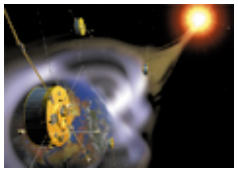

CLUSTER

The mid-altitude polar cusp as seen by Cluster

C. P. Escoubet[1], F. Pitout[2], J. Berchem[3], J. M. Bosqued[4], M. G. G. T. Taylor[1], K. J. Trattner[5], H. Laakso[1], A. Masson[1], M. Dunlop[6], I. Dandouras[4], H. Reme[4], A. Fazakerley[7]

[1]ESA/ESTEC (NL), [2]LPG (F), [3]UCLA/IGPP (USA), [4]CESR (F), [5]Lockheed Martin ATC, [6]RAL (UK), [7]MSSL (UK),

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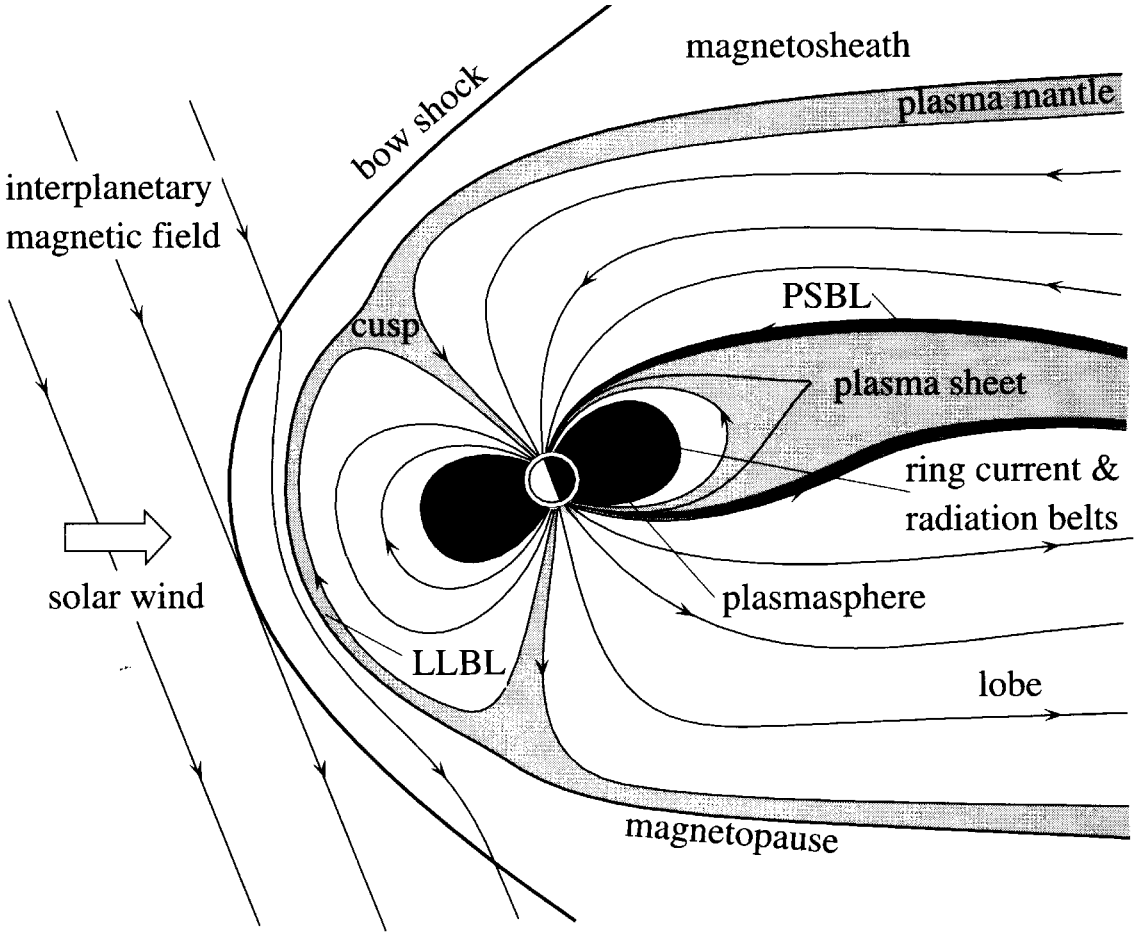

- Three examples of cusp crossings during IMF change:
  - IMF change from Bz negative to Bz positive
  - IMF change from Bz positive to Bz negative
  - IMF is northward and constant

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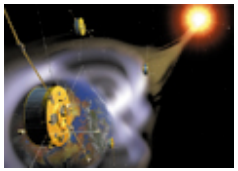

CLUSTER

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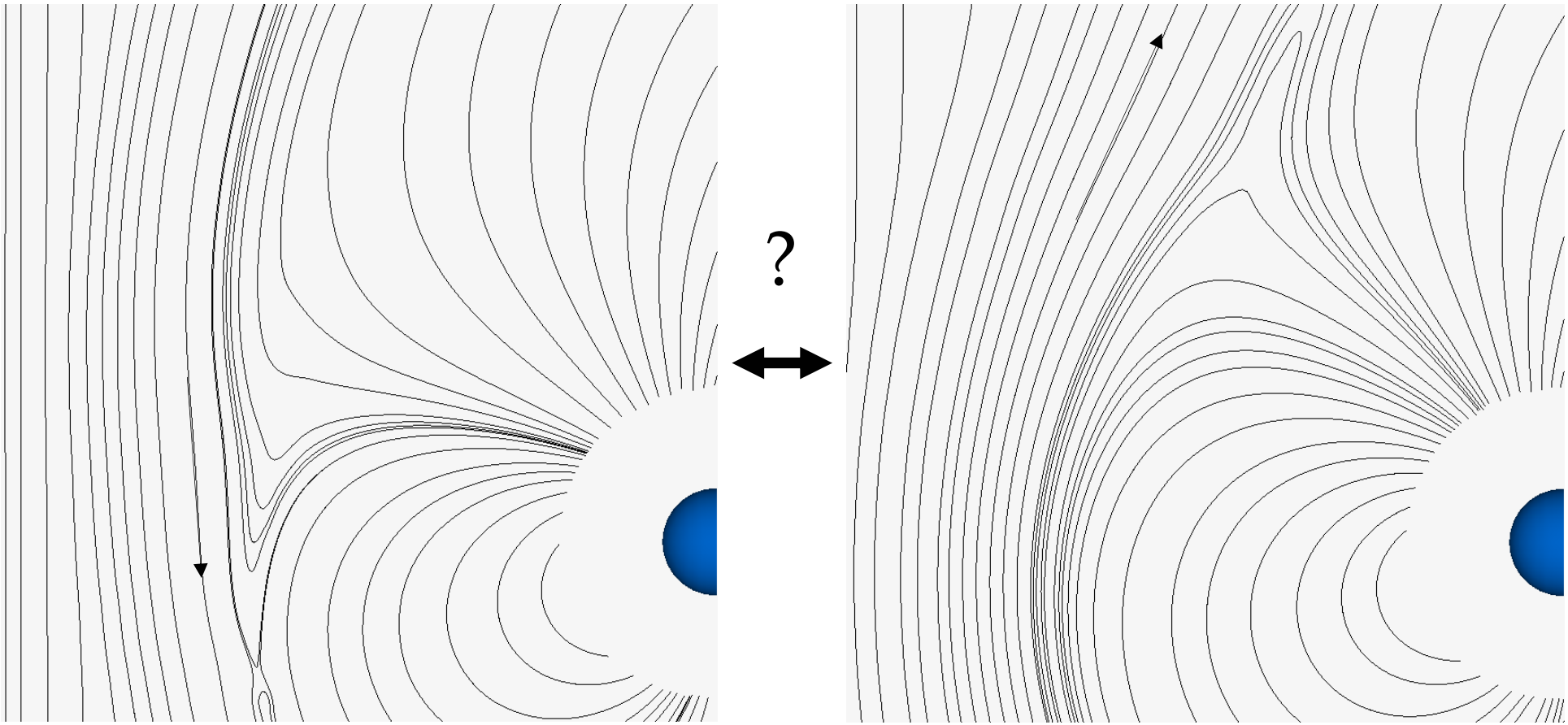
Change of IMF: effect on cusp



IMF Bz < 0 (MHD UCLA/IGPP model)

IMF Bz > 0

What is the intermediate state? IMF-By?

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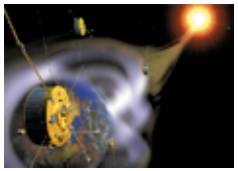
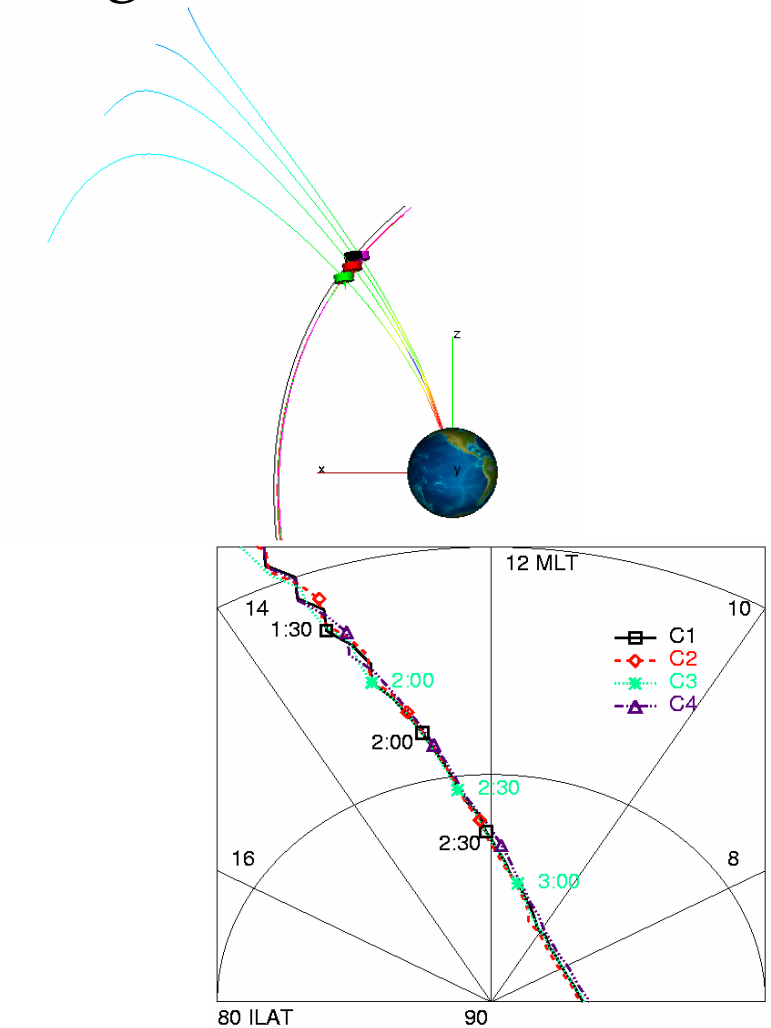


CLUSTER

7 Aug. 2004 02:10 UT



dt41=4 min, dt42=9 min, dt43=18min
dlat41=0.5º, dlat42=1.2º, dlat43=2.5º

Why using Cluster at mid-altitude to study the cusp:

- Four spacecraft following each other from a few minutes up to a few hours (separate temporal from spatial structures)
- Four spacecraft exactly on the same meridian: no MLT effect
- Very well equipped spacecraft: particles, fields and waves

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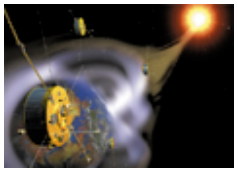
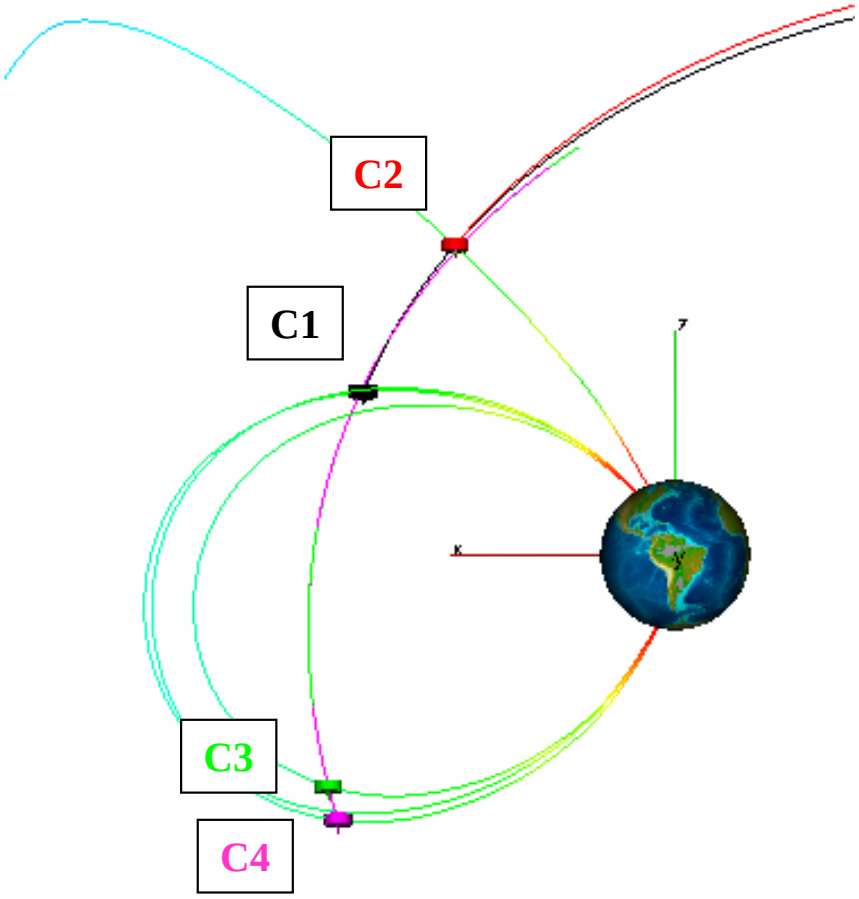


CLUSTER



2005

Spacecraft time delays at mid-altitude

Year	dt (min) 1st – 2nd	dt 1st– 3rd	dt 1st– 4th	Tetrahedron in tail (km)
2001	C42: 2	C41: 3	C43: 45	2000
2002	C12: 6	C14: 18	C13: 54	4000
2003	C13: 1	C12: 2	C14: 3	200
2004	C41: 2	C42: 7	C43: 13	1000
2005	C21: 60	C13: 120	C34: 12	1000-10000

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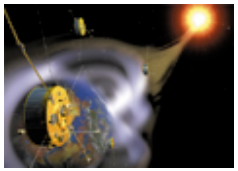
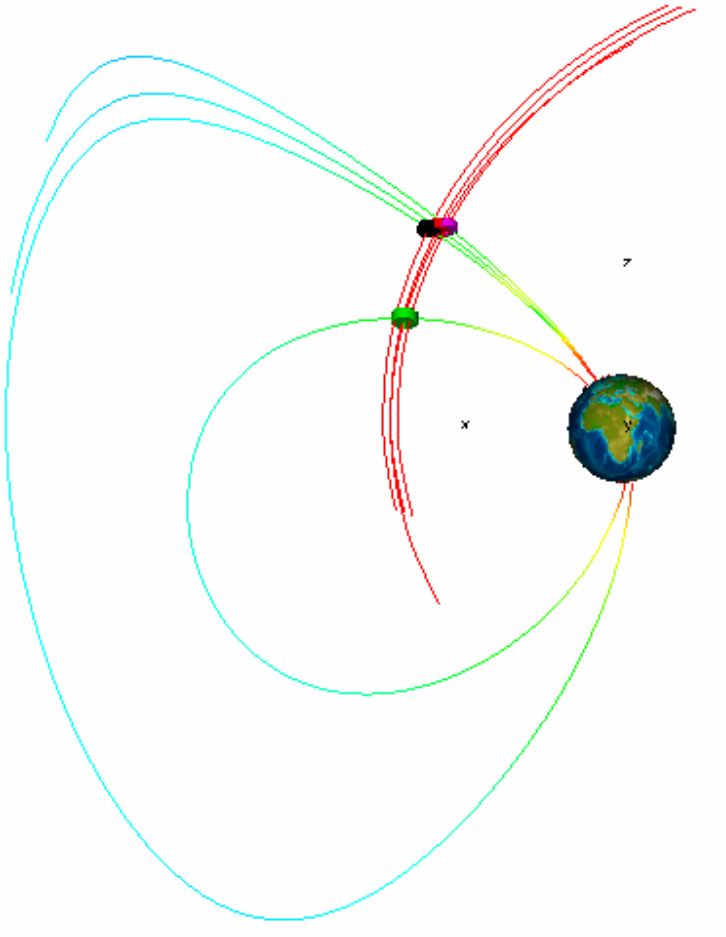
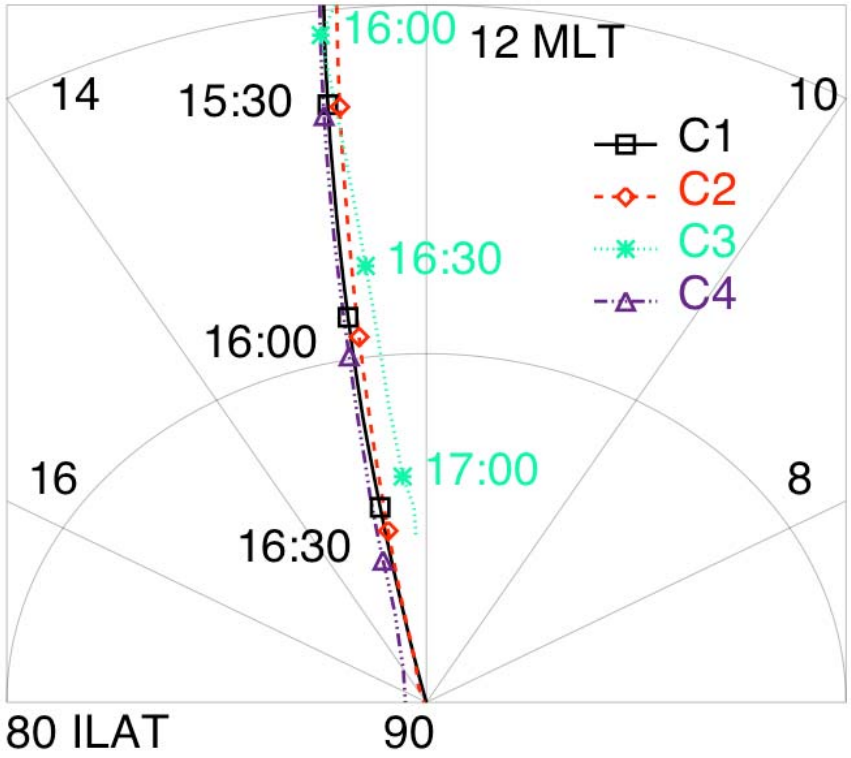


CLUSTER

1st cusp example : Bz <0 => Bz>0





dt41=2 min, dt42=5 min, dt43=41 min
dlat41=0.5°, dlat42=1.1°, dlat43=9.2°

30 Aug. 2001 16 UT Tsy87, KP=3

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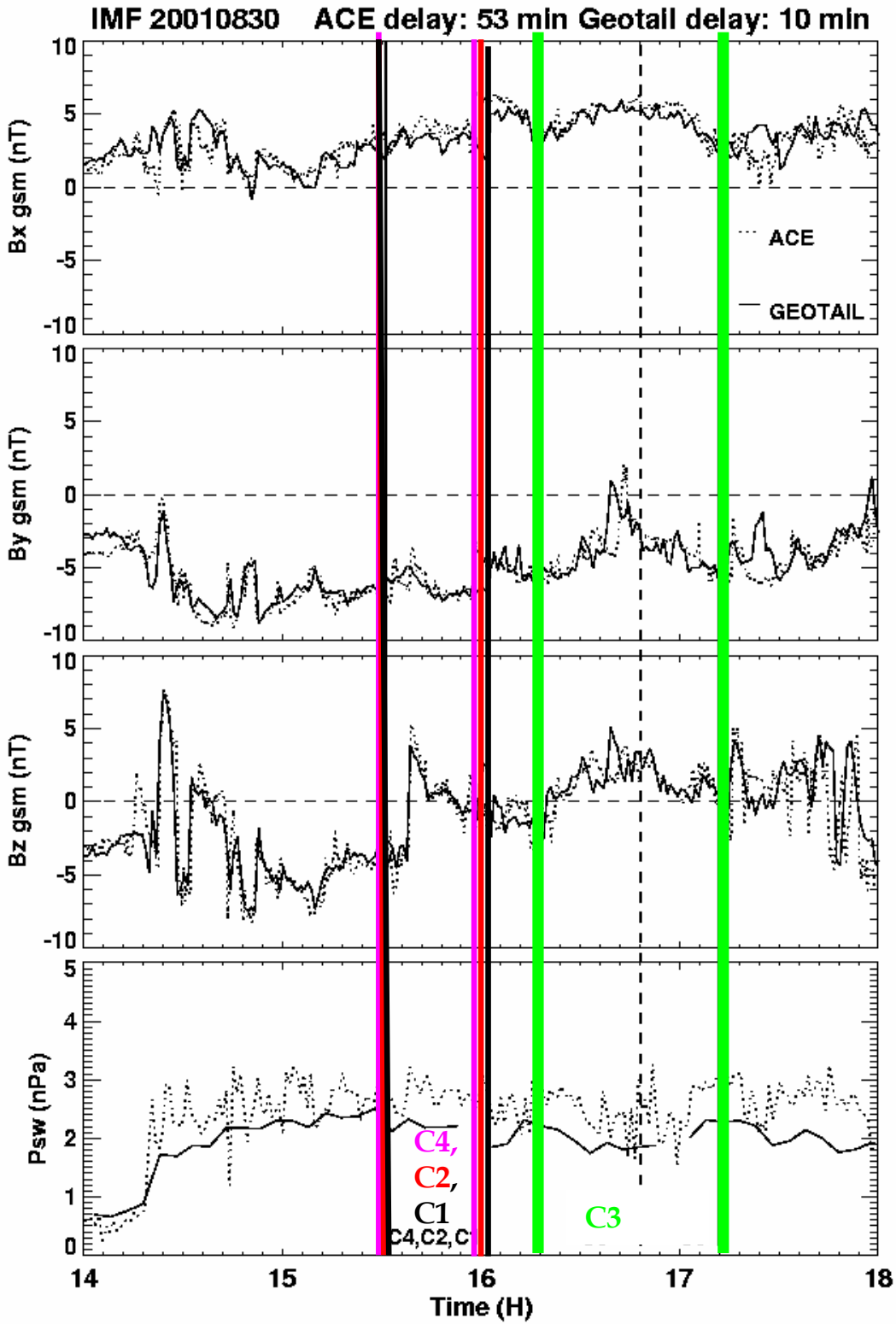

ACE (16UT)
X=234 Re
Y=-40 Re
Z=9 Re

Geotail
X=17 Re
Y=-12 Re
Z=-1 Re

N=6 cm-3
Psw=2.3 nPa

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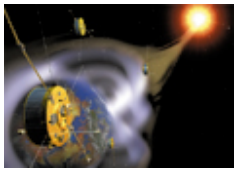
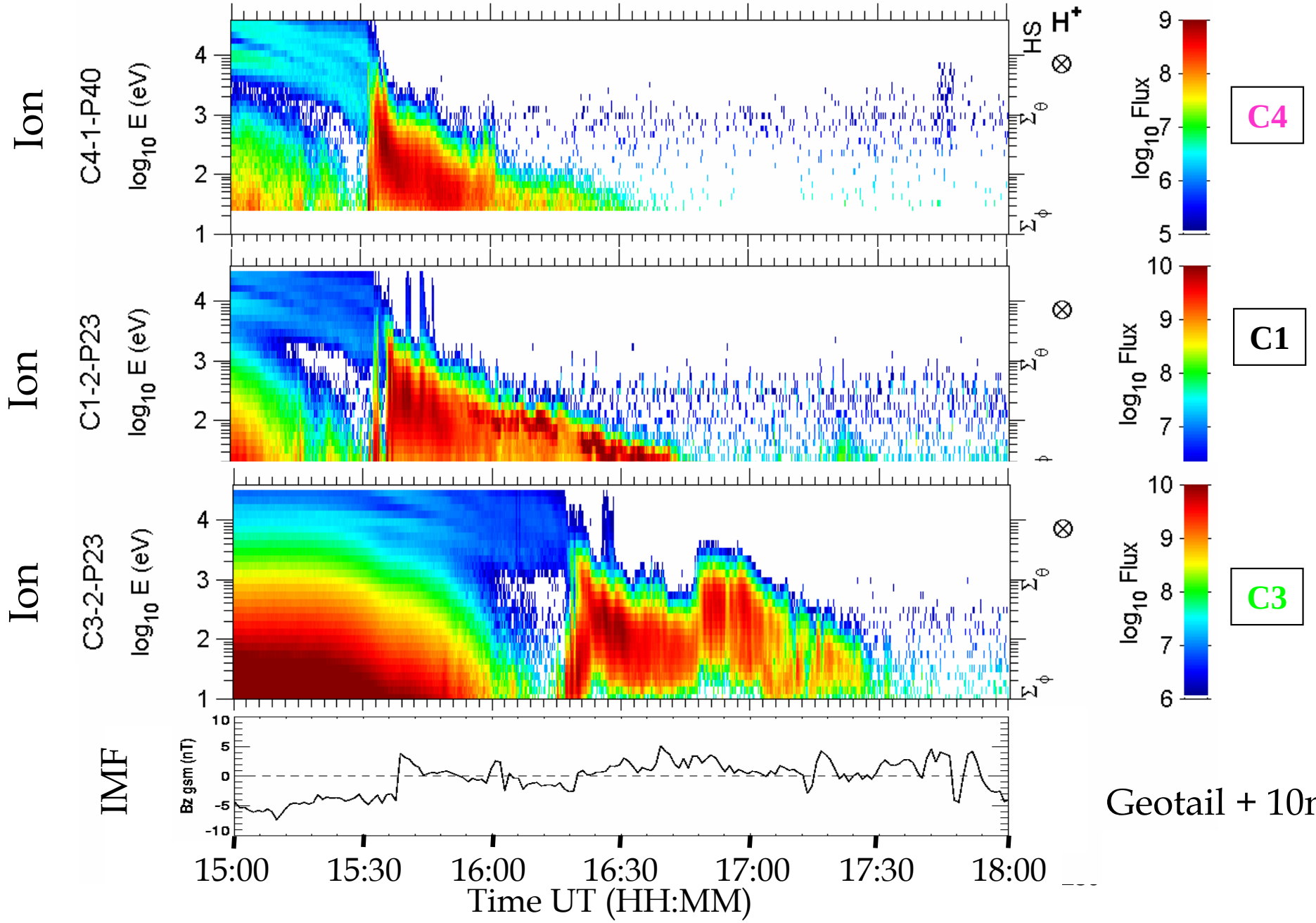
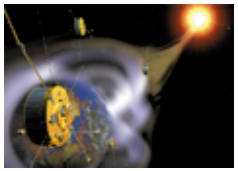


CLUSTER

CLUSTER - CIS - DAY=30-08-2001



Geotail + 10mn



CLUSTER

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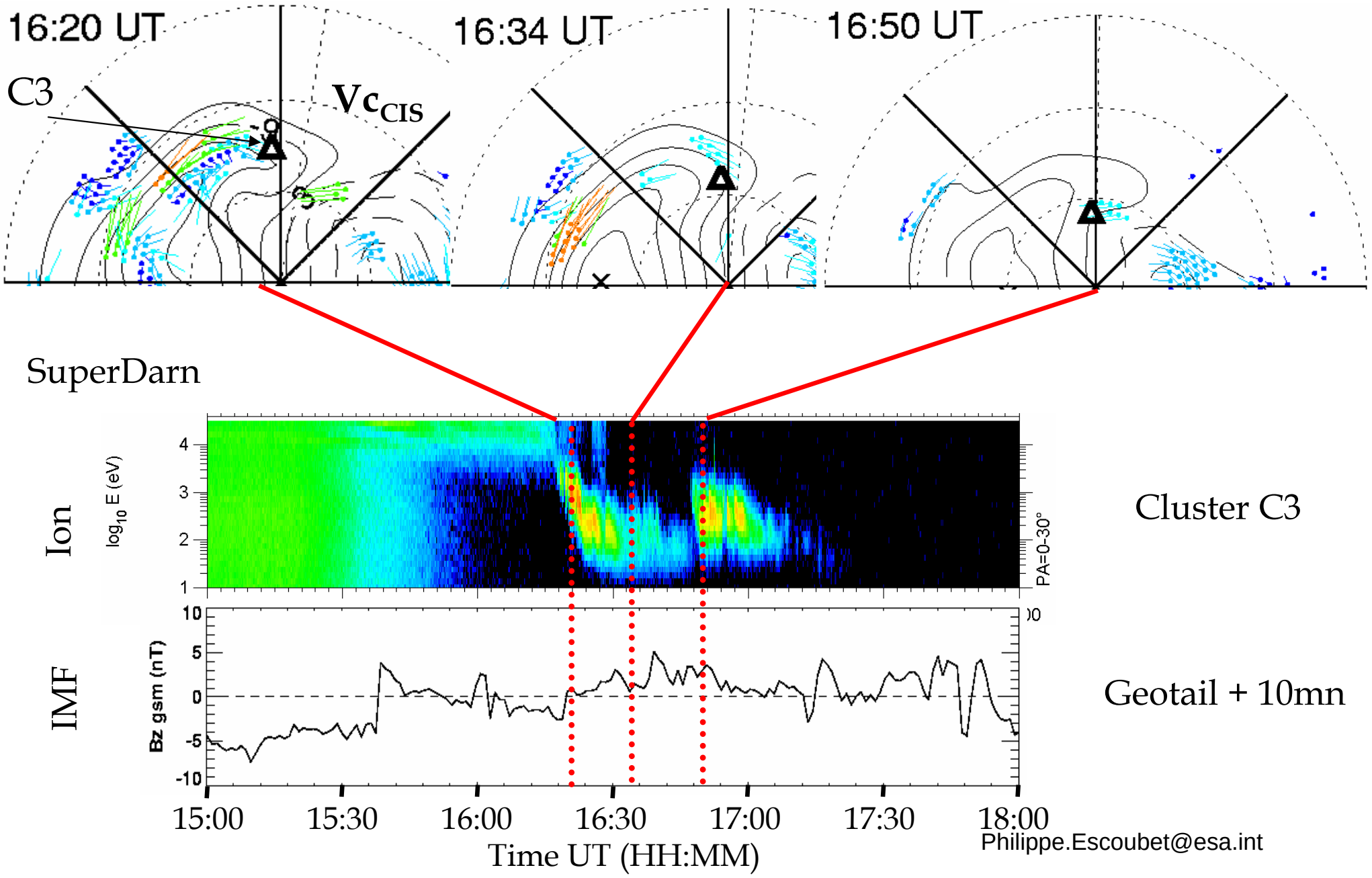

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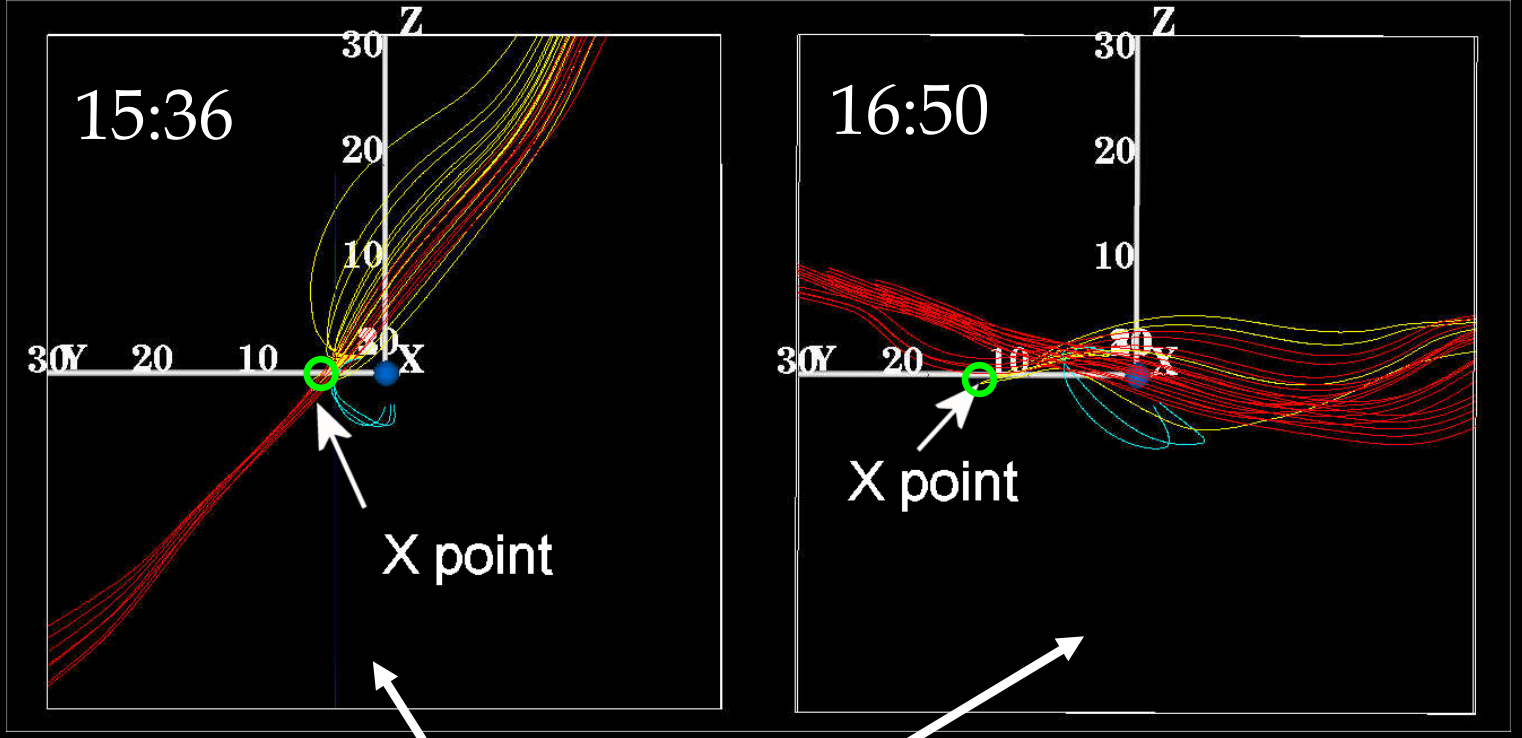
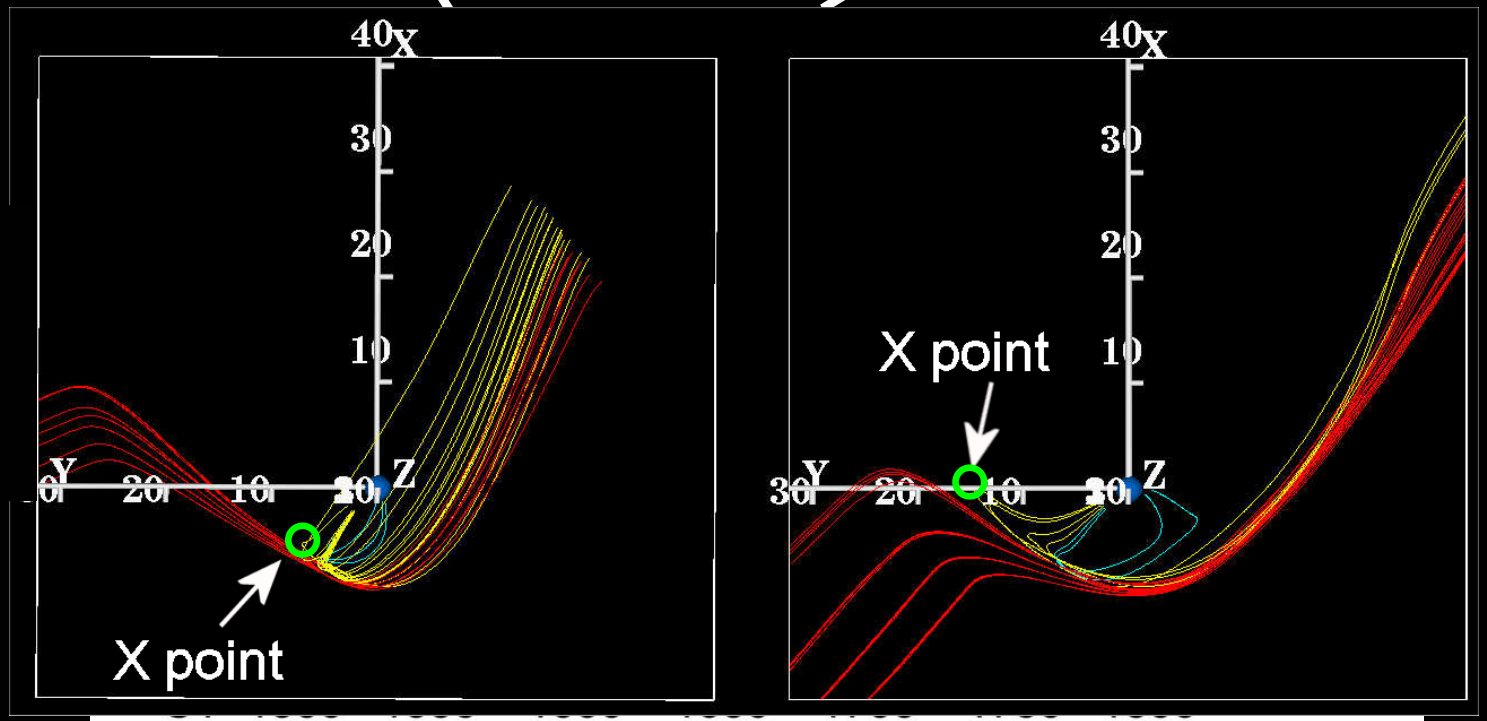
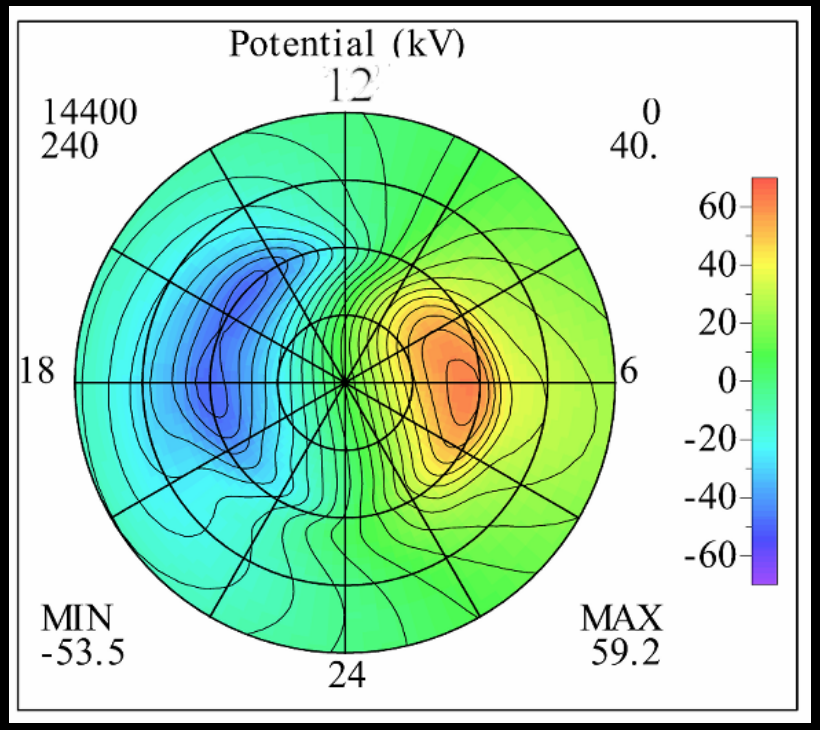
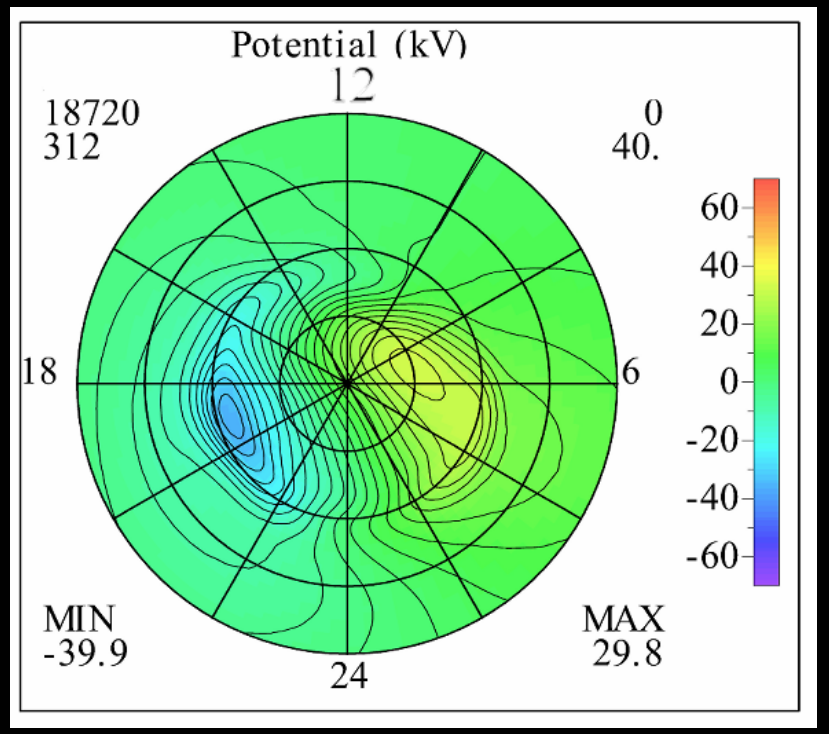
Sun View

Top View

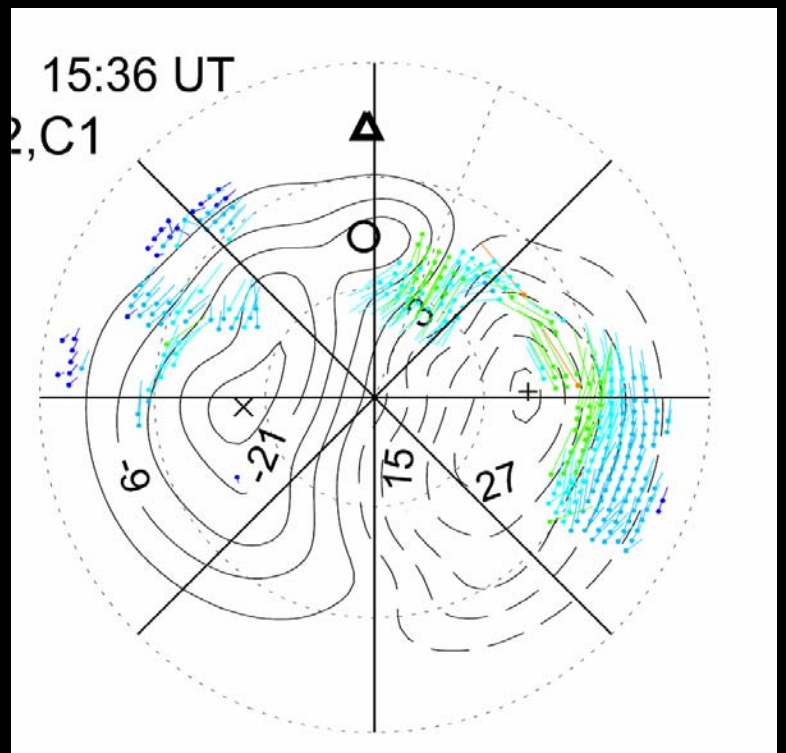


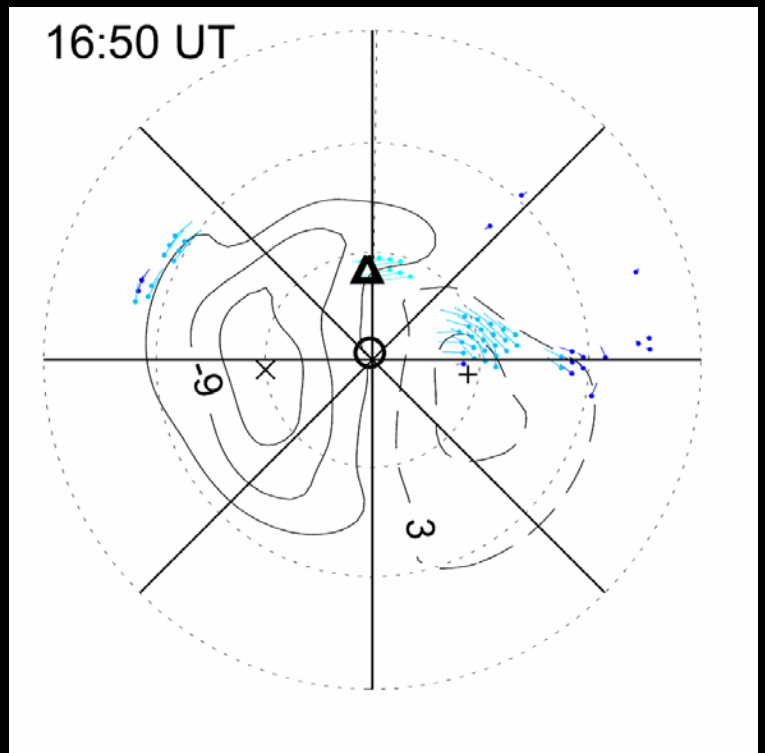






MHD



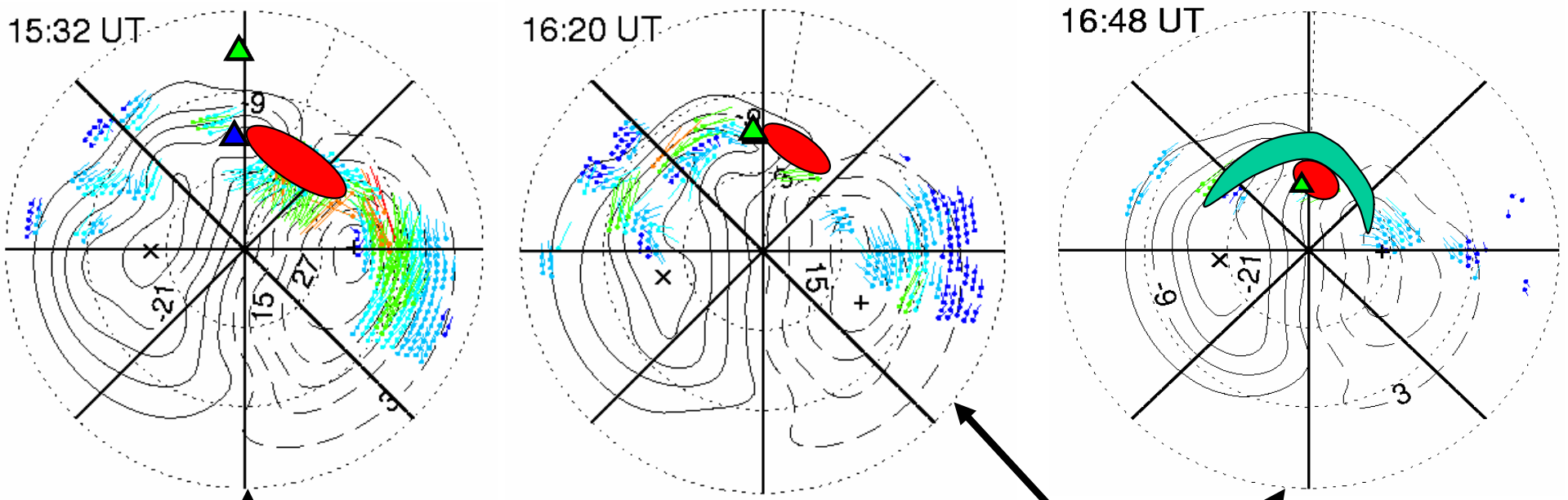


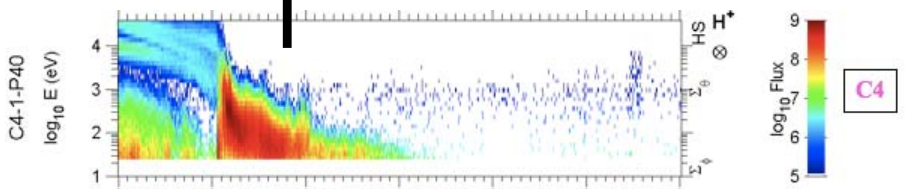
SuperDARN

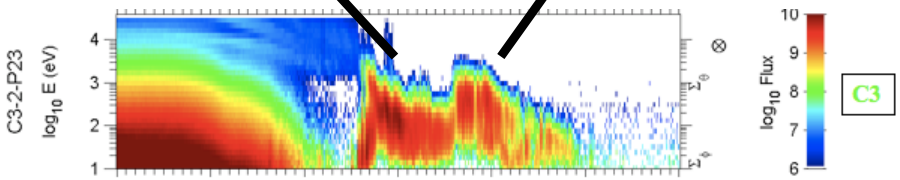
Sketch of cusp motion to explain double cusp

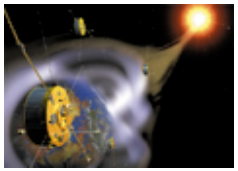
Cusp
Cleft/LLBL
Cluster 124
Cluster 3

Bz<0 Bz~0 Bz>0



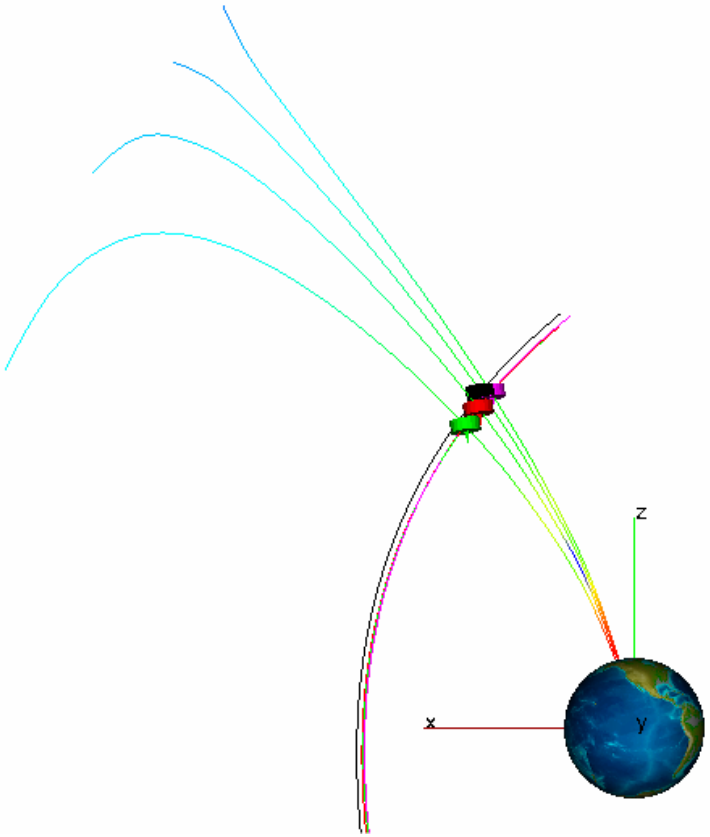


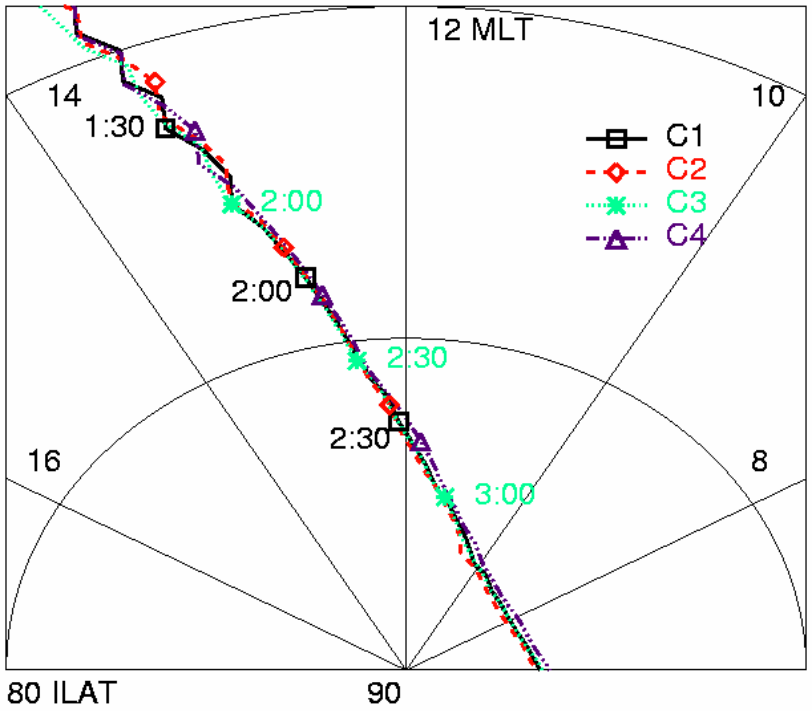




CLUSTER

2nd cusp example: Bz >0 => Bz<0





7 Aug. 2004 02:10 UT

dt41=4 min, dt42=9 min, dt43=18min
dlat41=0.5°, dlat42=1.2°, dlat43=2.5°

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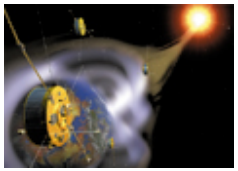
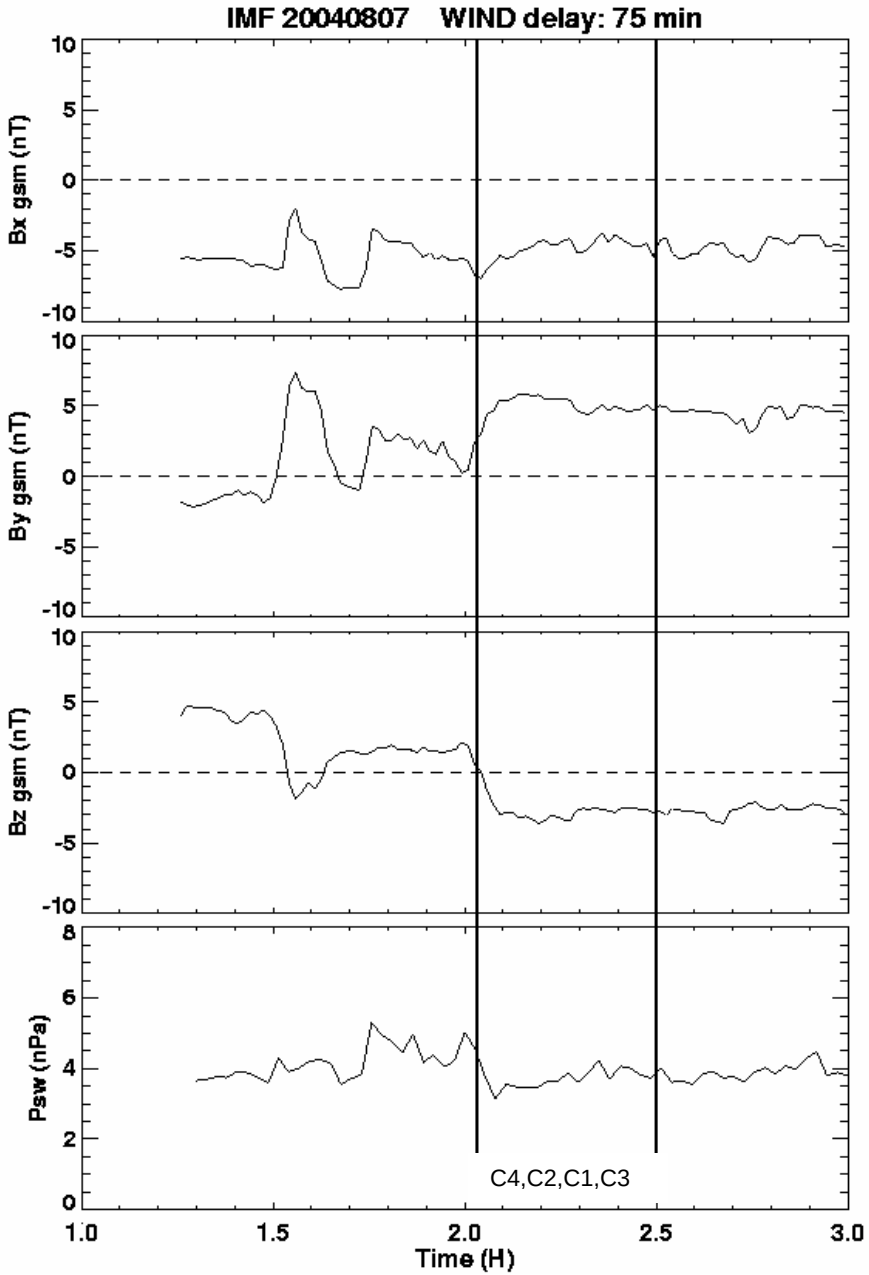


CLUSTER



- IMF southward turning around 02 UT
- By increases to 5 nT
- Bx is constant around –5 nT
- Pressure decreases from 5 to 3.5 nPa
- IMF and Pressure are constant throughout the cusp crossings (around 30 min)

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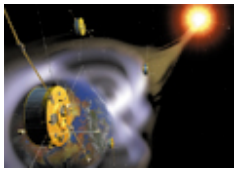

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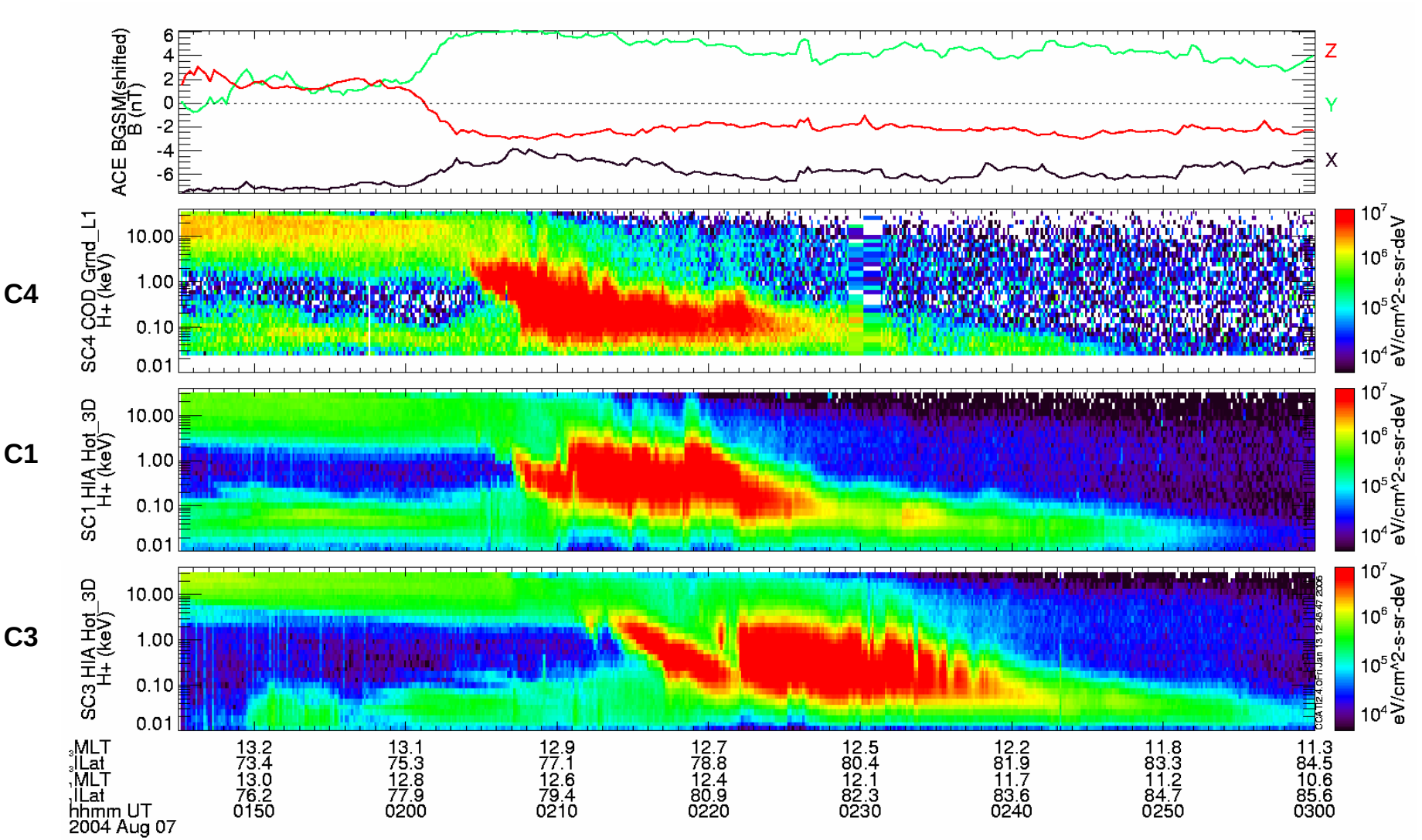

1st characteristics of cusp: energy step & energy dispersion

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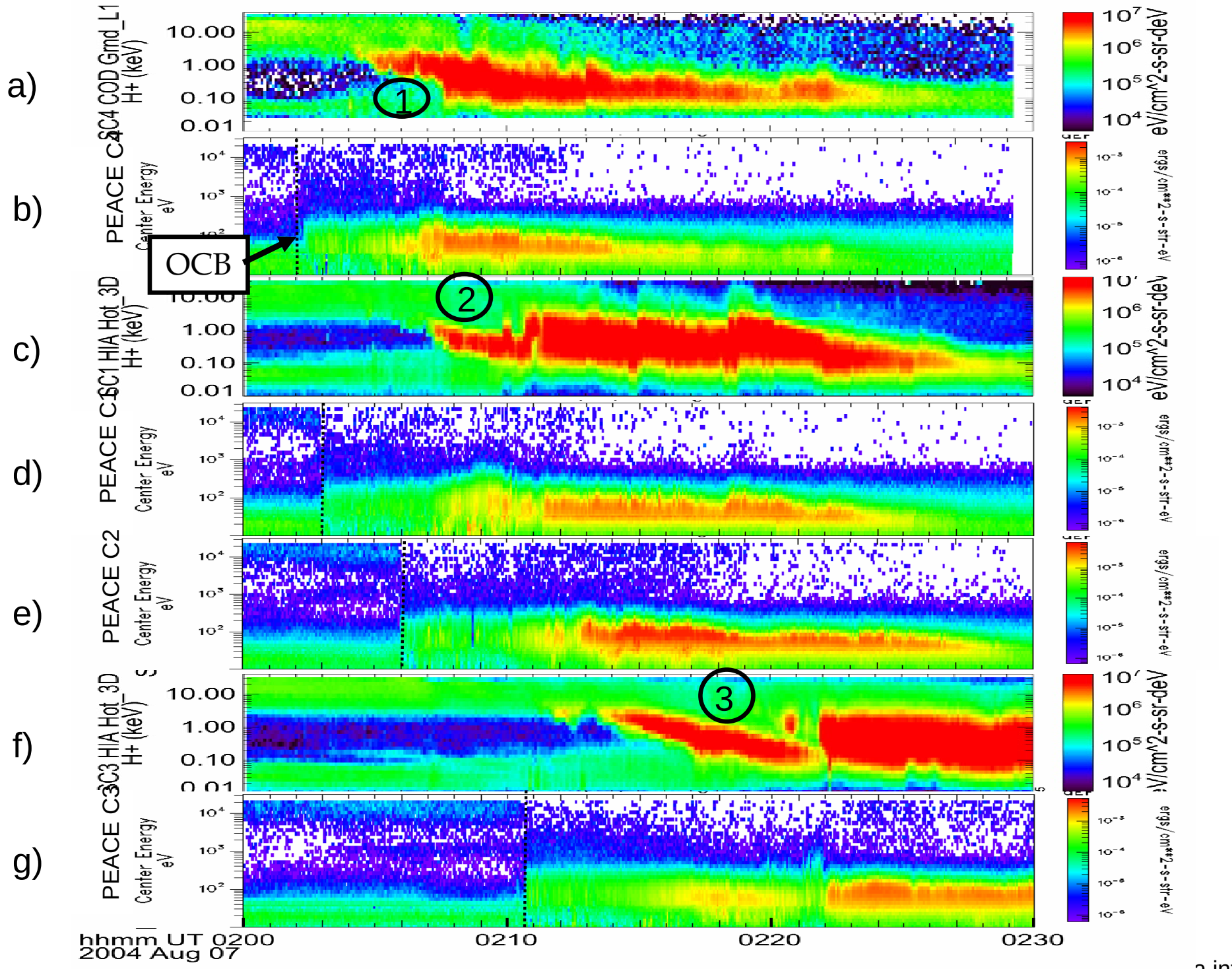
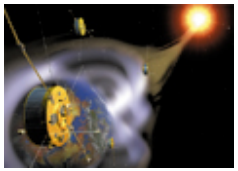

a)
b)
c)
d)
e)
f)
g)
C4 CODGmd_L1 H+ (keV)
PEACE C4
Center Energy eV
OCB
C1 HIA Hot_3D H+ (keV)
PEACE C1
PEACE C2
C3 HIA Hot_3D H+ (keV)
PEACE C3
10.00
1.00
0.10
0.01
1
2
3
eV/cm**2-s-sr-eV
ergs/cm**2-s-str-eV
hhmm UT 0200
0210
0220
0230
2004 Aug 07

a.int



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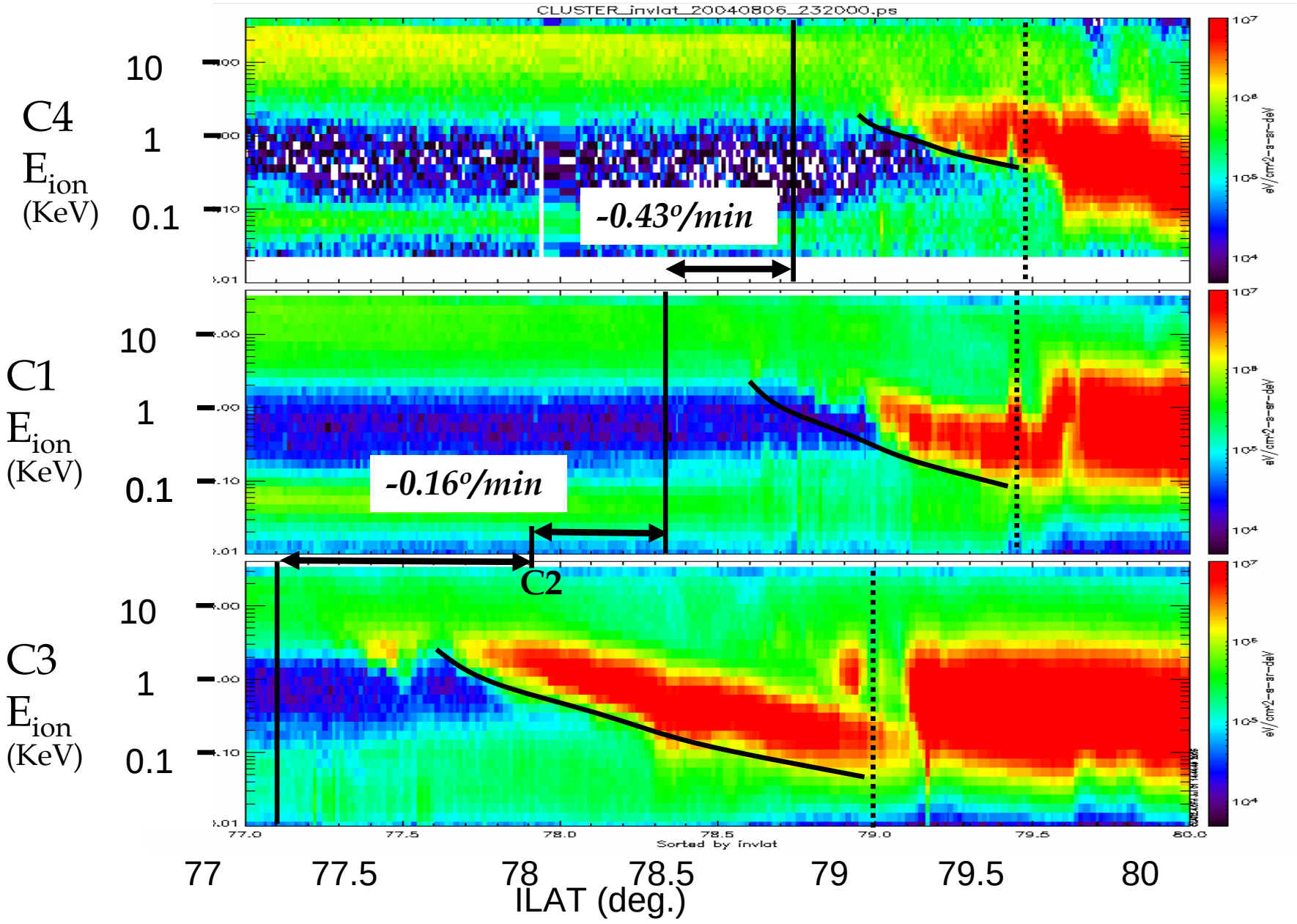

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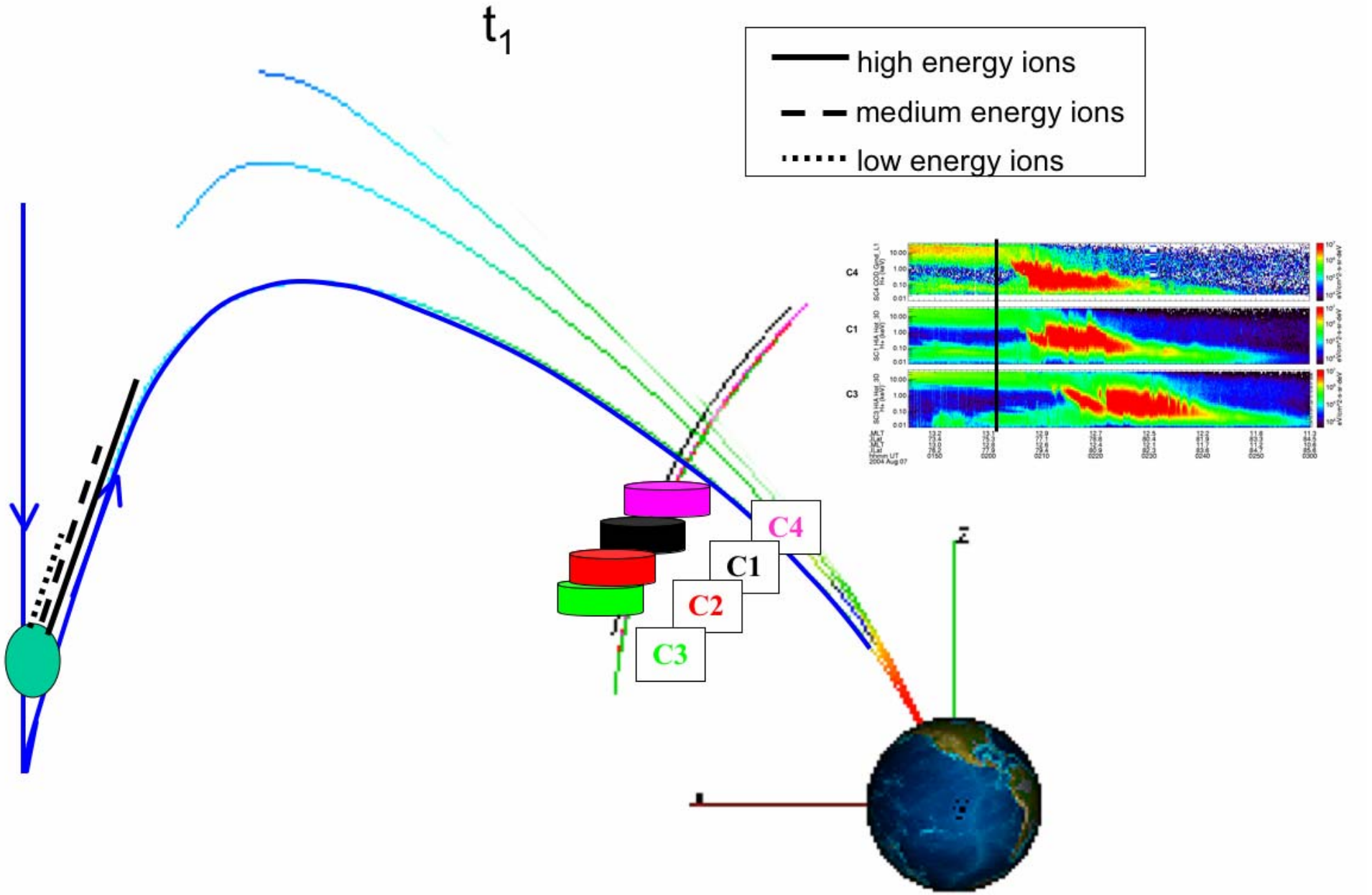
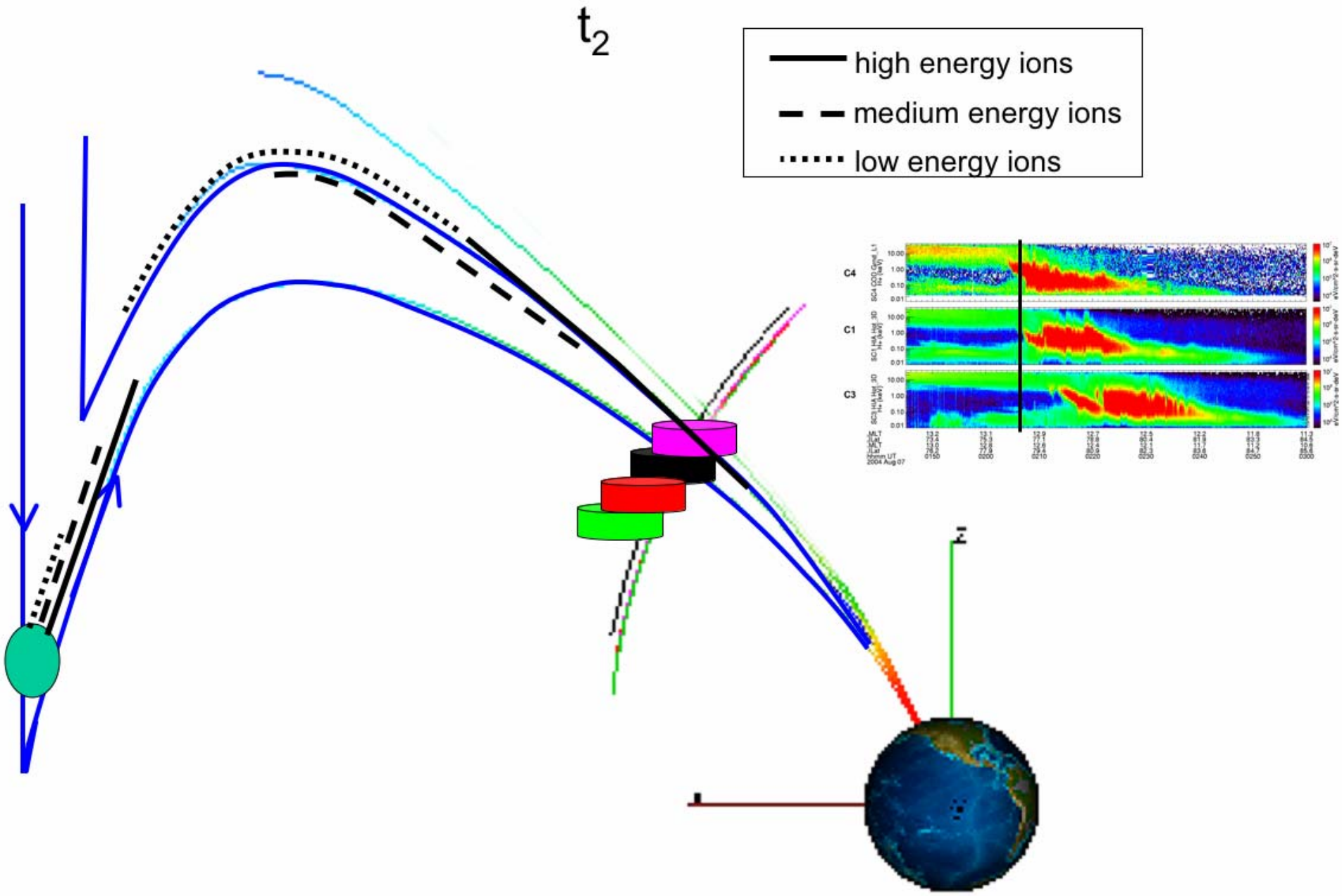
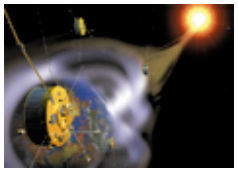

t1
high energy ions
medium energy ions
low energy ions
C4
C1
C3
C4
C1
C2
C3
Z


t2
high energy ions
medium energy ions
low energy ions
C4
C1
C3
z



CLUSTER

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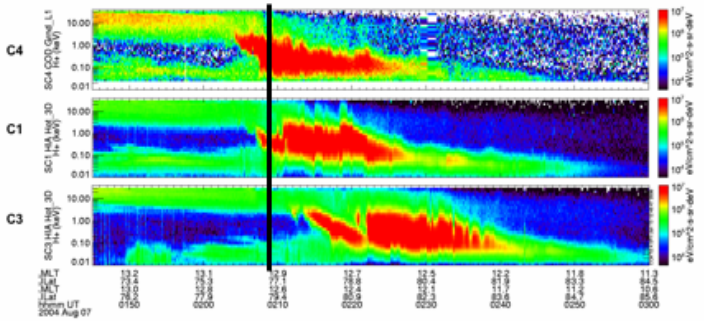
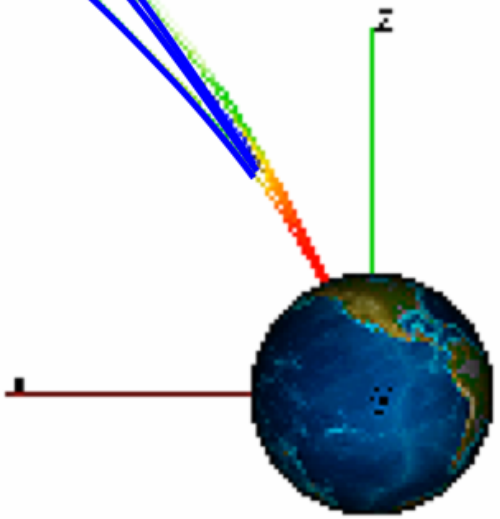
t_3

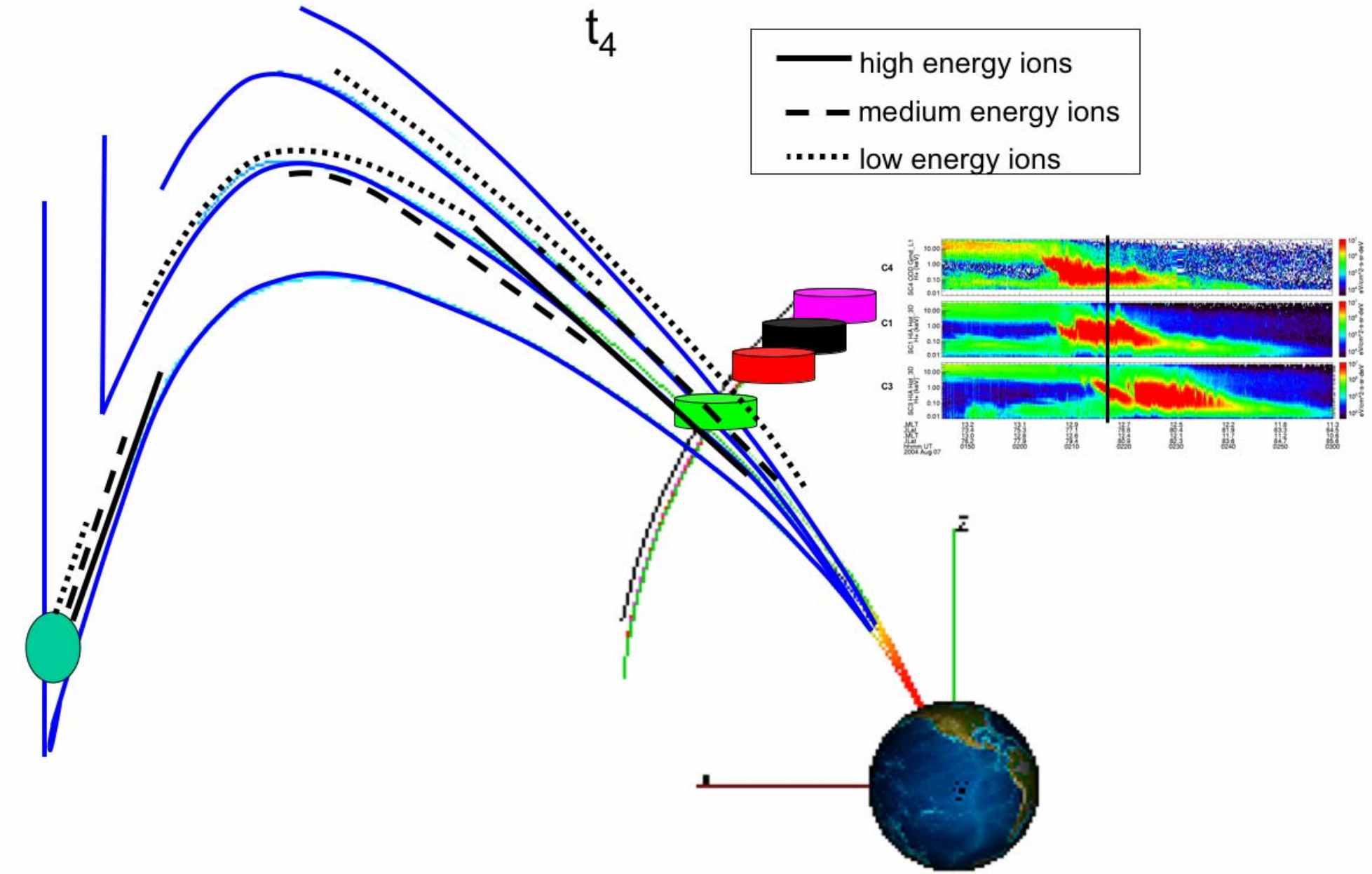
high energy ions

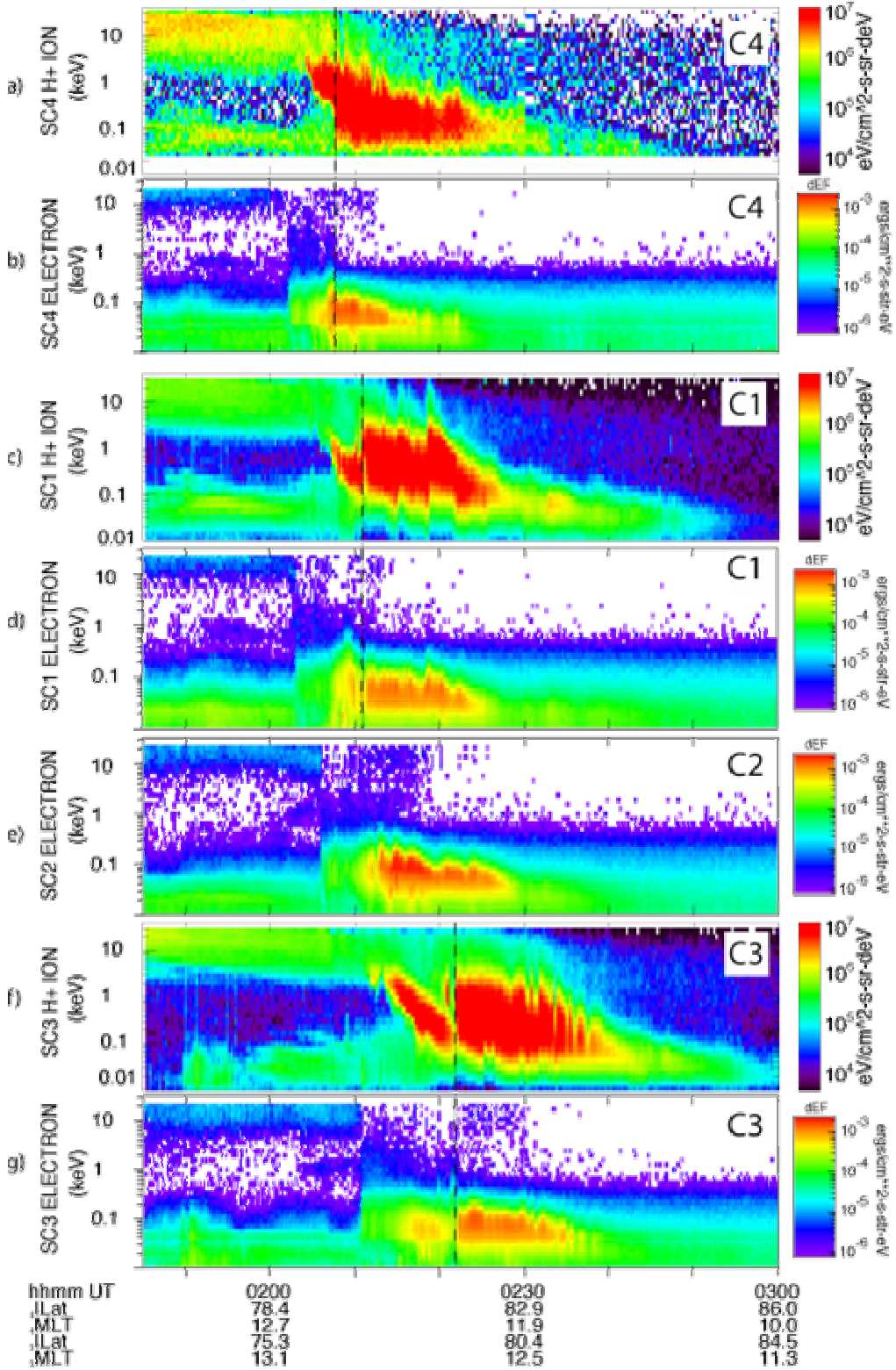
medium energy ions

low energy ions






t4
high energy ions
medium energy ions
low energy ions
C4
C1
C3



2nd characteristics of cusp:

- Two regions (dashed line):
  - Equatorward ion step/dispersion with moderate flux of e-
  - Poleward dense ion precipitation and intense flux of e-

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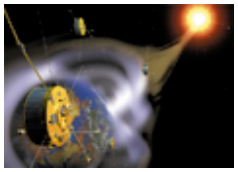

CLUSTER

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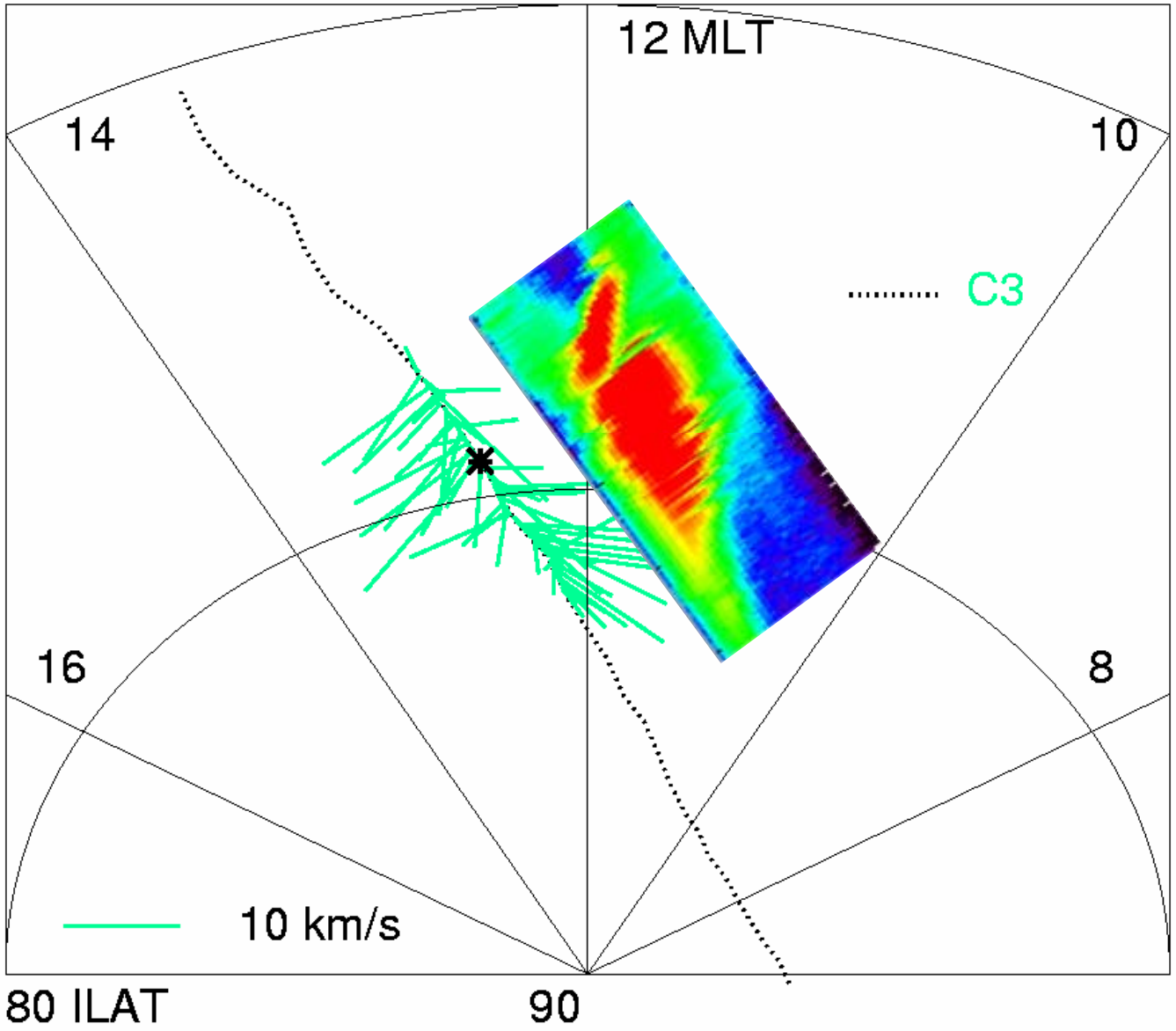
Flows opposite in the two regions



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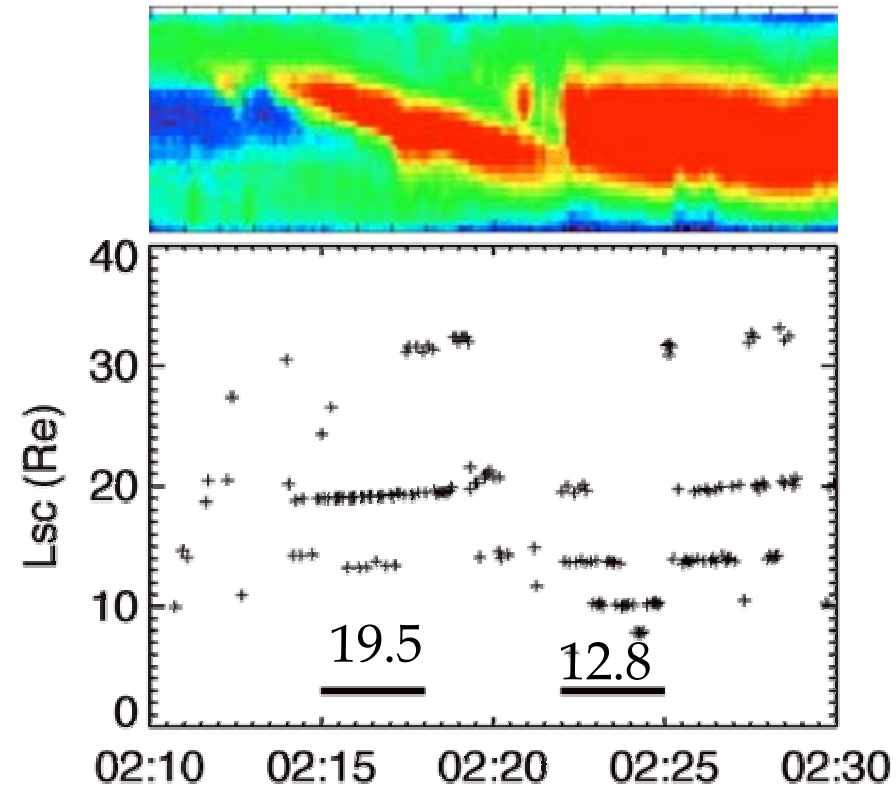
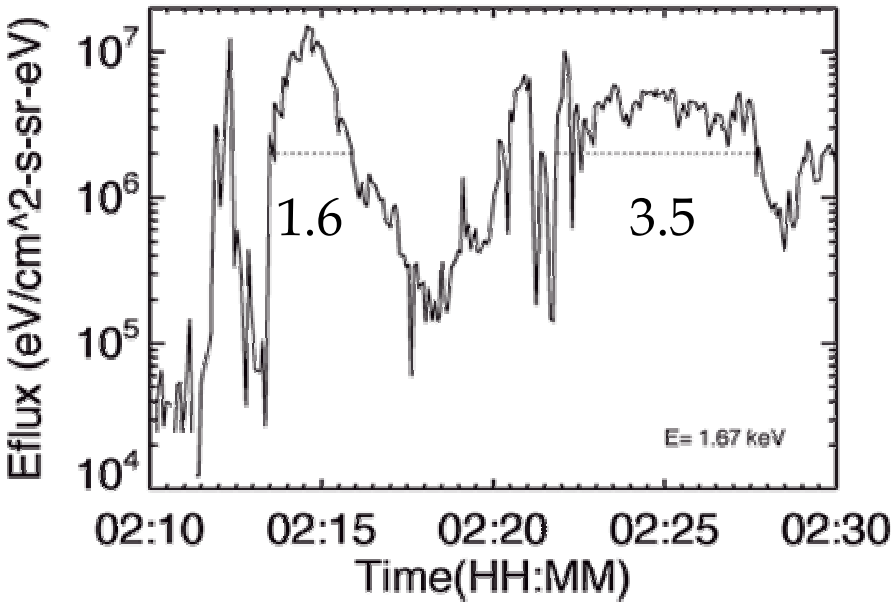


Source differences

Injection distance using up and downgoing ions:

19.5 Re equatorward

12.8 Re poleward



Source size using Menietti and Burch [1988] method:

1.6 Re equatorward

3.5 Re poleward

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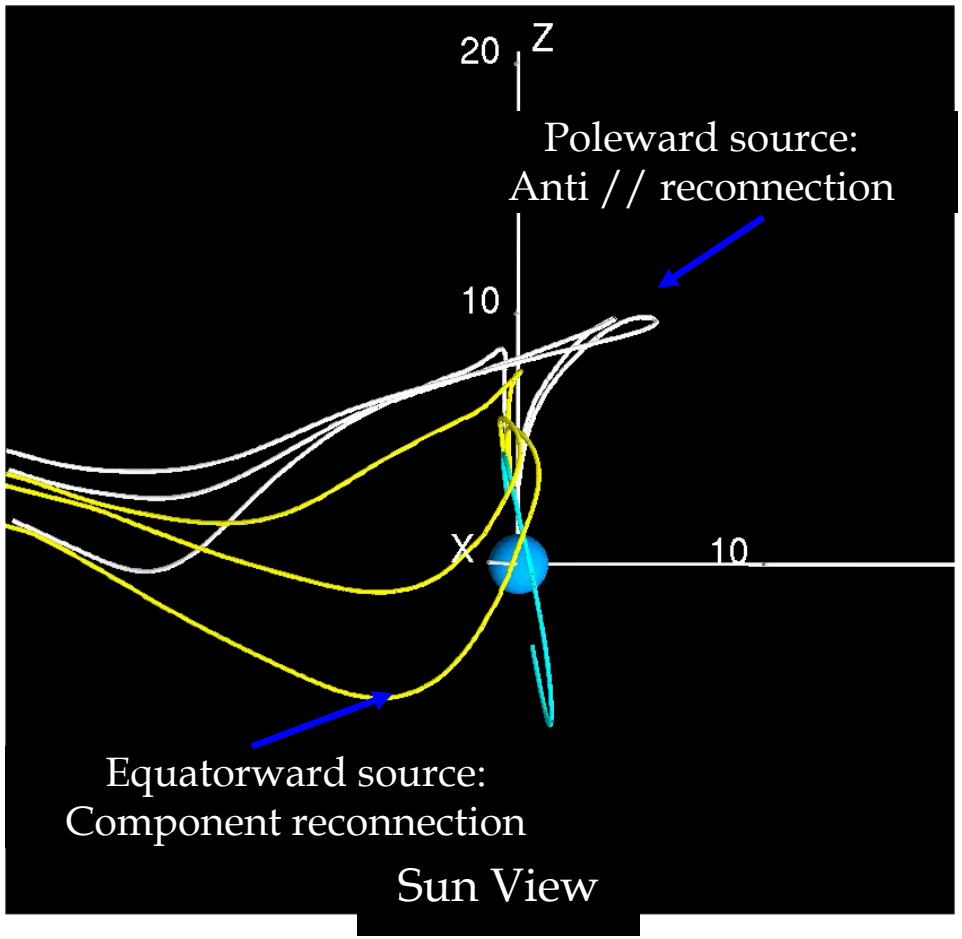
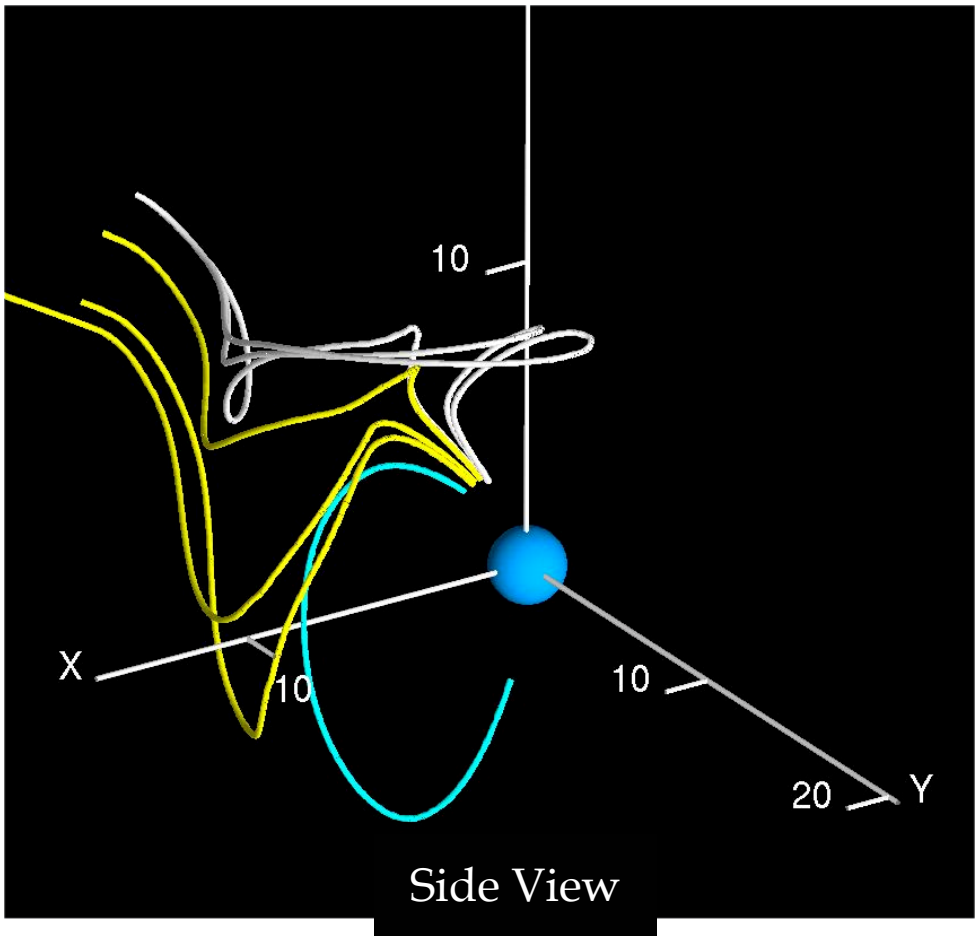
MHD run for the cusp crossing





=> Two sources simultaneously when IMF-By important

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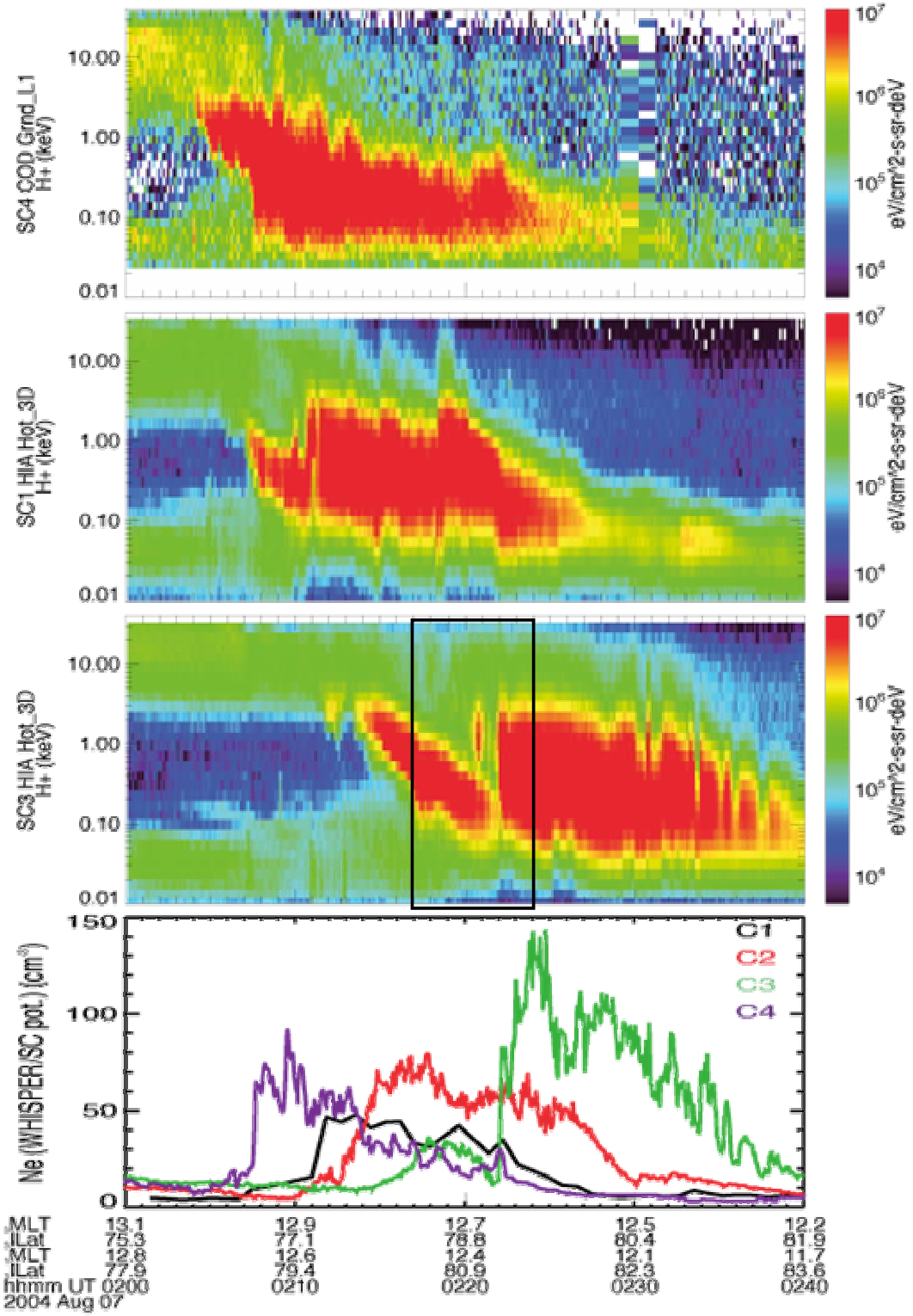
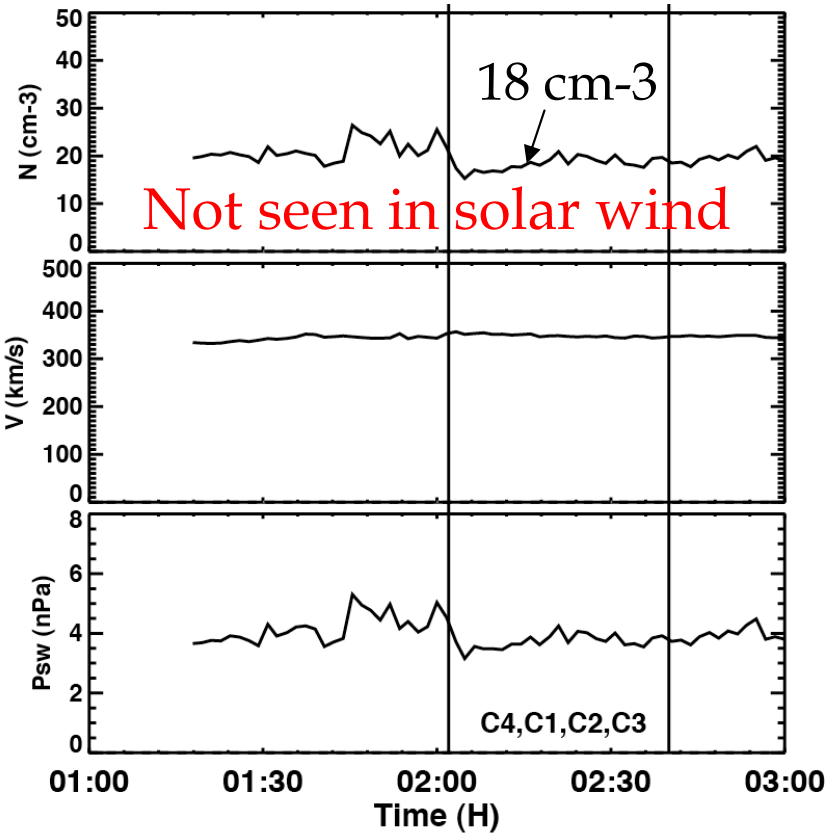


3rd characteristics of cusp:

- Density increase (x2) from 1st spacecraft to last
- 140 cm-3 on C3

=> 45 cm -3 in solar wind



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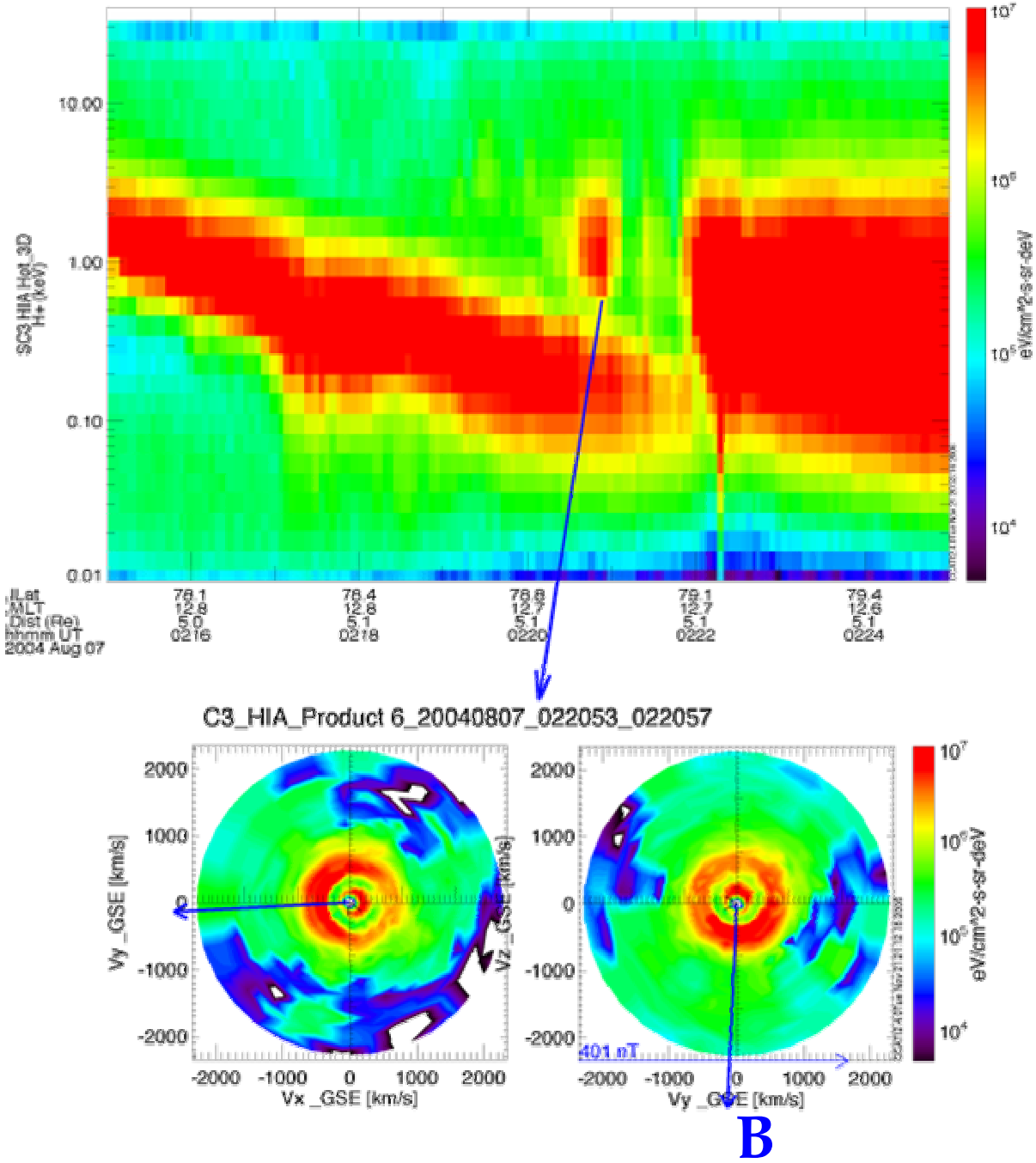

Energy overlap:

- low energy population around 20 eV
- High energy around 1.5 keV
- On 3D: two concentric distinct shells with low energy going up and high energy down

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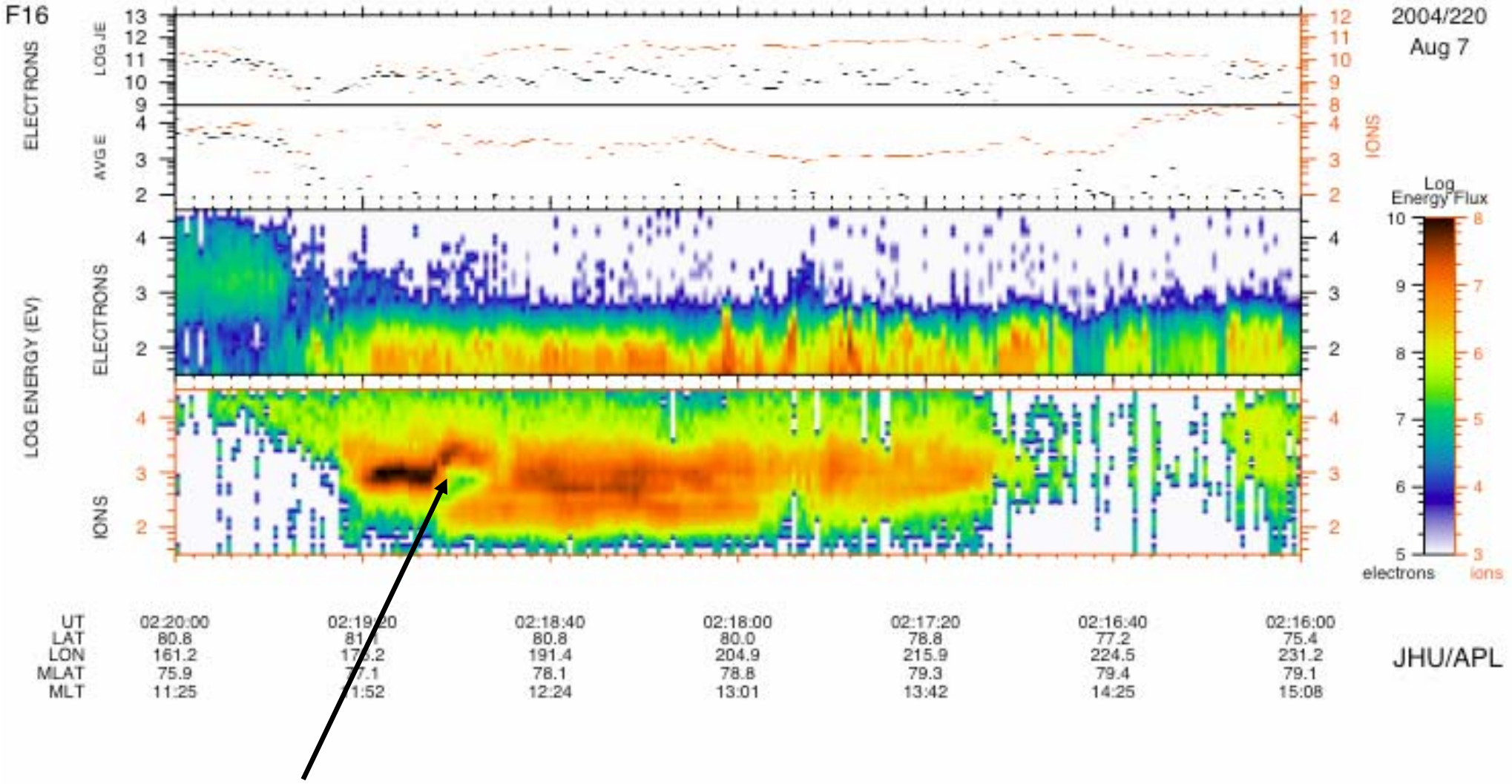
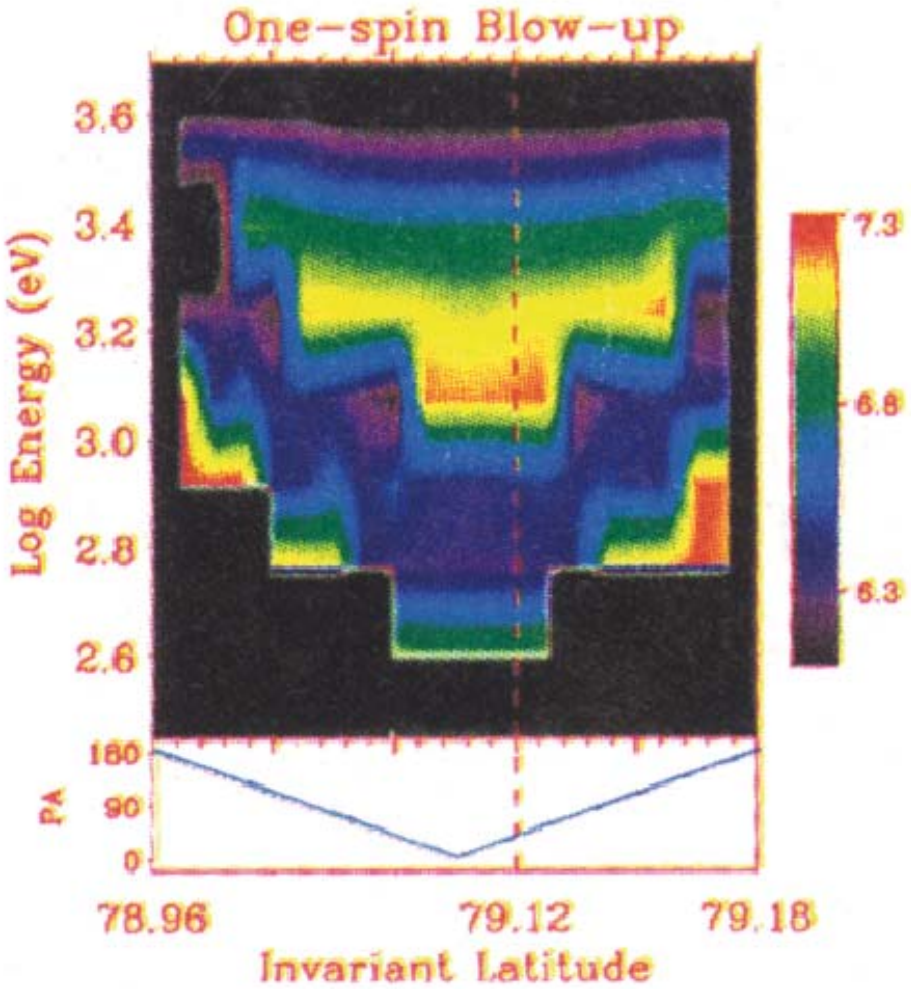
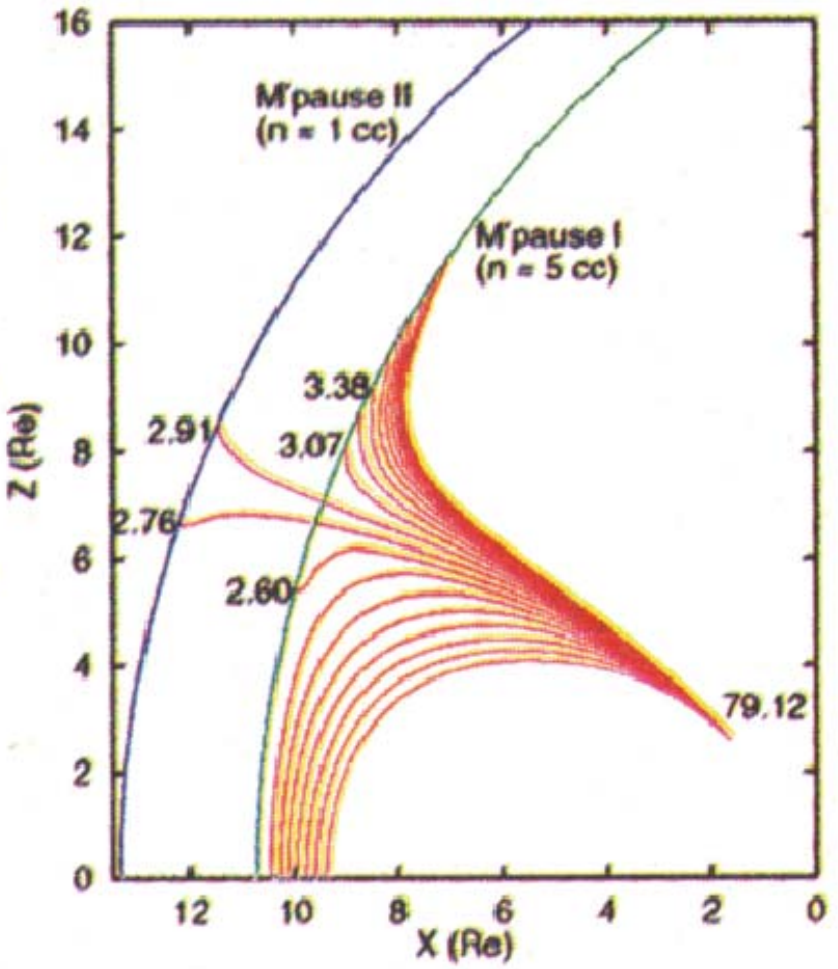
Dispersion overlap also seen on DMSP F16



Dispersion overlap, 2 min before Cluster 3





Viking, [Yamauchi and Lundin, 1994]

Pressure Model, Xue el al., 1997

Psw increase => overlap energy

=> Density increase in front of magnetosphere

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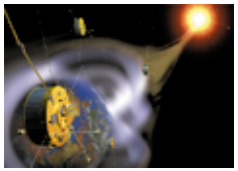

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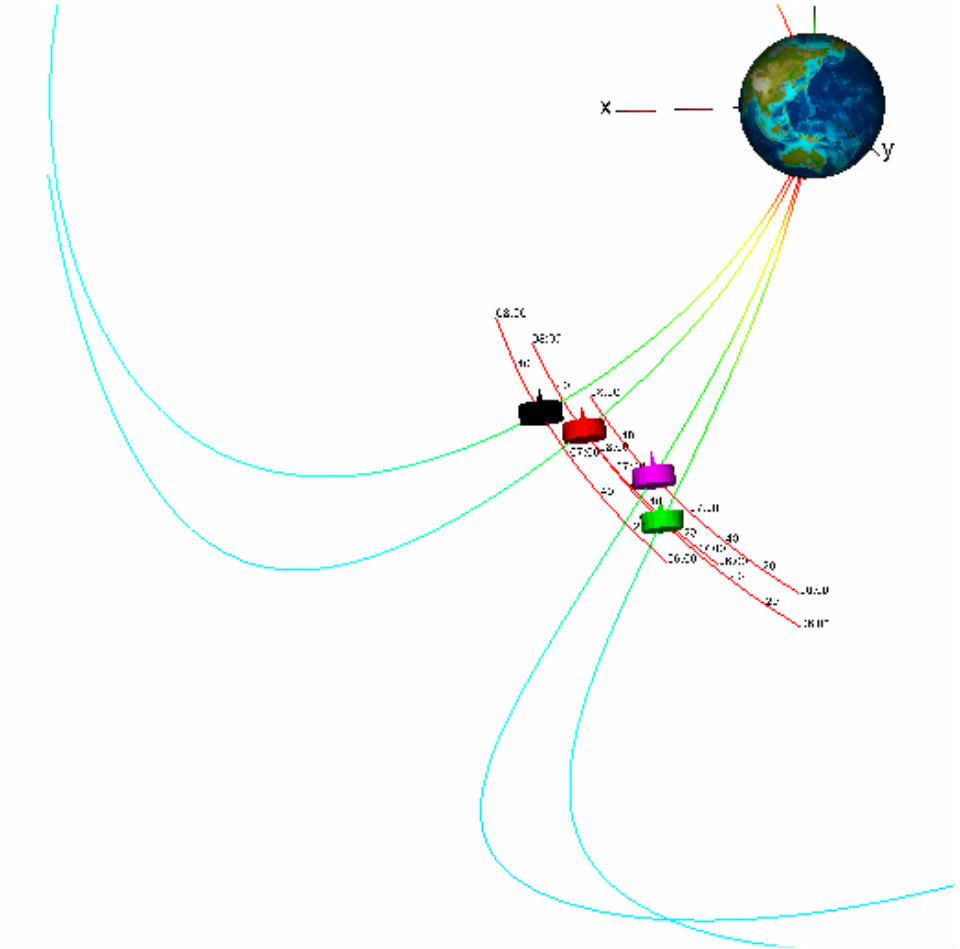
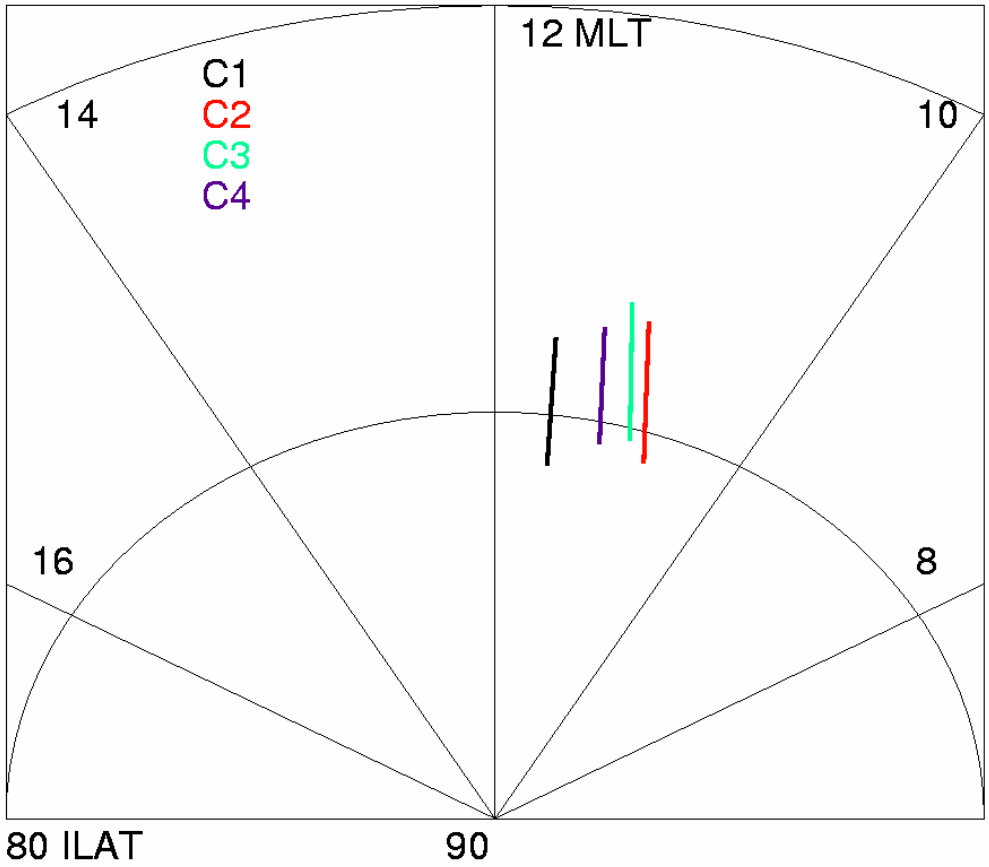
3rd cusp crossing, Bz>0 constant





dt12=20 min, dt14=50 min, dt13=65 min

03 Sept. 2002 07:20 UT (OVT)

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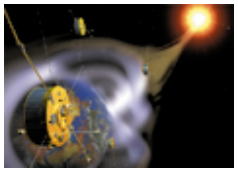

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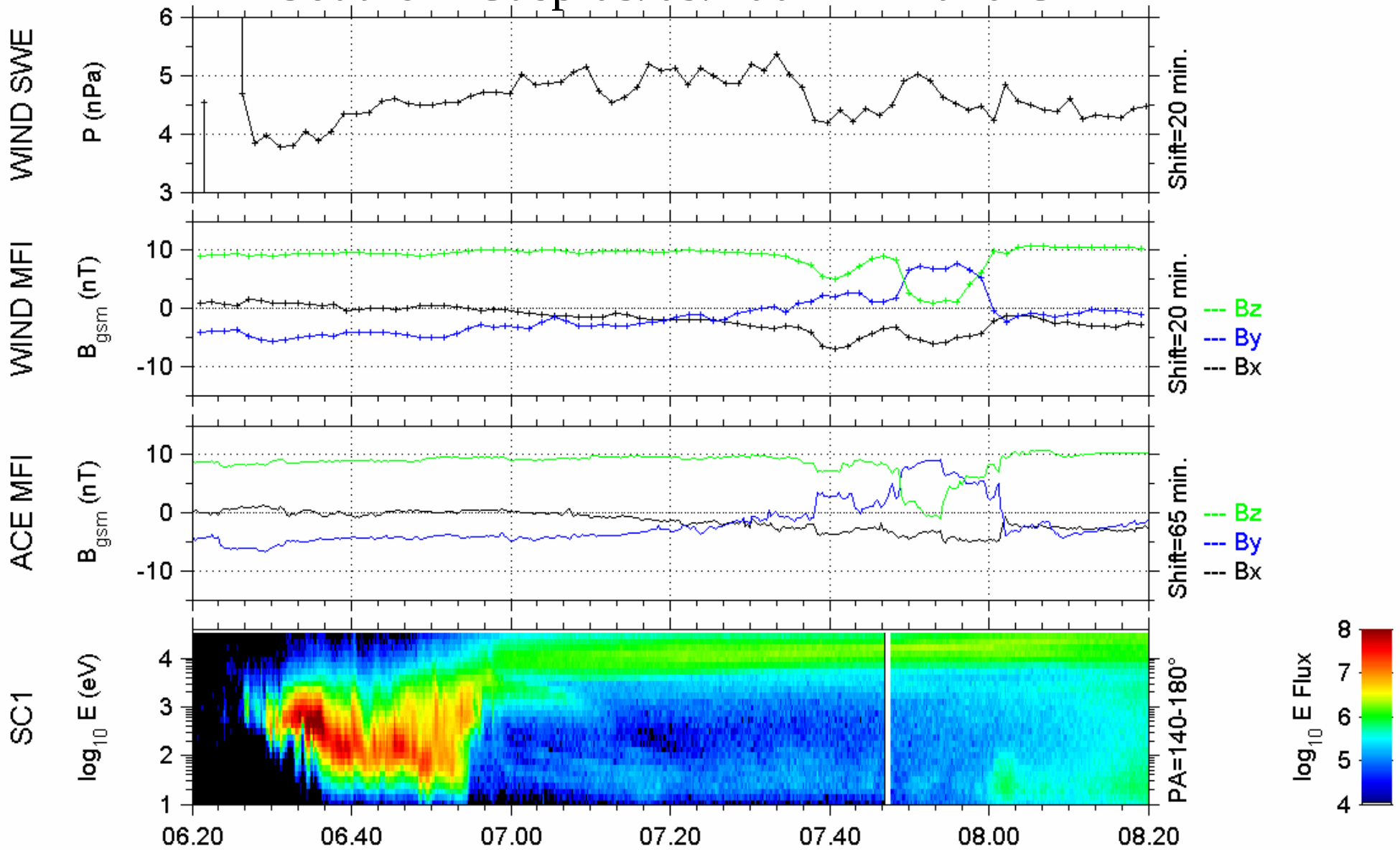
Southern Cusp 03/09/2002 IMF and C1



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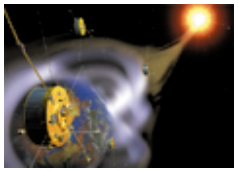

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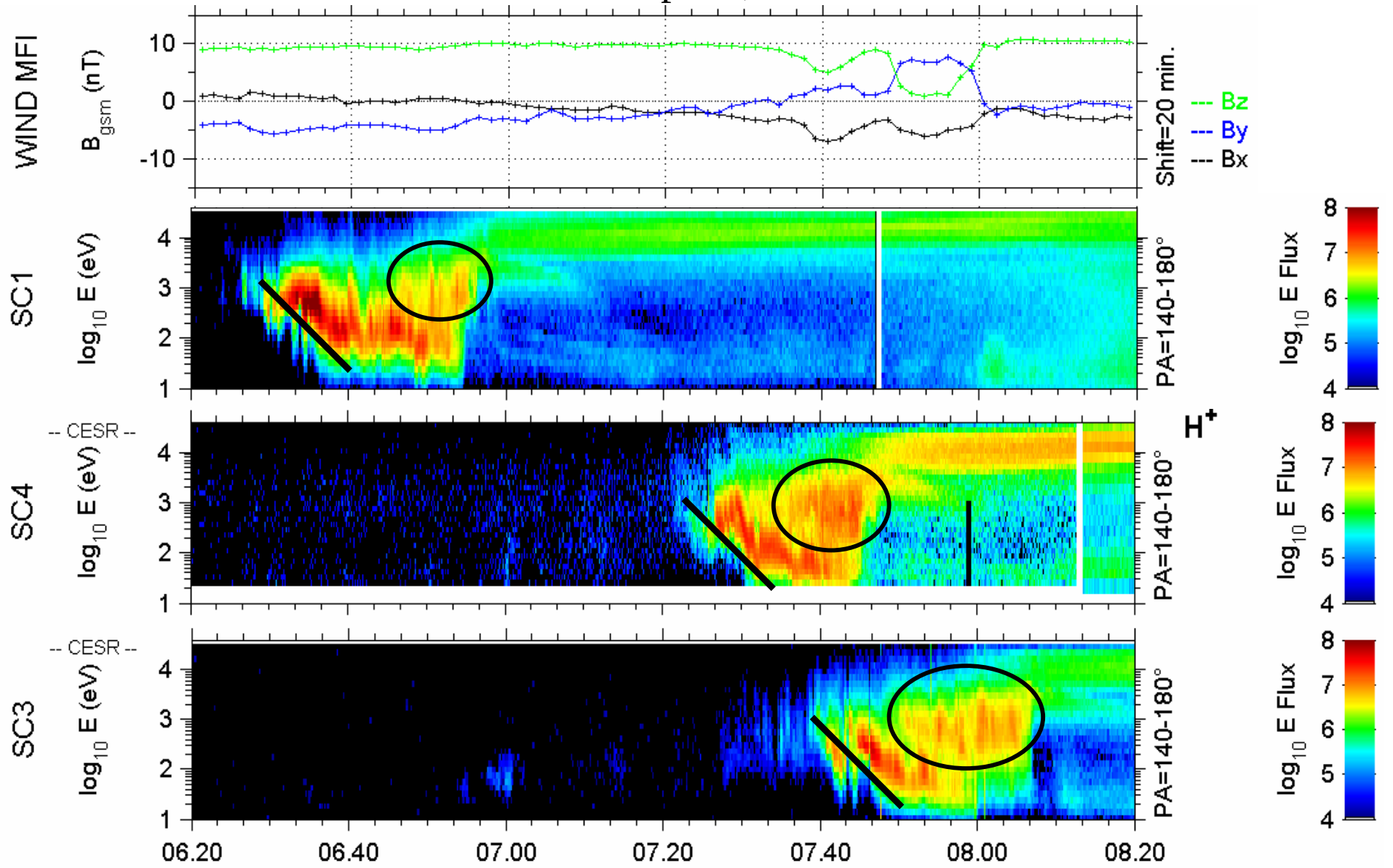
Southern Cusp C1, C4 and C3



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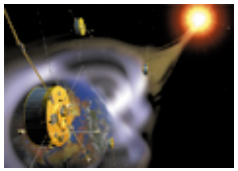

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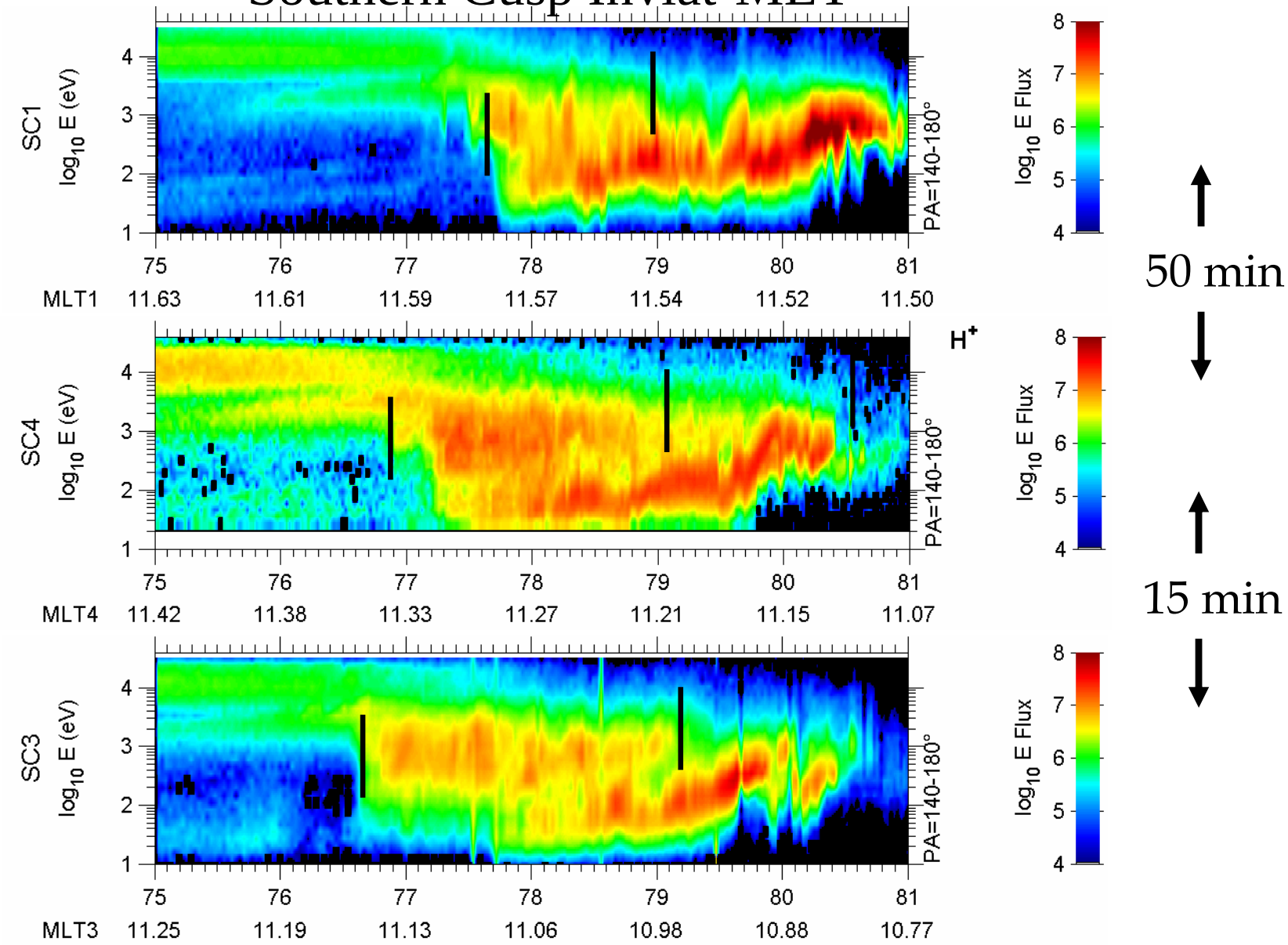
Southern Cusp Invlat-MLT



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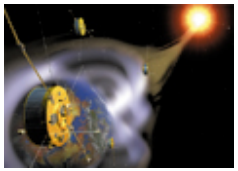

Summary 1

- 1st cusp crossing, motion of cusp reconnection point:
  - observed when turning of IMF from South to North and dominant IMF-By negative.
  - MHD model shows reconnection moving from dayside to dawn flank after the IMF change.
- 2nd crossing, polar cusp with equatorward step:
  - observed when turning of IMF from North to South and dominant IMF-By negative.
  - Erosion of magnetosphere observed (fast and then slower)
  - Ion step observed by C4, short dispersion by C1 and then full dispersion by C3 equatorward of main cusp precipitation
  - Step produced by onset of reconnection and then as reconnection goes on the dispersion developped fully
  - 2 distinct populations: on the equatorward side, the ion step/dispersion produced by component reconnection and on the poleward side the dense population produced by anti-parallel reconnection

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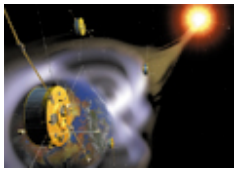

Summary 2

- 3rd cusp crossing, polar cusp under strong Northward Bz:
  - Reversed ion dispersion observed on 3 spacecraft
  - Lobe reconnection can last for more than 1h20
  - 2nd population on equatorward side, equivalent to LLBL, and growing with time mainly on the equatorward side
  - Double reconnection may produce this 2nd population by mixing plasma injected in North and South hemisphere

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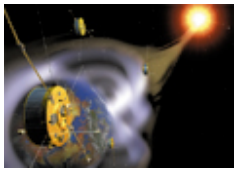

Conclusions

- Mid-altitude cusp is important to study since it maps to the dayside and lobes magnetopause and can be crossed in fairly short time
- Cluster can observe changes in mid-altitude cusp on 1 few minutes to a few hours time scale
- Any changes of IMF are almost immediately visible in the structure and position of cusp
- If IMF constant the polar cusp does not change significantly on large scale but many sub-structures can appear.

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