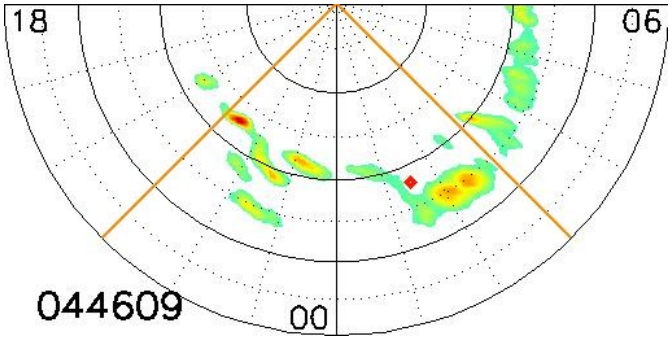
Auroral Poleward Boundary Intensifications (PBIs) and Plasma Sheet Dynamics

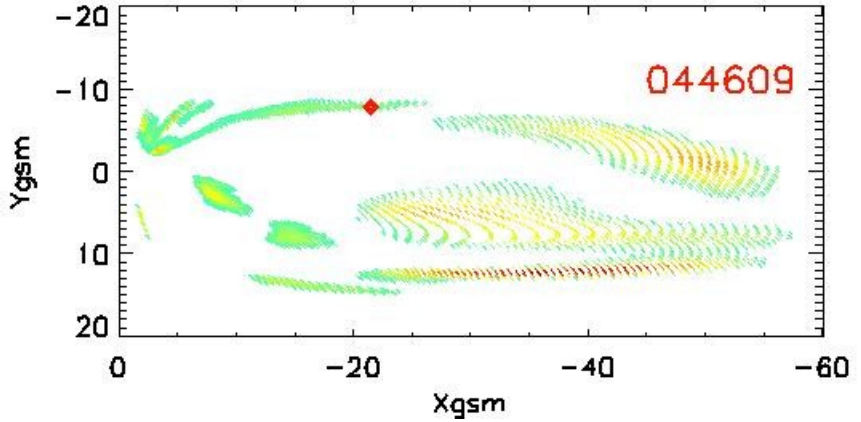
Eftyhia Zesta

ΑΡΙΣΤΟΤΕΛΕΙΟ ΠΑΝΕΠΙΣΤΗΜΙΟ ΘΕΣΣΑΛΟΝΙΚΗΣ

ΤΜΗΜΑ ΦΥΣΙΚΗΣ

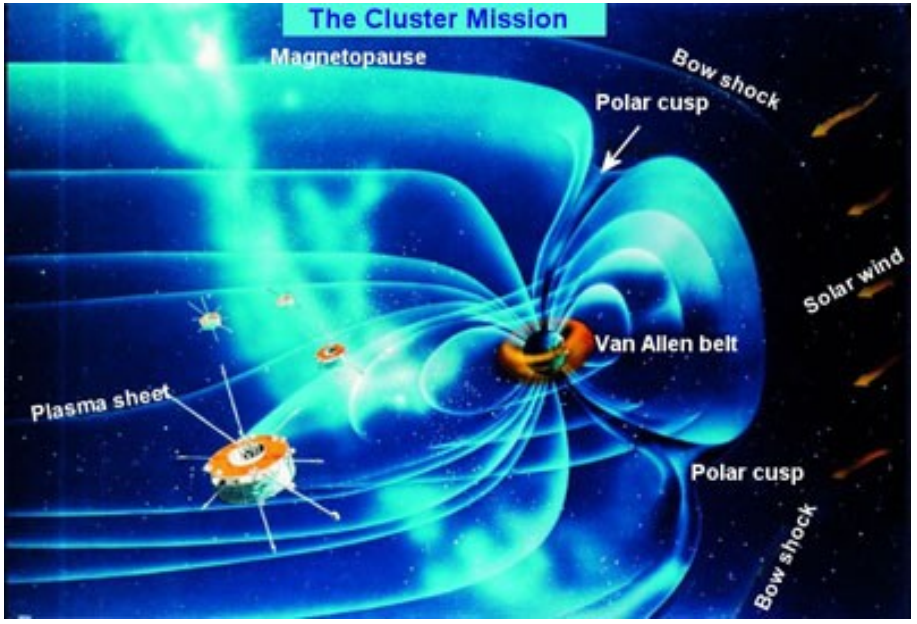
September 13, 2006



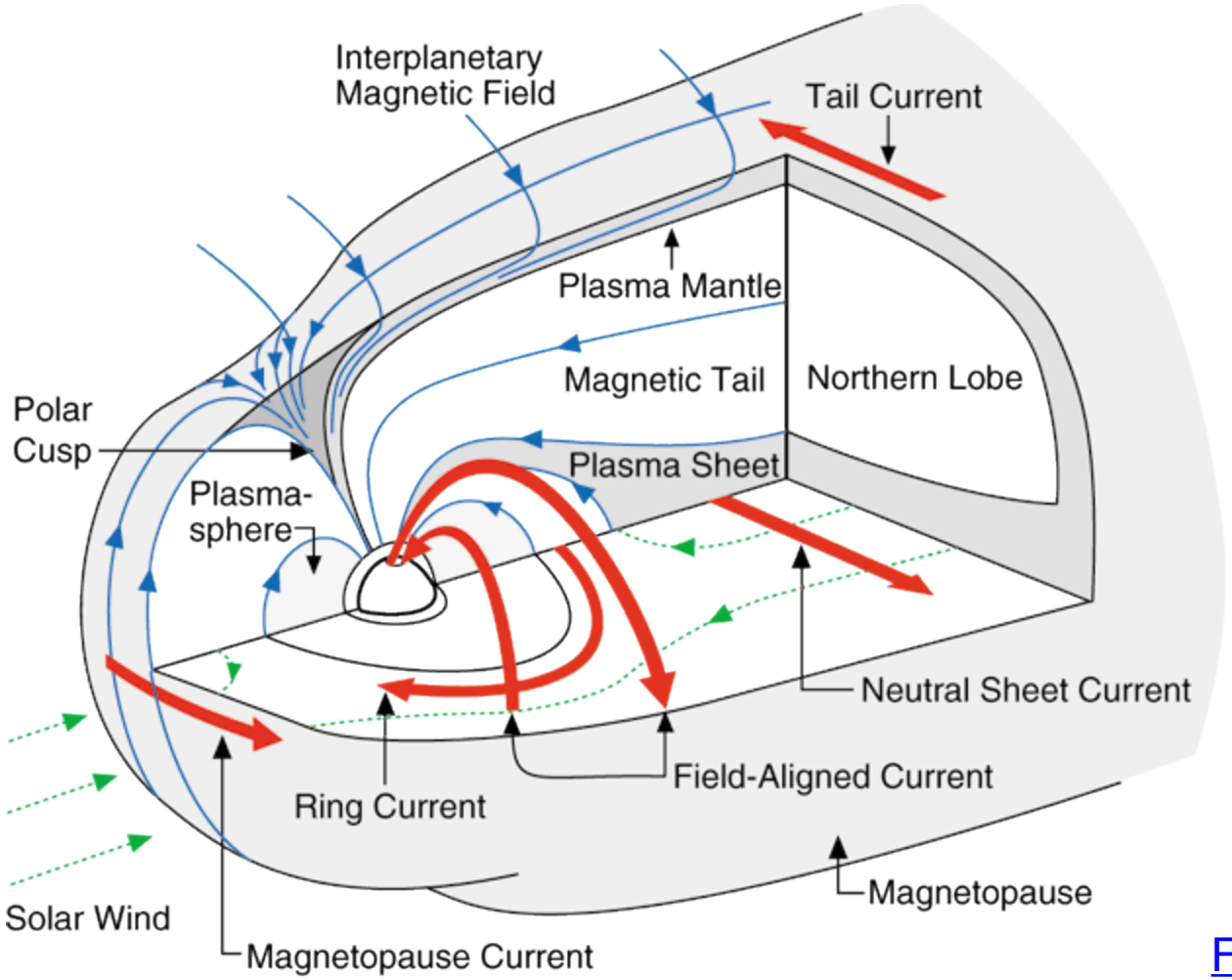


OUTLINE

- Introduction on the magnetosphere and energy transport through the tail
- Introduction on plasma sheet flows and PBIs
- Correlation between PBIs and sheet flows
- 2-D structure of PBIs and IMF conditions
- Event of 010103 – global observations of PBIs and associated flows
- Correlation of PBI orientation and IMF By



Artist's depictions of the magnetosphere and the CLUSTER spacecraft (from ESA website)



From Kivelson and Russell 2005

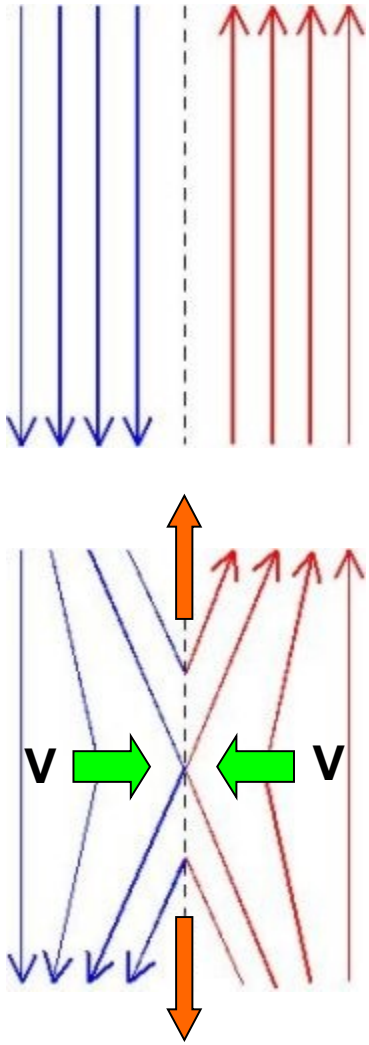
Frozen-in-flux condition

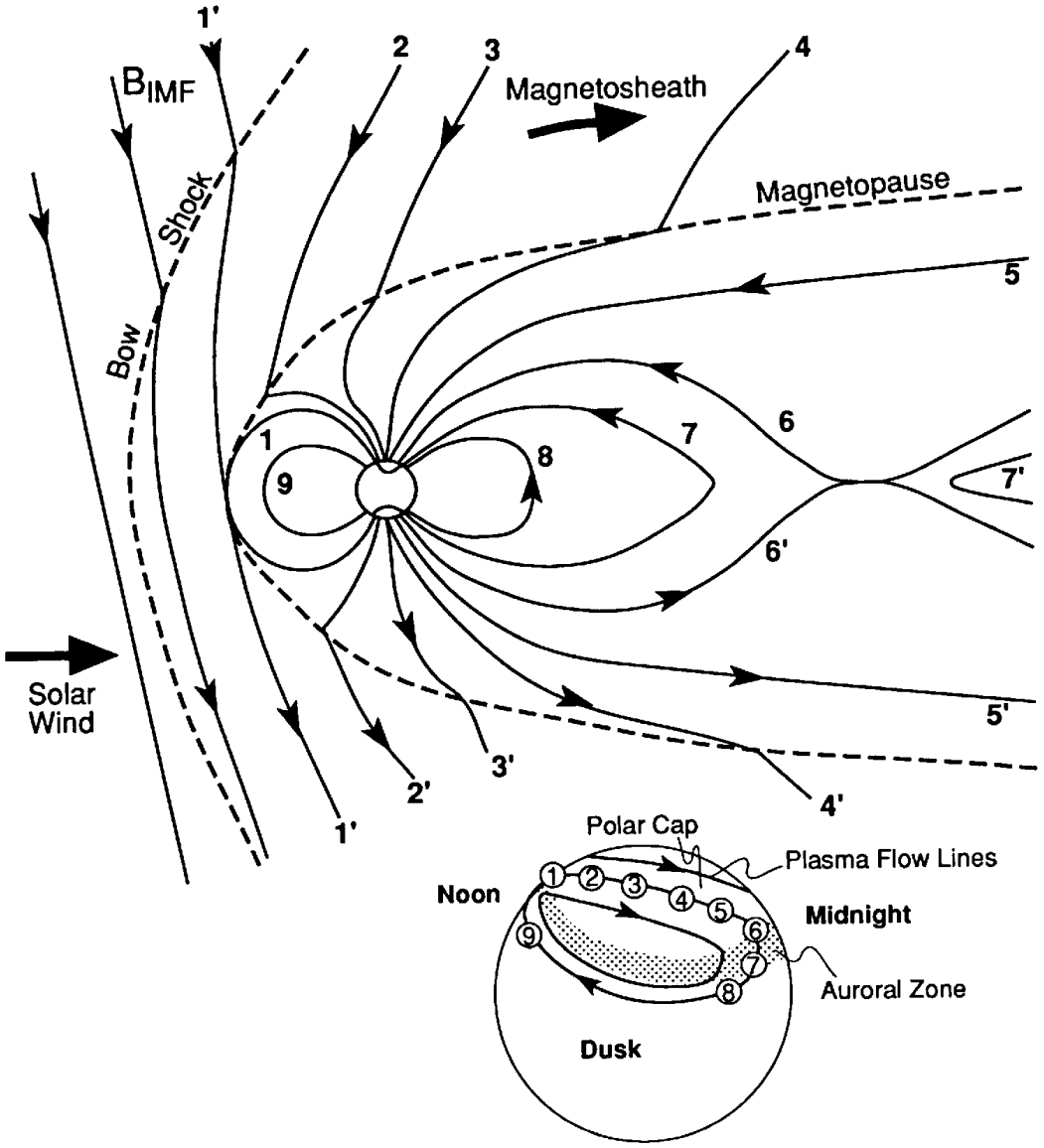
$\mathbf{j} = \sigma(\mathbf{E} + \mathbf{u}\times\mathbf{B})$

For fluid with $\sigma \rightarrow \infty$

$\mathbf{E} = -\ \mathbf{u}\times\mathbf{B}$

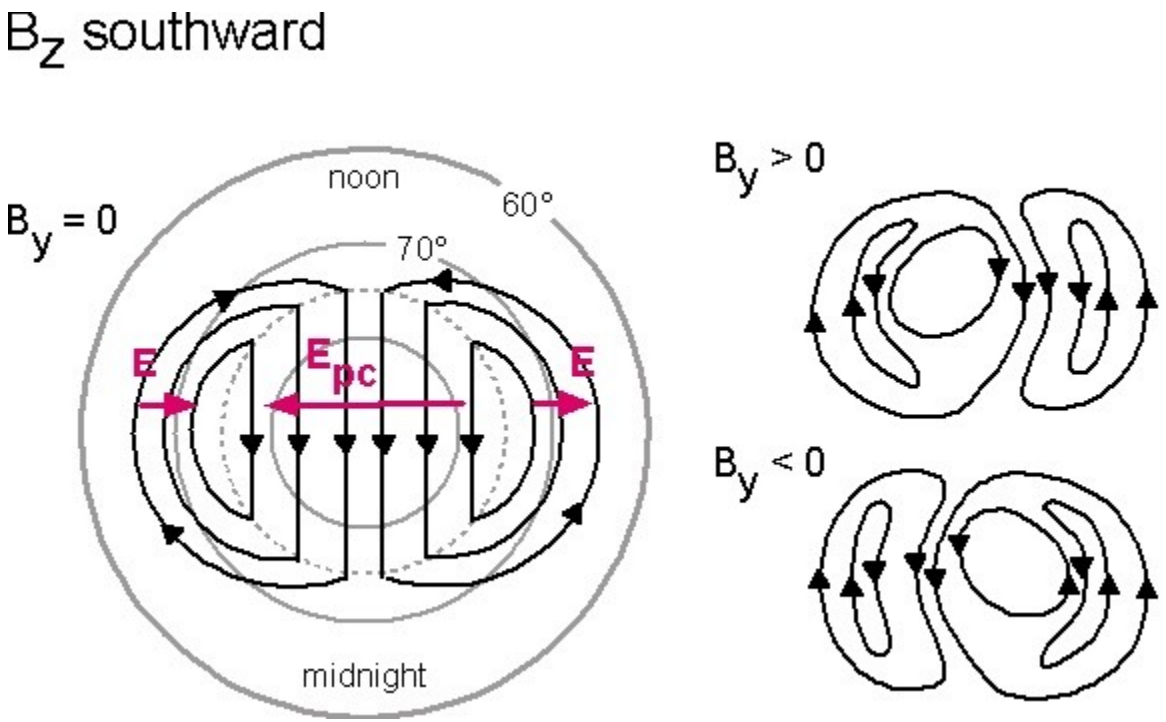
Process of Reconnection





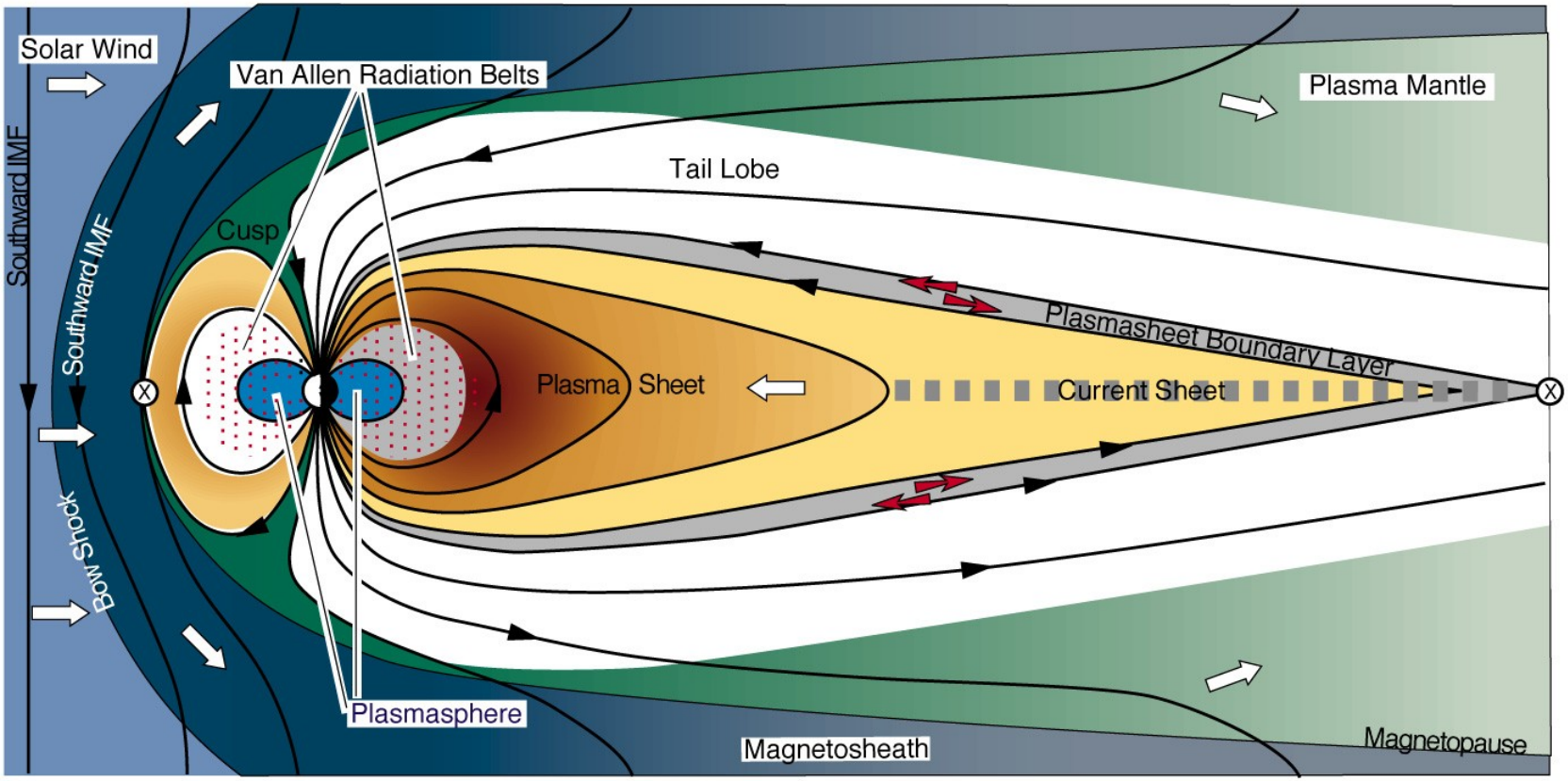
Flow of plasma within the magnetosphere (convection) driven by magnetic reconnection.

(from chapter by Hughes in Kivelson and Russel book, 1995)

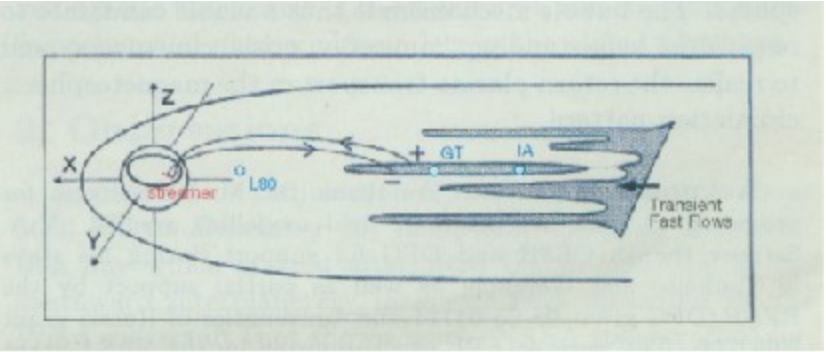


Two-cell “convection” pattern at high latitudes in the ionosphere.

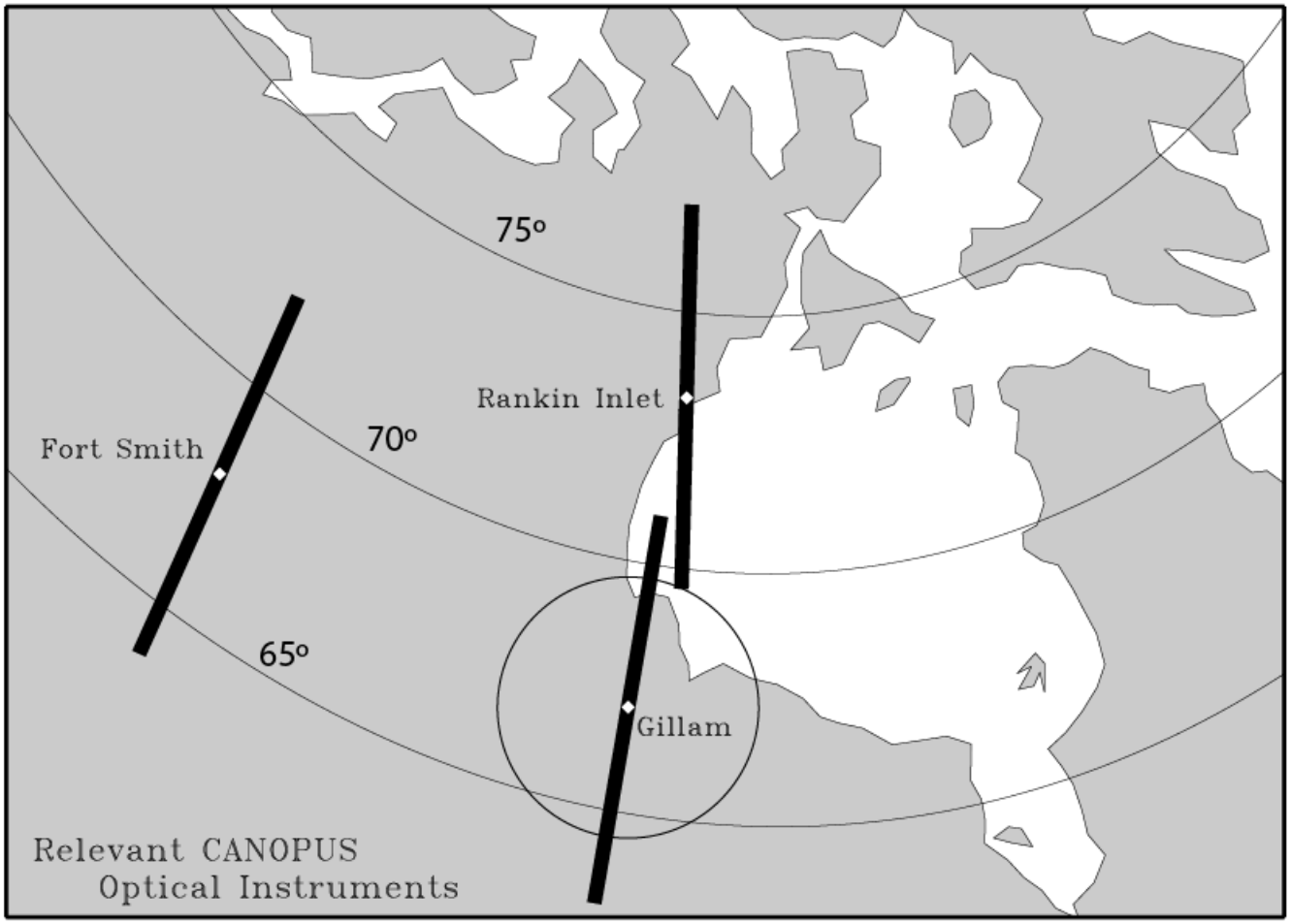
Flow pattern is roughly stationary in a sun-fixed coordinate system

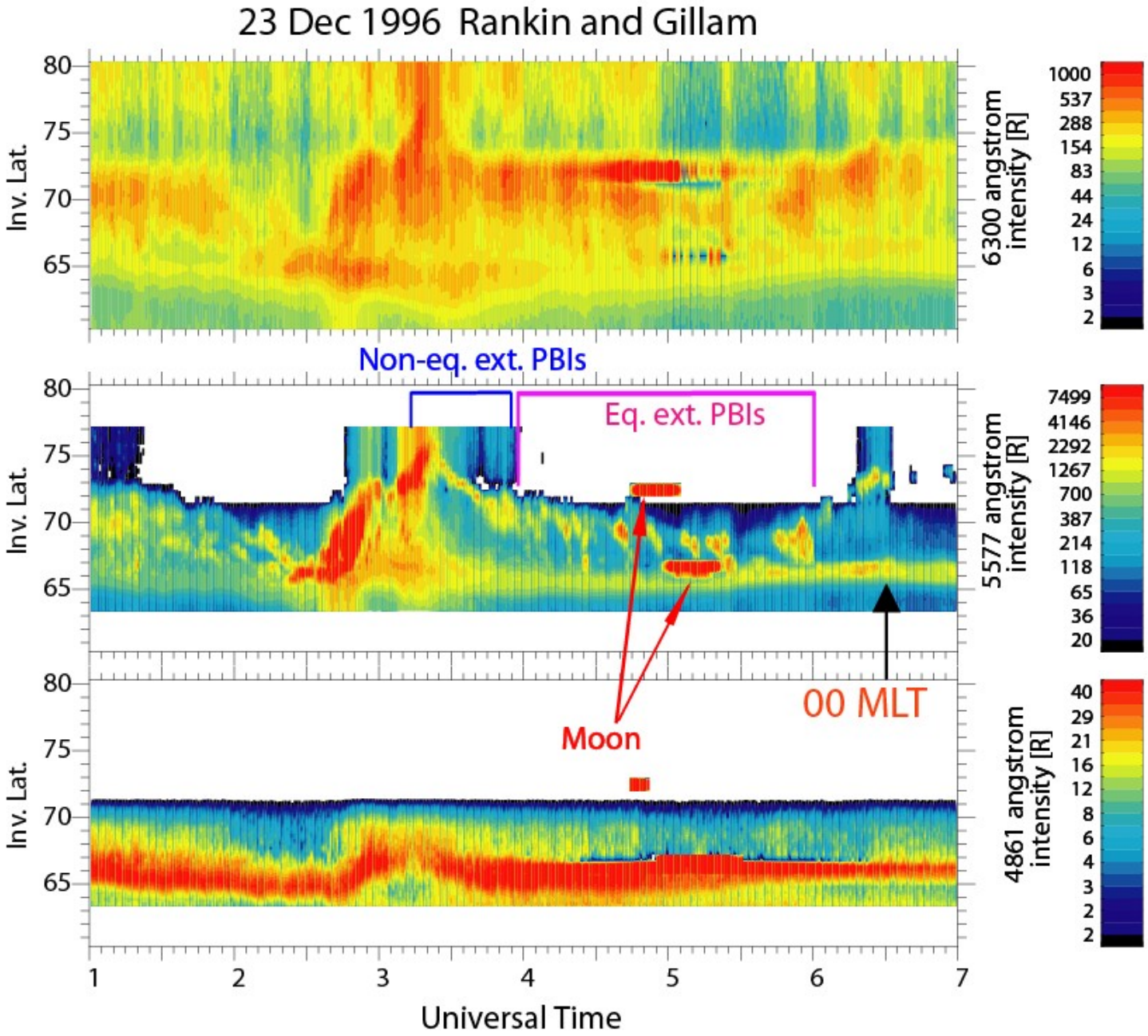

Solar Wind
Van Allen Radiation Belts
Plasma Mantle
Tail Lobe
Southward IMF
Southward IMF
Cusp
Plasmasheet Boundary Layer
Plasma Sheet
Current Sheet
Bow Shock
Plasmasphere
Magnetosheath
Magnetopause

Introduction on plasma sheet fast flows (BBF) and the search for their ionospheric signature

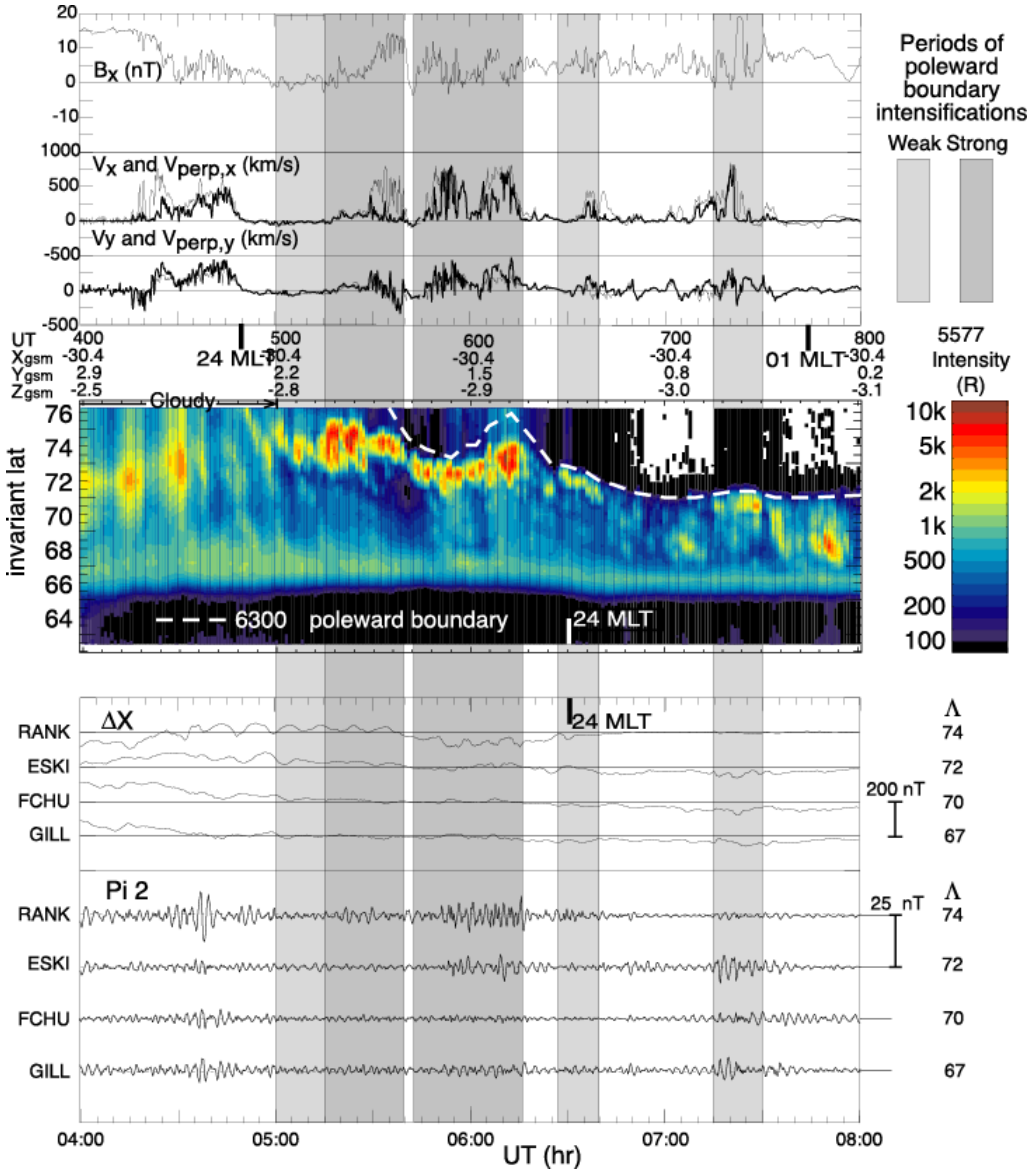


- Baumjohann et al. [1990]: First to show, using IRM data (-9 to -19 Re), that fast flows occur through the whole plasma sheet, not only PSBL. For high AE more probable to detect fast flows in CS than in PSBL.
- Angelopoulos et al. [1992,1994]: Using IRM and ISEE 2 data did a large statistical survey of fast flows and the name “BBF” was born. He showed that (a) BBFs occur during both quiet and disturbed times in the central CS but are most frequent during the expansion phase, (b) **BBFs responsible for 60-100% of transport of mass, energy, and magnetic flux**
- Henderson et al. [1998]; Sergeev et al. [1999, 2000]: Associated BBFs with auroral streamers (mostly indirectly)
- Kauristie et al. [2000, 2003]: Studied ionospheric currents of streamers and showed they are consistent with the source being fast flow channels in the tail
- Nakamura et al. [2001]: Associated BBFs with auroral streamers and auroral activations. BBFs responsible for streamers occur tailward of 15 Re and those responsible for activations occur earthward of 15 Re

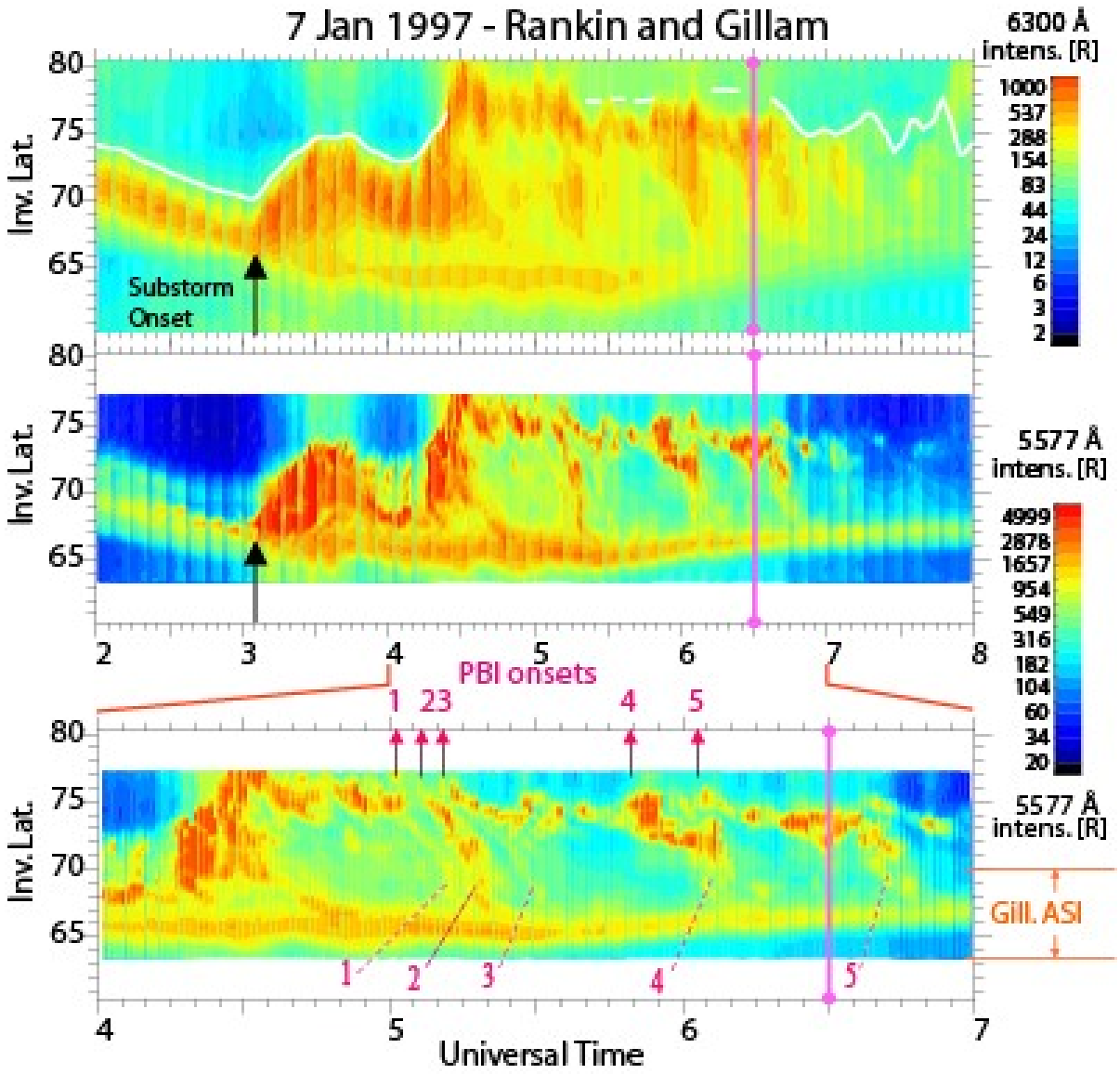

75°
70°
65°
Rankin Inlet
Fort Smith
Gillam
Relevant CANOPUS
Optical Instruments


23 Dec 1996 Rankin and Gillam
Inv. Lat.
80
75
70
65
6300 angstrom intensity [R]
1000
537
288
154
83
44
24
12
6
3
2
Non-eq. ext. PBIs
Eq. ext. PBIs
5577 angstrom intensity [R]
7499
4146
2292
1267
700
387
214
118
65
36
20
00 MLT
Moon
4861 angstrom intensity [R]
40
29
21
16
12
8
6
4
3
2
2
1
2
3
4
5
6
7
Universal Time

General correlation of PBIs and BBFs

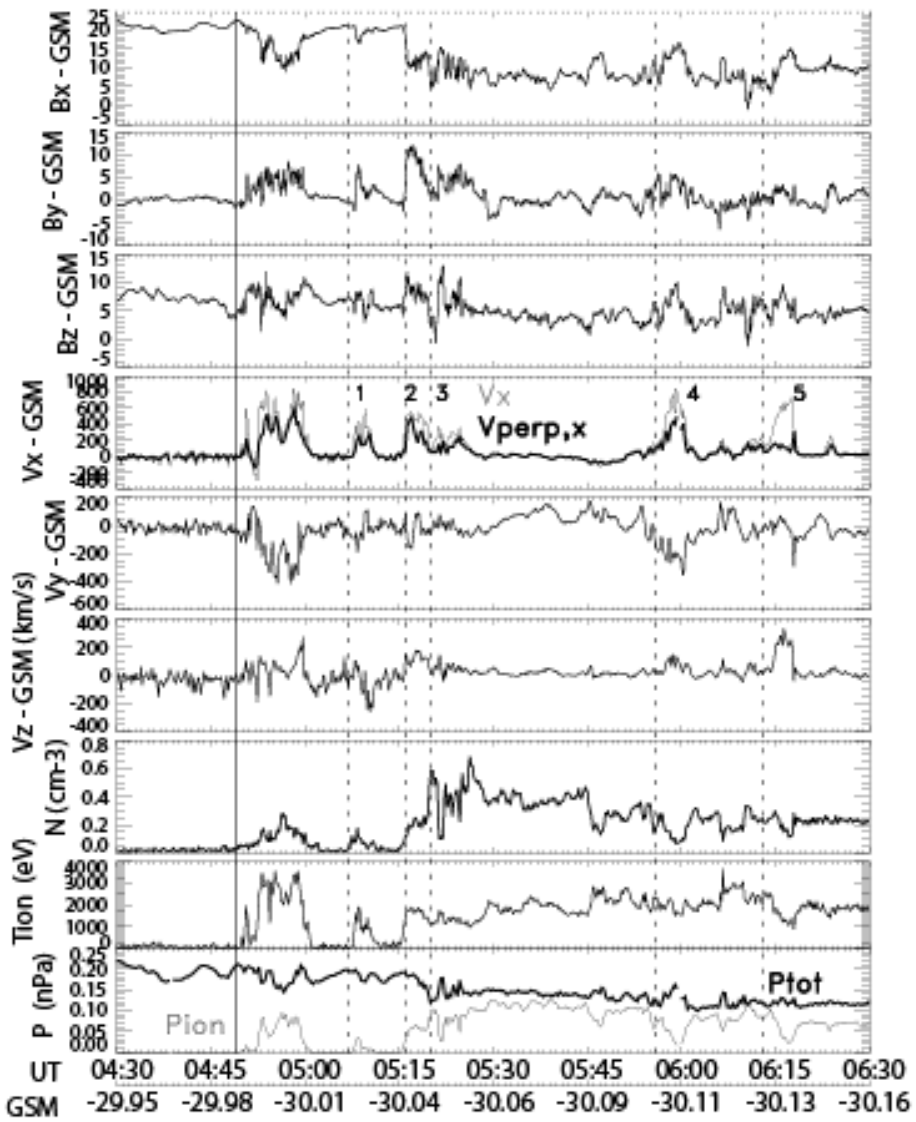


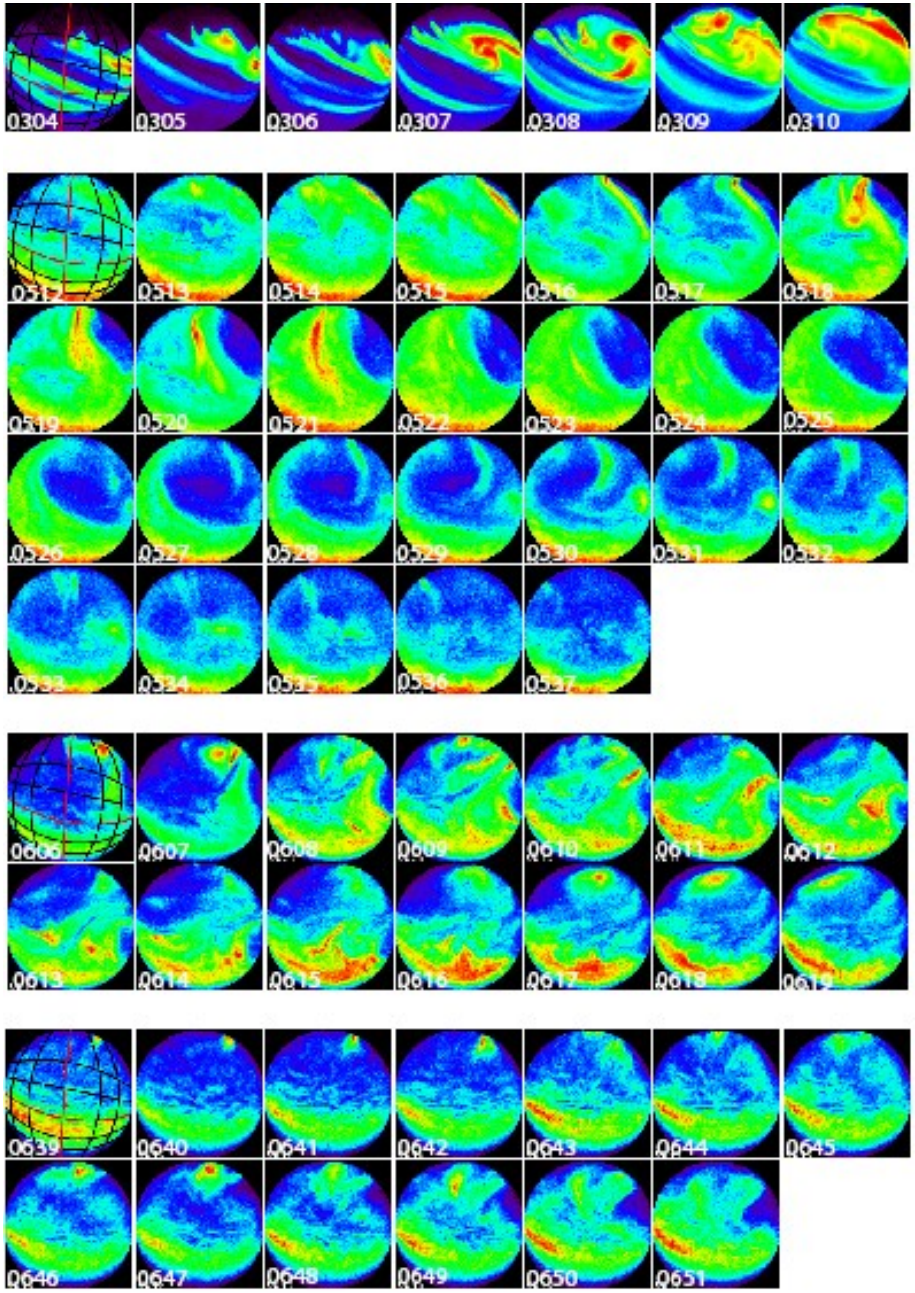
From Lyons et al. [1999]



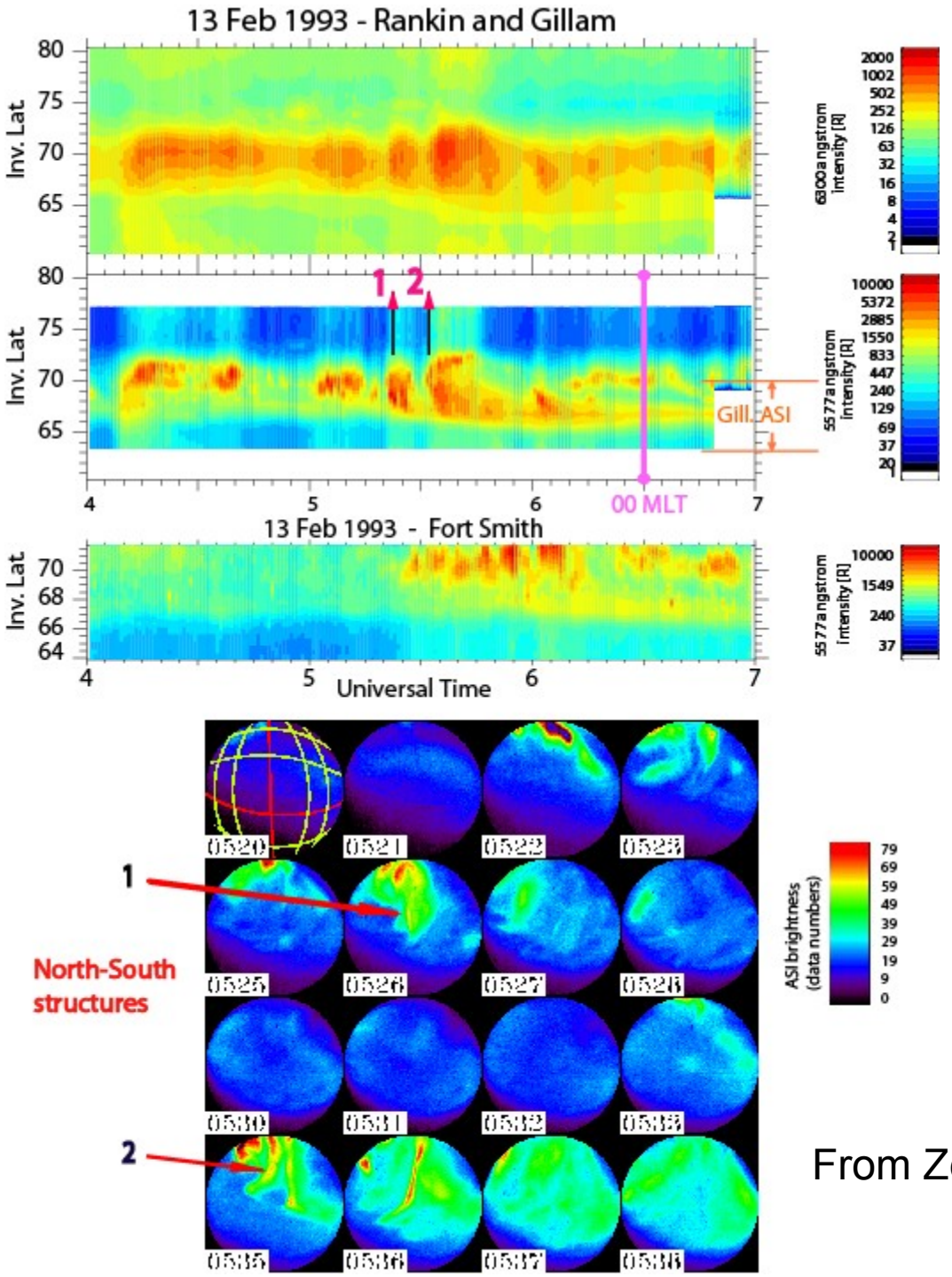
From Zesta et al. [2000]

Jan 7, 1997 – GEOTAIL

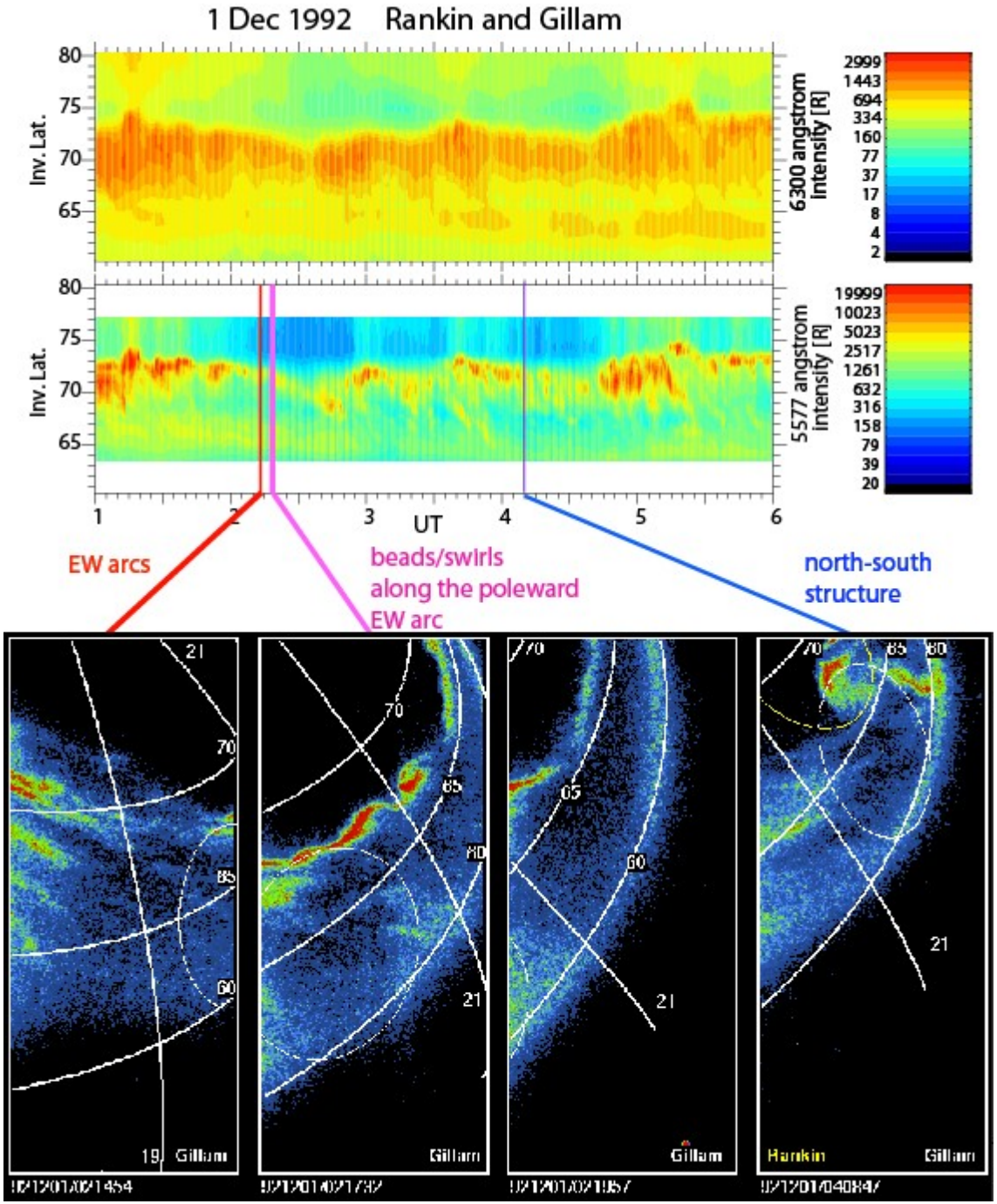




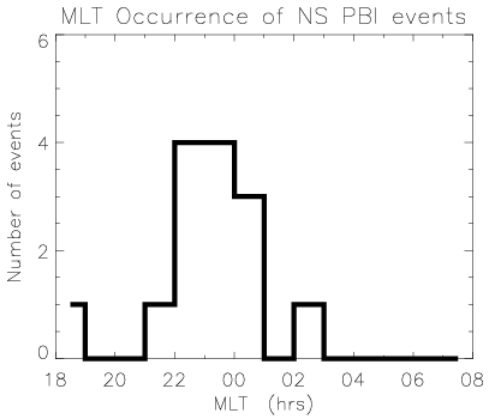
From Zesta et al. [2000]

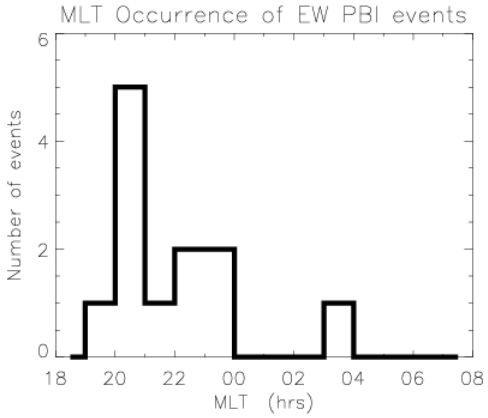


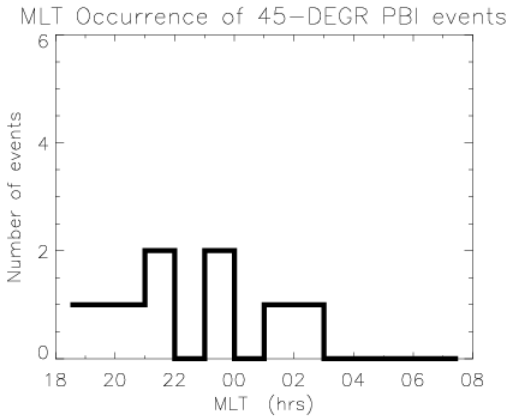
From Zesta et al. [2002]

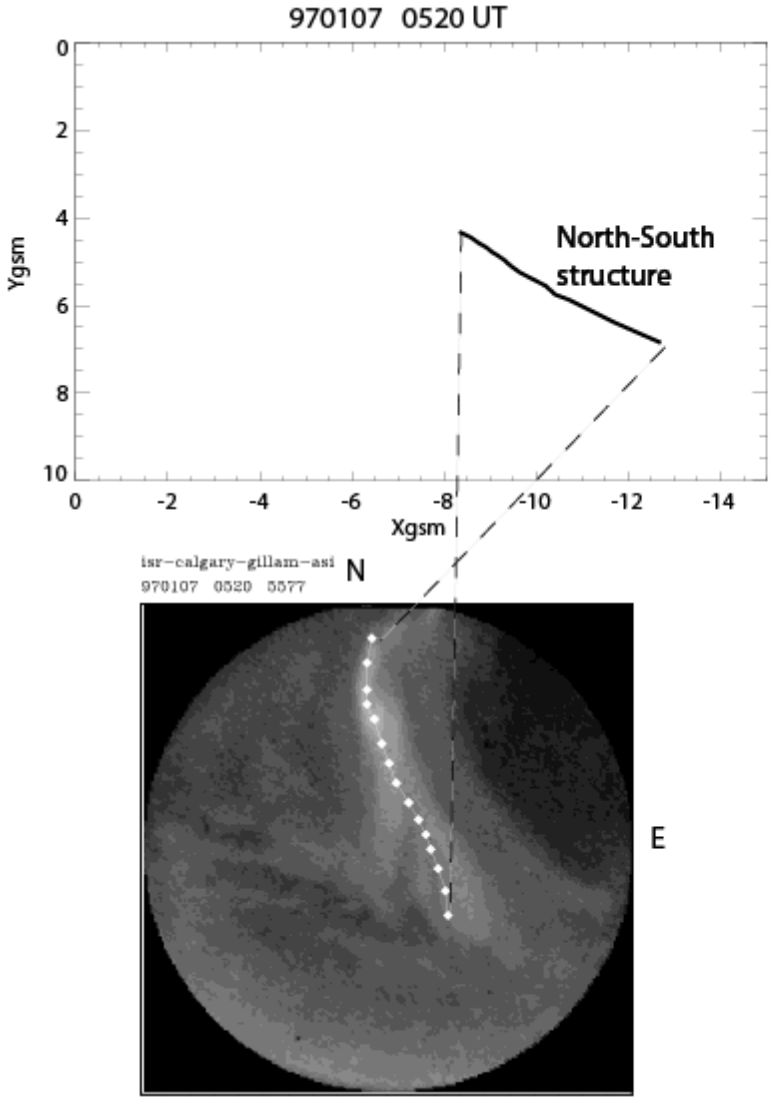


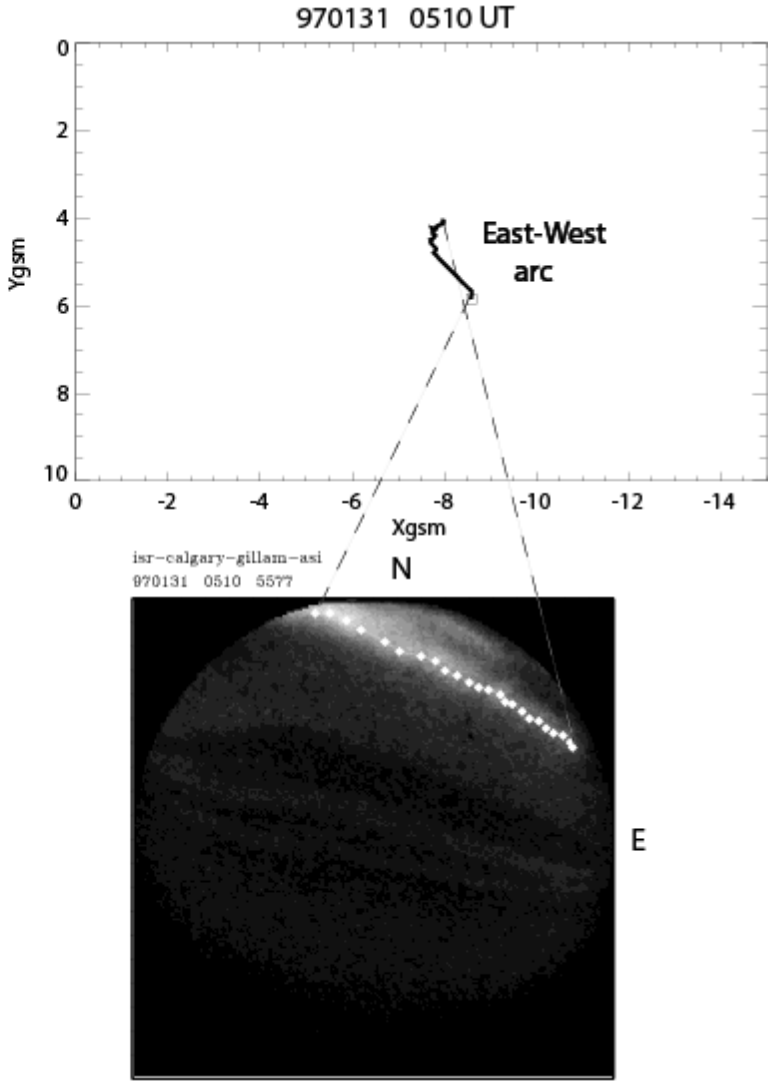
From Zesta et al. [2002]


MLT Occurrence of NS PBI events
Number of events
0
2
4
6
18
20
22
00
02
04
06
08
MLT (hrs)

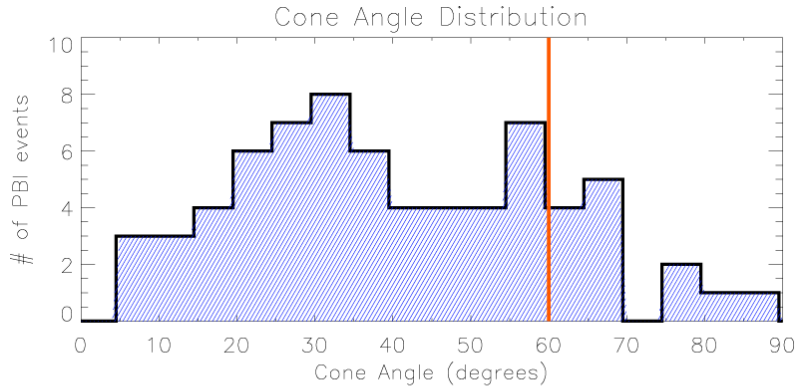

MLT Occurrence of EW PBI events
Number of events
0
2
4
6
18
20
22
00
02
04
06
08
MLT (hrs)

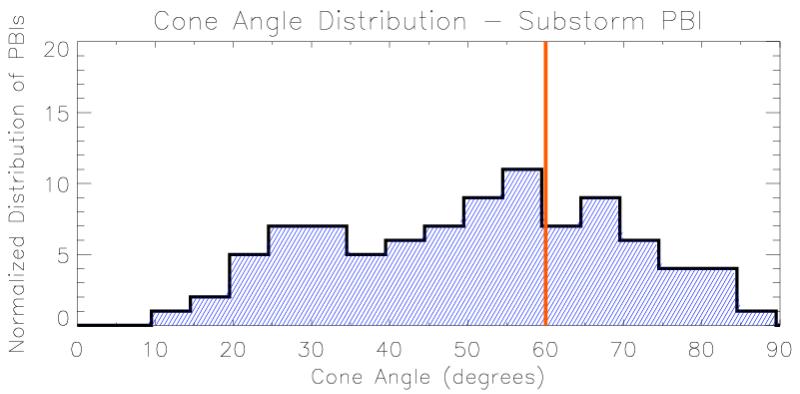

MLT Occurrence of 45-DEGR PBI events
Number of events
0
2
4
6
18
20
22
00
02
04
06
08
MLT (hrs)

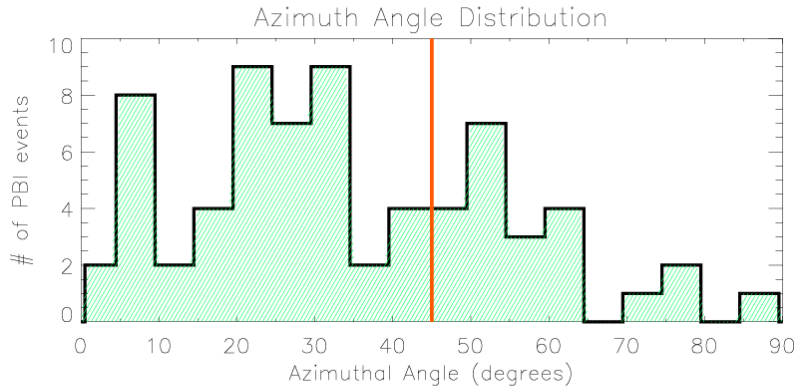


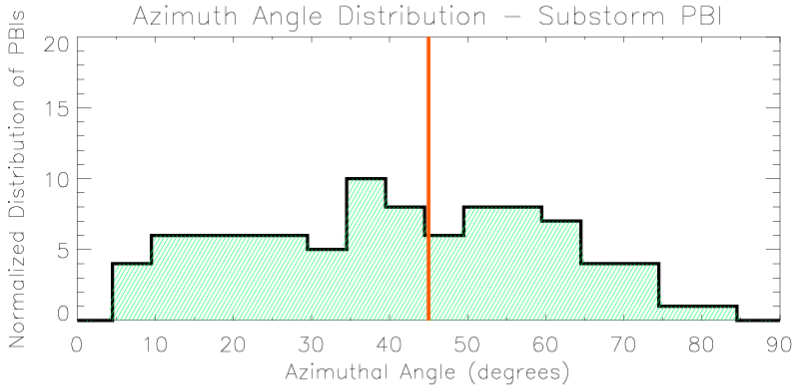


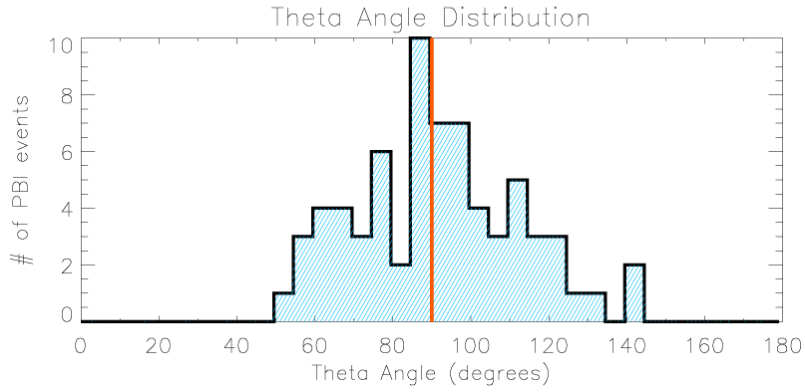
From Zesta et al. [2002]

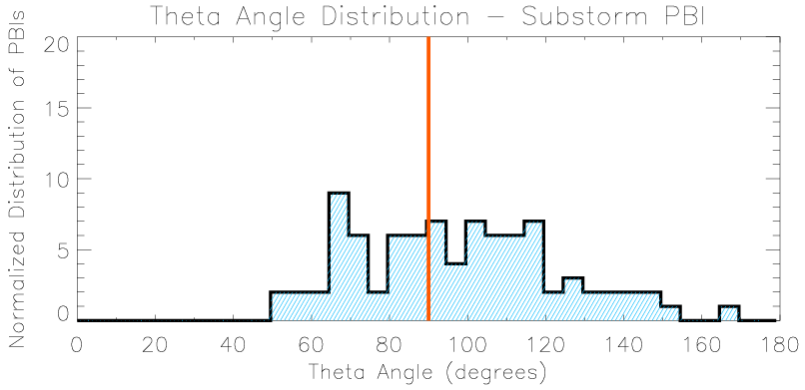

Cone Angle Distribution
# of PBI events
Cone Angle (degrees)

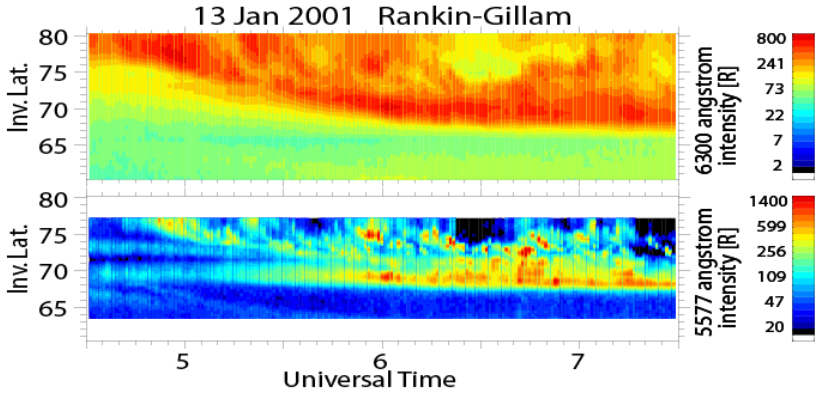

Cone Angle Distribution – Substorm PBI
Normalized Distribution of PBIs
Cone Angle (degrees)


Azimuth Angle Distribution
# of PBI events
Azimuthal Angle (degrees)

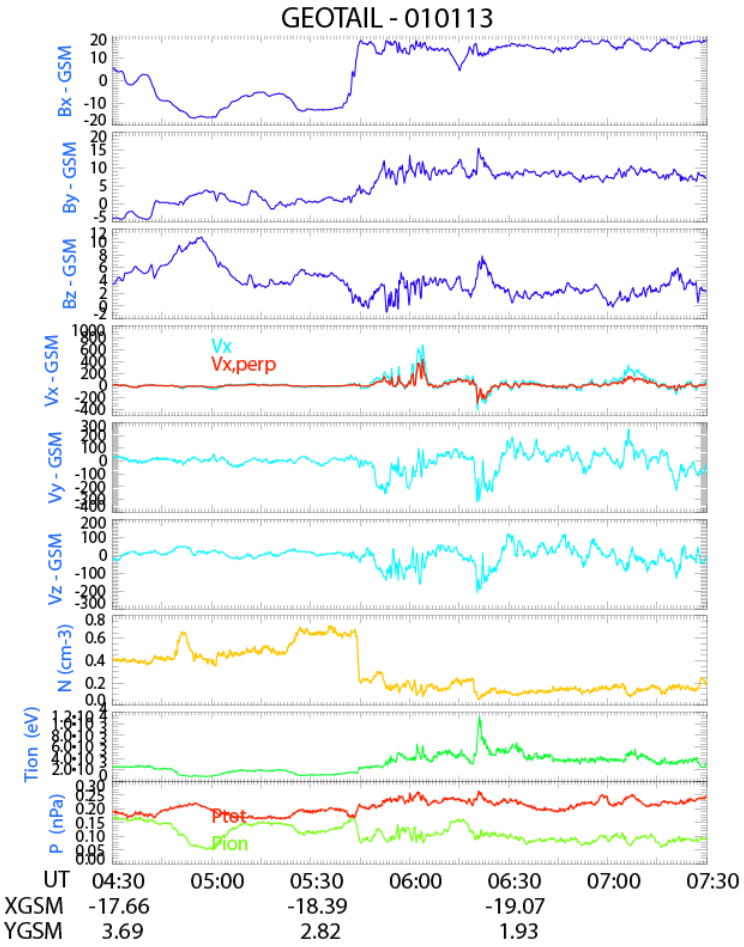

Azimuth Angle Distribution – Substorm PBI
Normalized Distribution of PBIs
Azimuthal Angle (degrees)

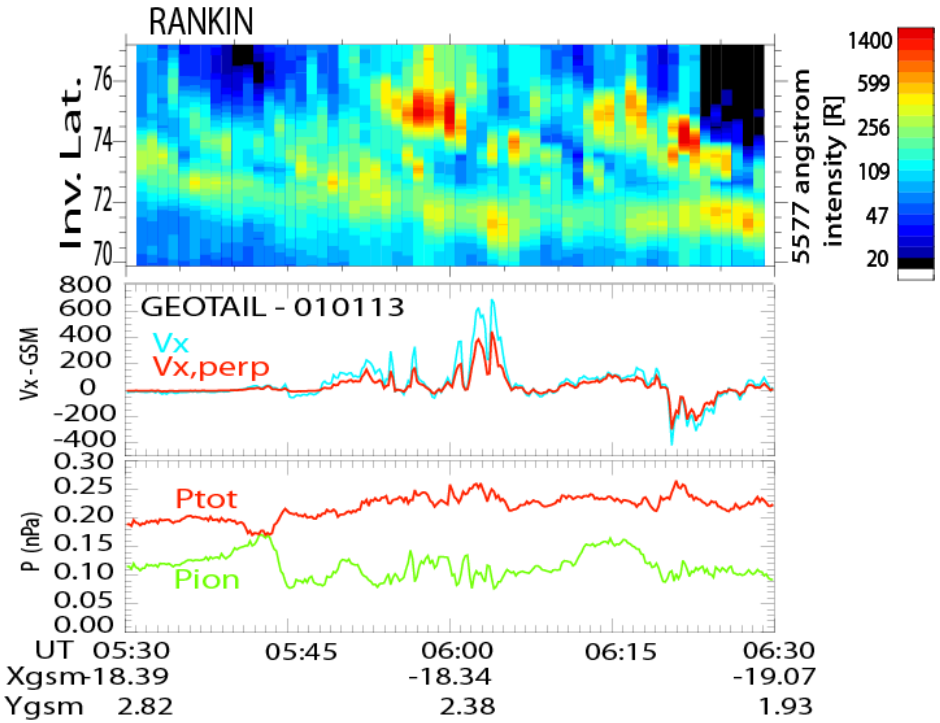

Theta Angle Distribution
# of PBI events
Theta Angle (degrees)


Theta Angle Distribution – Substorm PBI
Normalized Distribution of PBIs
Theta Angle (degrees)

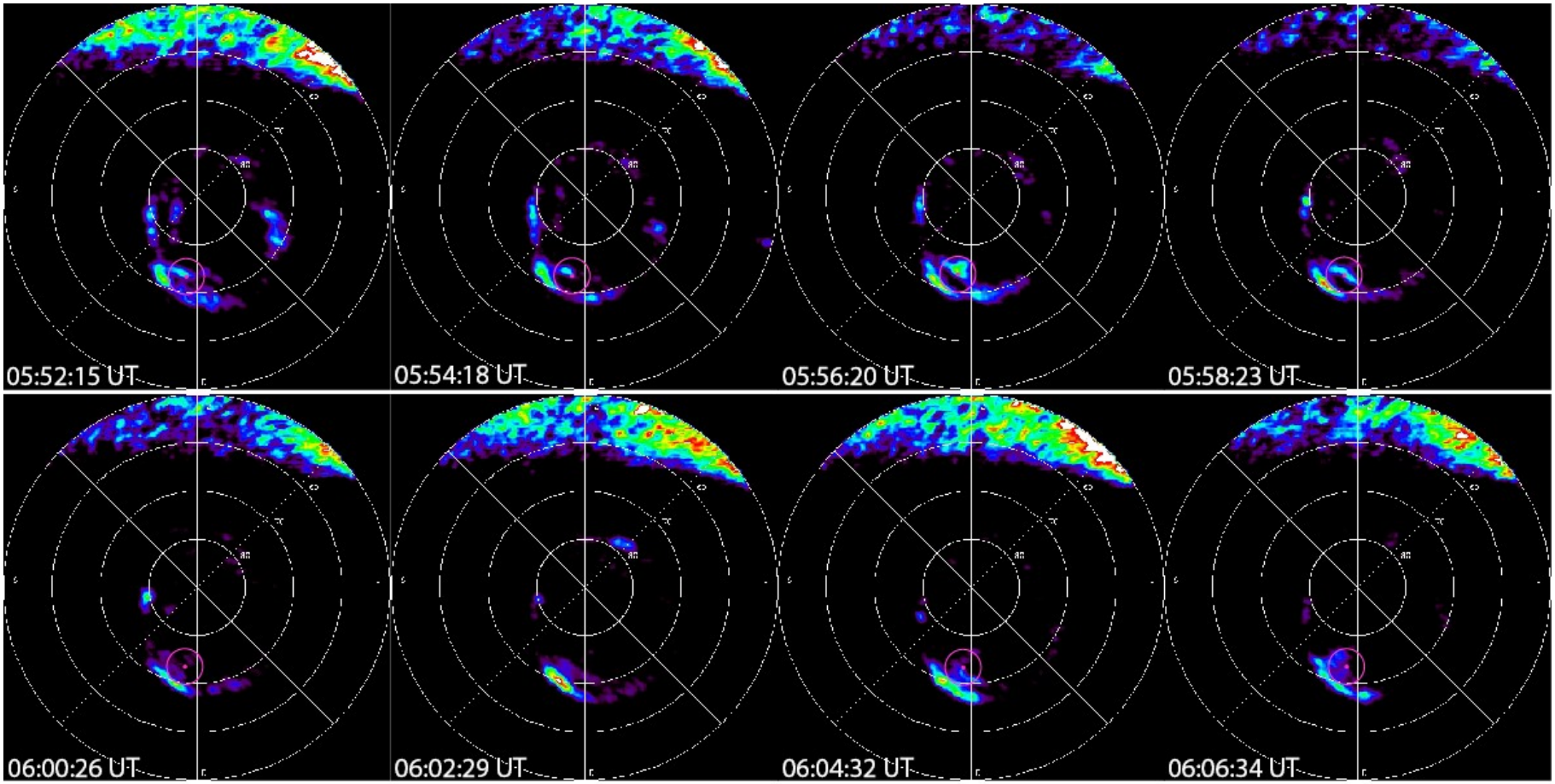


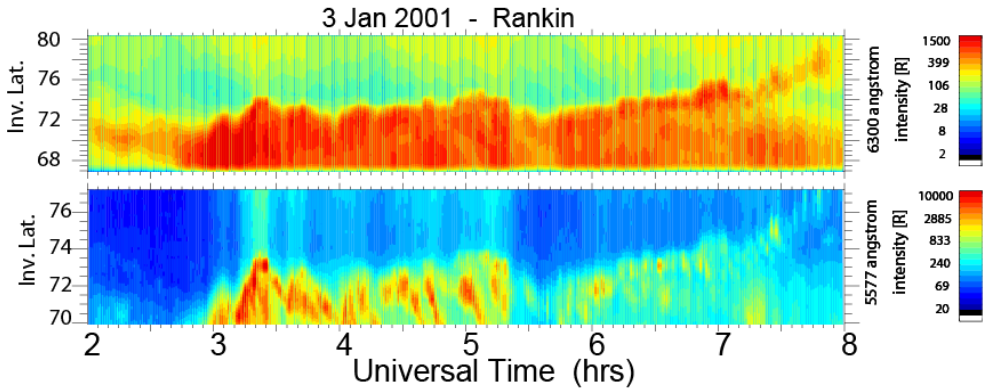
IMF Bz northward during this interval

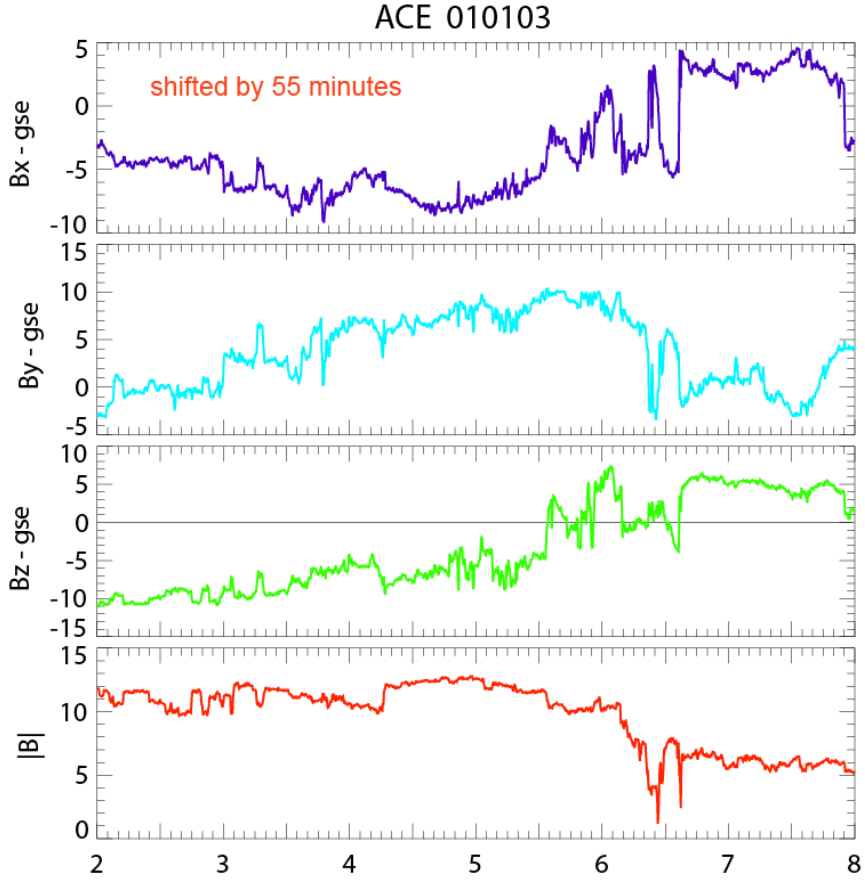


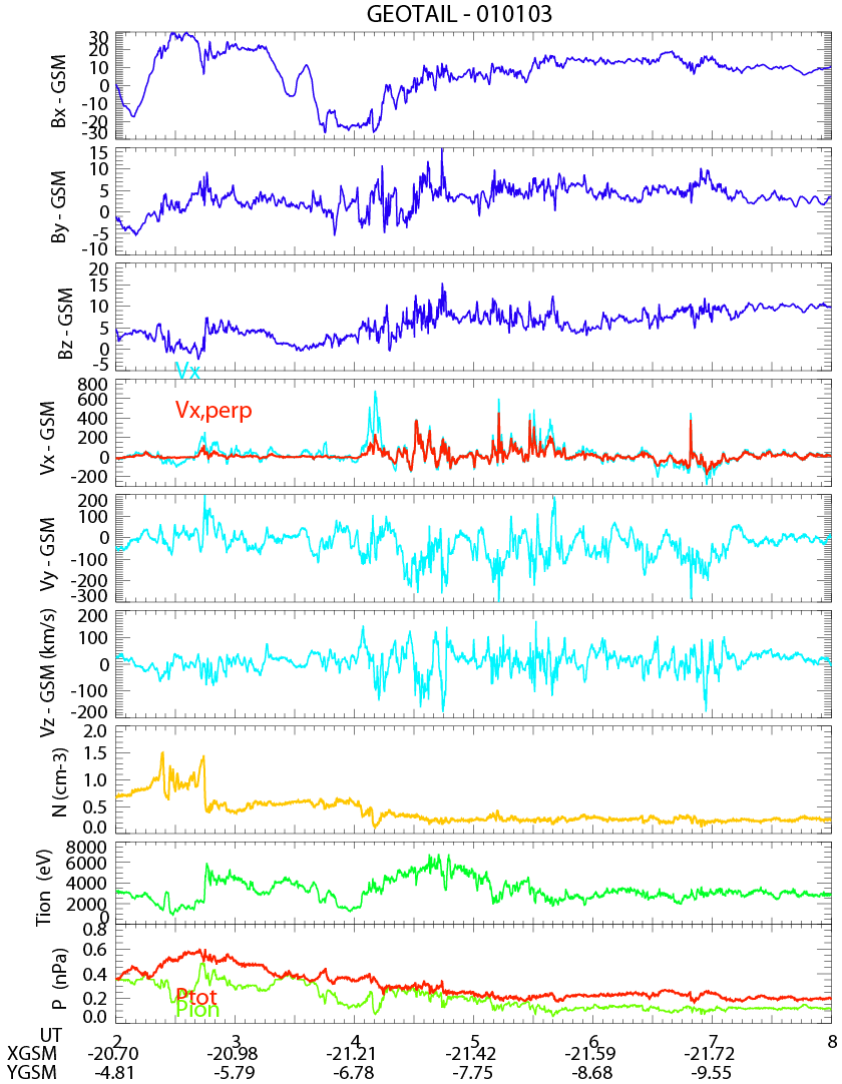


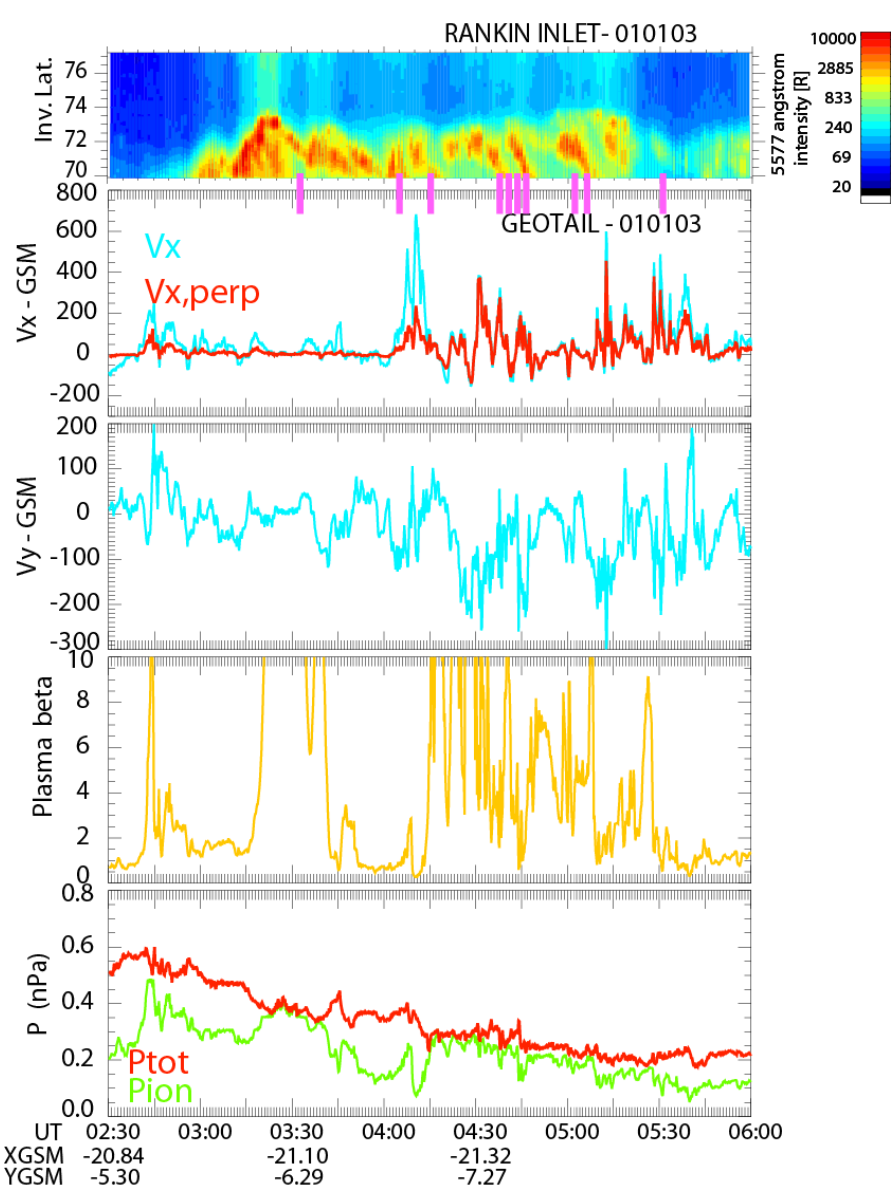
Jan 13, 2001 – FUV images

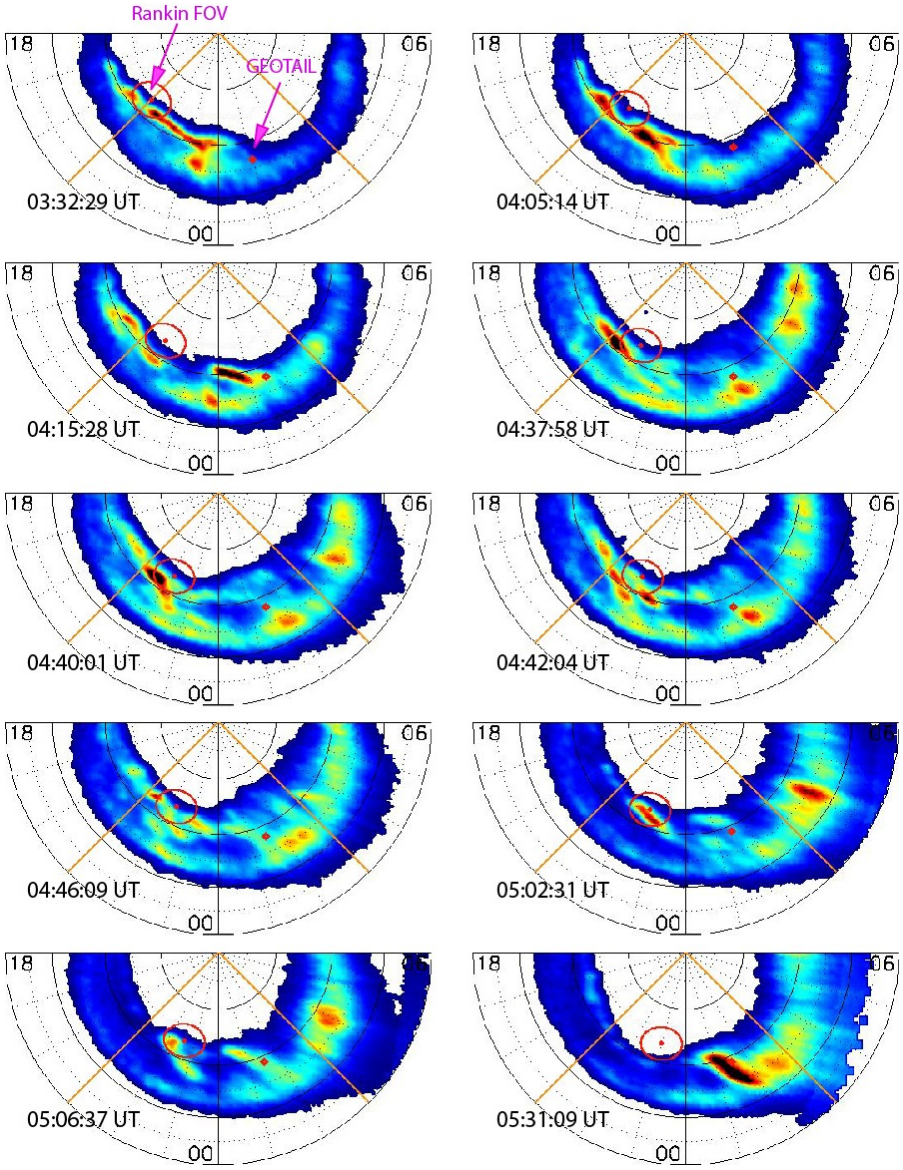


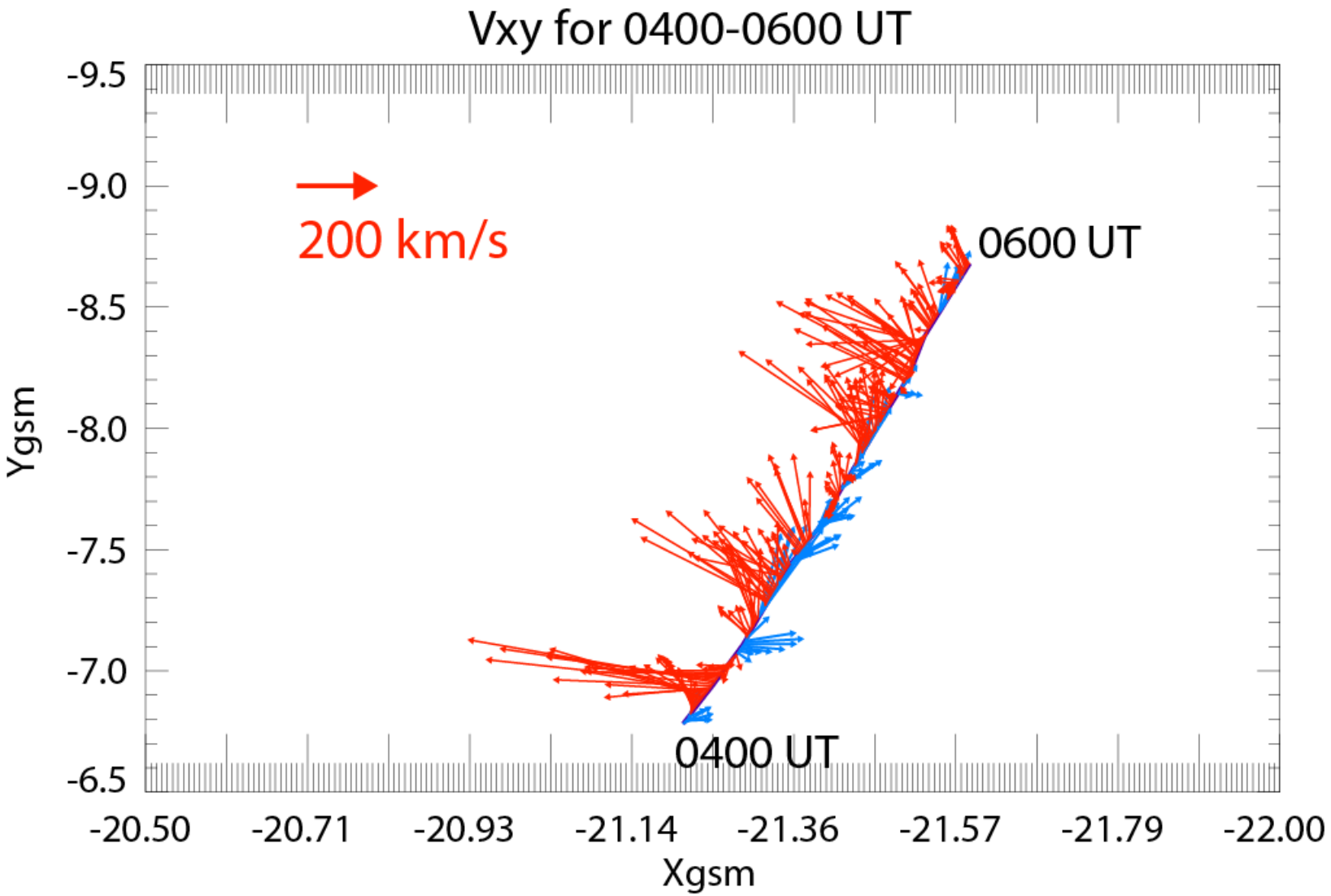

3 Jan 2001 - Rankin
Inv. Lat.
80
76
72
68
6300 angstrom intensity [R]
1500
399
106
28
8
2
Inv. Lat.
76
74
72
70
5577 angstrom intensity [R]
10000
2885
833
240
69
20
2
3
4
5
6
7
8
Universal Time (hrs)

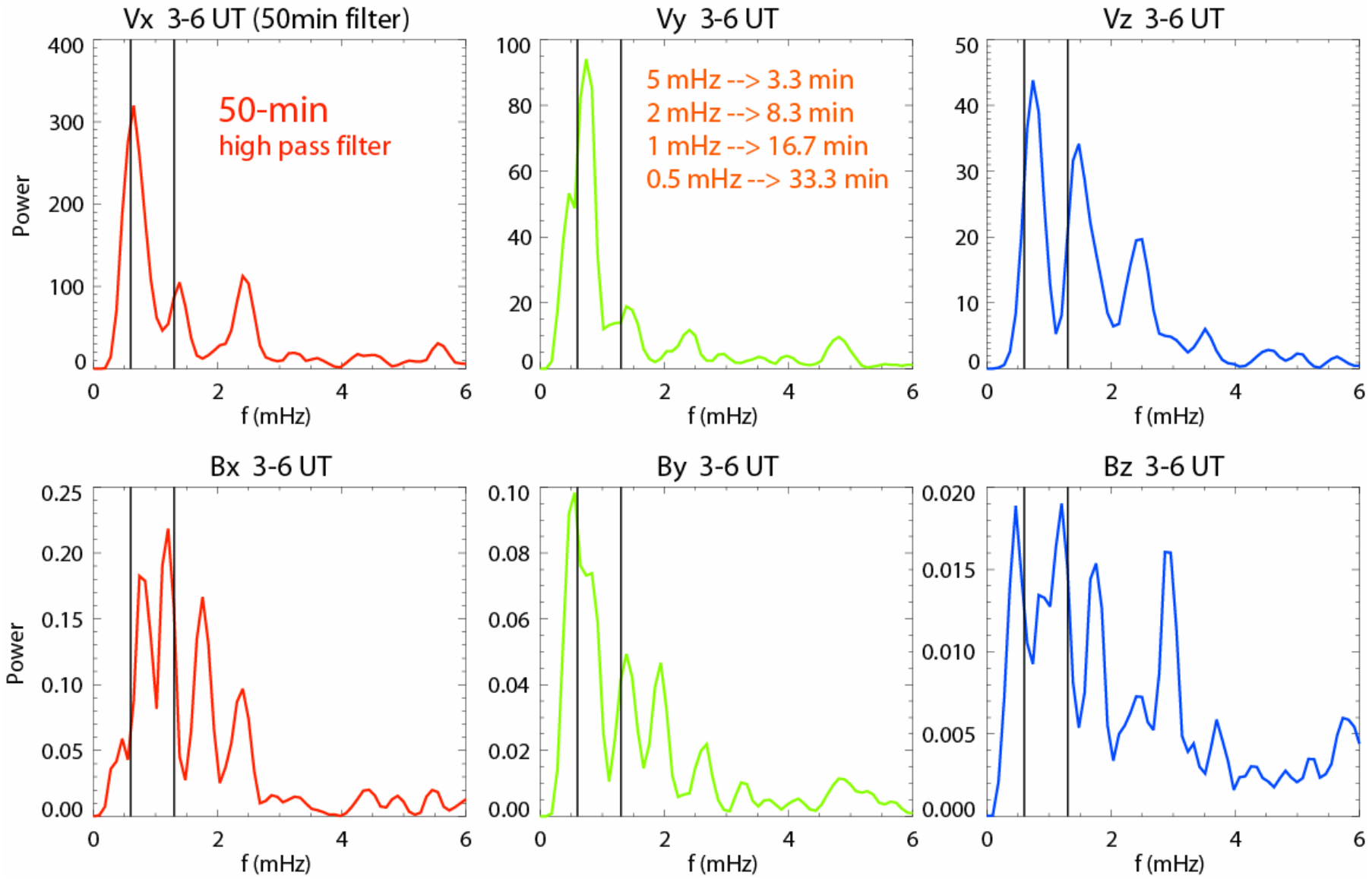

ACE 010103
shifted by 55 minutes
Bx - gse
By - gse
Bz - gse
|B|
2
3
4
5
6
7
8


GEOTAIL - 010103
Bx - GSM
By - GSM
Bz - GSM
Vx
Vx,perp
Vx - GSM
Vy - GSM
Vz - GSM (km/s)
N (cm-3)
Tion (eV)
Ptot
Pion
P (nPa)
UT
2
3
4
5
6
7
8
XGSM -20.70 -20.98 -21.21 -21.42 -21.59 -21.72
YGSM -4.81 -5.79 -6.78 -7.75 -8.68 -9.55

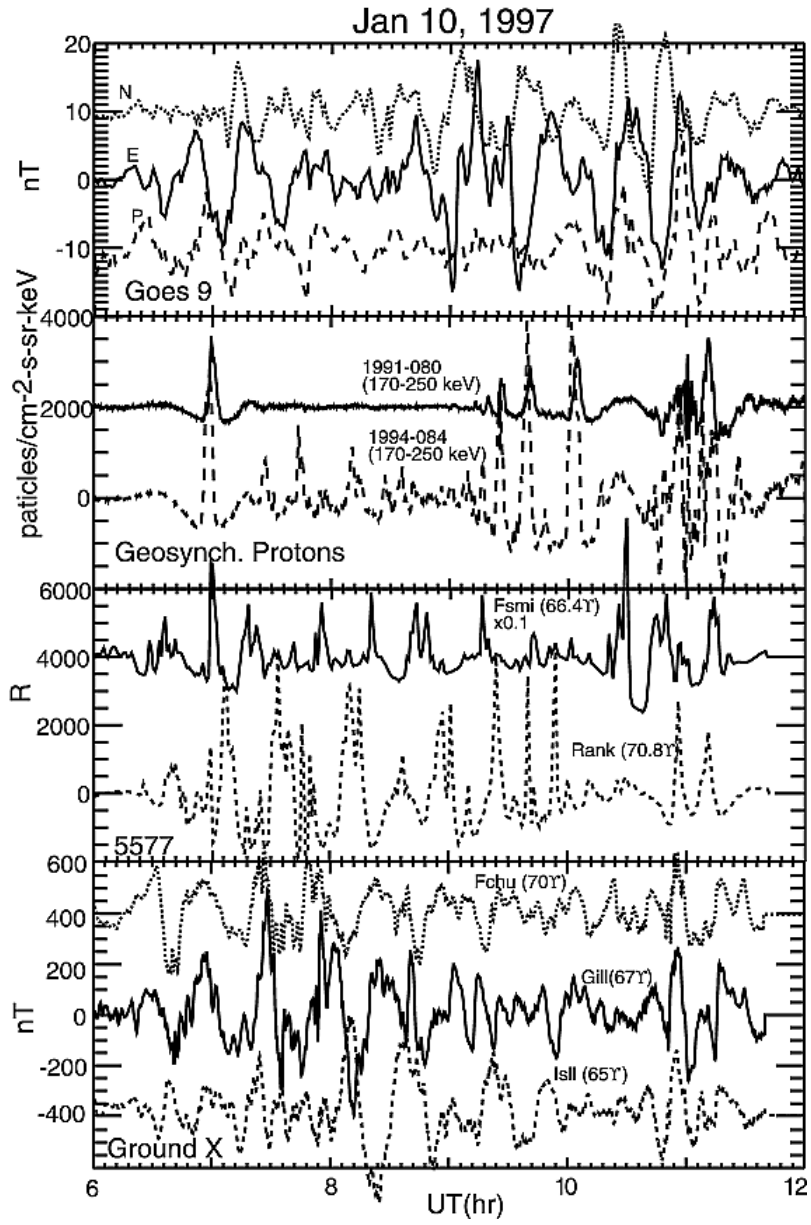

RANKIN INLET- 010103
Inv. Lat.
76
74
72
70
10000
2885
833
240
69
20
5577 angstrom intensity [R]
GEOTAIL - 010103
Vx
Vx,perp
Vx - GSM
800
600
400
200
0
-200
Vy - GSM
200
100
0
-100
-200
-300
Plasma beta
10
8
6
4
2
0
P (nPa)
0.8
0.6
0.4
0.2
0.0
Ptot
Pion
UT 02:30 03:00 03:30 04:00 04:30 05:00 05:30 06:00
XGSM -20.84 -21.10 -21.32
YGSM -5.30 -6.29 -7.27


Rankin FOV
GEOTAIL
18
06
00
03:32:29 UT
04:05:14 UT
04:15:28 UT
04:37:58 UT
04:40:01 UT
04:42:04 UT
04:46:09 UT
05:02:31 UT
05:06:37 UT
05:31:09 UT


Vxy for 0400-0600 UT
200 km/s
0600 UT
0400 UT
-9.5
-9.0
-8.5
-8.0
-7.5
-7.0
-6.5
Ygsm
-20.50
-20.71
-20.93
-21.14
-21.36
-21.57
-21.79
-22.00
Xgsm

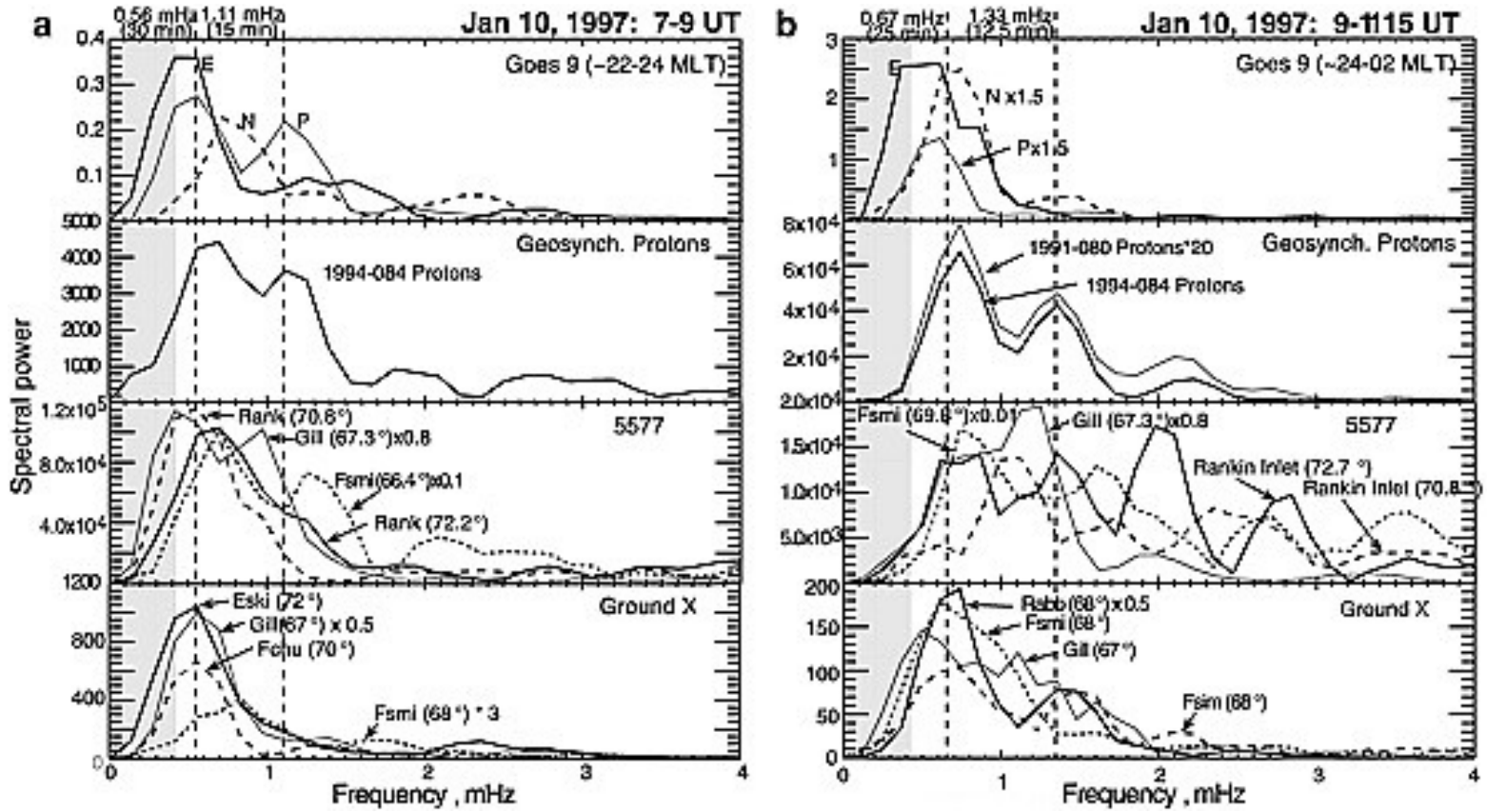


Look into Lyons et al. [2002]



From Lyons et al. [2002]

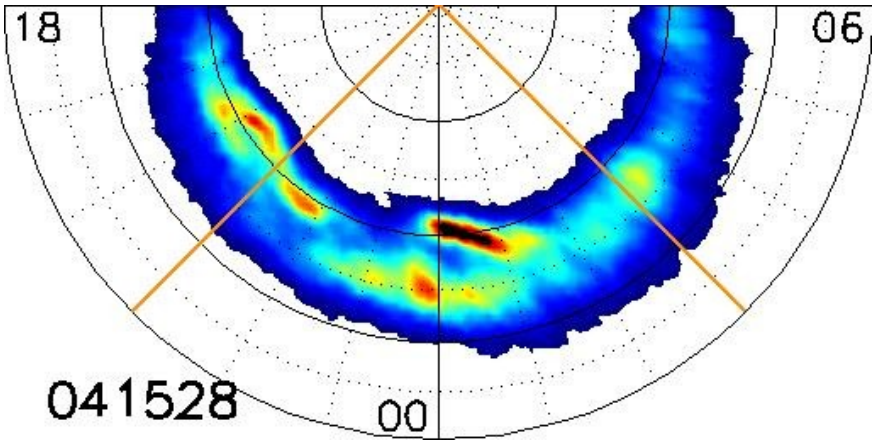
Examples of high-pass filtered data used to make the power spectra for 0600–1200 UT during period 1. The filter had a low-frequency limit of 0.417 mHz (40 min period).

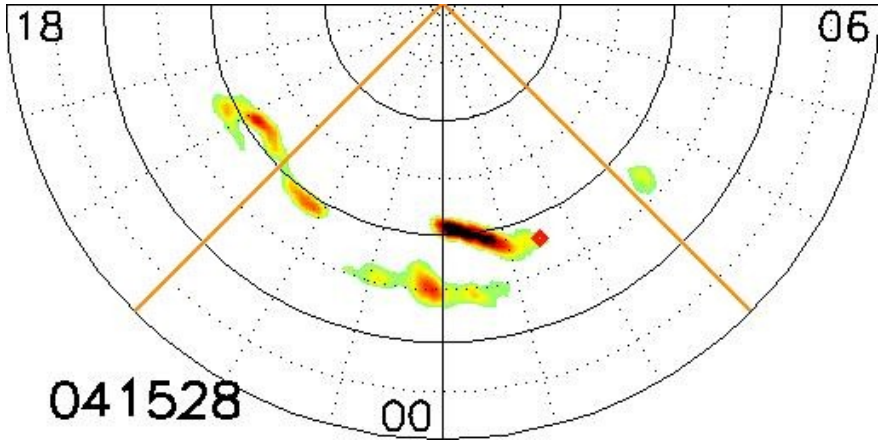


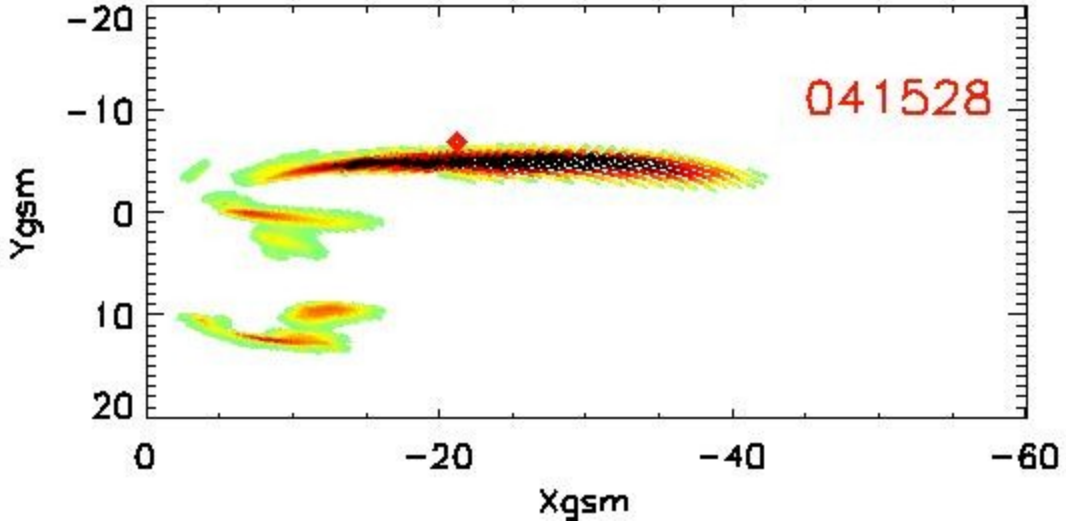
From Lyons et al. [2002]

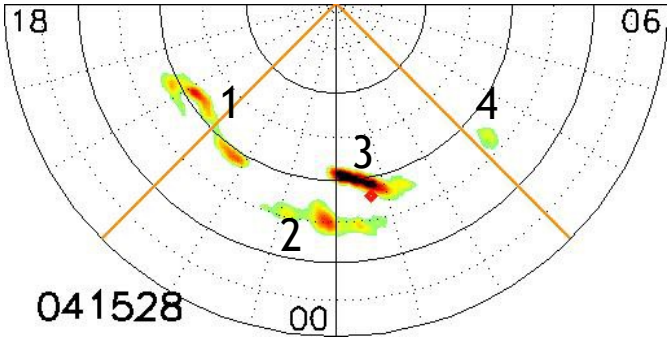
Power spectra from GOES, LANL, ground photometer, and ground magnetometer

Tail projection of PBIs during the 010103 event





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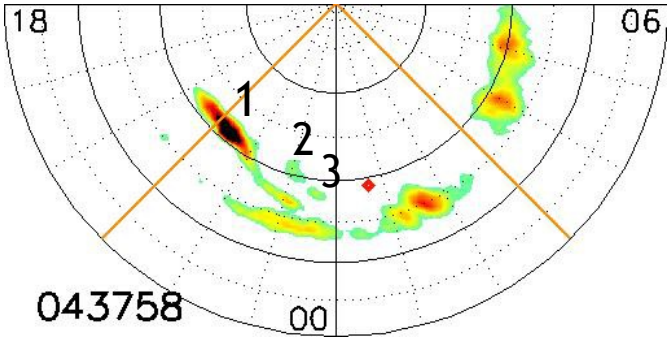
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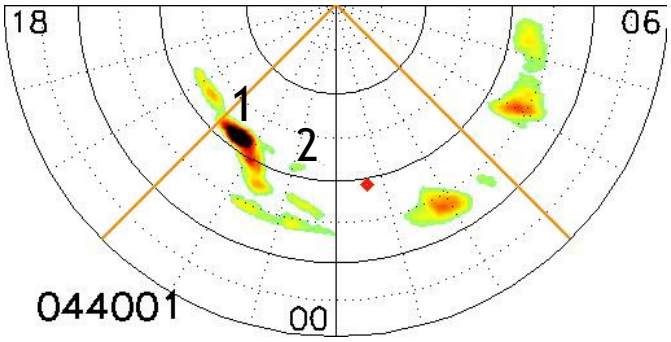
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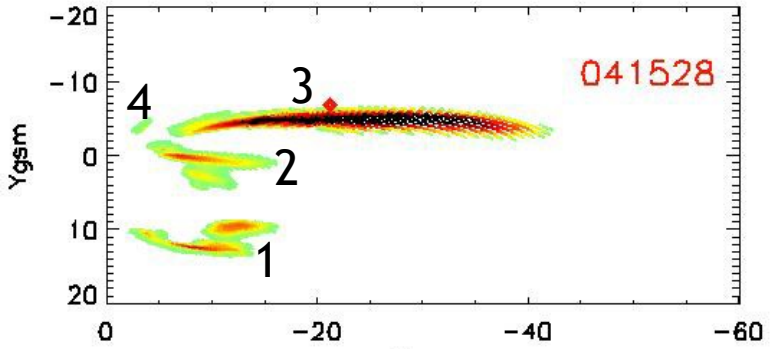
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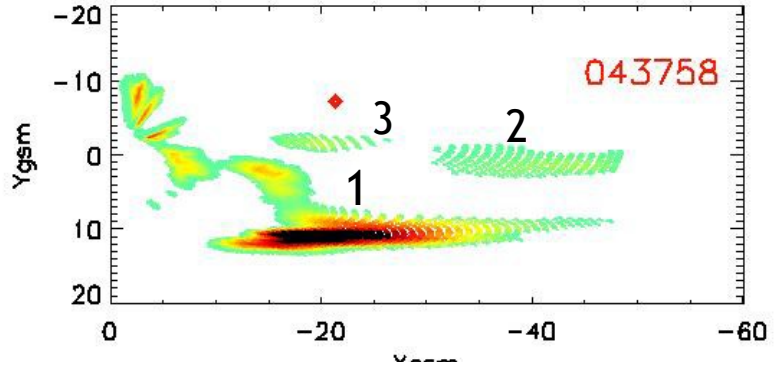
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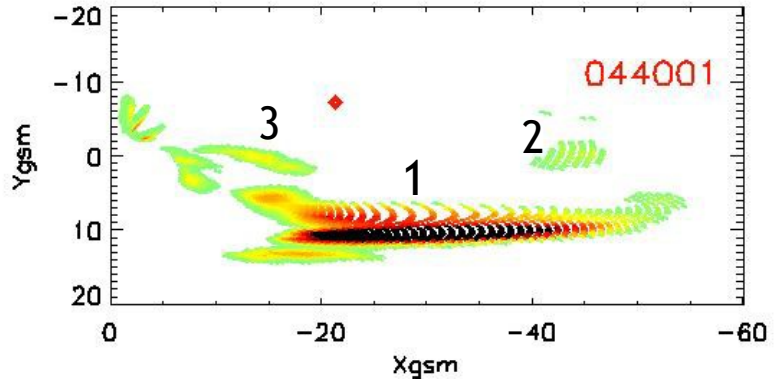
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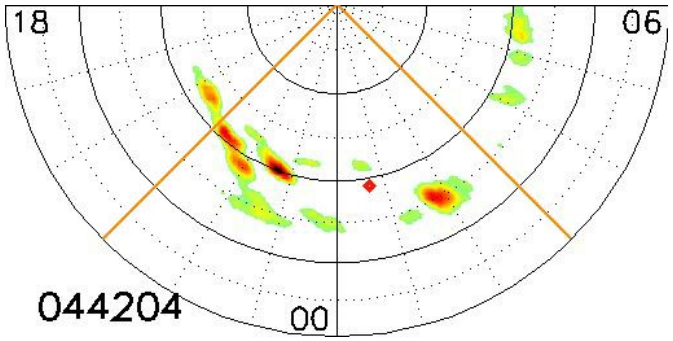
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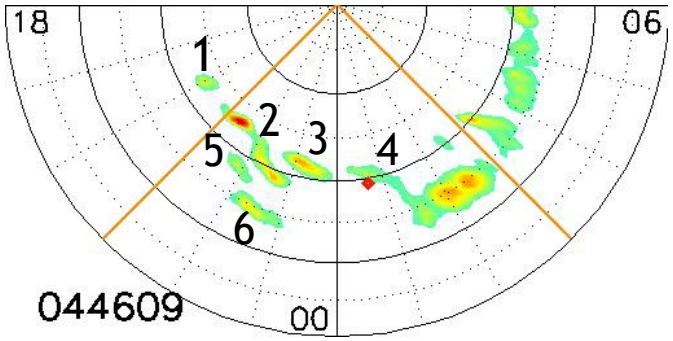
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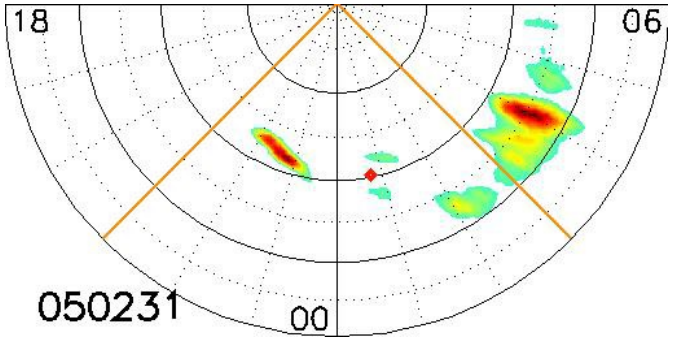
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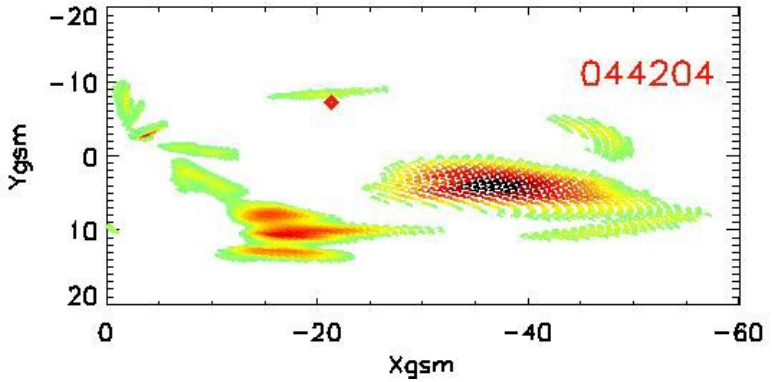
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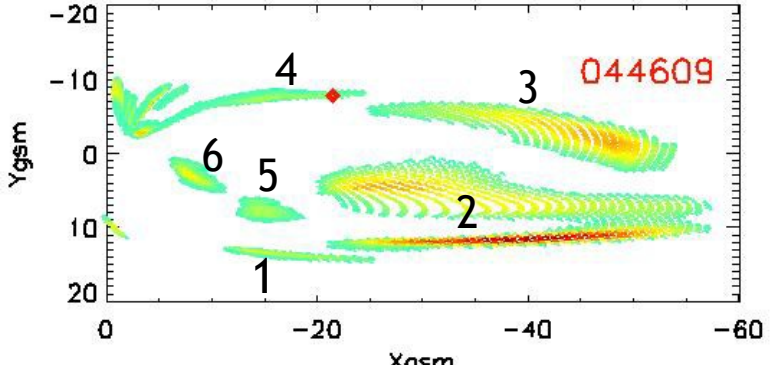
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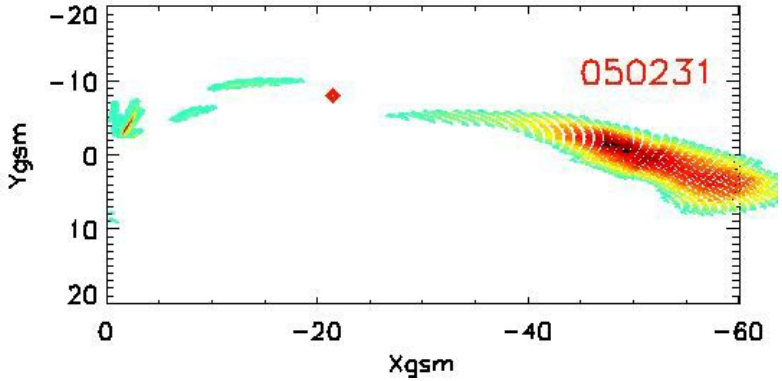
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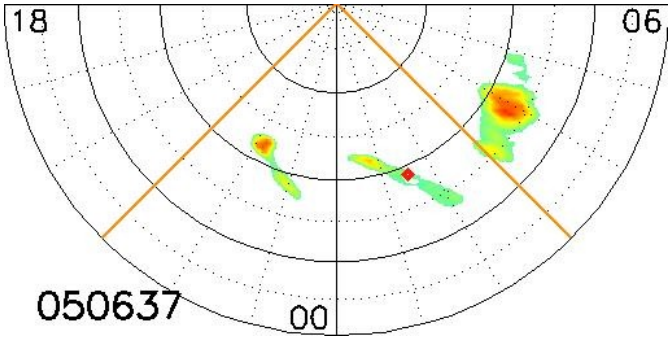
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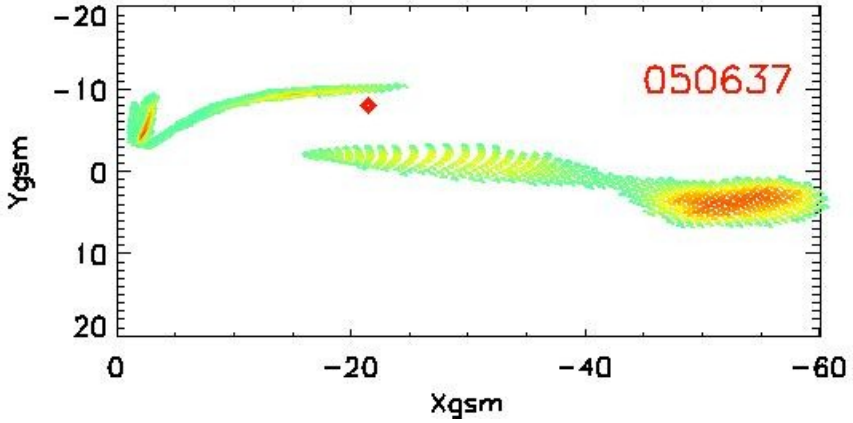
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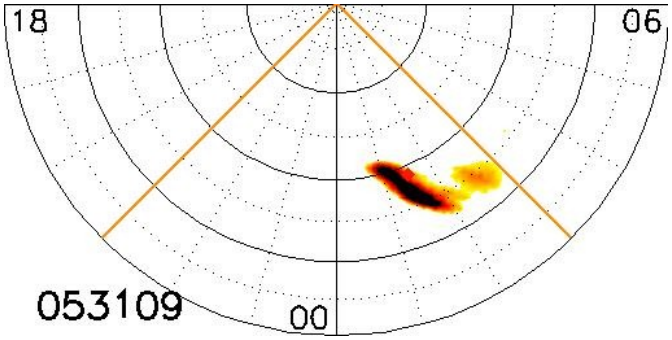
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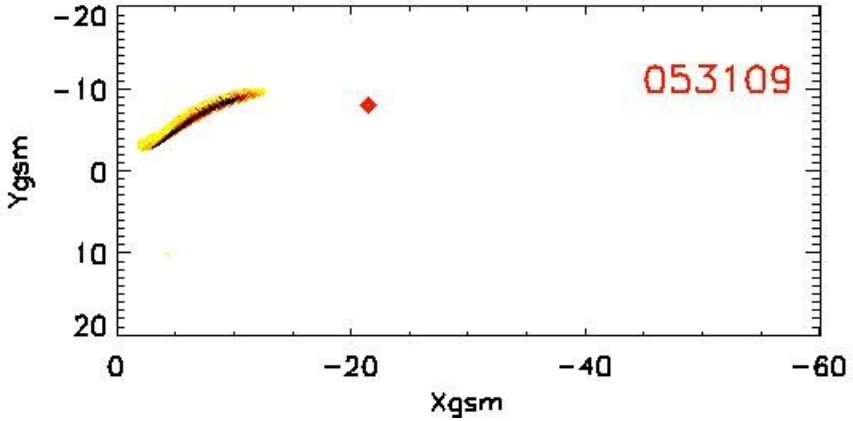
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SUMMARY OF 010103 EVENT

- PBIs correlate well with plasma sheet fast flows observed within the local time sector of the PBIs. Where PBIs are not seen no fast flows are seen either.
  - Multiple PBIs can occur over the whole width of the plasma sheet or in a more restricted local sector.

- Most PBIs observed with IMAGE are EW arcs that initiate near the poleward boundary and then propagate equatorward. They often tilt and become ~NS structures as they propagate equatorward.
  - There is local time dependence for PBIs. Most are narrow structures aligned with the 02 to 17 MLT line. Thus PBIs are seen as NS in the postmidnight sector and EW in the dusk sector.

- Suggests that same dynamics produce EW and NS structures.

- Large Vy velocities that exist during the PBI fast flows may be the result of the tail convection (earthward and dawnward) during positive IMF By. This likely explains the alignment of PBIs in the ionosphere along the 02-17 MLT line and why PBIs start as EW and turn to NS structures. **However, projection of PBIs to tail with T96 shows only radially stretched channels.**

- Frequency analysis indicates the PBI/BBF period is characterized by oscillations in the velocity and magnetic field with frequencies of ~0.6 mHz and ~1.3-1.5 mHz. This oscillation in velocity is superposed in the background strong convection.