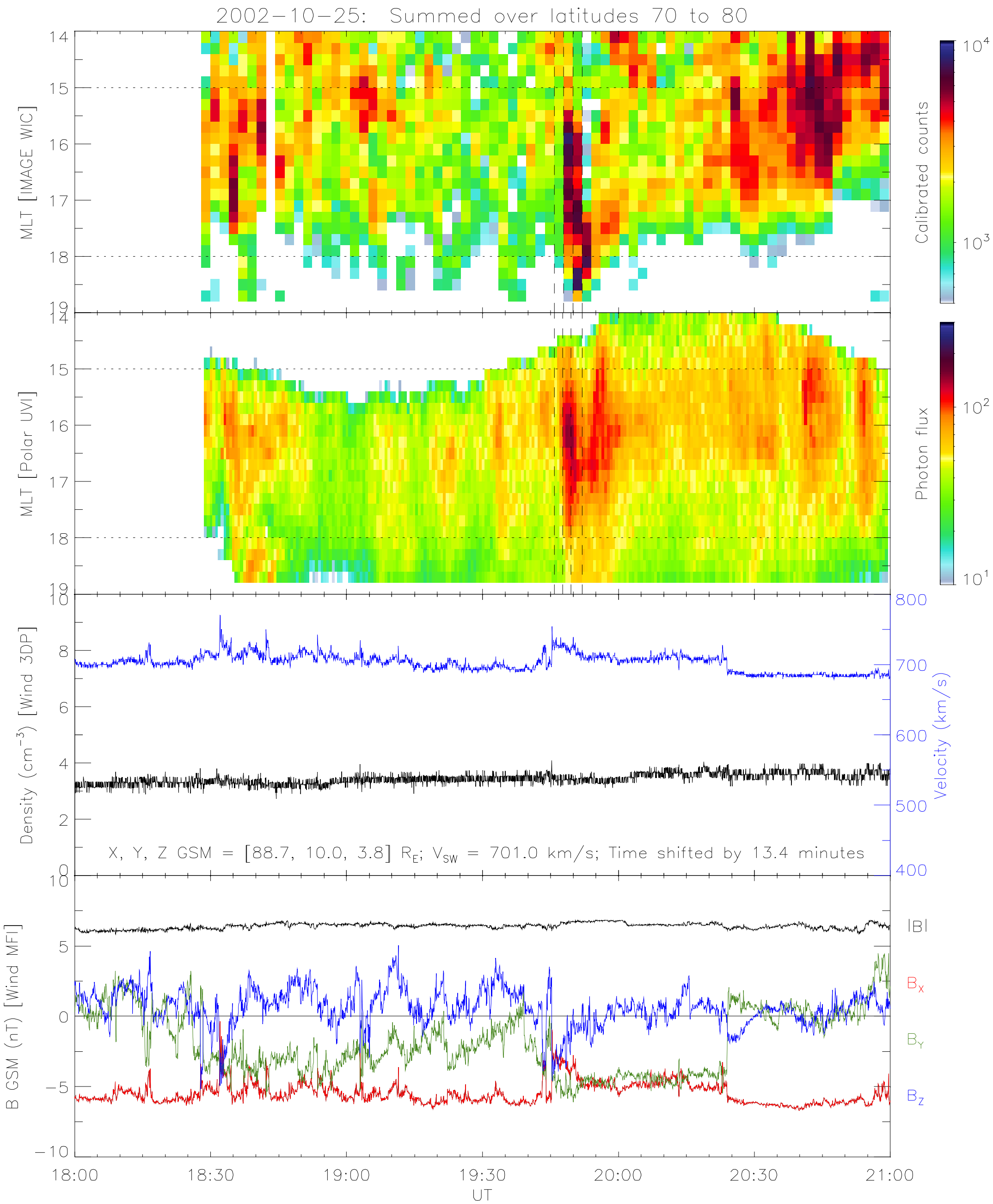

Simultaneous widespread brightening at 19:47 UT in both hemispheres

Other brightenings and structure (and lots of it) non-conjugate

SW density constant; SW velocity large with minor variations

IMF $B_X < 0$
$B_Y < 0$ (mostly)
$B_Z > 0$ w/fluctuations

Summary

Prediction: For $B_Y > 0$, afternoon aurora enhanced in SH
For $B_Y < 0$, afternoon aurora enhanced in NH

22 October 2002:
Quiet interval for $B_Z > 0$; more discrete in NH for $B_Y < 0$ ✔
2 November 2002:
Brightening in north aurora absent in south for $B_Y > 0$ ✗
⇒ Large decrease in dynamic pressure and IMF rotation
25 October 2002:
Sporadic brightenings in north and south for $B_Y < 0$ ✗
⇒ High solar wind velocity and large B_Z fluctuations

Seeing short-lived response to changes in solar wind and IMF and not quasi-steady state conditions of 4 November 2002
⇒ M-I system responds asymmetrically to solar wind variability

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⇒ M-I system responds asymmetrically to solar wind variability

Summary

Prediction: For $B_Y > 0$, afternoon aurora enhanced in SH
For $B_Y < 0$, afternoon aurora enhanced in NH

22 October 2002:
Quiet interval for $B_Z > 0$; more discrete in NH for $B_Y < 0$ ✔
2 November 2002:
Brightening in north aurora absent in south for $B_Y > 0$ ✗
⇒ Large decrease in dynamic pressure and IMF rotation
25 October 2002:
Sporadic brightenings in north and south for $B_Y < 0$ ✗
⇒ High solar wind velocity and large B_Z fluctuations

Seeing short-lived response to changes in solar wind and IMF and not quasi-steady state conditions of 4 November 2002
⇒ M-I system responds asymmetrically to solar wind variability