THEMIS observations of a gap in whistler mode chorus emissions inside the source region

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THEMIS-D
2008/10/23, 06:00 – 07:00

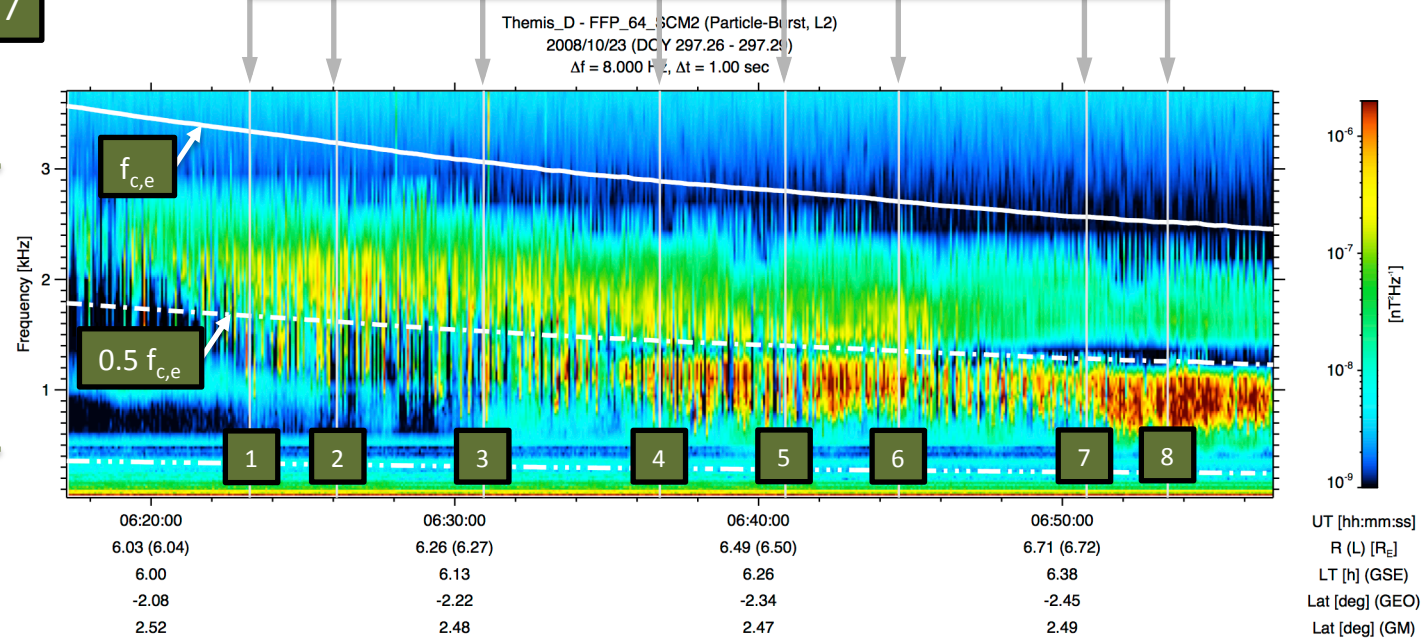
GEOSPACE REVISITED
Rhodes, Greece
September 15 - 20, 2014

THEMIS-D
2008/10/23, 06:17 – 06:57

Times of high-resolution wave-burst mode observations

Magnetic Spectrum
Search Coil Magnetometer
Particle Burst (FFP)

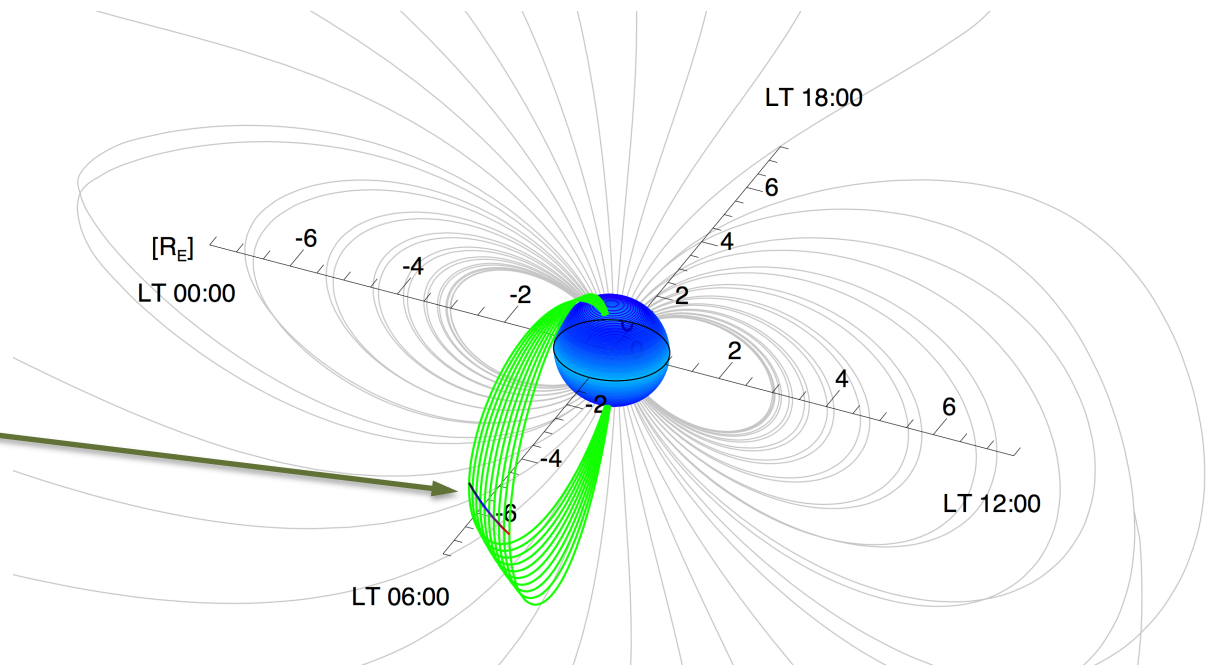
whistler mode
chorus/rising tones



T96-Model for $\mathbf{B_0}$

THD-Orbit
2008/10/23, 06:00 – 07:00
(SM coordinates)

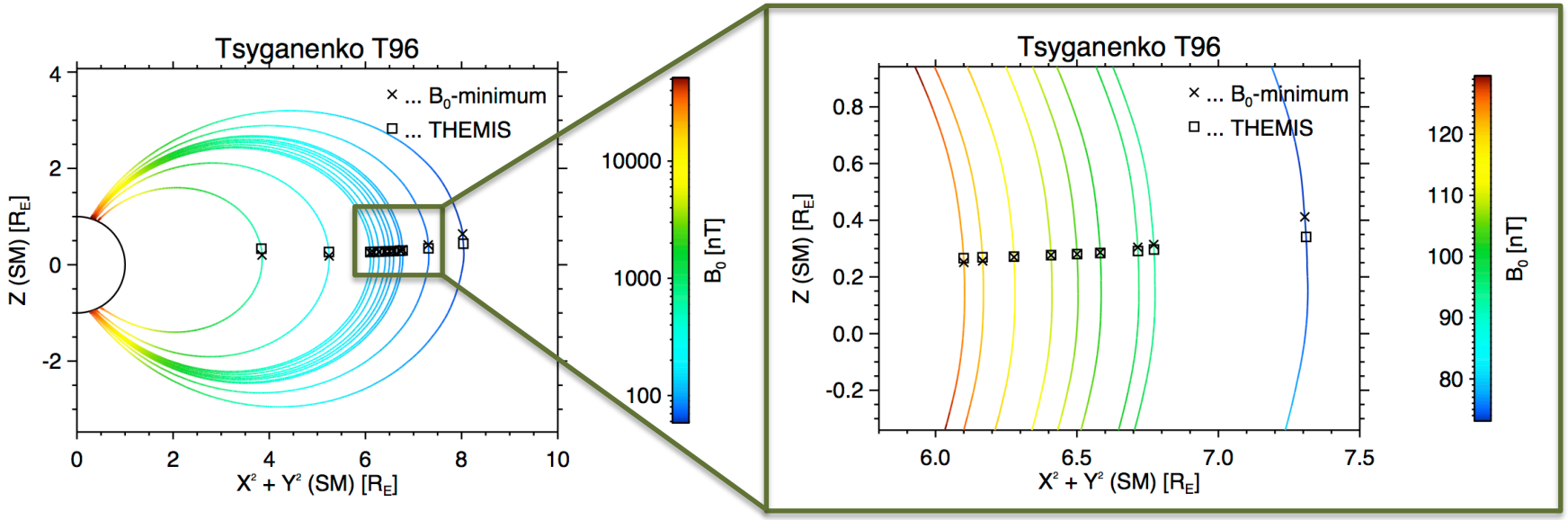
6.0 < L < 6.8
MLAT ≈ 2.5°
6.0 < MLT < 6.4

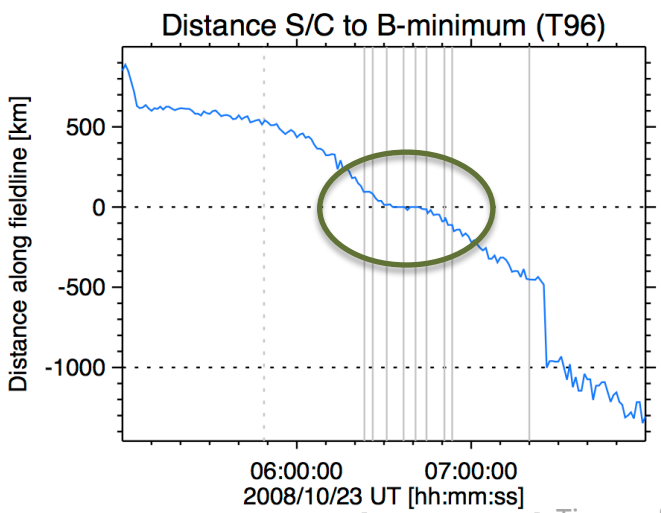


THEMIS-D
2008/10/23, 05:00 – 08:00

Chorus-source in B_0-minimum along active fieldline;
get B_0-minimum from Tsyganenko-T96 model

Find distance of spacecraft to B_0-minimum in T96-Model





Times of wave-burst snapshots

At times of wave-burst snapshots, THD is actually crossing the B_0-minimum

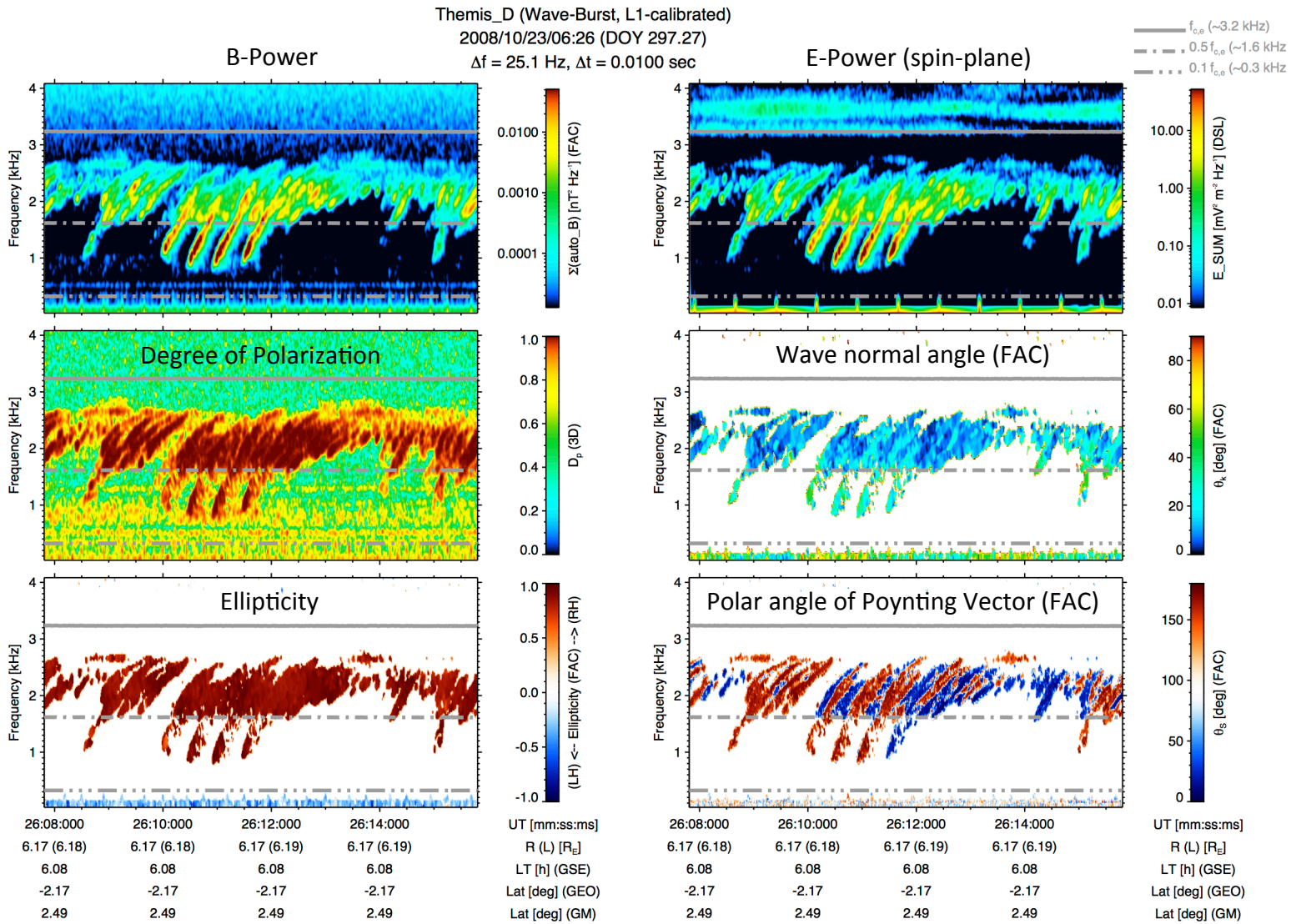
(THD below B_0-minimum => negative distance)

Model has uncertainty of a few 100 km

THEMIS-D
2008/10/23, 06:26

SCM, wave-burst mode, snapshot no. 2

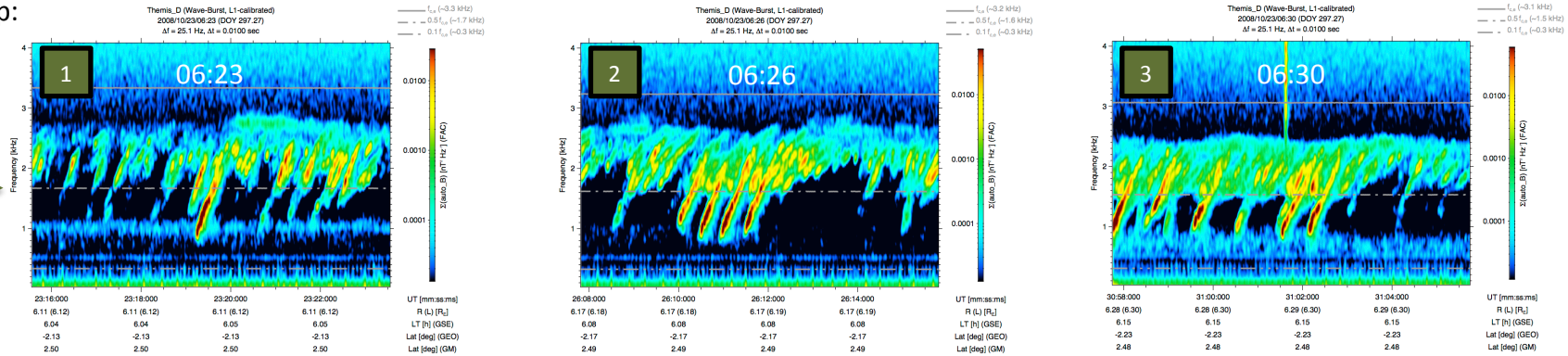
- Chorus rising tones
- Bursts crossing 0.5 $f_{c,e}$
- degree of polarization $D_p \approx 1$
- Ellipticity ≈ +1 (RH)
- $\theta_k < 30°$ (FAC); **k** quasi-parallel $\mathbf{B_0}$
- $\theta_S < 30°$ and $\theta_S > 150°$; Poynting Vector **S** along/against $\mathbf{B_0}$-direction



Magnetic Spectra - $\Sigma_i \langle B_i B_i^* \rangle$ (sum of auto-correlations)

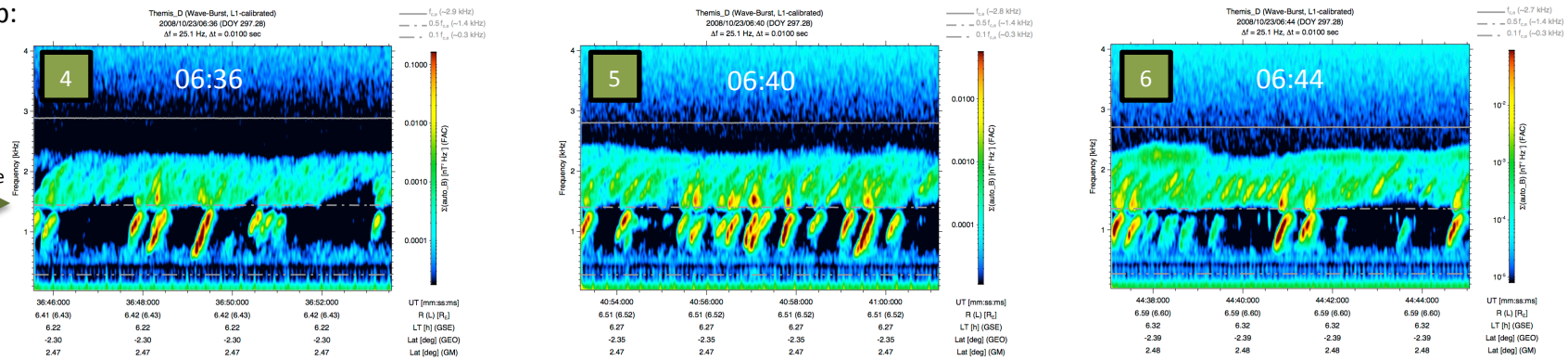
no gap:

0.5 $f_{c,e}$



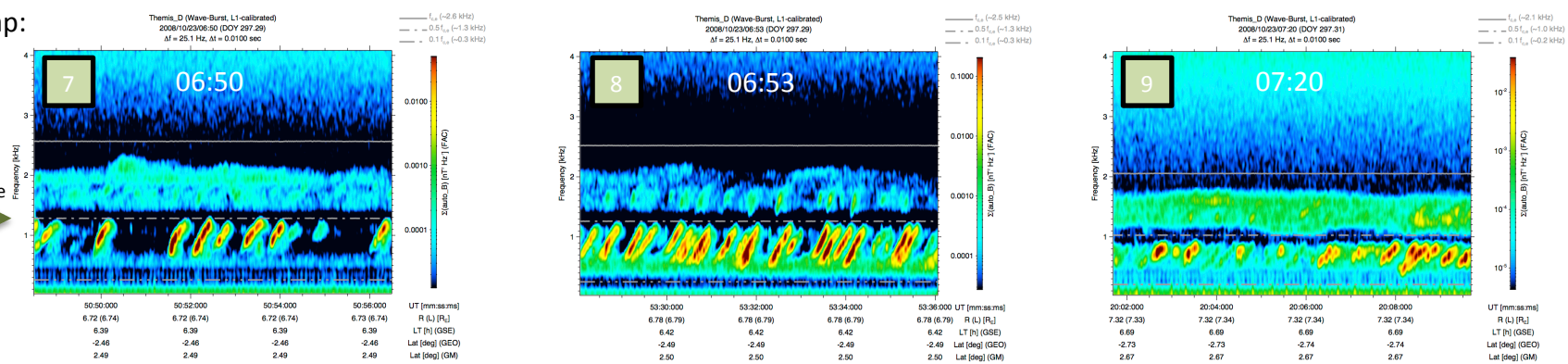
small gap:

0.5 $f_{c,e}$



gap:

0.5 $f_{c,e}$

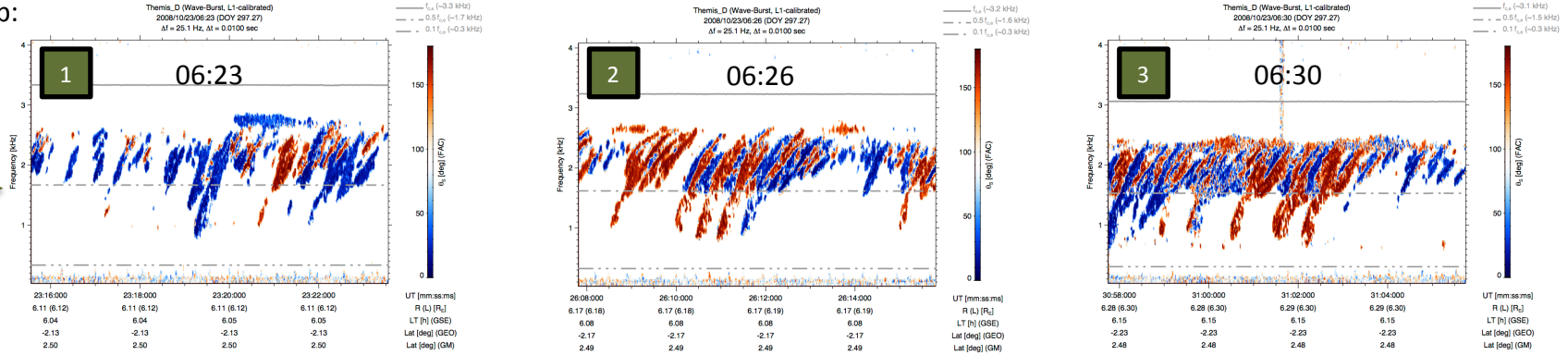


θ_S-Spectra (polar angle of Poynting Vector **S**; FAC)

(blue ... **S** along $\mathbf{B_0}$, red ... **S** against $\mathbf{B_0}$)

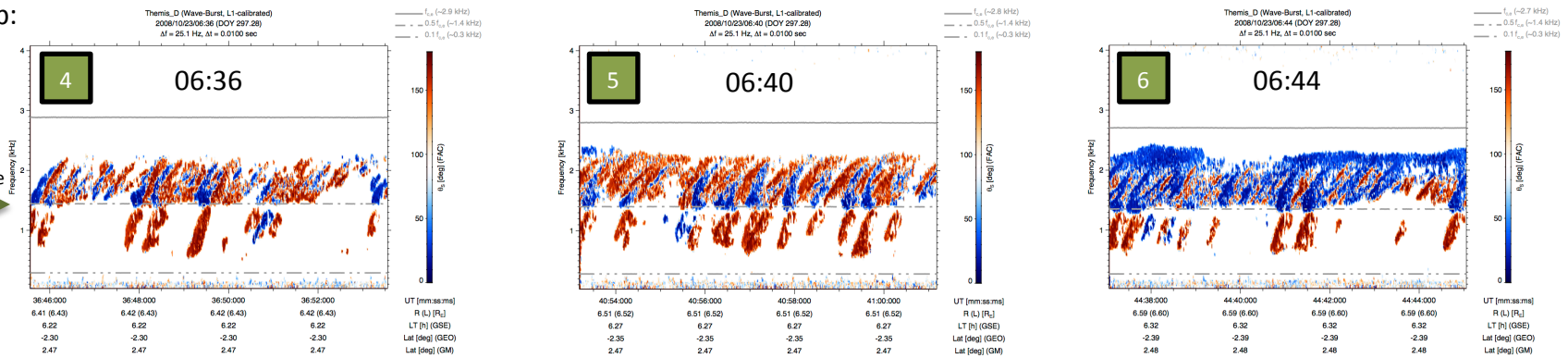
no gap:

0.5 $f_{c,e}$



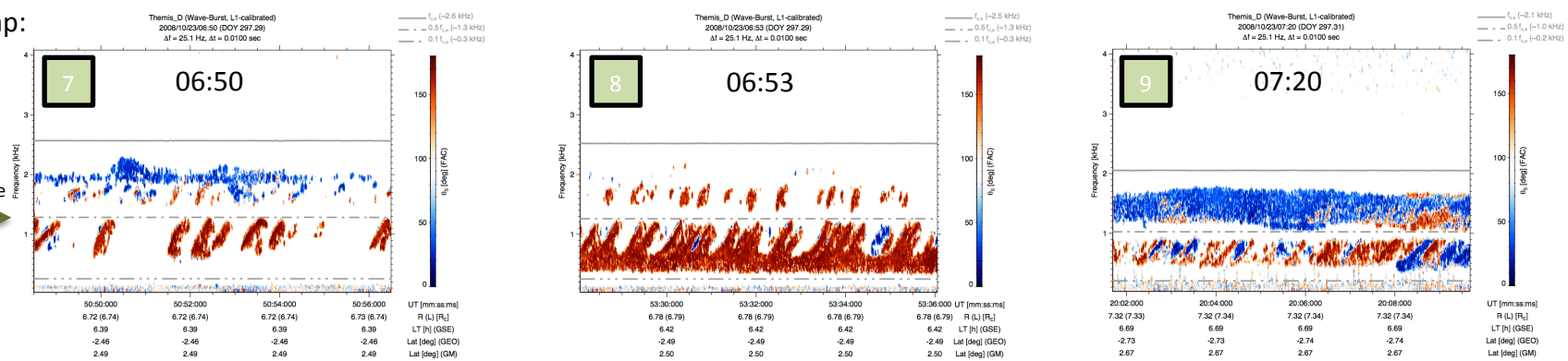
small gap:

0.5 $f_{c,e}$



gap:

0.5 $f_{c,e}$



THEMIS-D
2008/10/23, 06:23 – 07:20

9 wave-burst mode snapshots (~ 8 seconds each);

234 scanned rising tones; 11485 scanned points (along chorus trace)

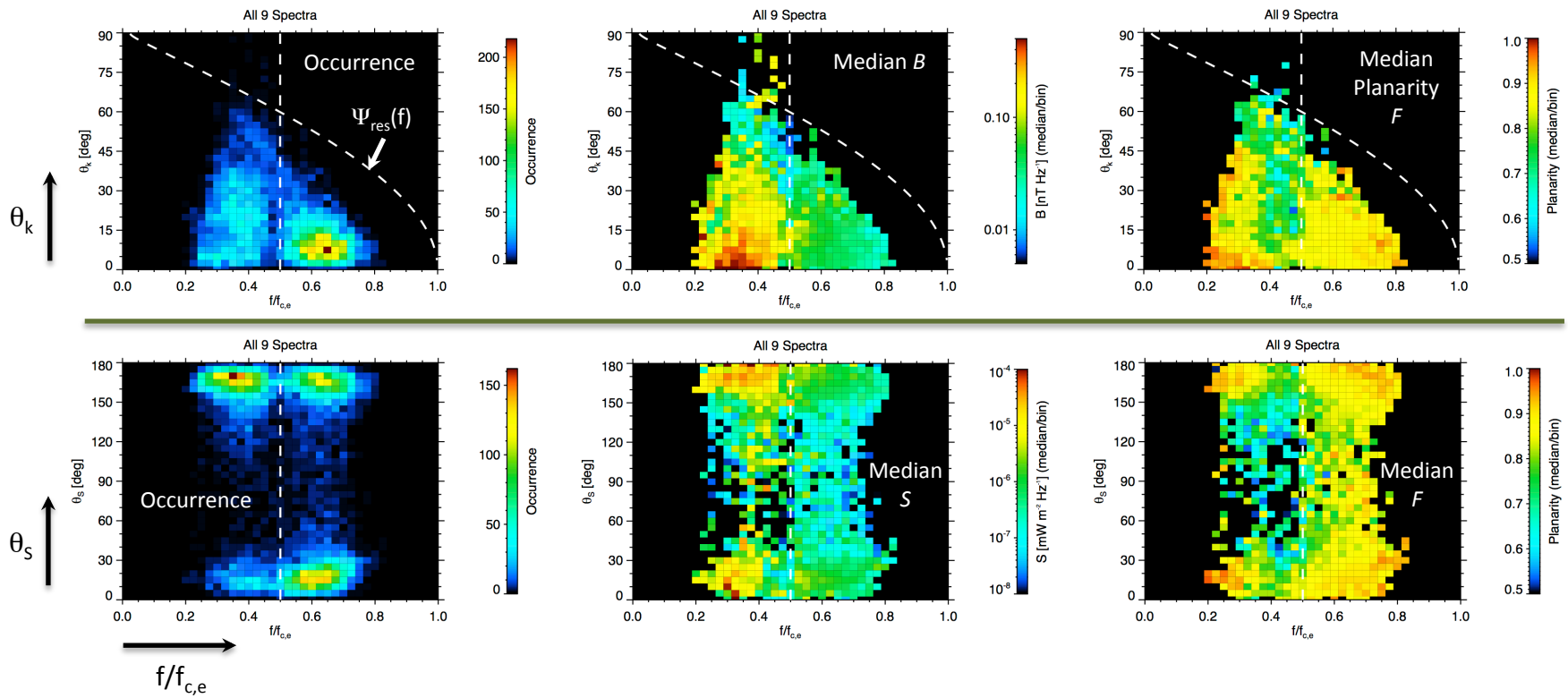
-) **k** quasi-parallel $\mathbf{B_0}$; $\theta_k < 30°$;
($\theta_k << \Psi_{res}$ ... resonance cone angle)

-) more bursts in upper band

-) *B*-Amplitude stronger in lower band; peaks at a few 100 pT $Hz^{-1/2}$

-) Lower Planarity *F* at $0.4 < f/f_{c,e} < 0.5$

-) Superposition of many waves with different **k**-directions



-) 2 groups of chorus:
$\theta_S < 30°$ vs. $\theta_S > 150°$
(along/against $\mathbf{B_0}$-direction)

-) Poynting Flux *S* stronger in lower band
-) *S* stronger for more field-aligned propagation

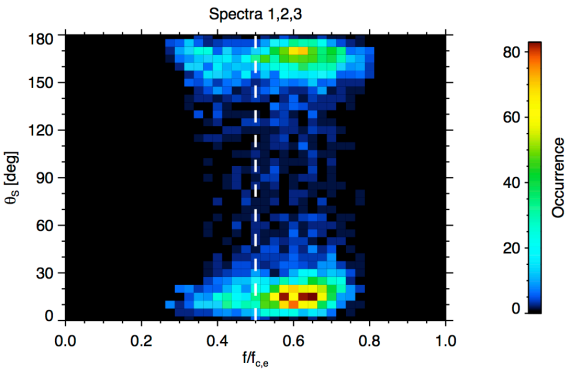
-) Lower Planarity around $\theta_S \sim 90°$

THEMIS-D
2008/10/23, 06:23 – 07:20

9 wave-burst mode snapshots (~ 8 seconds each);

234 scanned rising tones; 11485 scanned points (along chorus trace)

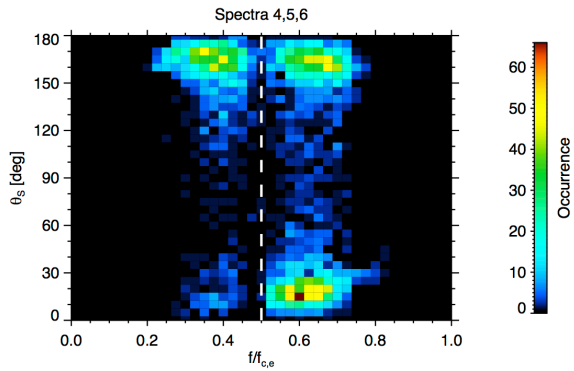
Wave-bursts 1,2,3
06:23 – 06:31



-) 2 groups of chorus:
$\theta_S < 30°$ vs. $\theta_S > 150°$
(along/against $\mathbf{B_0}$-direction)

-) both groups crossing 0.5 $f_{c,e}$

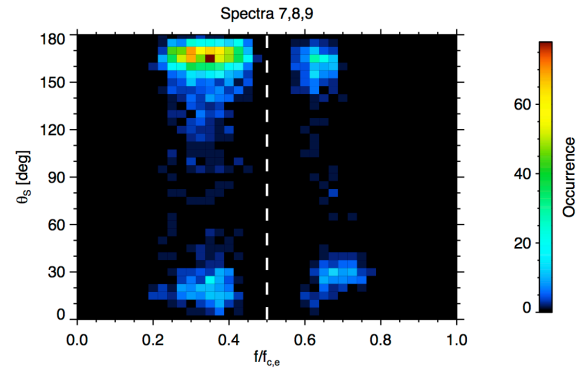
Wave-bursts 4,5,6
06:36 – 06:45



-) 2 groups of chorus:
$\theta_S < 30°$ vs. $\theta_S > 150°$
(along/against $\mathbf{B_0}$-direction)

-) $\theta_S > 150°$: still a few bursts crossing 0.5 $f_{c,e}$
$\theta_S < 30°$: small gap at $0.45 < f/f_{c,e} < 0.50$

Wave-bursts 7,8,9
06:50 – 07:20



-) 2 groups of chorus:
$\theta_S < 30°$ vs. $\theta_S > 150°$
(along/against $\mathbf{B_0}$-direction)

-) gap at 0.5 $f_{c,e}$ for both groups

-) Dominant direction => $\theta_S > 150°$
(THD left the source region?)

THEMIS-D , ESA
2008/10/23,
05:00 – 08:00

N_{tot} ... total electron density
(from S/C-potential)

smooth along trajectory
(after plasmapause crossing)

Injection of hot electrons at 06:20
--> anisotropy of keV electrons

E_{min} ... minimum resonant energy for electrons (function of B_0, N_{tot}, $f/f_{c,e}$)

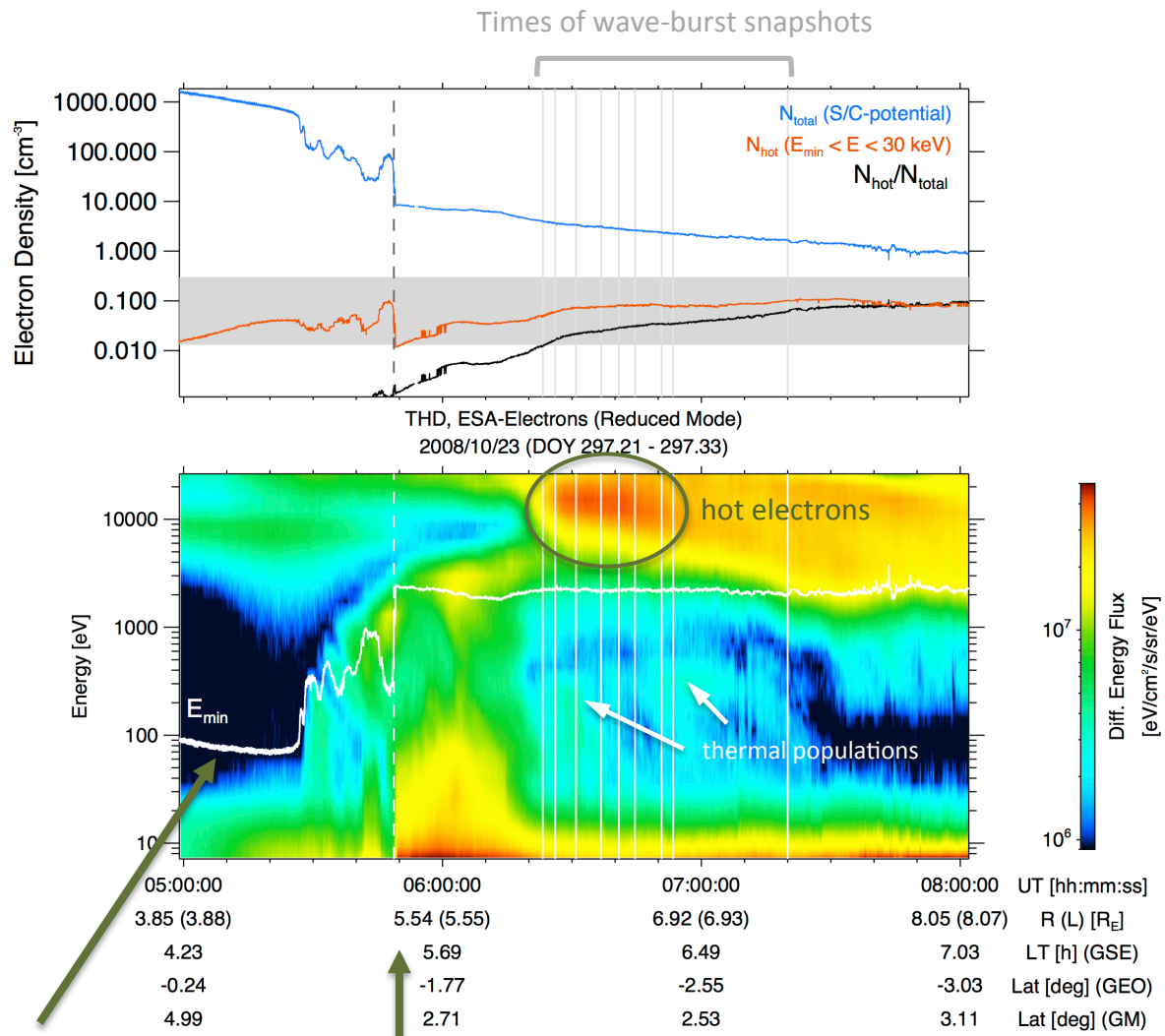
Integration of N above E_{min} yields N_{hot}

Chorus rising tones need nonlinear generation mechanism

Effective nonlinear wave growth for

$$0.013 < N_{hot}/N_{tot} < 0.3$$

--> fulfilled after 06:23 (1st wave-burst snapshot)



E_{min} for $f/f_{c,e} = 0.5$

Plasmapause crossing

Conclusions

THEMIS-D is crossing the source region of whistler mode chorus rising tones on 10/23/2008.

Comparison with the Tsyganenko-T96 magnetic field model: THD is flying through the B_0-minimum along consecutive fieldlines

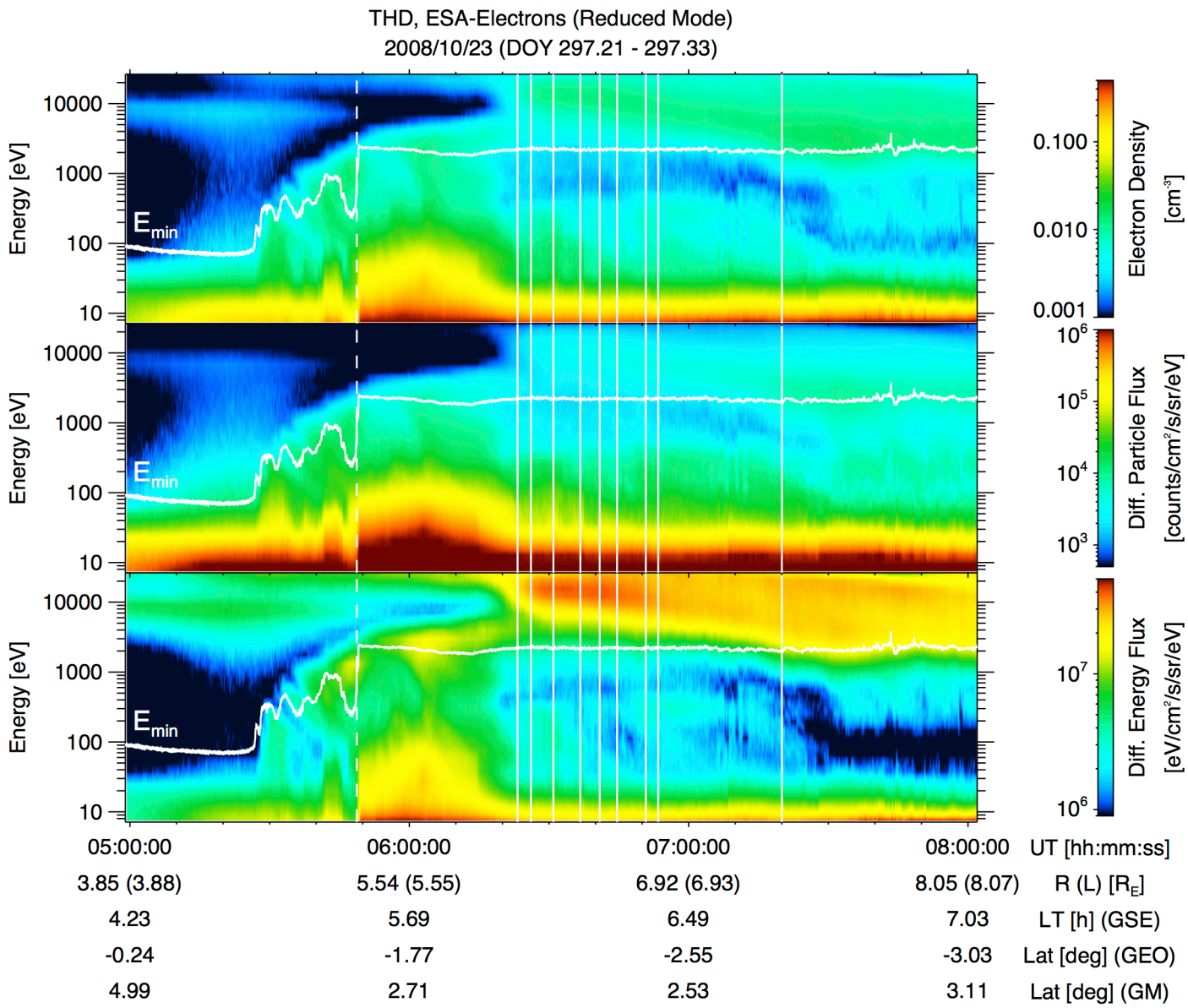
Injection of hot electrons at energies > 10 keV

$0.013 < N_{hot}/N_{tot} < 0.3$ ---> effective nonlinear wave growth (electron cyclotron resonance)

N_{tot}, $\mathbf{B_0}$ show no strong gradients along THD-trajectory

06:23 – 06:30: no gap at 0.5 $f_{c,e}$, opposite Poynting fluxes
--> source region extends at least 1537 km into direction perp. to B_0

06: 36 – 06:44: gap at 0.5 $f_{c,e}$, but still opposite Poynting fluxes
--> nonlinear damping in source region (for oblique **k**)

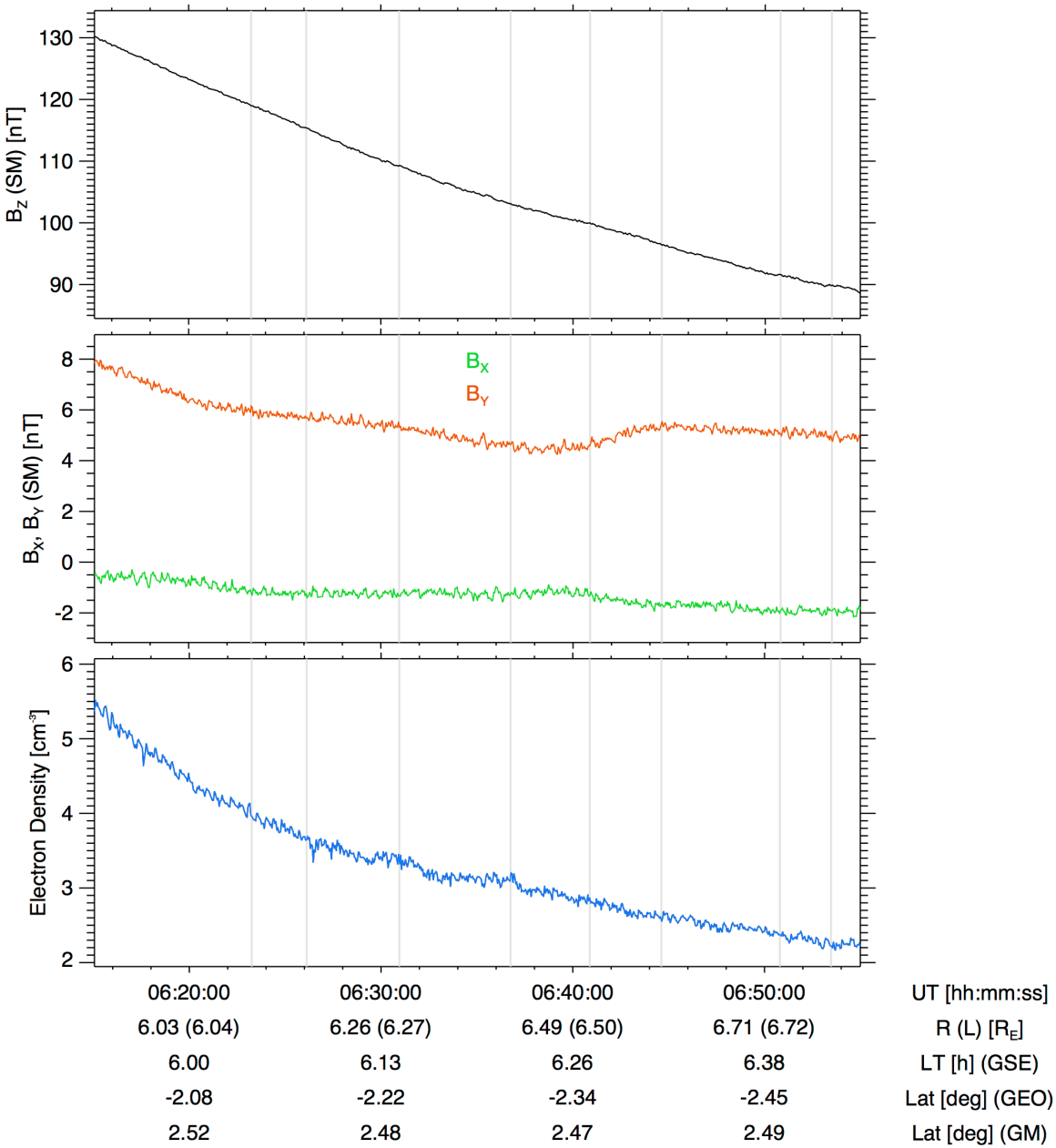

THD, ESA-Electrons (Reduced Mode)
2008/10/23 (DOY 297.21 - 297.33)
Energy [eV]
10000
1000
100
10
E min
0.100
0.010
0.001
Electron Density [cm⁻³]
10⁶
10⁵
10⁴
10³
Diff. Particle Flux [counts/cm²/s/sr/eV]
10⁷
10⁶
Diff. Energy Flux [eV/cm²/s/sr/eV]
05:00:00
06:00:00
07:00:00
08:00:00
UT [hh:mm:ss]
3.85 (3.88)
5.54 (5.55)
6.92 (6.93)
8.05 (8.07)
R (L) [R_E]
4.23
5.69
6.49
7.03
LT [h] (GSE)
-0.24
-1.77
-2.55
-3.03
Lat [deg] (GEO)
4.99
2.71
2.53
3.11
Lat [deg] (GM)

THEMIS-D
2008/10/23,
06:15 – 06:54

smooth variations in magnetic field

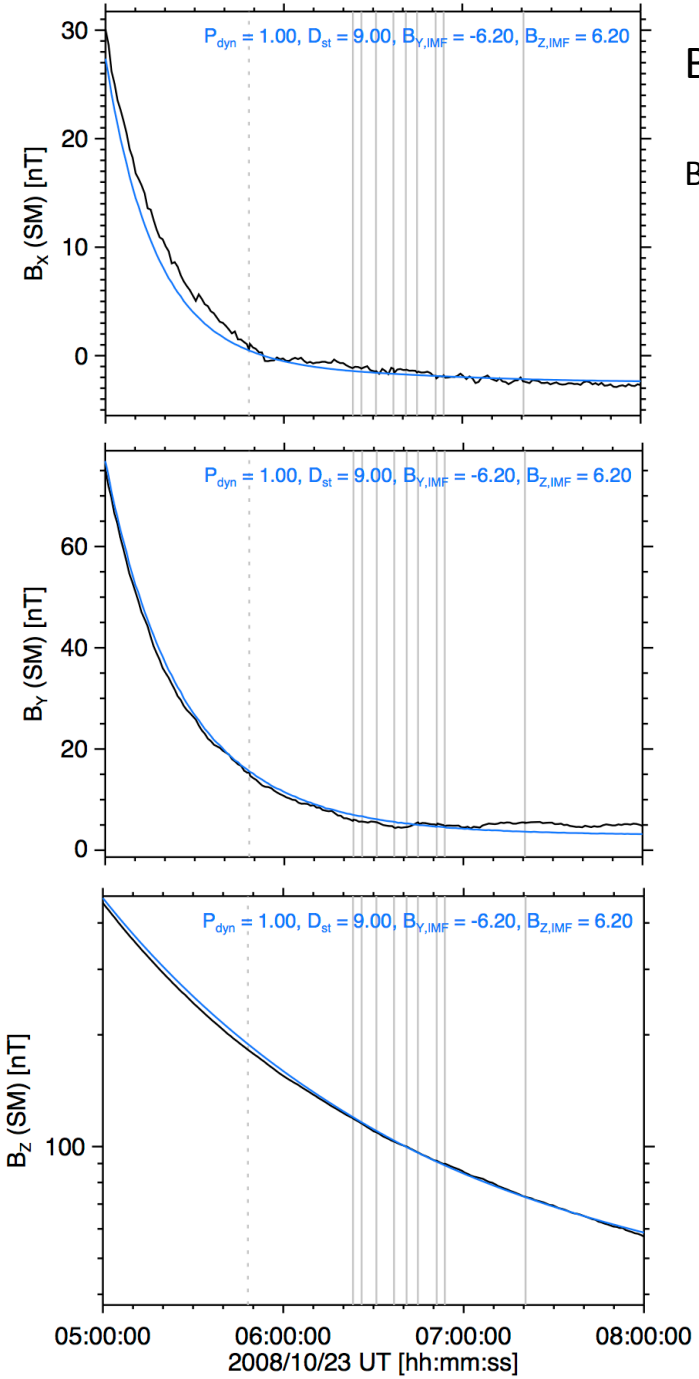
smooth variations in electron density

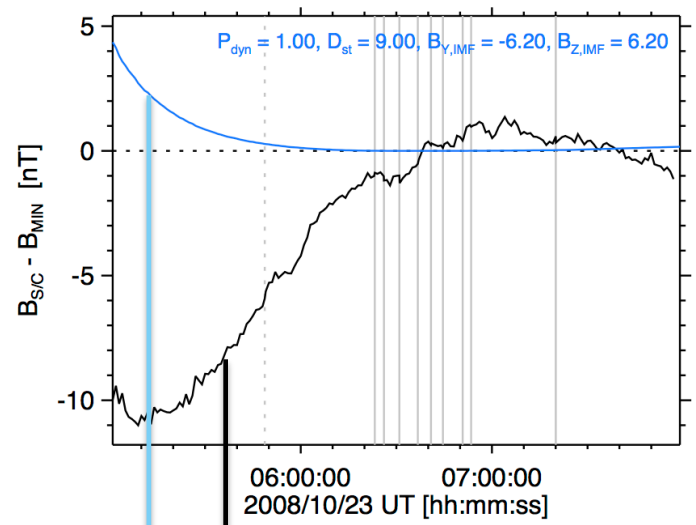
no strong gradients – only microfluctuations



B-measured vs. B-model

Best fit between observation & model





black graph:
B_{THD}-measured minus B_{min}-model
gets close to 0 nT during source crossing
=> T96-model works well

blue graph:
B_{THD}-model ≈ B_{min}-model for > 1h
=> THD is "grazing" the source