Observations of the Magnetosphere and its Coupling to the Ionosphere: Relating Plasma Sheet Observations to Global Auroral Images

M. O. Fillingim, G. K. Parks,
E. Lee, and S. B. Mende
Space Sciences Laboratory
University of California, Berkeley

Read This First!

What we did:

- Combined in-situ plasma sheet data with global auroral images to understand the relationship of plasma sheet dynamics to aurora
- Used plasma sheet data from **Wind** (perigee passes) and **Cluster** and global auroral images from **Polar UVI** and **IMAGE FUV**
- Not a new idea: e.g., *Angelopoulos et al.* [1997]; *Fairfield et al.* [1999]; *Fillingim et al.* [2000; 2001; 2003]; *Baker et al.* [2002]; *Nakamura et al.* [2002]; and ***many, many*** others

What we found:

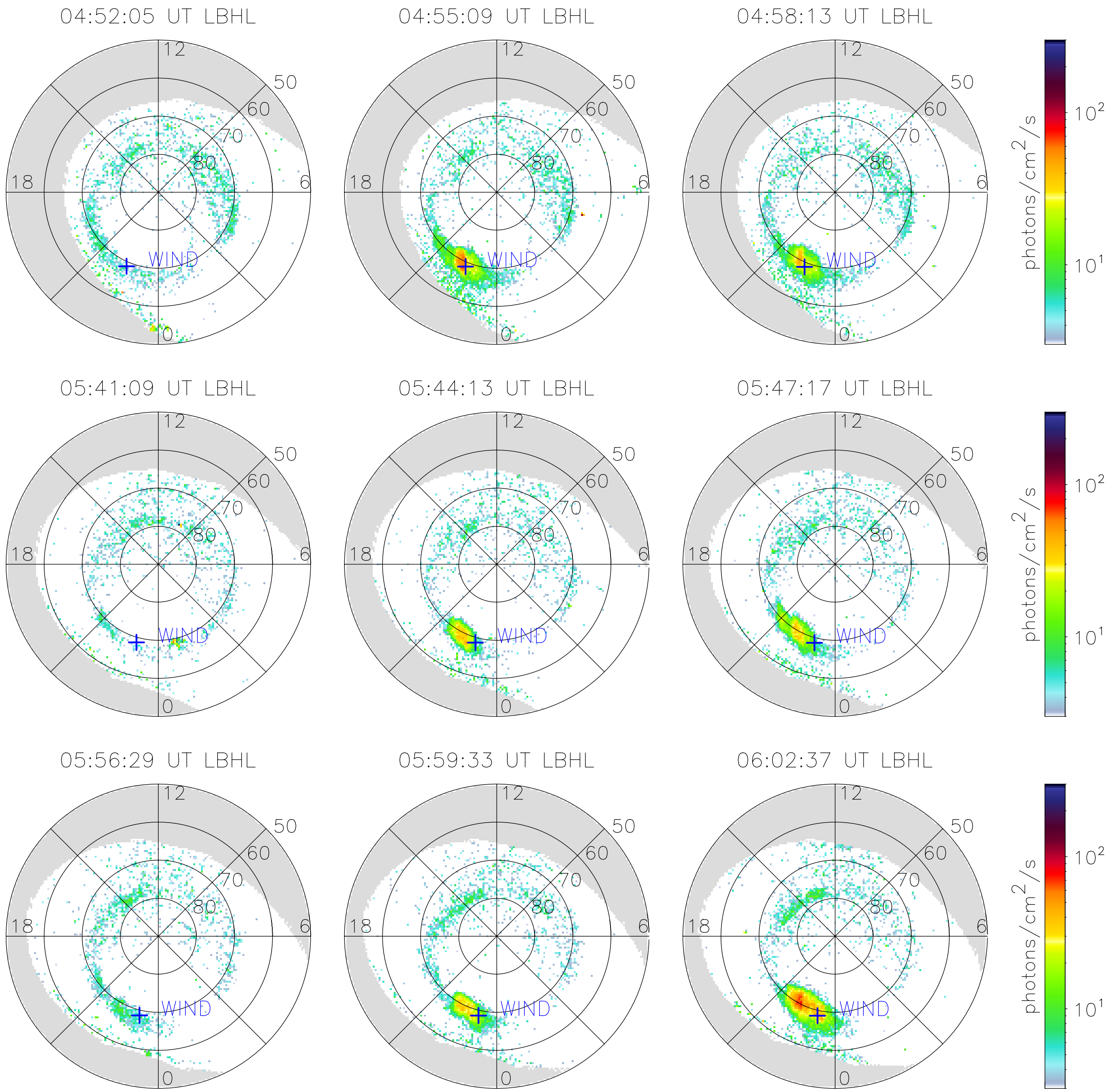
- In the near-Earth plasma sheet ($X < \sim -20\ R_E$), plasma sheet activity is **magnetically connected** to intense auroral emission

What we concluded:

- Plasma sheet disturbances propagated tailward as intense auroral emission moved poleward → **implies source ~ 10 R_E**

Example 1: 1997-07-26

- Instrument: **Polar UVI**
- Integration period: 37 sec
- Cadence: ~ 3 min
- Filter: LBHL (160 – 180 nm)



Example 1: 1997-07-26

- **Polar UVI** observed a series of small scale, short lived auroral brightenings – pseudobreakups and/or small substorms (also see *Fillingim et al.* [2000; 2001; 2003])

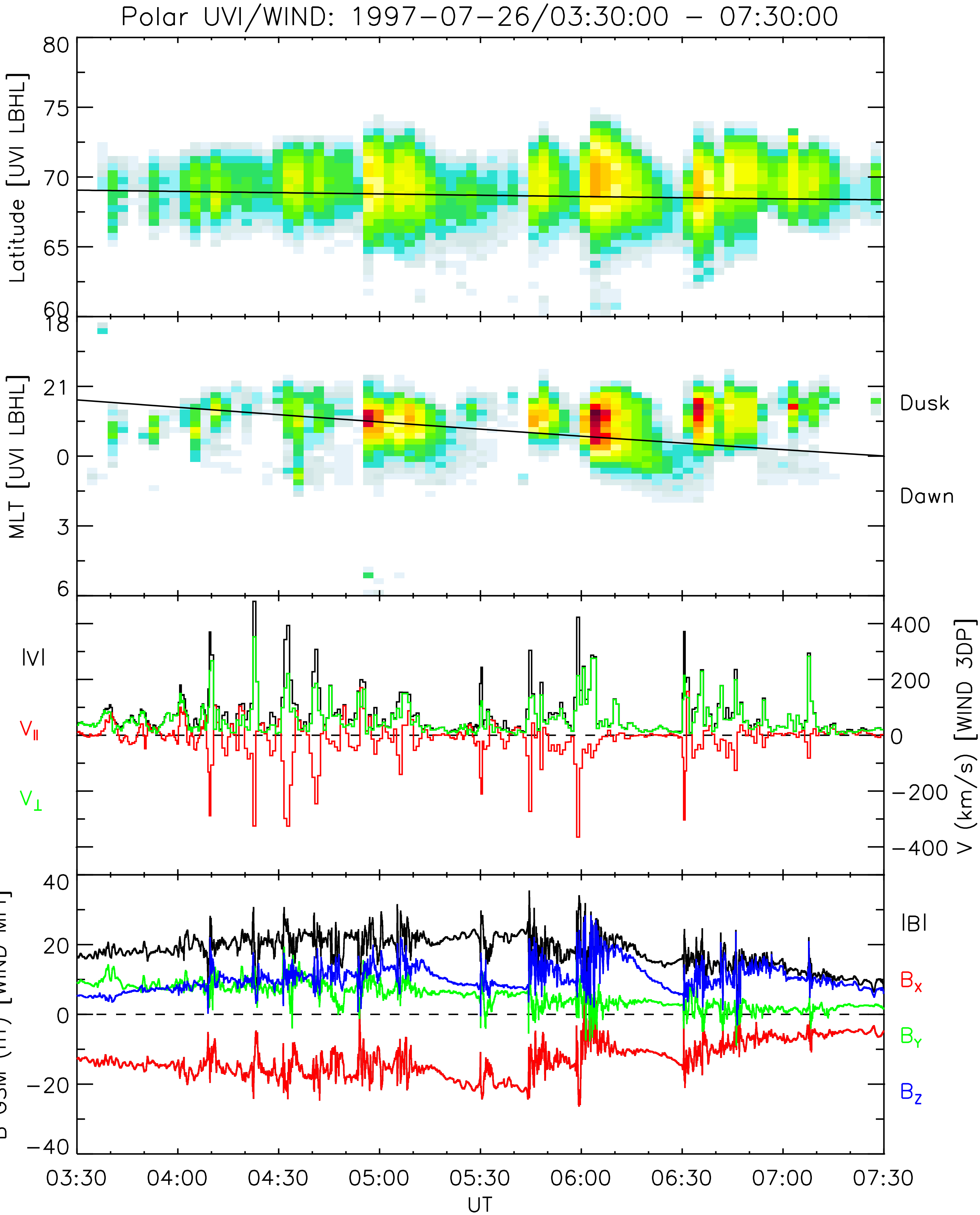
- **Wind** located in the near-Earth plasma sheet at $X \sim -10\ R_E$

- Excellent correlation between large **<v>**, ΔB, and auroral brightenings near Wind footprint

- Plasma sheet activity and auroral brightenings ***simultaneous*** within resolution of instruments (~ 1 minute)

- Most intense plasma sheet signatures ≠ most intense auroral signatures

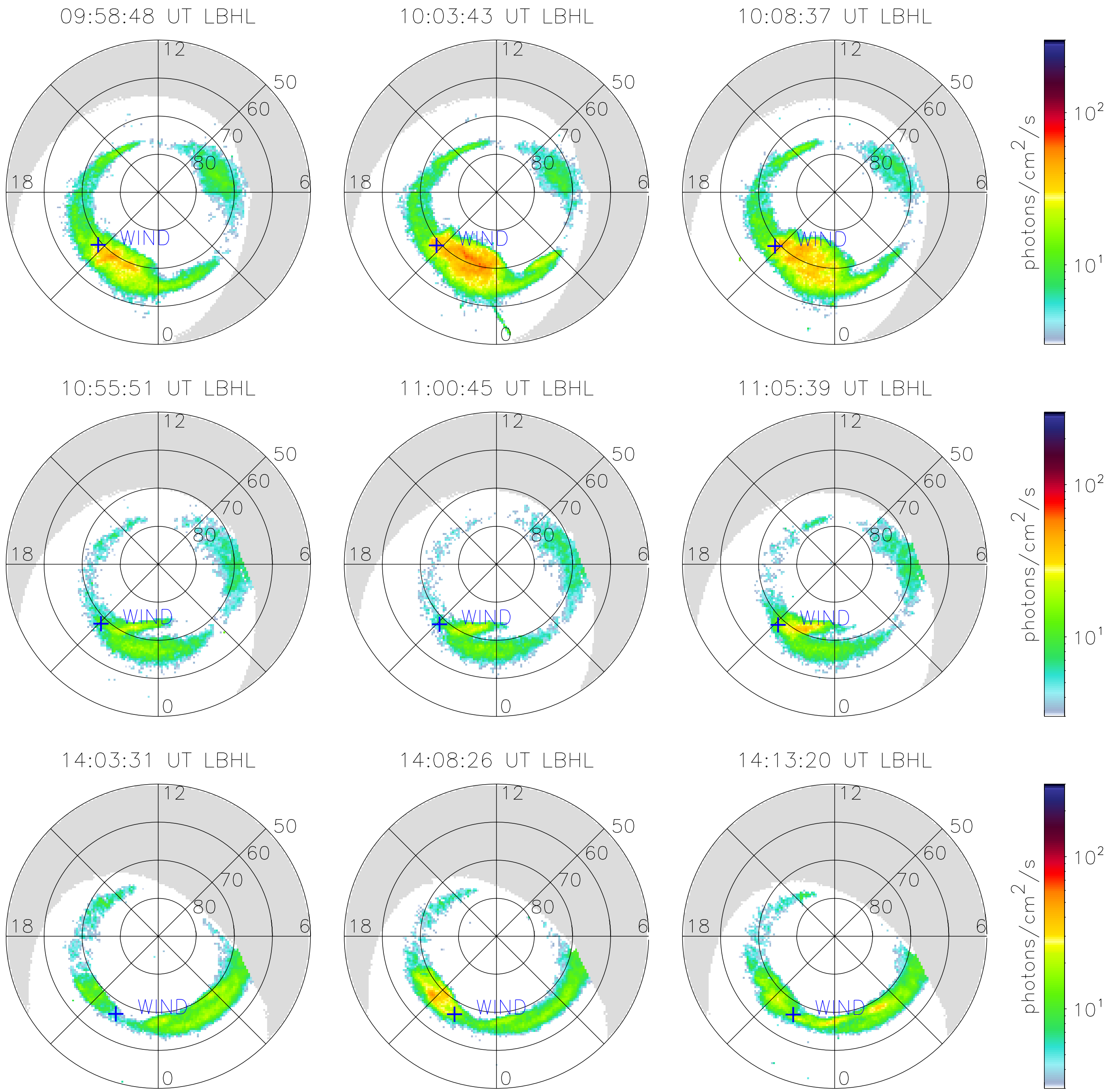
- Description of data plot shown below:
  Top two panels: latitude and local time keograms
  Spacecraft footprint also shown
  Bottom two panels: plasma sheet **<v>** and **B**



Polar UVI/WIND: 1997-07-26/03:30:00 - 07:30:00
Latitude [UVI LBHL]
MLT [UVI LBHL]
Dusk
Dawn
|V|
V∥
V⊥
V (km/s) [WIND 3DP]
|B|
Bx
By
Bz
B GSM (nT) [WIND MFI]
UT

Example 2: 1996-03-27

- Instrument: **Polar UVI**
- Integration period: 37 sec
- Cadence: ~ 5 min
- Filter: LBHL (160 – 180 nm)



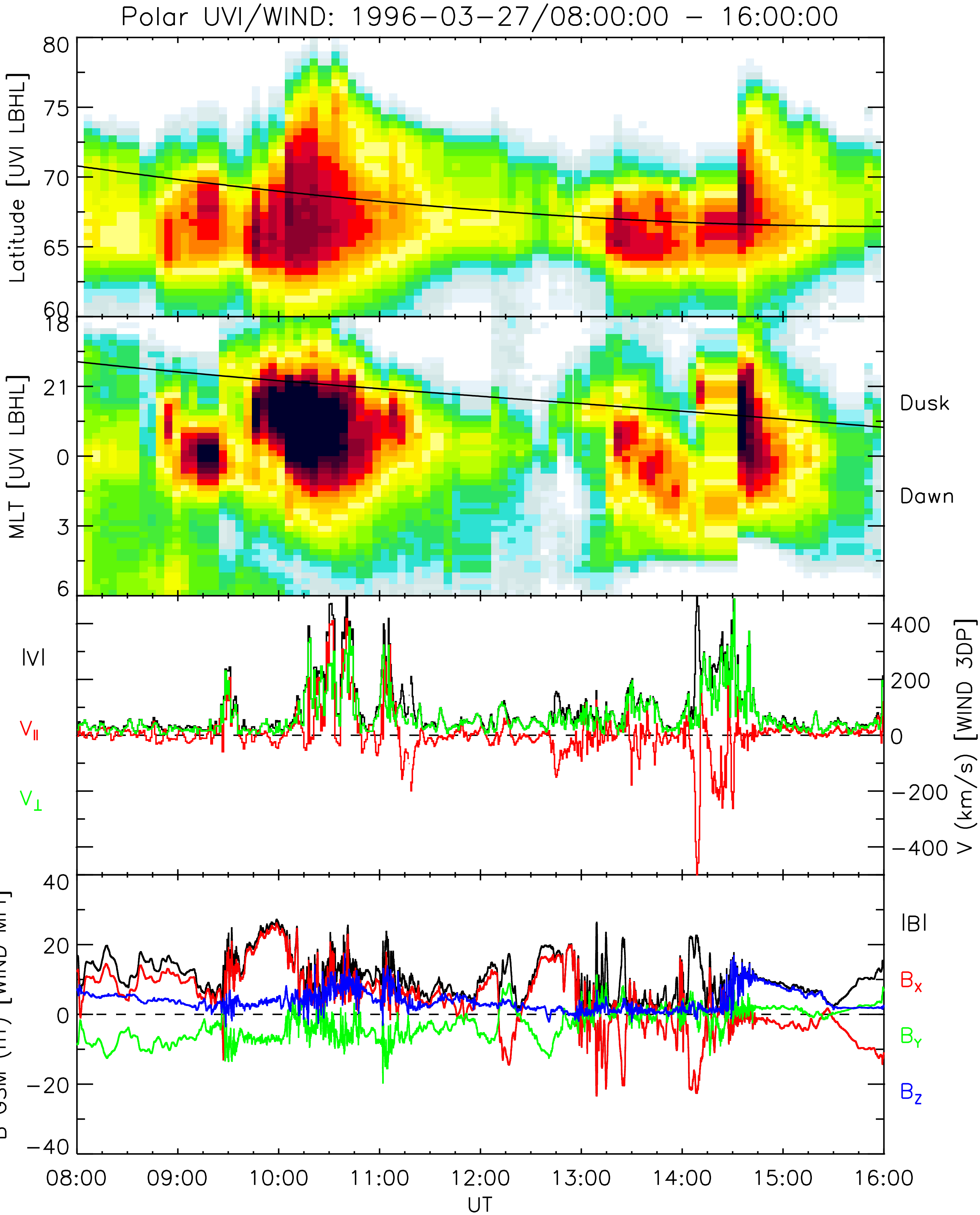
Example 2: 1996-03-27

- **Polar UVI** observed two major multi-onset (multi-intensification) substorms (also see *Angelopoulos et al.* [1997]; *Fillingim et al.* [2001; 2003])

- **Wind** in the plasma sheet at X ~ −15 R_E

- Large **<v>** only seen when **(1)** region of intense aurora expands to encompass Wind footprint or **(2)** intensification occurs near Wind footprint (Note: UVI data gap from 14:13 to 14:32 UT)

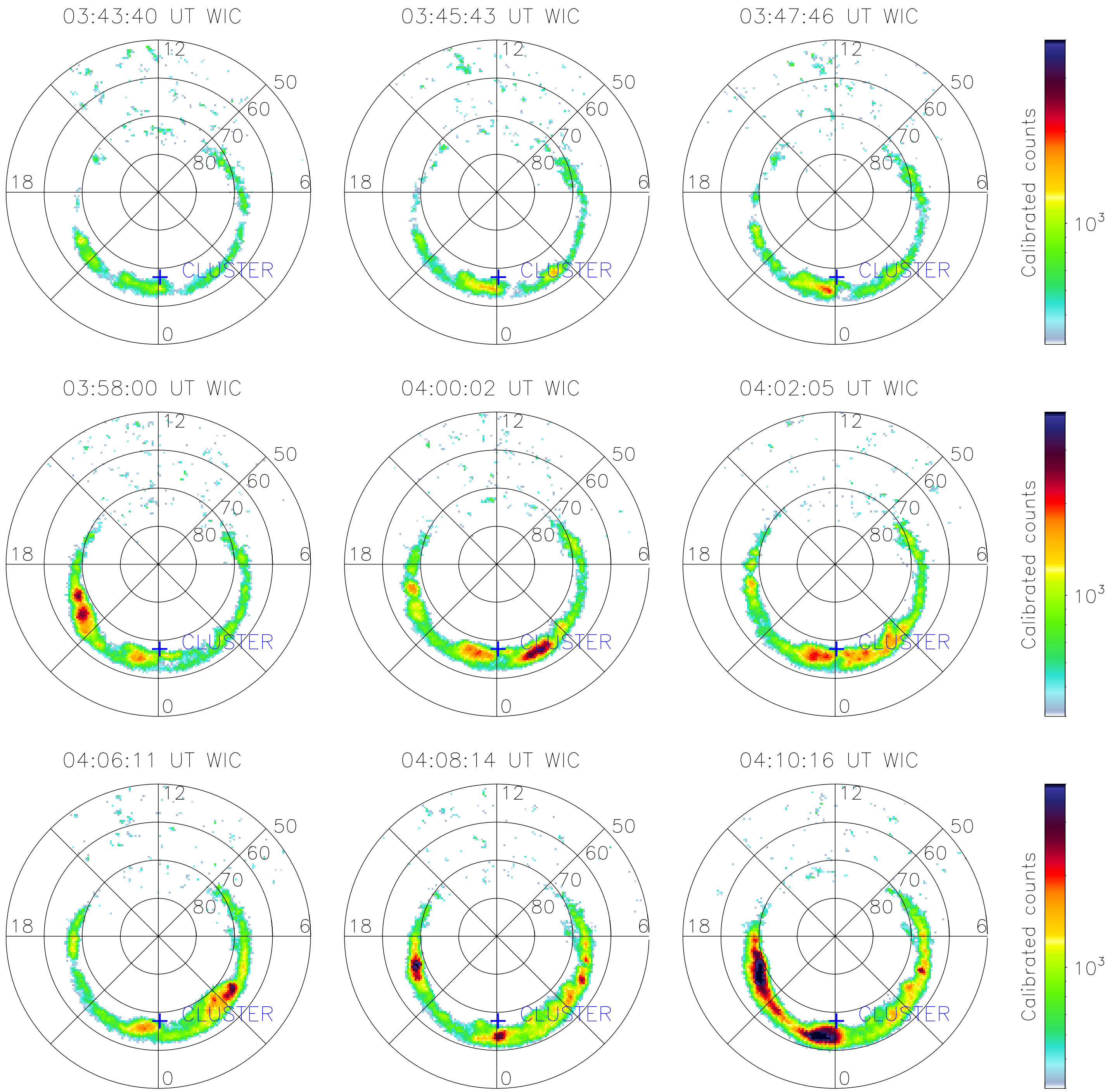
- Large changes in **B** can be associated with current sheet crossings and PSBL excursions; ***however***, large amplitude, high frequency fluctuations of **B** well correlated with large **<v>**



Polar UVI/WIND: 1996-03-27/08:00:00 - 16:00:00
Latitude [UVI LBHL]
80
75
70
65
60
MLT [UVI LBHL]
18
21
0
3
6
Dusk
Dawn
|V|
V∥
V⊥
400
200
0
−200
−400
V (km/s) [WIND 3DP]
B GSM (nT) [WIND MFI]
40
20
0
−20
−40
|B|
Bx
By
Bz
08:00
09:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
UT

Example 3: 2001-08-27

- Instrument: **IMAGE FUV WIC**
- Integration period: 10 sec
- Cadence: ~ 2 min
- Filter: WIC (140 – 190 nm)



Example 3: 2001-08-27

- **IMAGE FUV** observed precursor activity followed by substorm onset at ~ 04:08 UT (also see *Baker et al.* [2002])

- **Cluster** in the plasma sheet at X ~ −18 R_E

- Large **<v>** seen by **C1** and **C3** during **precursor activity** (before 03 UT, ~ 03:45 and ~ 04:00 UT), near **substorm onset** (~ 04:09 UT), and during ensuing **intensifications** (~ 04:14, 04:22 UT) when aurora brightens near Cluster footprint
  → Large **<v>** seen when Cluster maps to regions of intense auroral emission

- Different interpretation than *Baker et al.* [2002]: NENL reconnection commences at ~ 04:01 UT, 7 minutes prior to major substorm expansion – "magnetic reconnection …apparently begin[s] well before near-Earth and auroral effects"
- *However*, at ~ 04:01 UT Cluster maps to localized precursor activity (cf. Example 1)

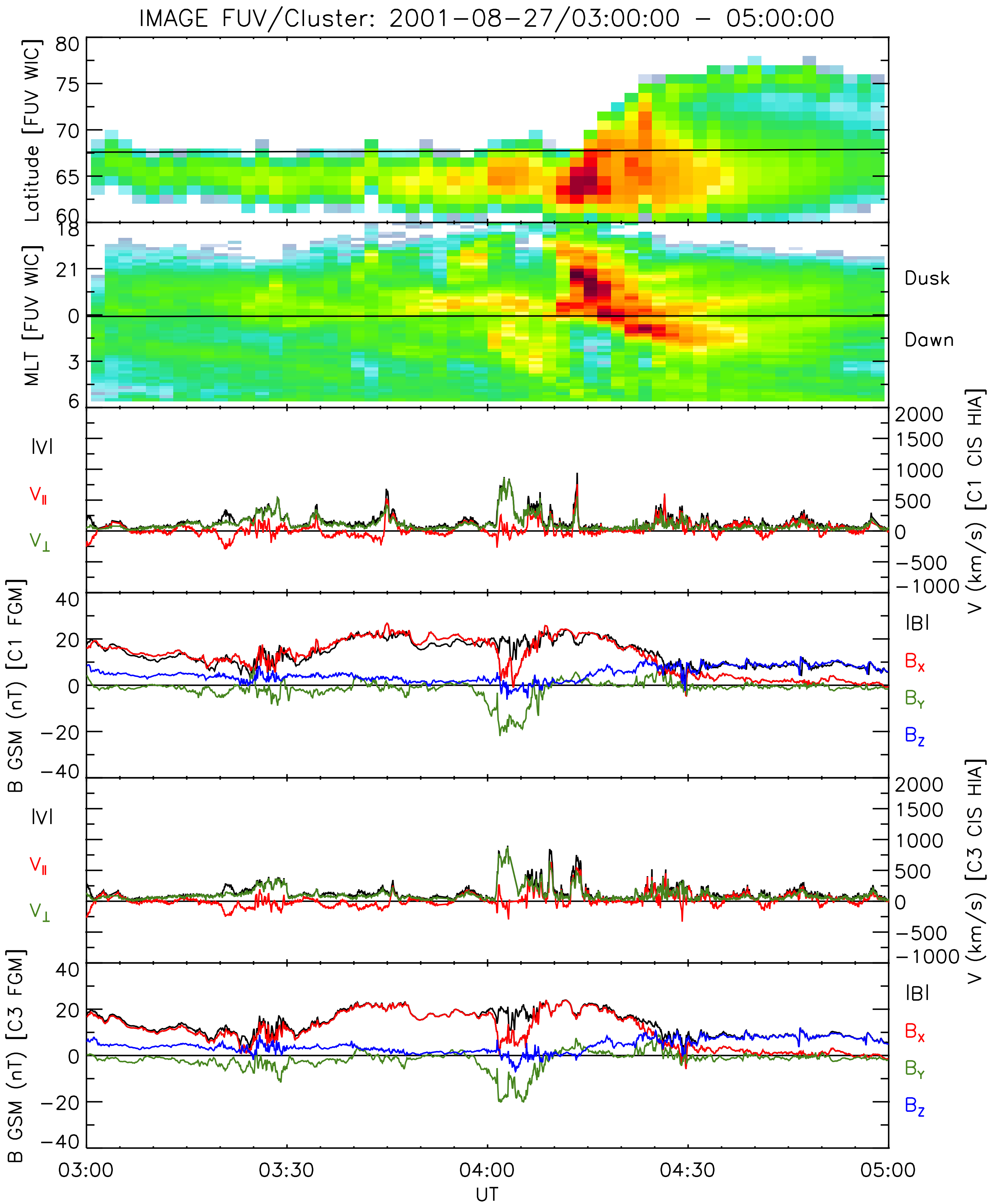
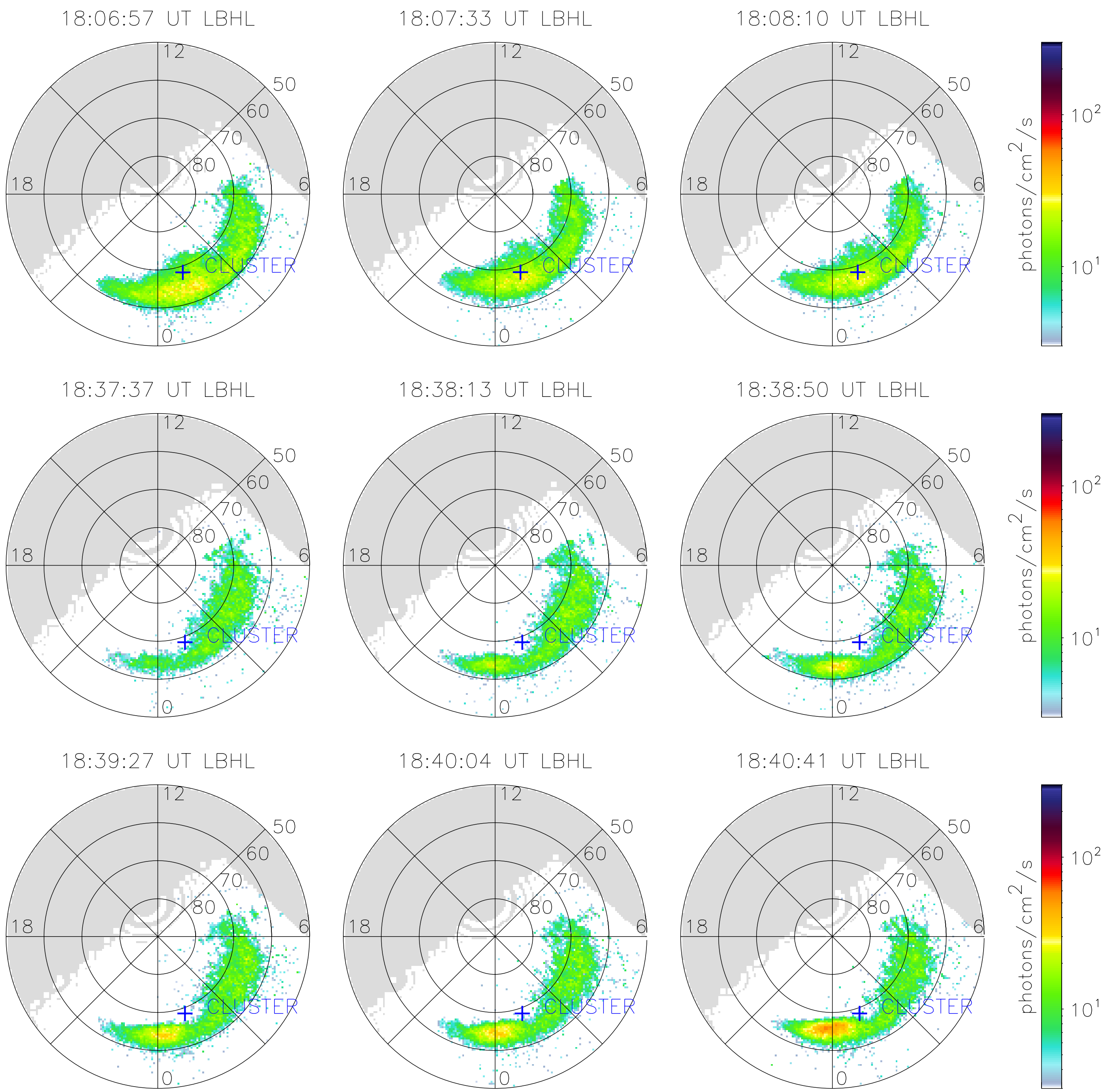


IMAGE FUV/Cluster: 2001-08-27/03:00:00 - 05:00:00
Latitude [FUV WIC]
MLT [FUV WIC]
Dusk
Dawn
|V|
V∥
V⊥
V (km/s) [C1 CIS HIA]
B GSM (nT) [C1 FGM]
|B|
Bx
By
Bz
|V|
V∥
V⊥
V (km/s) [C3 CIS HIA]
B GSM (nT) [C3 FGM]
|B|
Bx
By
Bz
03:00
03:30
04:00
04:30
05:00
UT

Example 4: 2001-08-12

- Instrument: **Polar UVI**
- Integration period: 37 sec
- Cadence: 37 sec
- Filter: LBHL (160 – 180 nm)



Example 4: 2001-08-12

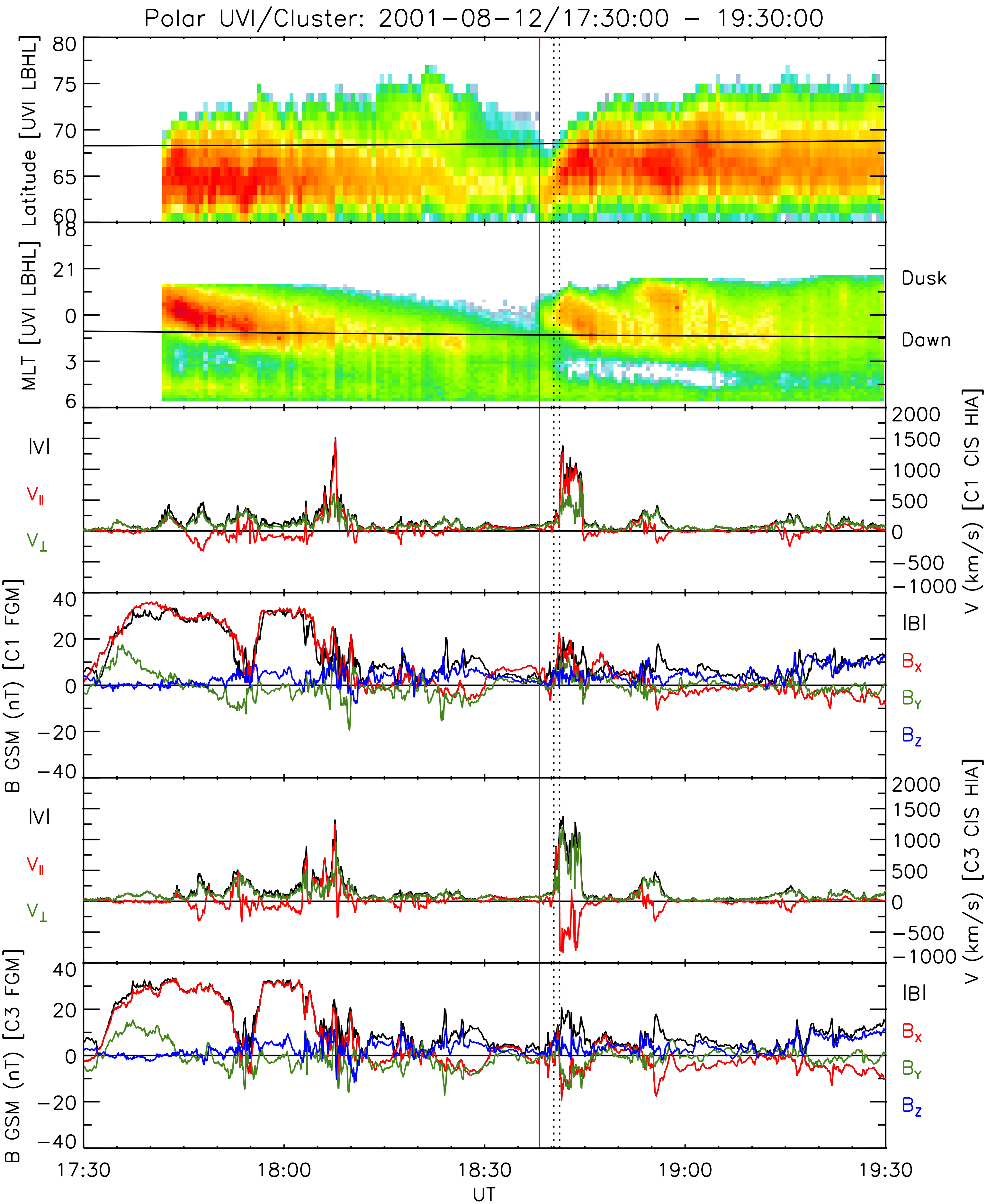
- **Polar UVI** (shown) and **IMAGE FUV** observed substorm onset at ~18:38 UT (also see *Nakamura et al.* [2002])

- **Cluster** in the plasma sheet at X ~ −18 R_E

- From UVI data, substorm onset occurs at 18:38:30 UT ± 18 sec (red line)
- Keogram shows that from onset to 18:44 UT, aurora expands poleward at ~ 1°/min
  → ~2 km/s in ionosphere
  → > 50 km/s in plasma sheet
- Emission reaches Cluster footprint at ~ 18:40 UT

- Plasma sheet activity (large **<v>** and ΔB) seen by **C3** at ~ 18:40 UT (closest to neutral sheet)
- Plasma sheet activity seen by **C1** at ~ 18:41 UT (footprint further poleward and eastward of C3)

→ As intense auroral emission moves poleward, plasma sheet activity propagates tailward



Polar UVI/Cluster: 2001-08-12/17:30:00 - 19:30:00
Latitude [UVI LBHL]
MLT [UVI LBHL]
Dusk
Dawn
|V|
V∥
V⊥
V (km/s) [C1 CIS HIA]
B GSM (nT) [C1 FGM]
|B|
Bx
By
Bz
V (km/s) [C3 CIS HIA]
B GSM (nT) [C3 FGM]
17:30
18:00
18:30
19:00
19:30
UT

Coupling through Currents

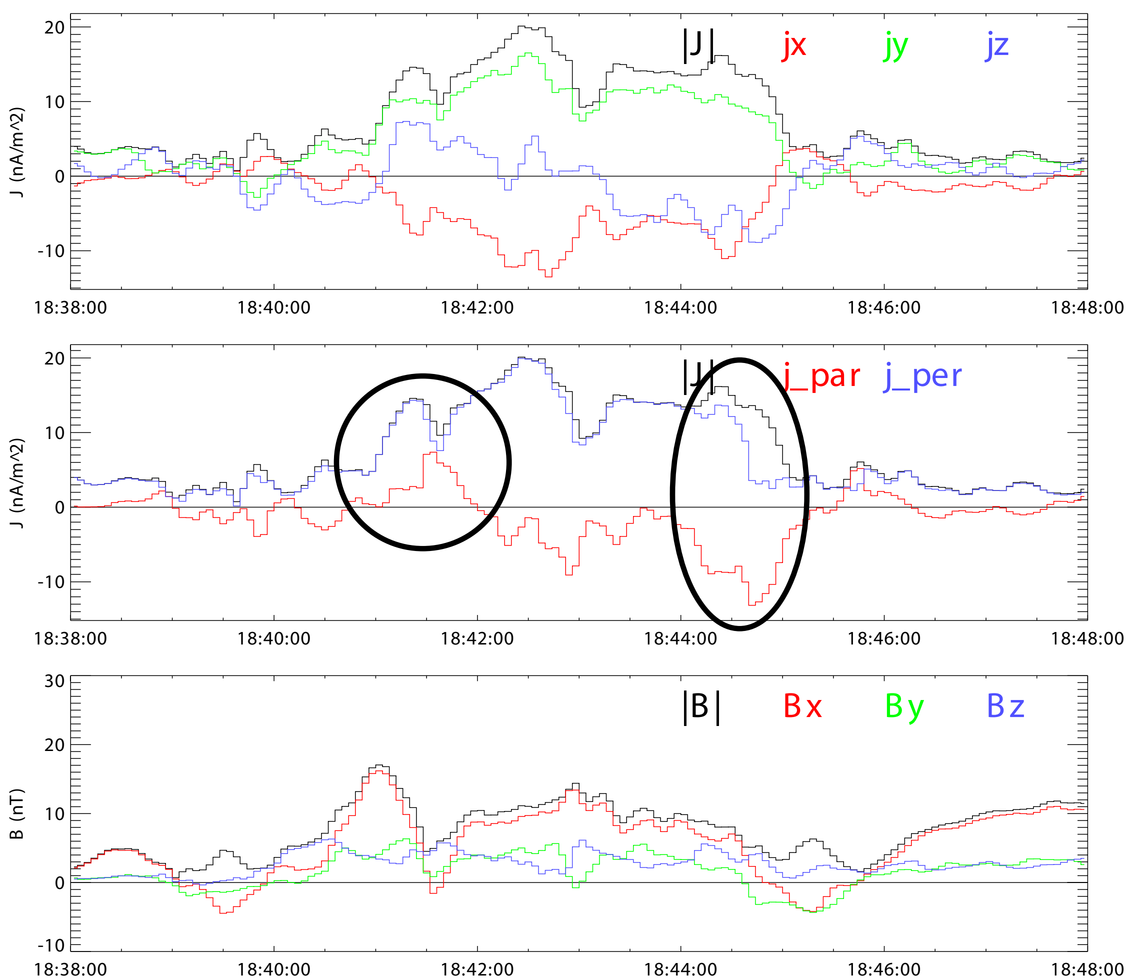
- Field-aligned currents (FAC) provide connectivity between plasma sheet and ionosphere

- Determine currents using curlometer (**J** = ∇ X **B**)

➔ Significant FAC during large <**v**> event (circled)

- Plasma sheet-ionosphere travel time for thermal (½ - 1 keV) electrons ~ 10 seconds

➔ "Simultaneous" within resolution of detectors



<u>Summary and Conclusions</u>

- In the near-Earth plasma sheet (X < ~ -20 R_E), **plasma sheet activity** (large **<v>** and ΔB) is **magnetically connected** to regions of **intense auroral emission**
  ➔ FACs provide M-I connection

- This suggests near-Earth (~ 10 R_E) source
  ➔Plasma sheet activity propagates **tailward** as intense auroral emission moves **poleward**

- Can't exclude NENL interpretation:
  Reconnection occurs prior to auroral onset;
  flows propagate Earthward in "thin" layer;
  breaking and pile-up creates tailward motion
  ➔ *However*, "thin" layer not observed
  All flows have auroral footprint

- ***<u>Caveat</u>:*** Interpretation relies on accuracy of magnetospheric model (*Tsyganenko* [1996])
  ➔ static model, dynamic conditions

Implications for THEMIS

- Coordinated quasi-global, ground-based auroral observations and radially spaced plasma sheet observations will directly address this problem

- ***We predict***
  THEMIS will see plasma sheet disturbances originate near-Earth and propagate tailward as intense auroral emission propagates poleward

- Regardless, THEMIS should have an excellent view of the show