Source Location of the Wedge-like Dispersed Ring Current in the Morning Sector During a Substorm

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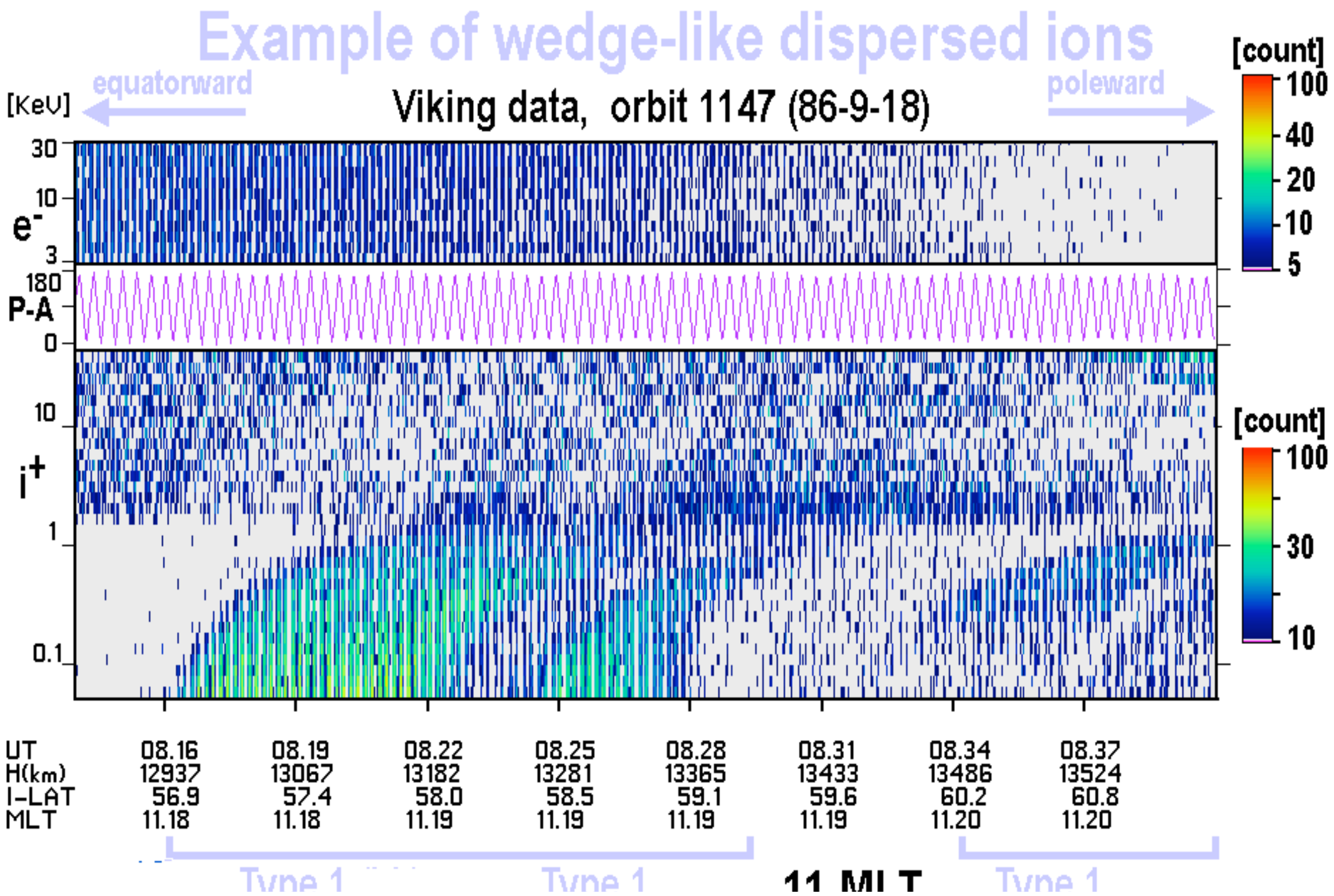
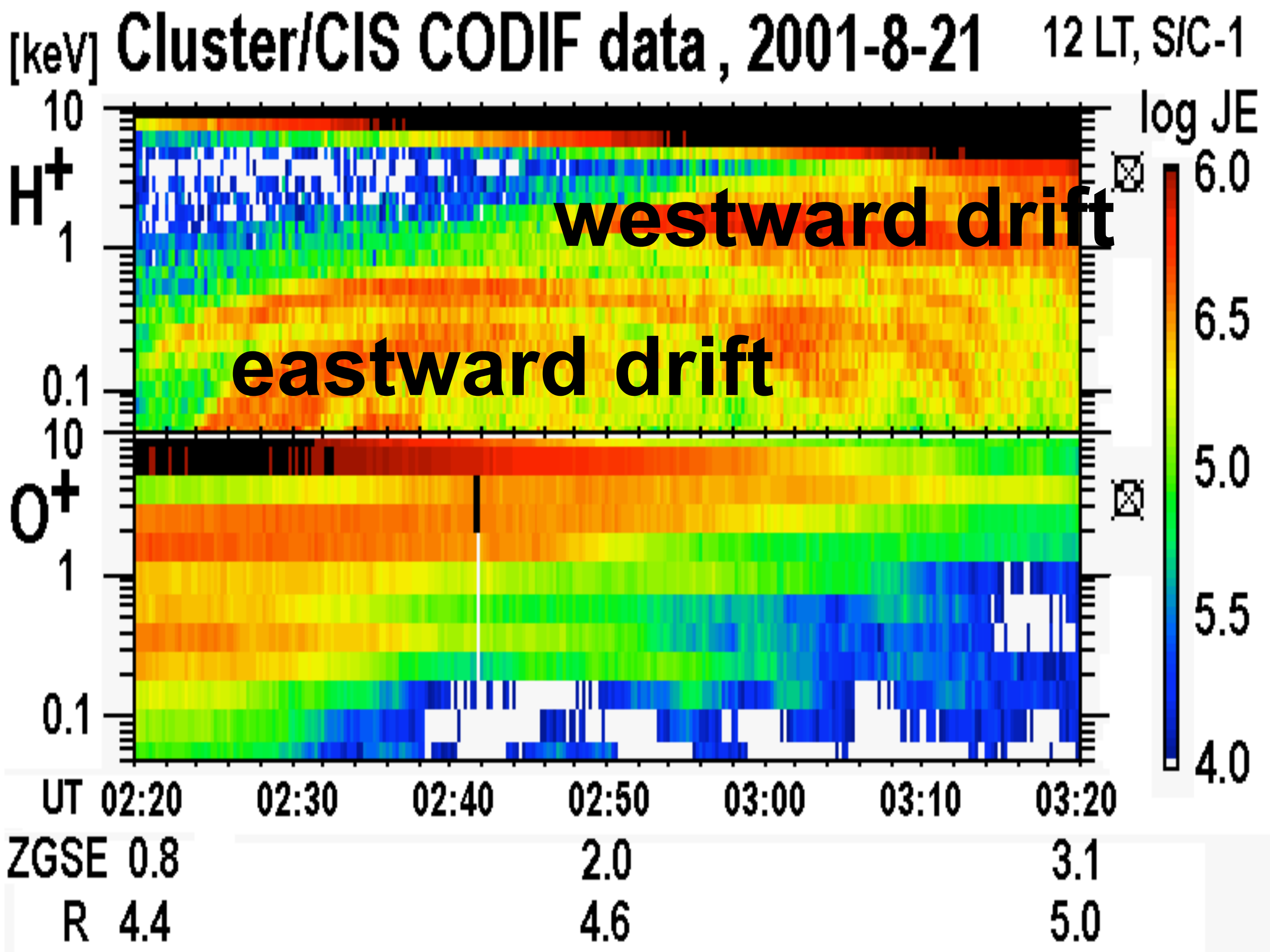
XY0863 (EGU06-A-05934) 2006-4-6 / see also XY0868 in this session.

What is "wedge-like dispersion" / What is the problem?





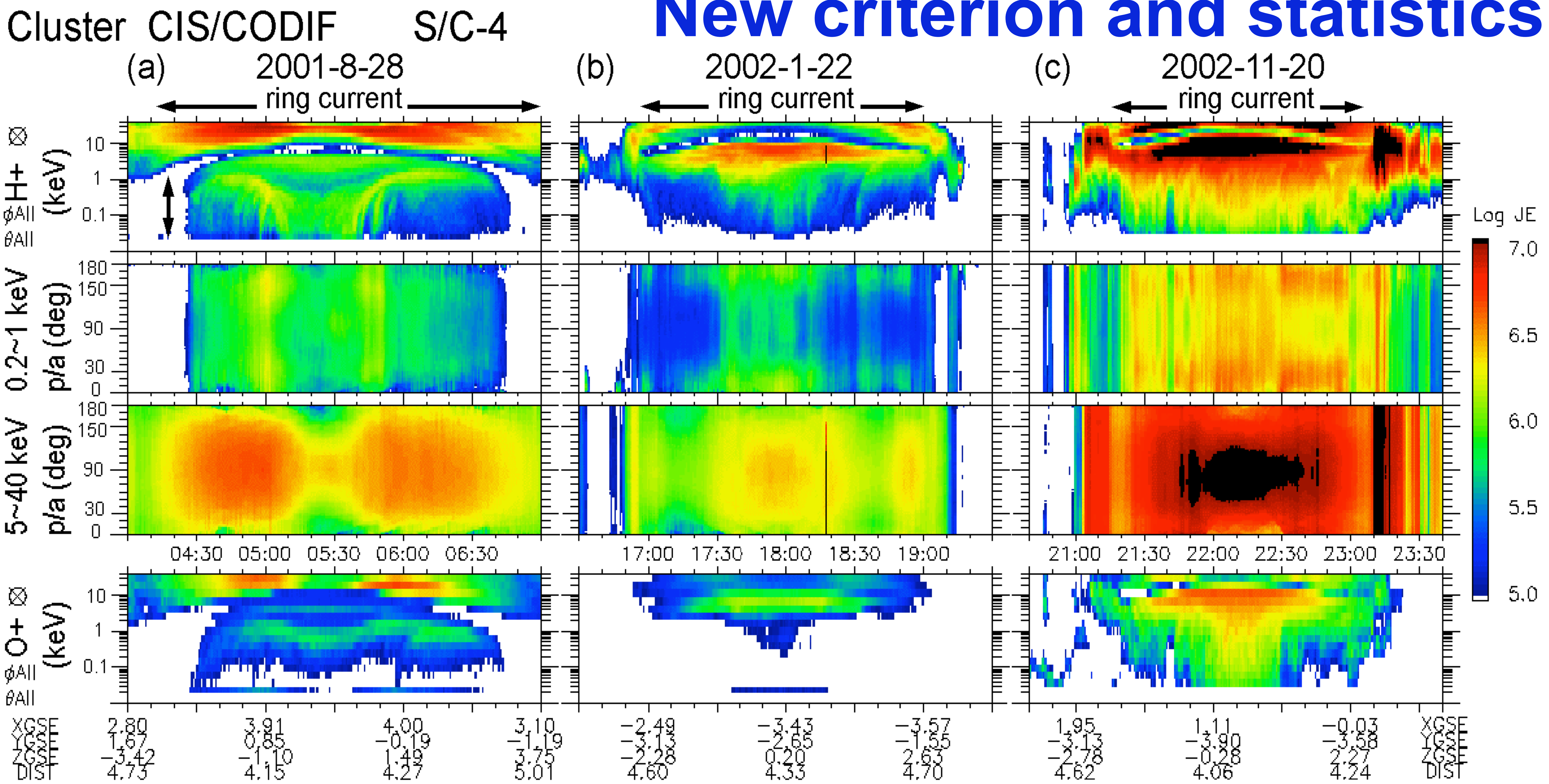
Sub-keV trapped ions seen almost all satellites at around L=4-6. They are **wedge-like** energy-latitude dispersed as shown in both Viking data (mid-altitude) and Cluster data (equatorial plane). See **Poster XY0868** by Yamauchi and Lundin in this session.

Data analyses and simulation confirmed that they are drifting trapped ions (I.e., Cluster should see the same phenomena as Viking). **Past analyses raised two main questions.**

(1) Past identification of "wedge" observed by Cluster was in-appropriate because the resultant distribution does not agree with the simulation or other satellites. We need to refine the criterion.

(2) Past statistics suggests that the source can be in the morning sector during substorms. We need to identify the source location from event study.

New criterion and statistics



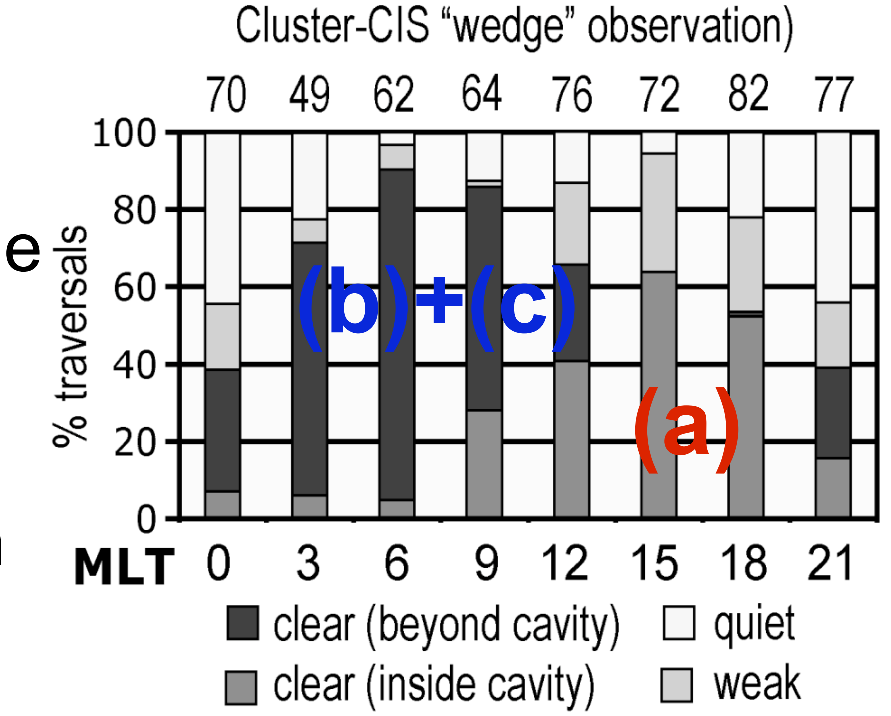
Past criterion: completely isolated from > 5 keV ring current.

⇒ **Only (a) is identified as "wedge" but not (b) or (c)**

New criterion: isolated from > 5 keV component at the wedge location, as long as wedge is extended from sub-keV.

⇒ **All of (a), (b), and (c) are identified as "wedge"**

New statistics shows morning peak, which is consistent with the other statistics and simulation.



Case study

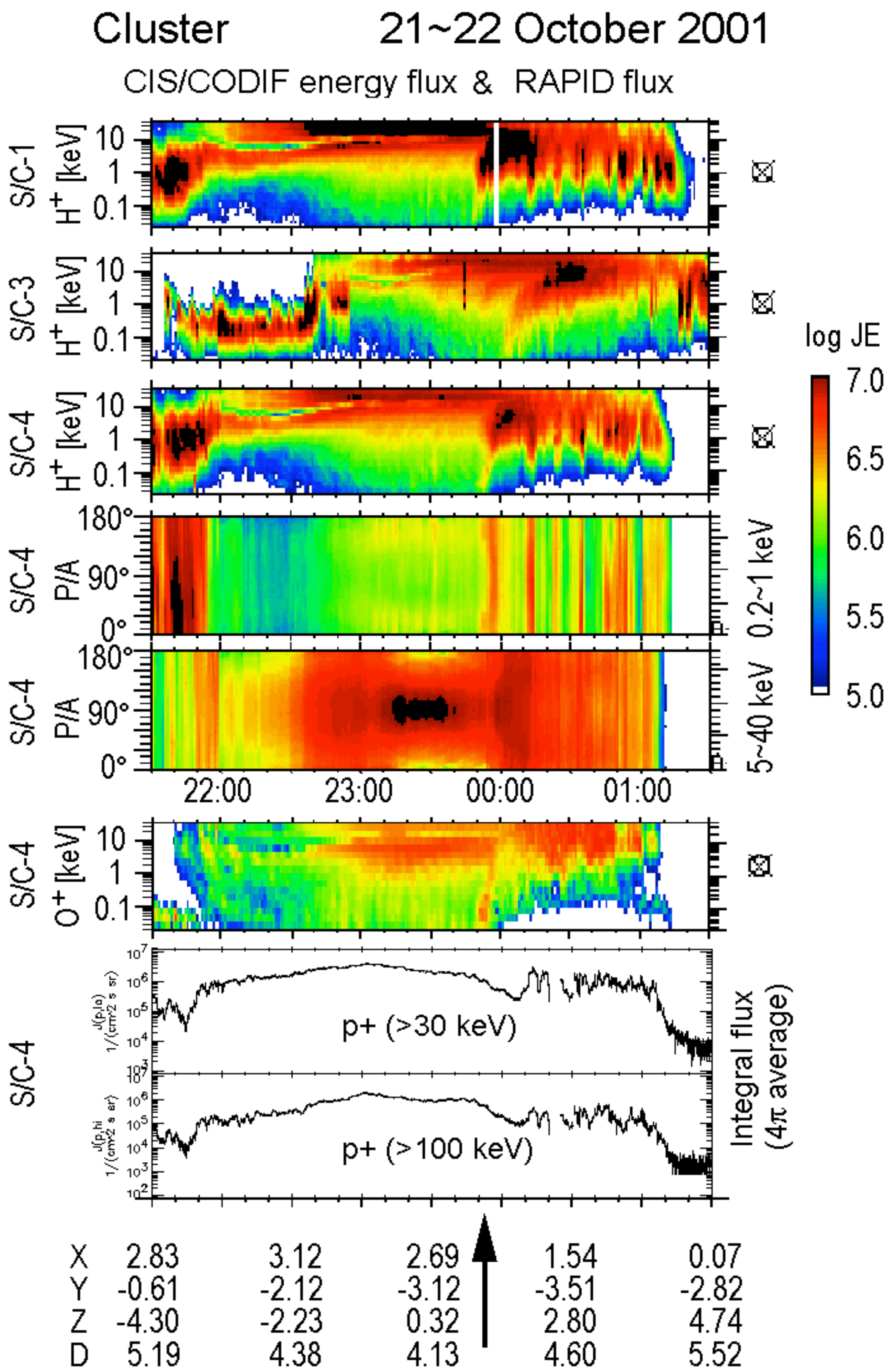
We confirmed the morning peak, suggesting that a substantial amount of the wedge might be formed in the morning. Pitch-angle distribution suggests the ionospheric source (also consistent with morning source).

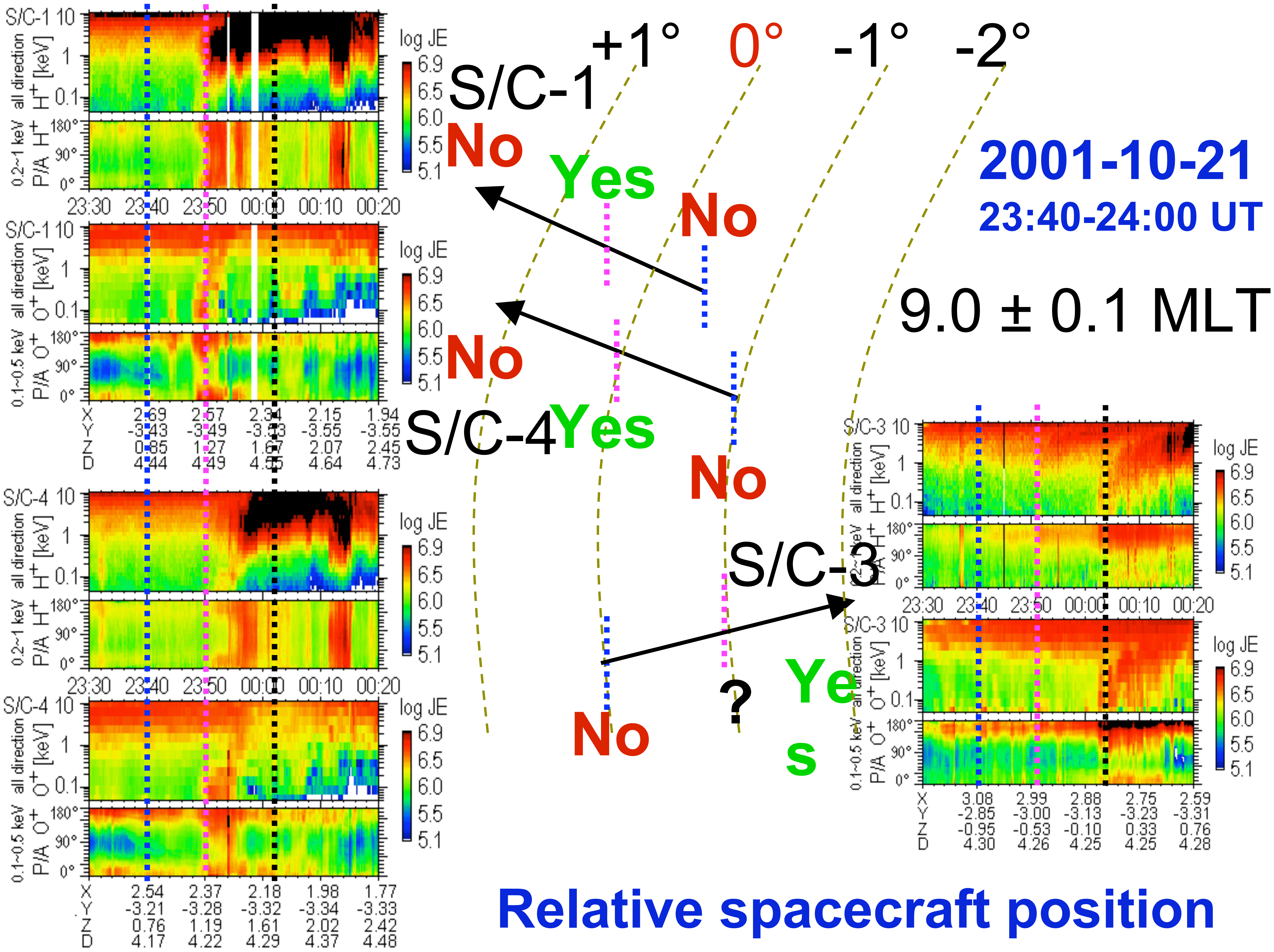
We have several possibilities in terms of the location of dense ion formation and location that dispersion starts:

Ion source	dispersion	scenario
night	night	No !
night	morning	(A)
morning	morning	(B) (C)

(A) Strong electric field push ions quickly.
(B) Energetic ions precipitate and scatter ionospheric ions into the space.
(C) Unknown local energization process.

⇒ Need to find events when the wedge is formed during substorms. We found one case. **Wedge is seen only at outbound**.





S/C-1
S/C-4
S/C-3
+1°
0°
-1°
-2°
No
Yes
No
No
Yes
No
No
?
Yes
2001-10-21
23:40-24:00 UT
9.0 ± 0.1 MLT
log JE
all direction H+ [keV]
0.2~1 keV H+ P/A
all direction O+ [keV]
0.1~0.5 keV O+ P/A
23:30 23:40 23:50 00:00 00:10 00:20
X 2.69 2.57 2.34 2.15 1.94
Y -3.43 -3.49 -3.53 -3.55 -3.55
Z 0.85 1.27 1.67 2.07 2.45
D 4.44 4.49 4.55 4.64 4.73
X 2.54 2.37 2.18 1.98 1.77
Y -3.21 -3.28 -3.32 -3.34 -3.33
Z 0.76 1.19 1.61 2.02 2.42
D 4.17 4.22 4.29 4.37 4.48
X 3.08 2.99 2.88 2.75 2.59
Y -2.85 -3.00 -3.13 -3.23 -3.31
Z -0.95 -0.53 -0.10 0.33 0.76
D 4.30 4.26 4.25 4.25 4.28
Relative spacecraft position

Observation summary

S/C-1 (23:45 UT), S/C-4 (23:50 UT), and S/C-3 (23:40 UT) passed through the same magnetic flux tube at 9 MLT (L≈4).

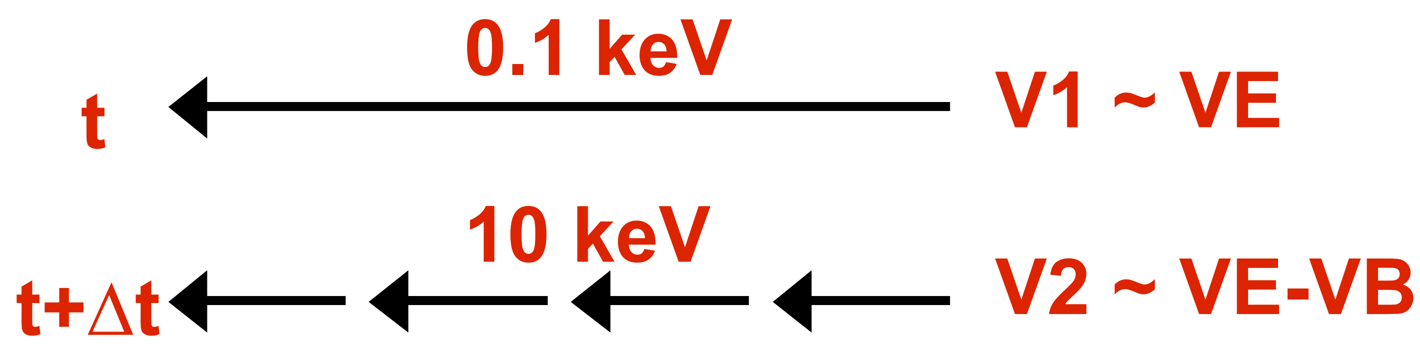
Wedge-like dispersion at 23:50 UT.
No low-energy signature at 23:40 UT.

Butterfly-trapped distribution
⇒ Bounce inside the geomagnetic bottle.
⇒ **Difference between 23:40 UT and 23:50 UT in the same flux tube means an temporal variation** although observation is made in the opposite hemisphere.

VE: eastward ExB drift speed = energy independent, MLT dependent
VB: westward magnetic (∇|B|+curvature) drift velocity = energy dependent
VE >> VB at low energy (<100 eV) and VE ~ VB at high energy (value depends on E-field strength). From dispersion curve, the last-coming ions are 10-20 keV. Therefore, **VE ~ VB at 20 keV in the present case.**

time-of-flight principal

V1 = VE-VB ~ VE @ 0.1 keV
V2 = VE-VB << VE @ 10 keV



$V1*t = V2*(t+\Delta t)$ or

$(t+\Delta t)/\Delta t = V1/(V1-V2)$

$\sim VE/VB$ (note : VB@10 keV)

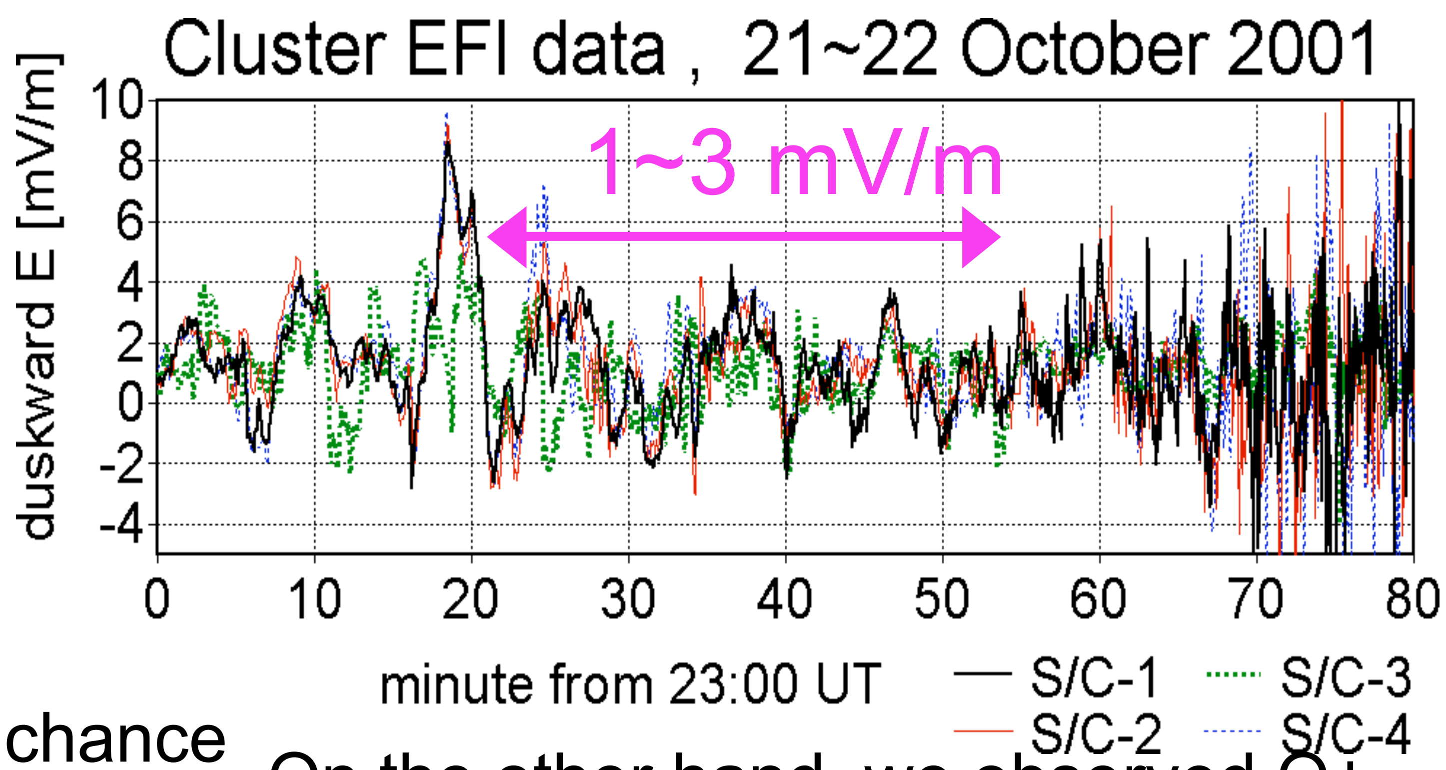
$= (E/B)*(q*R*B/3*W*g)$

$\sim E$ [mV/m]/g or

$t = \Delta t*E$ [mV/m]/g $- \Delta t$

for observation near equatorial plane, where
E and B are the field strengths,
q is the charge,
R = 4 RE is the geocentric distance,
W = 10 keV is the ion energy, and
g ~ 1, 0.9 &0.7 for 90°, 40° & 0° pitch angles

Dispersion analysis



Pitch angle of the "wedge" is about 40~90°
(g=0.9~1.0) ⇒ **t ≦ (1.1*E[mV/s] - 1) * Δt**

Electric field is 1~3 mV/m for half an hour
⇒ **t = 0.1~2.3*Δt** & **VE = 3~10 km/s**

(a) 0.1 keV @ 23:50 UT, S/C-1
⟸⟹ Nothing @ 23:40 UT, S/C-3 : temporal chance

(b) 10 keV @ 23:53 UT, S/C-1
⟸⟹ Nothing @ 23:40 UT, S/C-3 : temporal change

(c) 0.1 keV @ 23:50 UT, S/C-1
⟸⟹ 10 keV @ 23:53 UT, S/C-1 : temporal or spatial

Combination of (a) + (b) : **it is temporal change**
⇒ **Δt < 13 min ⇒ t < 30 min before 23:40 UT**
⇒ **drift distance = VE * t < 20000 km**
⇒ **dispersion started at 7~9 MLT.**

Combination of (b) + (c) : **if temporal**
⇒ **Δt ~ 3 min ⇒ t = 0.5~8 min before 23:50 UT**
⇒ **drift distance = VE * t = 100~5000 km**
⇒ **dispersion started at 8~9 MLT.**

On the other hand, we observed O+ "wedge" at 0.05-0.3 keV (20 km/s ~ 50 km/s). The 0.05 keV O+ takes 20~30 min to travel from the ionosphere to the Cluster location along B in best case. From this:

(1) **Source timing is about 20~30 min before, i.e., at 23:20~23:30 UT.**

(2) **The combination (b)+(c) cannot be true**, i.e., the observed dispersion is mostly the spatial structure.

(3) O+ should **not have mirror-bounced**, and this is confirmed from nearly uni-direction pitch angle.

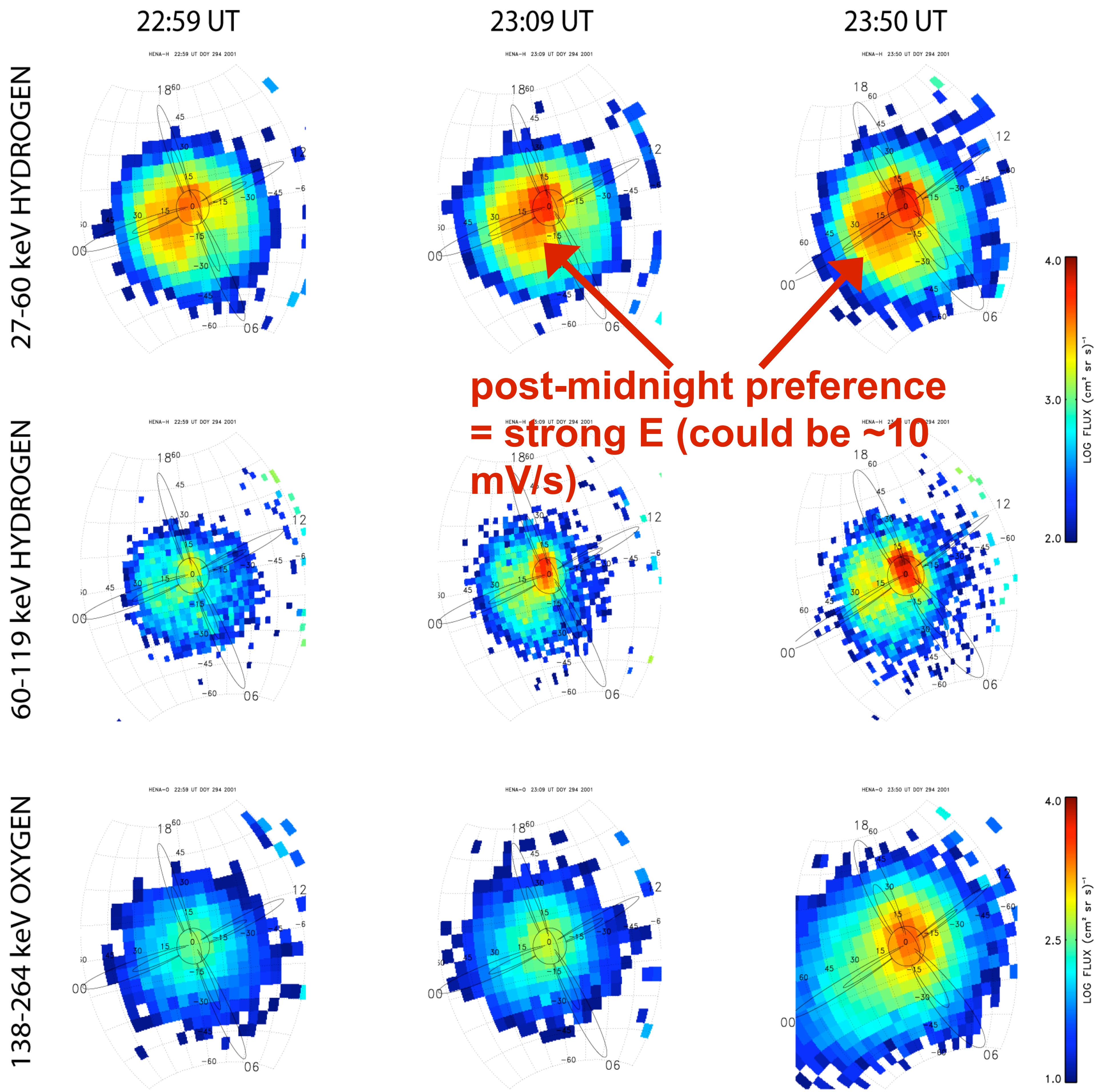
General context (deduced from ENA image)

ENA image indicates
(1) strong E
(2) No energetic H+ in the late morning sector
(3) qualitative difference between O+ and H+

Strong E $\Rightarrow$ scenario (A) in the Table:
Ions < 10 keV could have convected to the morning sector quickly without forming the dispersion.

No energetic H+ $\Rightarrow$ difficult for scenario (B) in the Table unless electron is important

H+ - O+ difference $\Rightarrow$ At least O+ wedge can be formed local



Summary and conclusions

Cluster statistics (9 MLT) shows that :

(a) New identification criterion works (for Cluster).

(b) Local time distribution suggests the morning source.

(c) Pitch-angle distribution suggest ionospheric source (consistent with morning source).

Case study from 2001-10-21 event (9 MLT) shows that

(d) The "wedge" suddenly appeared in the magnetic flux tube in which no signature was recognized 10 minutes before.

(e) The dispersion is formed within 3 Re distance from the spacecraft within 30 minutes before the observation.

(f) Observed oxygen ions of the "wedge" were not mirrored, i.e., they directly came from northern ionosphere 20-30 minutes before.