Fifth Workshop "Solar influence on the magnetosphere, ionosphere and atmosphere"

AURORAL AND GROUND MANIFESTATION OF DIFFERENT ION ACCELERATION MECHANISMS OPERATING IN PSBL

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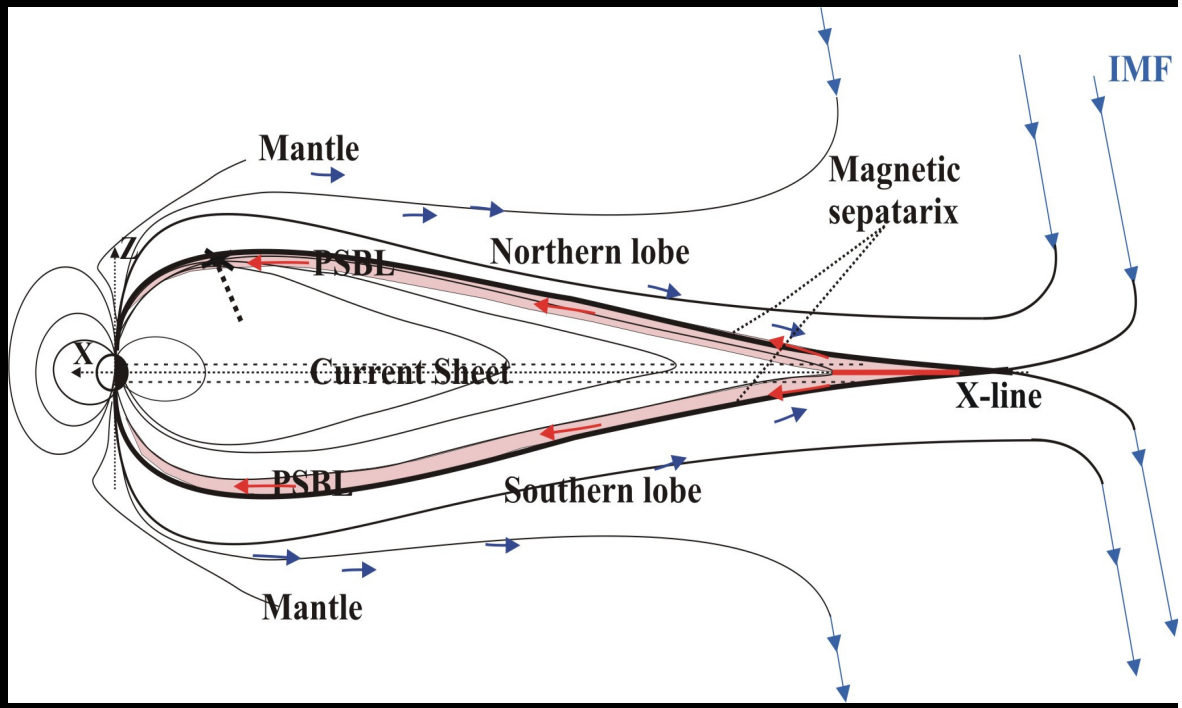
What is PSBL ?

Between the lobe and the plasma sheet exists a thin separatrix layer, which separates the tail regions with open (lobe) and closed (PS) field lines. It is projected to the current sheet in the vicinity of the magnetic separatrix where plasma could be accelerated.

Most prominent feature:

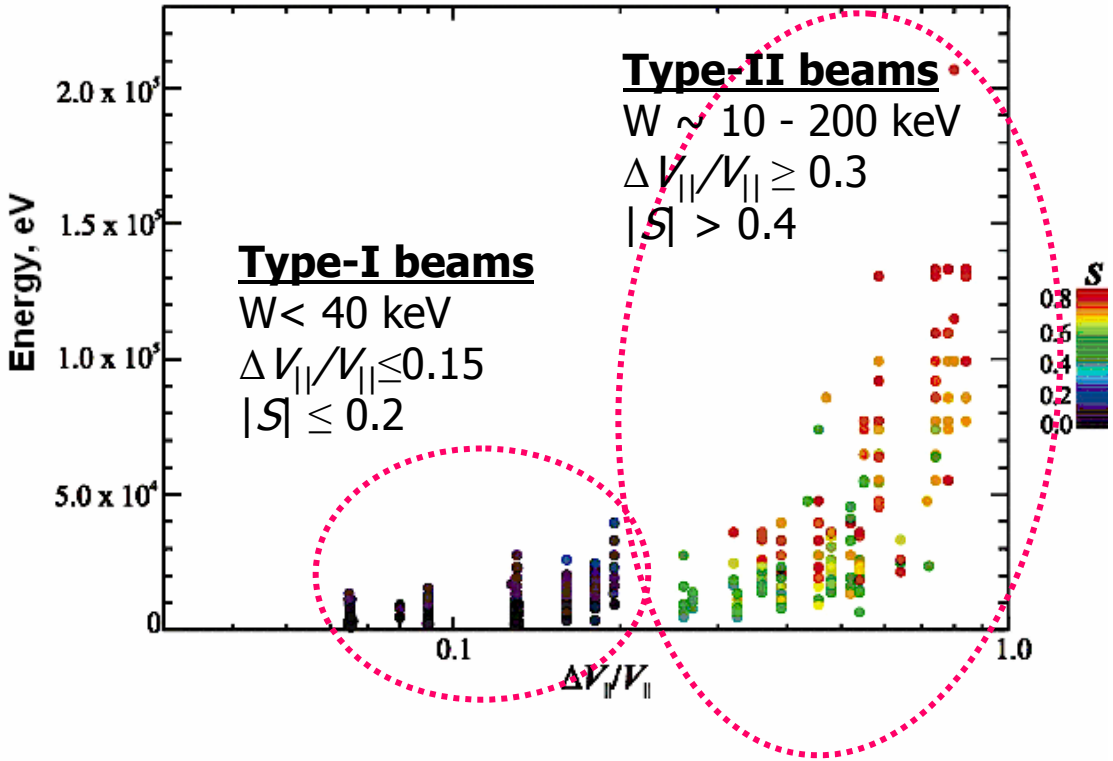
fast (> 400 km/s) ion flows



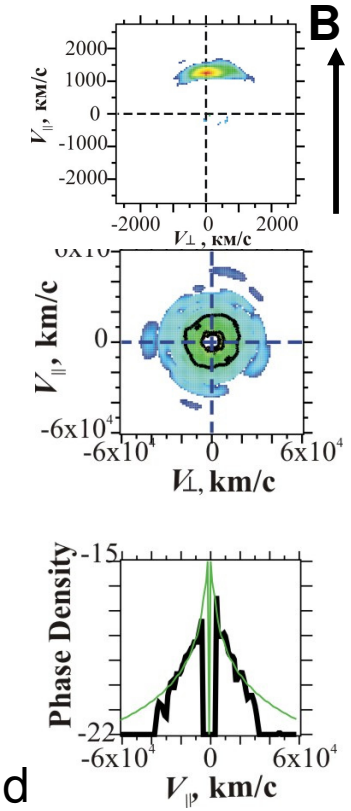
Diversity of ion beam characteristics in PSBL

(1642 PSBL crossings by Geotail and Cluster, Grigorenko et al.,

A common feature of accelerated ion beams:
their field-aligned velocity distribution functions

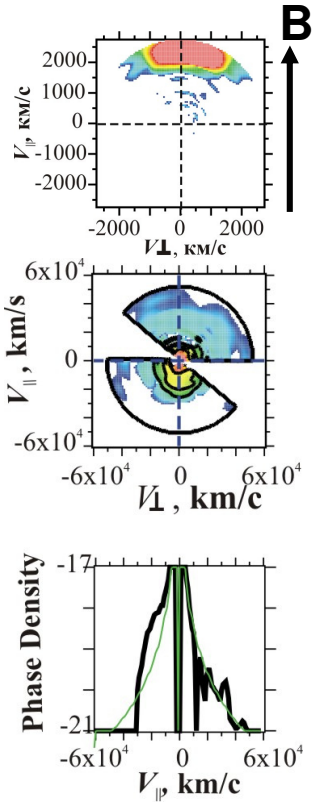


~ Isotropic $fe(V_{||})$ and collimated ion beam



$|S| = 0.07$

Anisotropic $fe(V_{||})$ and more energetic ion beam with large $\Delta V_{||}/V_{||}$

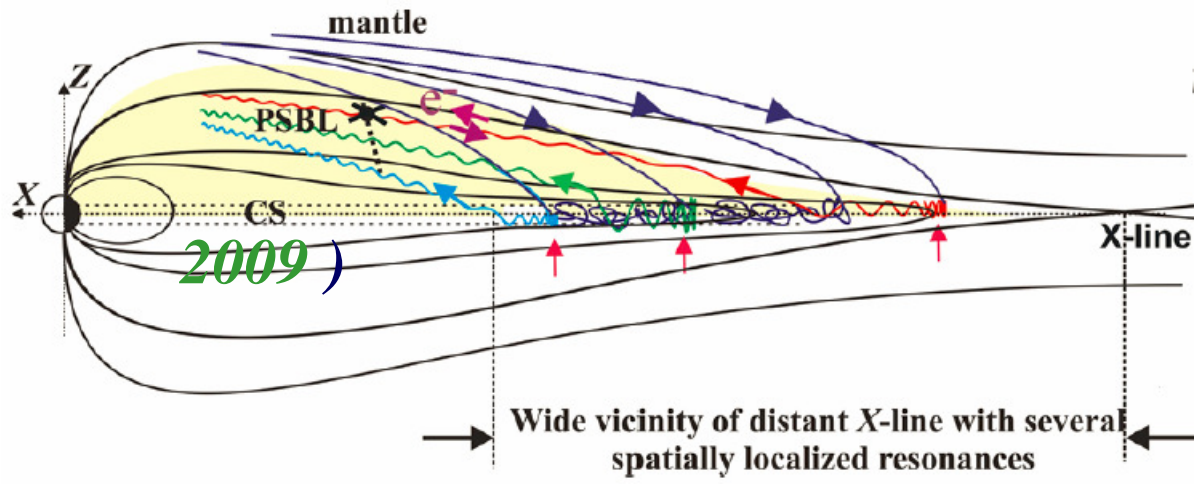


$|S| = 0.94$

To quantify the anisotropy of 1D cuts of electron velocity distribution functions along the magnetic field direction we used **skewness parameter *S***:

***S* characterizes the topology of magnetic field lines: open/closed one**

TYPE I: Predominantly occurs during quiet or moderately disturbed periods |AL| < 300 nT

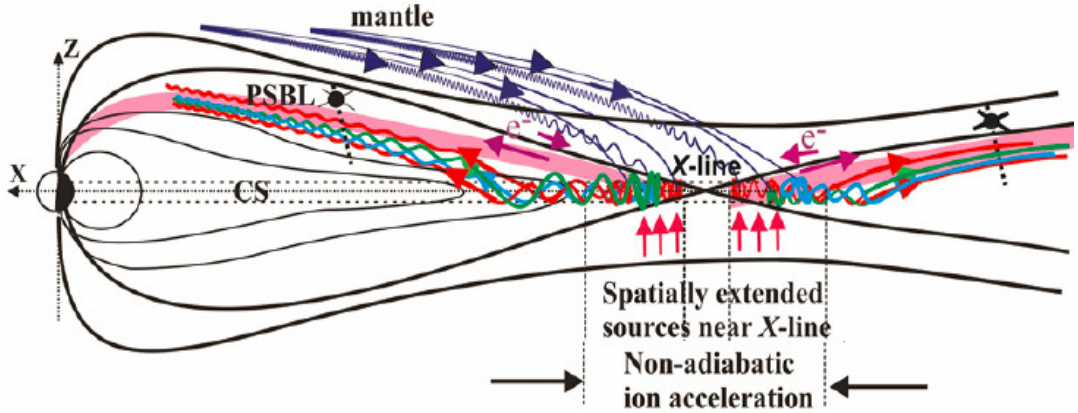


Magnetic reconnection in the distant tail:

- complicated topology?
- no clear magnetic separatrix manifestations
- quasi-steady ion acceleration on closed FL
- field-aligned ion beams with lower energies
- negligible FACs ≤ 2 nA/m²

(Grigorenko et al.,SSR, 2012)

TYPE II: Predominantly occurs during disturbed periods |AL| ≥ 300 nT



X-line in the near-Earth and in the mid-tail:

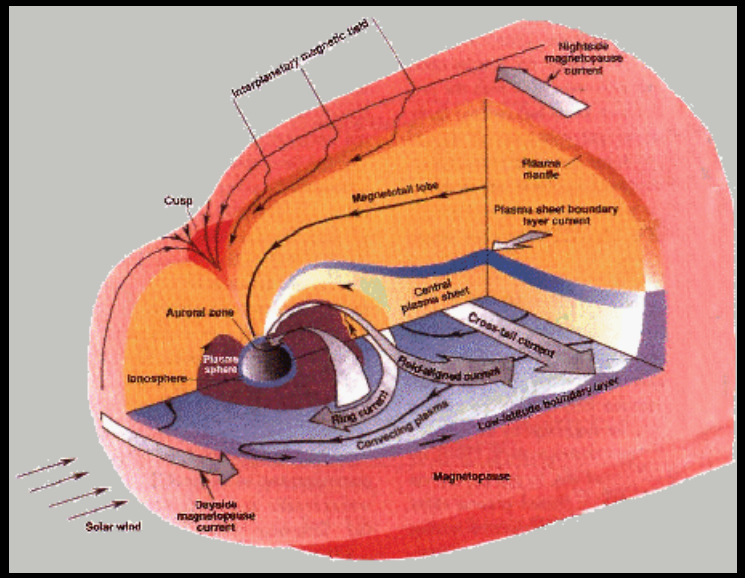
- clear magnetic separatrix manifestations
- energetic field-aligned ion beams
- rather transient than quasi-steady acceleration near the X-line
- a pair of downward/upward FACs

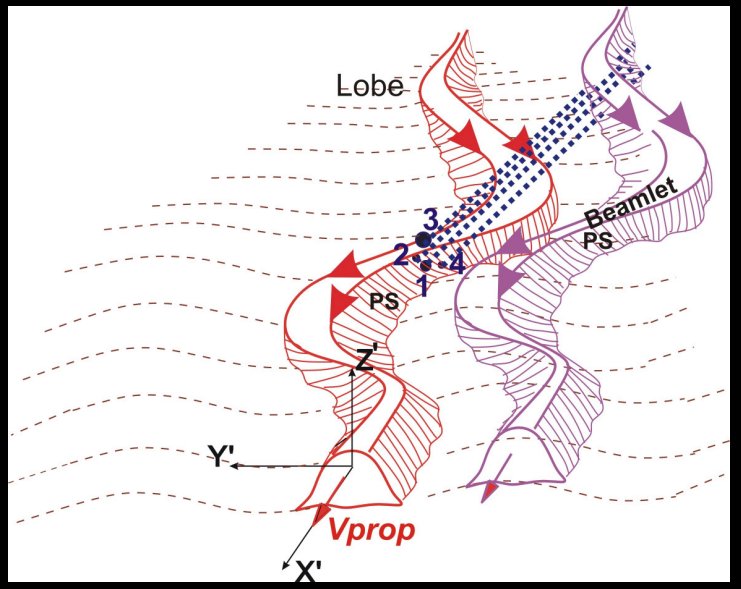
(Nagai et al., 2000;2001; Fujimoto et al., 2001; Nakamura et al., 2004; Grigorenko et al., 2012)

OBJE CTIVES

To check statistically:

- **Under what conditions the two types of ion beams, respectively the presence/absence of FACs are observed**
- **Are there any auroral and ground manifestations of the two types of beams**

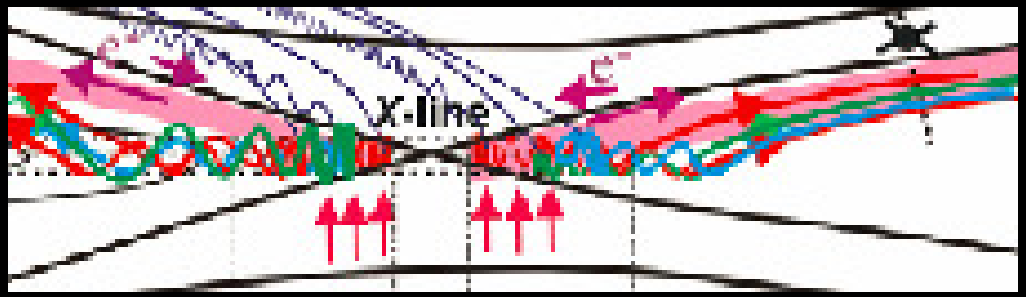




(Grigorenko & Koleva, 2009)

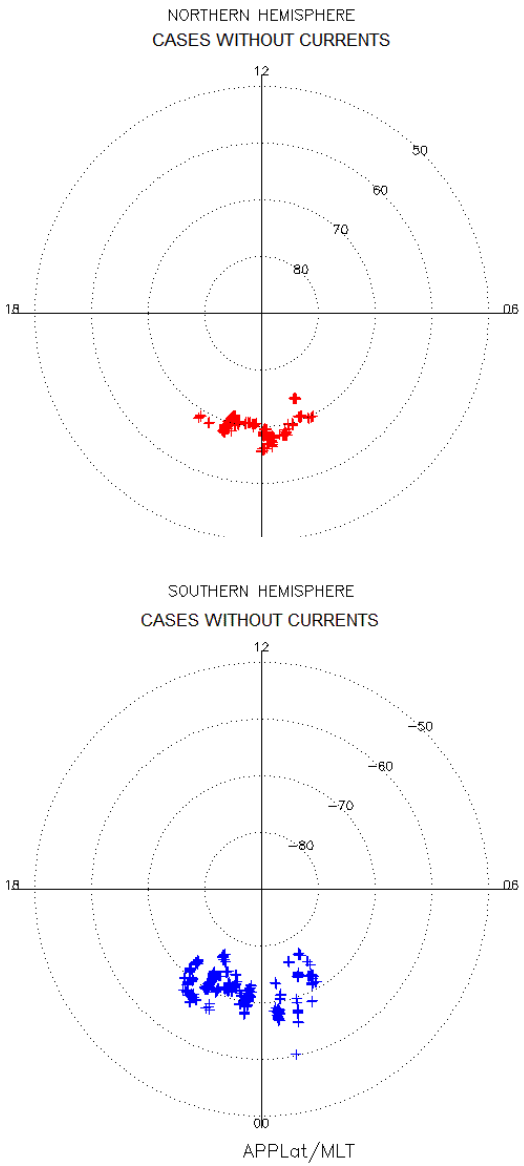
DATA

- Cluster ion (*HIA*) and electron (*PEACE*) distributions and magnetic field (*FGM*) at ~ 19 R_E; currents - *curlometer technique*
- Images from POLAR *(LBHL band)* and IMAGE
- Magnetograms from the SuperMag web page at *http://supermag.uib.no/*
- AL index*; quiet/disturbed boundary AL ~ - 300 nT*
- footprints - *Tsyganenko'96* model

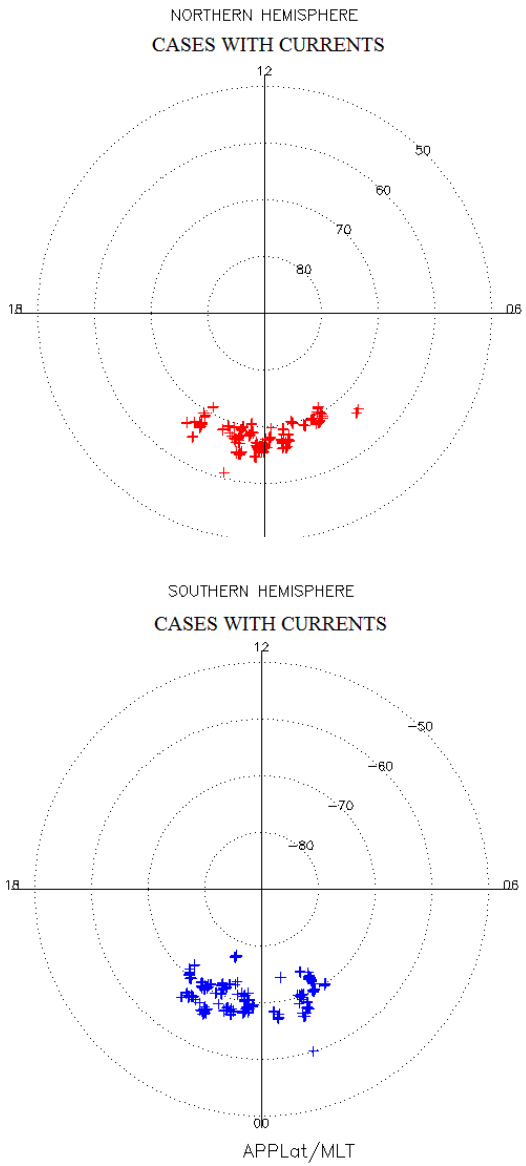


DATABASE: 364 CLUSTER encounters of PSBL with ion beams

127 cases of Type I beams (no currents)



237 cases of Type II beams, with currents (*curlometer technique)*



Type II ion beams

wide, energetic, accompanied with a pair of currents, generated at the vicinity of reconnection

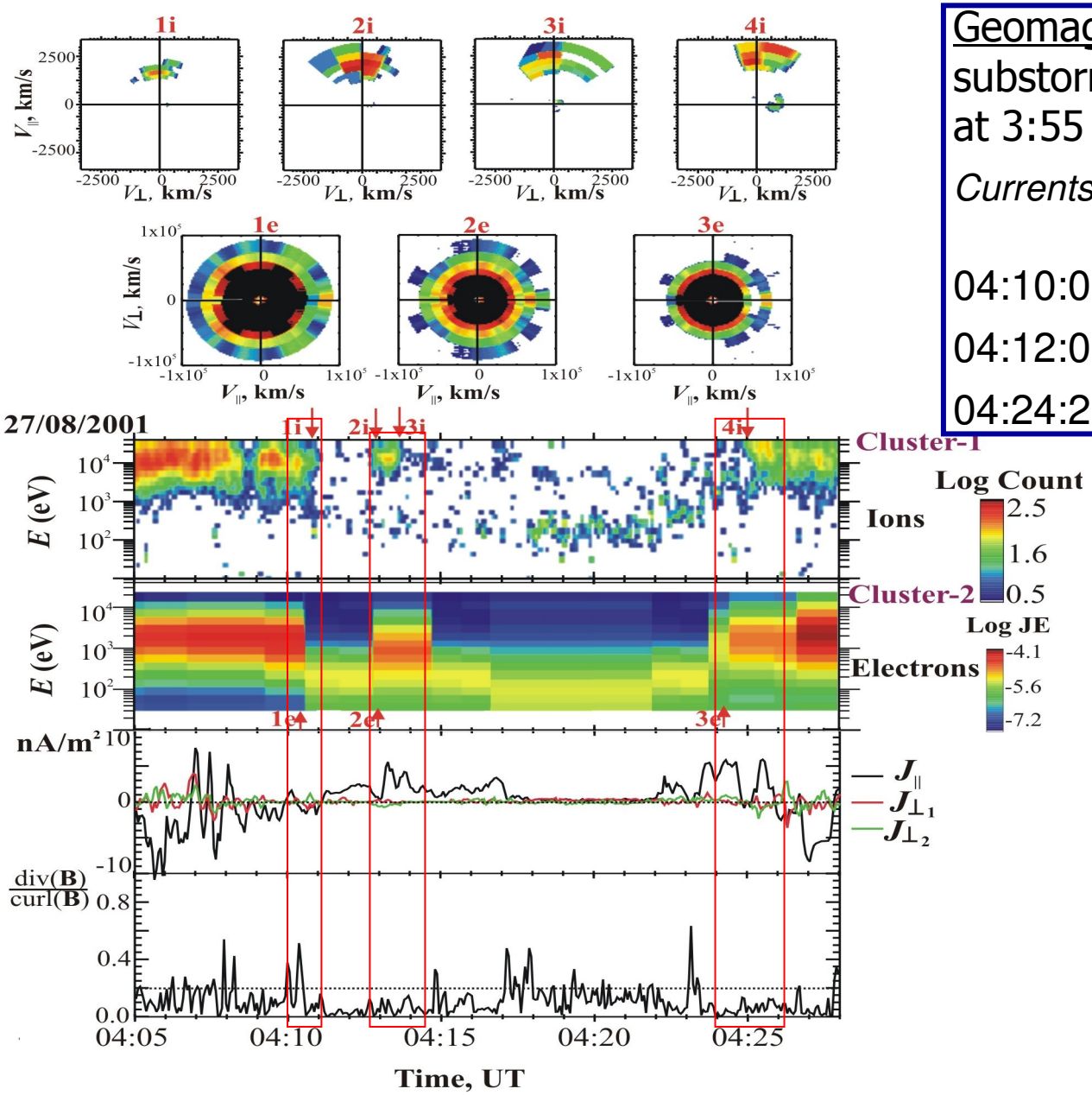
Out of 237 events:

107 events in the northern tail, 130 – in the southern.

137 - under |AL| > 300 nT (*disturbed conditions*)

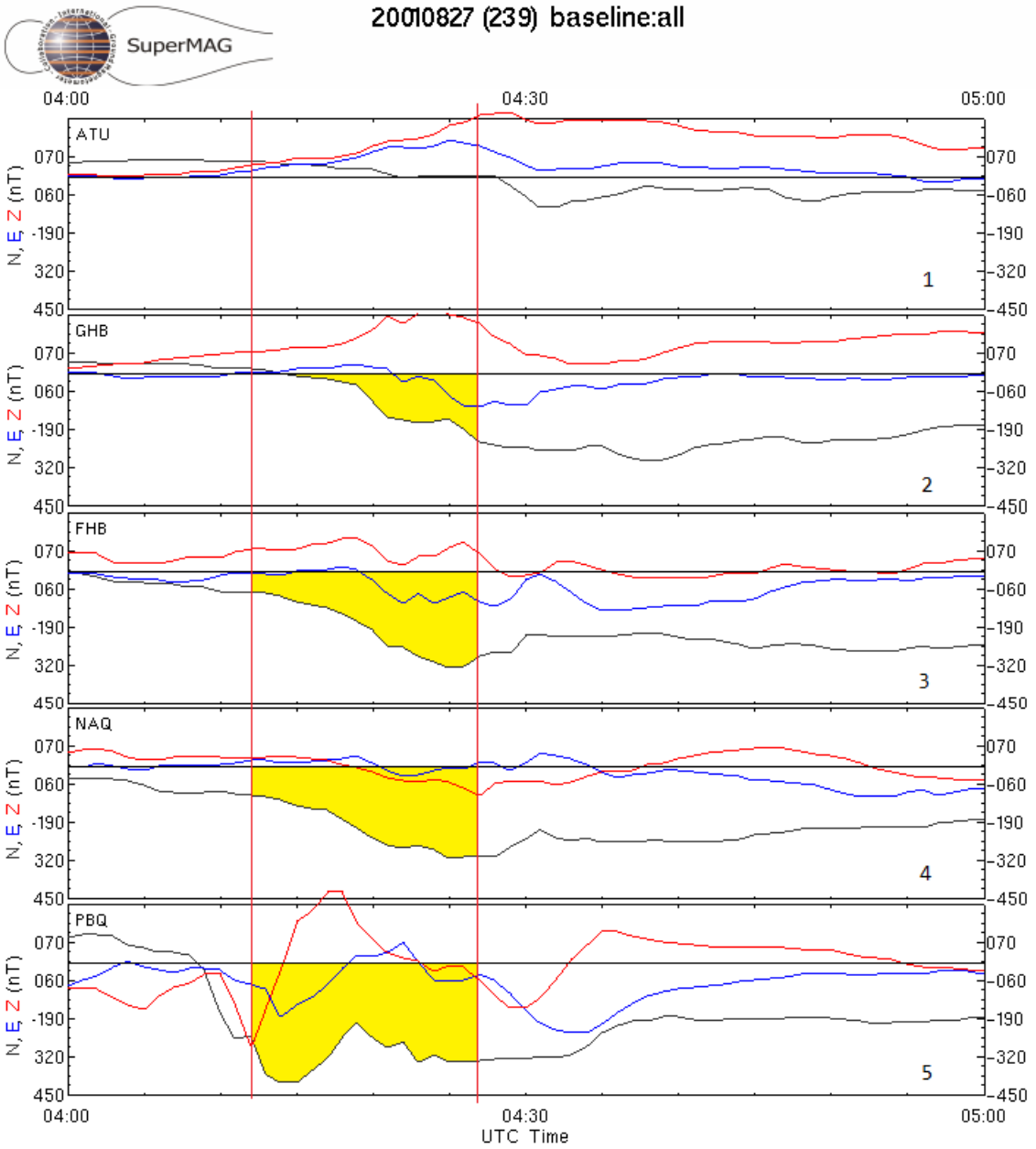
100 - under |AL| < 300 nT (quiet to moderate conditions)

TYPICAL Type II: Magnetic separatrix crossing in electron distribution - 27 Aug 2001



Geomagnetically disturbed period: substorm onset at ~ 04:10 UT or at 3:55 UT; |AL|> 400 nT

Currents at UT	*lobe*	*PS*
	[nA/m^2]	
04:10:00 - 04:11:00	2.4	-4.4
04:12:00 - 04:14:30	2.3	-4.5
04:24:22 - 04:26:11	2.8	-5.4



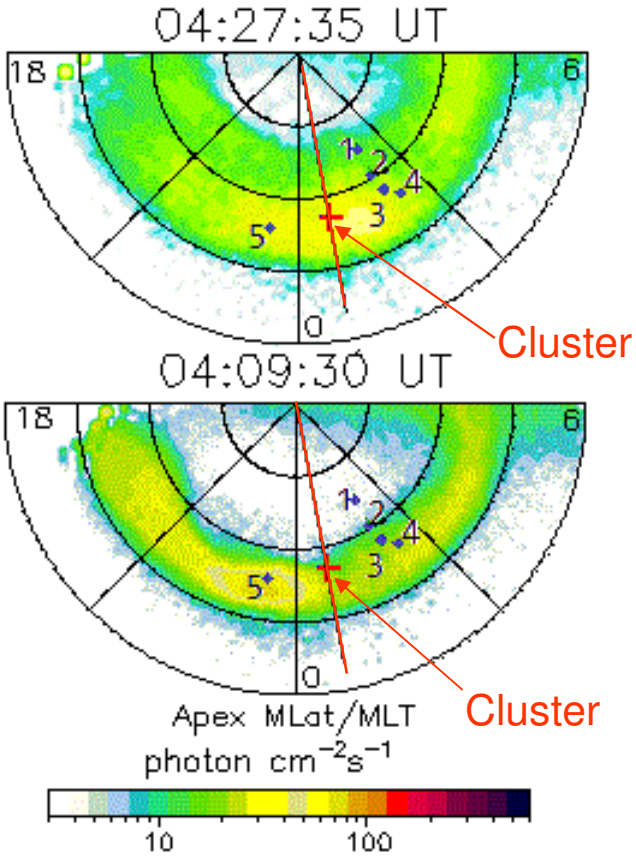
Currents at UT

04:10:00 - 04:11:00

04:12:00 - 04:14:30

04:24:22 - 04:26:11

POLAR



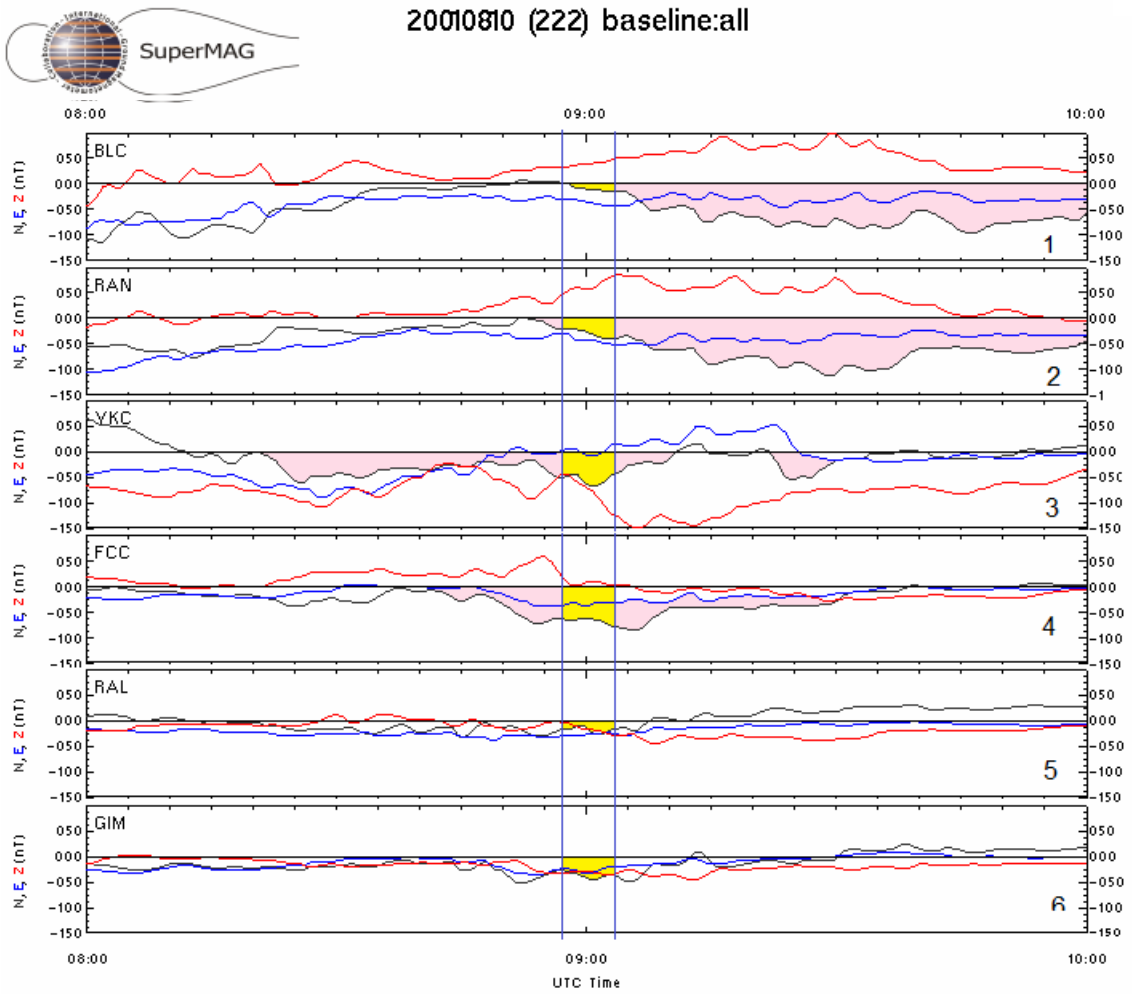
Type II ion beams and FACs when |AL| < 300 nT

100 cases

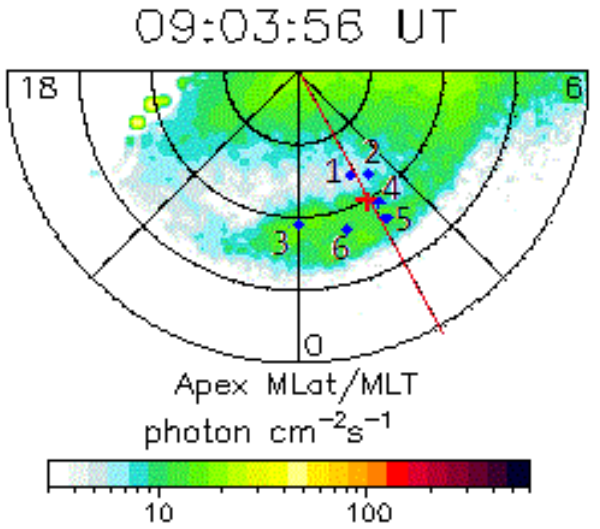
AL is a global index but a susbtorm or an auroral disturbance can be more localized. So we looked at the magnetograms of stations around s/c footprints and at satellite images when available

- ✓ **20 events are connected with small substorms according to IMAGE and SuperMag substorm lists**
- ✓ **7 are embedded in intervals of very disturbed conditions. For 19 events in the southern tail there were no appropriate magnetic stations or images**
- ✓ **54 events were carefully examined, combining with UV images where available. In all cases FACs are connected with local ground magnetic disturbances. Whenever UV images are available, FACs are projected to the polar boundary of the aurora lights – either a quiet oval (or a steady magnetospheric auroral convection), or a discreteform**

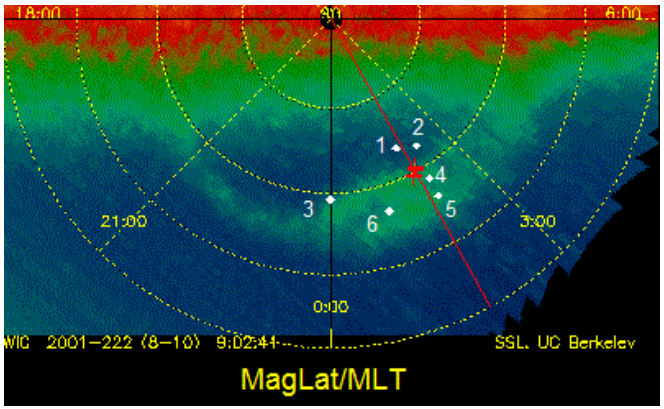
10 Aug 2001: *CLUSTER s/c encounters PSBL several times, each time registering field-aligned ion, but with varying velocity from ~1200 to ~ 2500 km/s, transient acceleration. Pairs of FAC at* 08:55:00 - 08:57:40 09:00:00 - 09:03:00. **71 nT < |AL| < 87 nT**



POLAR



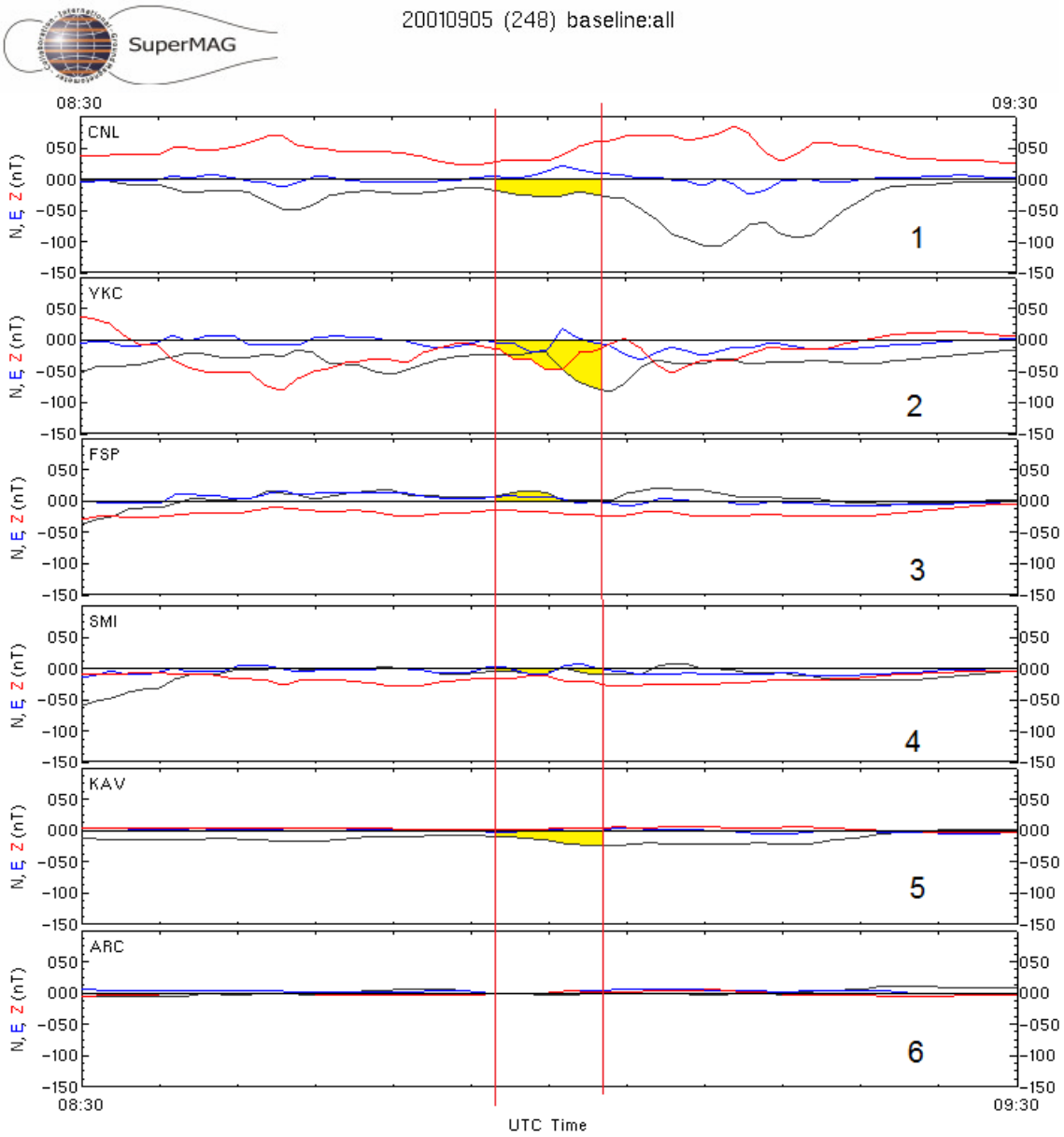
IMAGE



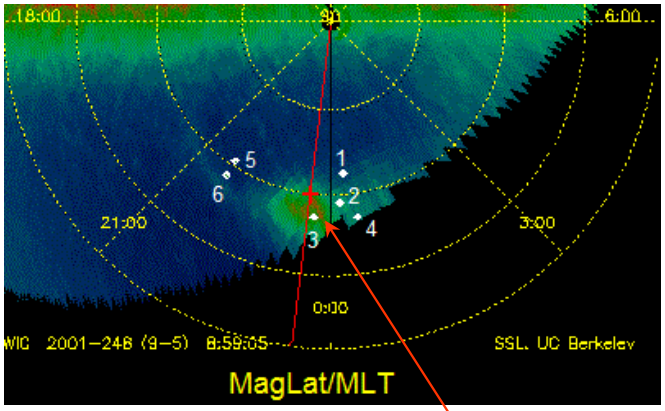
5 Sep 2001:

CLUSTER currents at 08:57:40 - 08:59:50 and 09:00:50 - 09:02:20

28 nT < |AL| < 72 nT



IMAGE



CLUSTER

pseudobreakup

Type I ion beams

collimated, less energetic, accompanied with isotropic electrons, negligible FACs, quasi-steady ion acceleration

Out of 127 events:

47 events in the northern tail, 80 – in the southern.

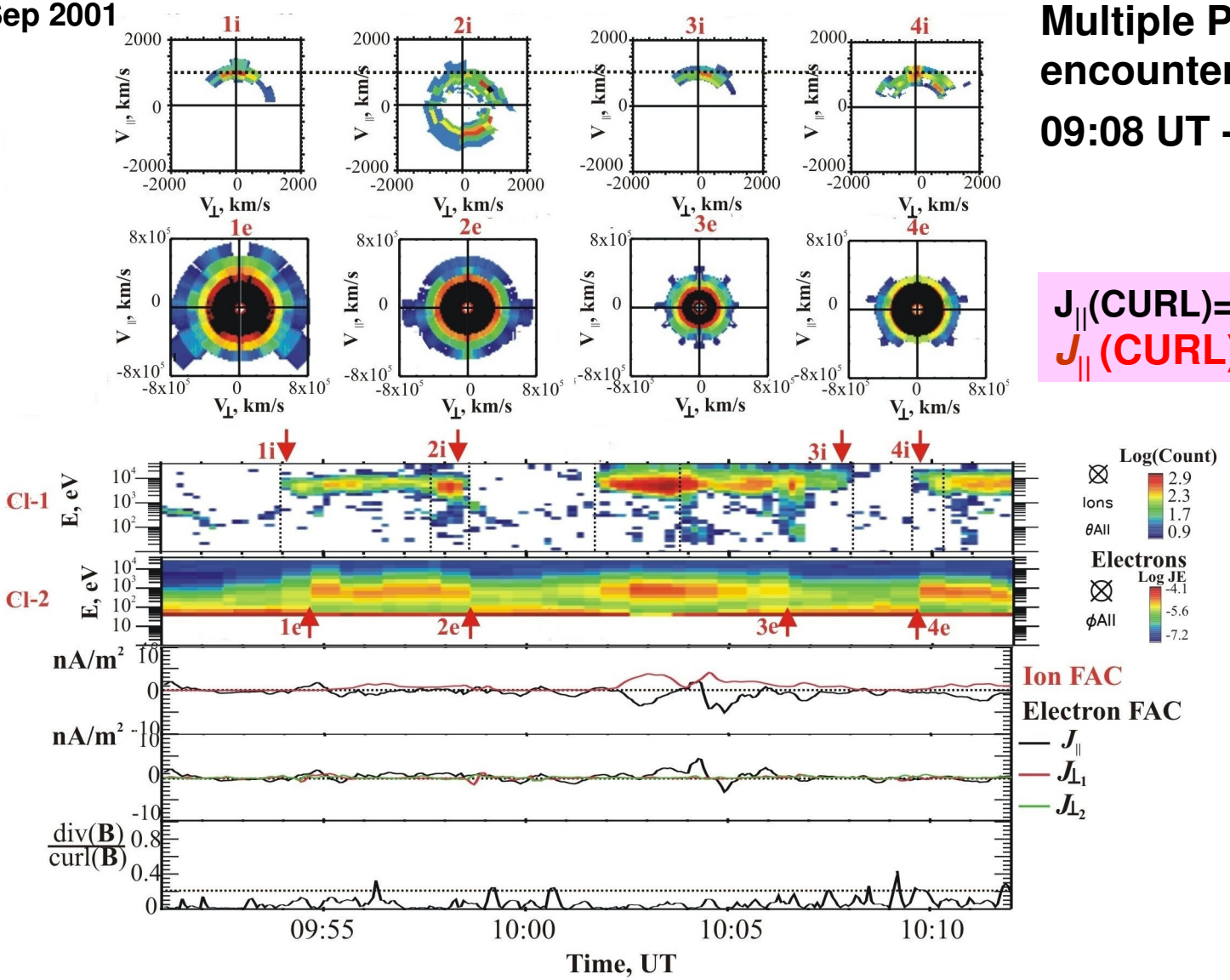
114 - under |AL| < 300 nT ('quiet' conditions)

13 - under |AL| > 300 nT (*disturbed conditions*)

TYPICAL Type I: 23 < |AL| < 28

($V_{||}$ ~ 1200 km/s; $\Delta V_{||}/V_{||}$ ~ 0.1, ~30 min)

12 Sep 2001

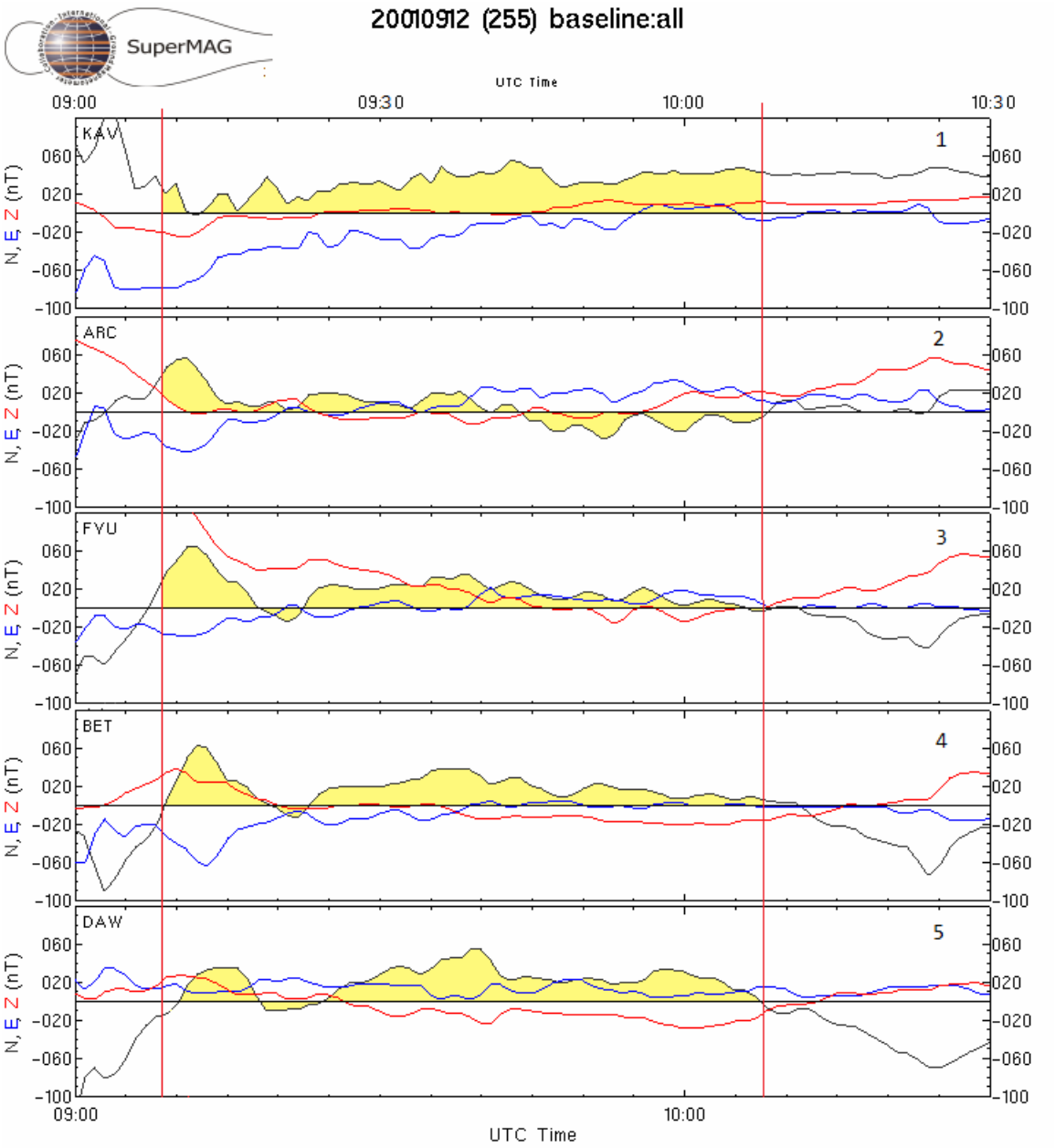


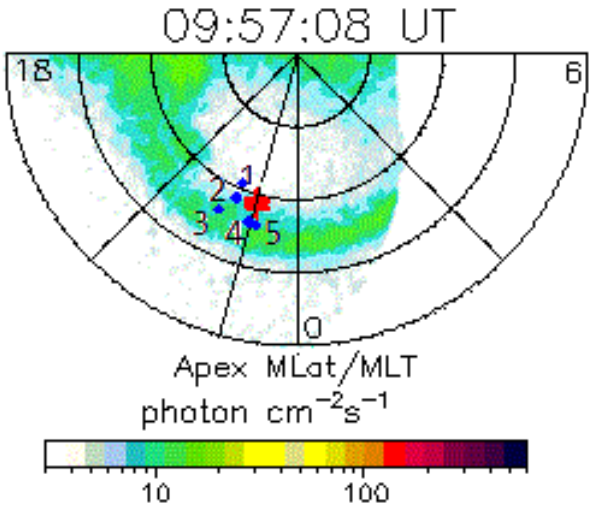
Multiple PSBL encounters

09:08 UT - 10:08 UT

$J_{||}(CURL)=J_{||}^{ion}+J_{||}^{ele}$

$J_{||}(CURL) \leq 2$ nA/m²

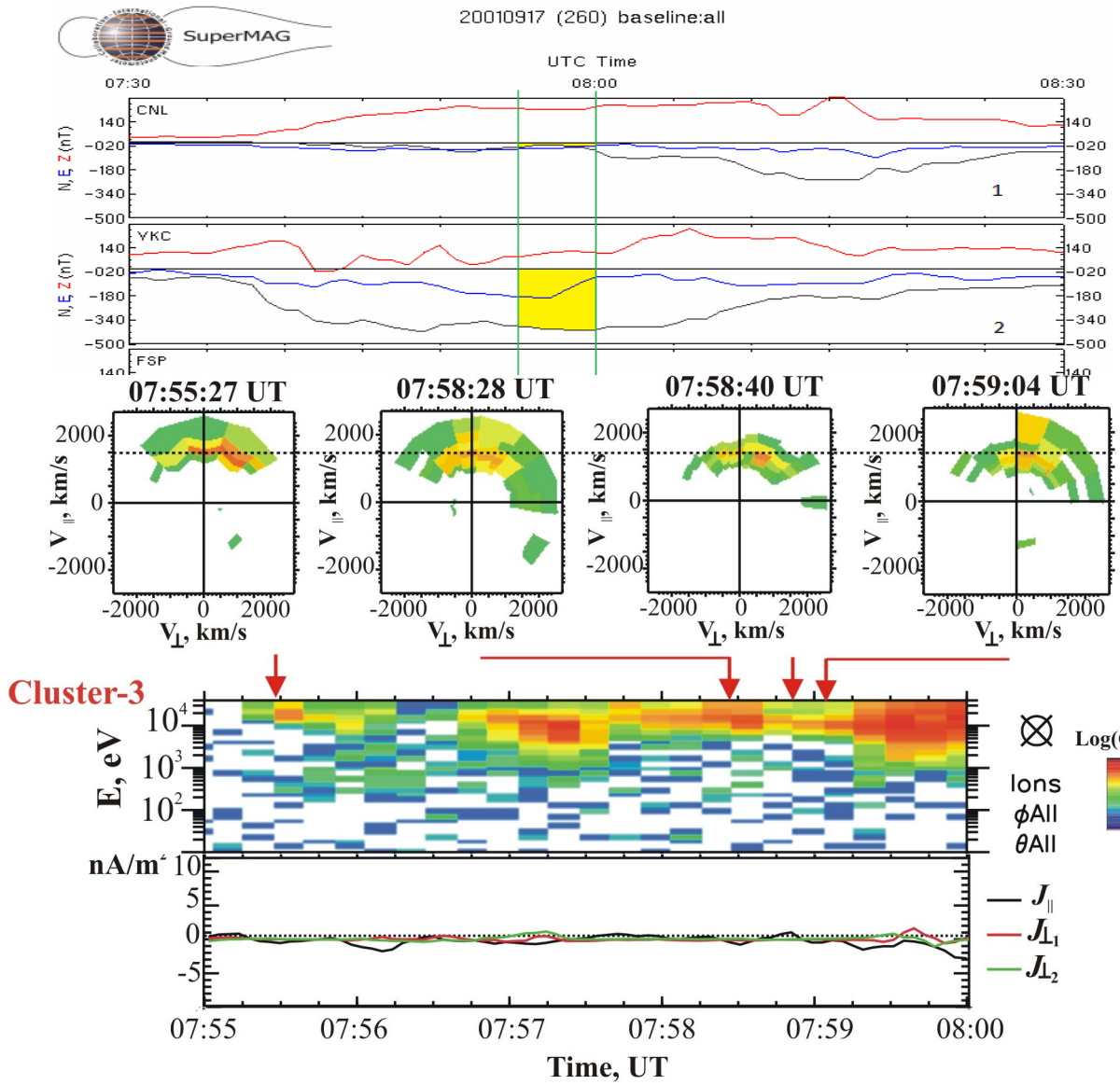


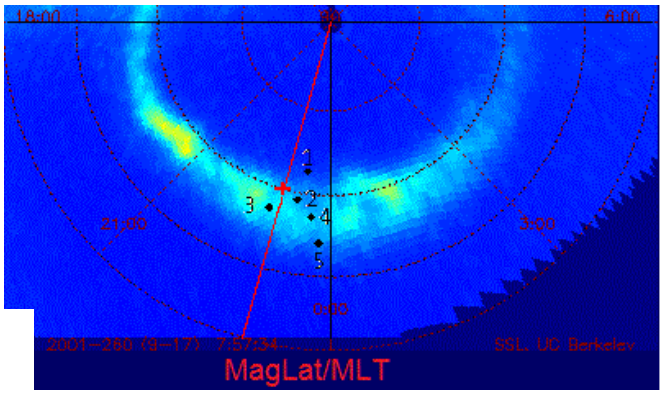


Quasi-stable arc exists at lower latitudes almost during the entire interval of interest. It decays by the end of interval.

Type I ion beam in disturbed conditions: |AL| ~ 390 nT

17 Sep 2001, 07:55:00 - 08:00:00 UT, FAC = 1 nA/m²





Lobeward edge: Type I, ***$V_{||}$ ~ 1500 km/s; $\Delta V_{||}/V_{||}$ ~ 0.2, ~4min, accelerated in the distant CS***

Deep PSBL: Type II,

$V_{||}$ ~ 2000 km/s, not stable, transient acceleration - additional source closer to Earth

CONCLUSIONS

Previous investigations of these beams, based on magnetotail data, showed that they are of two types:

Type I – observed mainly in quiet and moderately disturbed geomagnetic conditions (|AL| < 300 nT); highly collimated in velocity, long-lasting ion beams, accompanied by isotropic electrons; negligible ion FACs < 2 nA/m^2.

Type II – observed in mainly during disturbed periods (|AL| > 300 nT); anisotropic electrons with distributions comprised of cold electron beams (<1 keV) moving towards an acceleration source and by hot electrons (≥1 keV) streaming away from the source – a pair of electron (Hall current system) FACs.

It was suggested that Type I beams (rather – plasma structures) are generated by ion resonant acceleration on closed magnetic field lines at spatially localized sites which can arise rather far from the distant *X*-line; Type II – "reconnection beams", accelerated near the magnetic X-line, either quasi-stable or dynamic.

We have examined the auroral and ground manifestation of these PSBL ion beams in the vicinity of their possible footprints. These manifestations confirm the suggested acceleration mechanisms.

Irrespectively of the global geomagnetic activity:

Type I beams

- Magnetograms of appropriate stations do not exhibit any evident Bx varations
- beams are projected either well poleward of a quasi-stable auroral arc or at the poleward oval region in cases with no pronounced auroral forms;
- support the suggested mechanism of their resonant acceleration

Type II beams, with a pair of FACs. ***The small current density and the thin current sheets make it impossible to discriminate them from the background auroral electrojet current system. As FACs are generated in the course of tail reconnection, at auroral altitudes and on the ground we observe the result of the precipitating accelerated by the reconnection process electrons.***

- FACs are always associated with well pronounced disturbances in Bx at the vicinity of their footprints
- FACs footprints are located at the polar boundary of a bright discrete auroral form or of the quiet auroral oval.
- The presence of FACs at the polar boundary of a discrete auroral form suggest origin in a dynamic reconnection process
- The presence of FACs at the polar boundary of a quiet auroral oval implies that the FAC current system could be formed in the course of a quasi-steady magnetic reconnection

We have found evidence that both acceleration mechanisms can co-exist.

Thank you for your attention