# Electron Acceleration in the Near Earth Plasma Sheet


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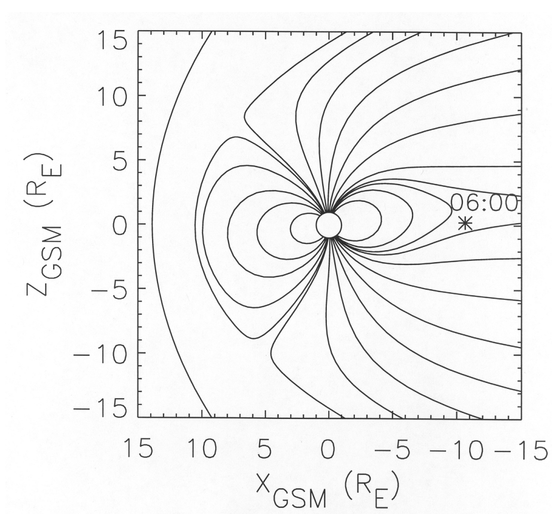


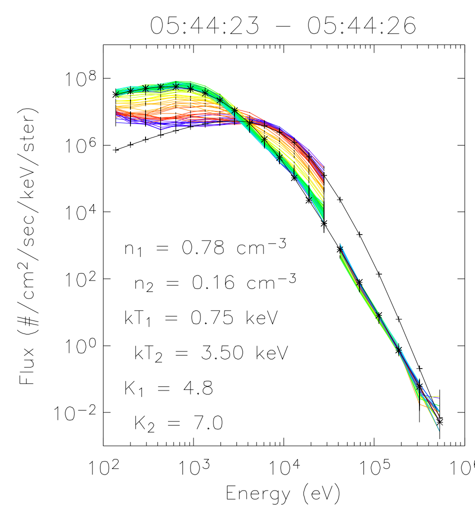



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# Outline

- Introduction
  - Electron spectra in the plasma sheet
  - Electron spectral changes in the plasma sheet

- Data

  ⇒ Rapid (~ 1 second) spectral change from Wind/3DP

- Analysis
  - In-situ acceleration → non-adiabatic
  - Spatial boundary motion

- Conclusion

  ⇒ Inconclusive, but leaning toward boundary motion

# Electron Spectra in the Plasma Sheet

- From 10s of eV to several 100 keV, electron spectra can be well characterized by a Kappa function [*Vasyliunas*, 1968]

$$f \sim [1 + E/\kappa E_o]^{-\kappa-1}$$

$$j \sim E[1 + E/\kappa E_o]^{-\kappa-1}$$

where $\kappa$ is a constant (spectral slope at large E),
$E_o$ is the energy of peak flux, and
$E_o = kT[1 - 3/2\kappa]$

  - Maxwellian for $E < \kappa E_o$
  - Power law for $E >> \kappa E_o$
  - Maxwellian as $\kappa \to \infty$
- During active (and quiet) times, electron spectra have multiple components [e.g., *Christon et al.*, 1991]

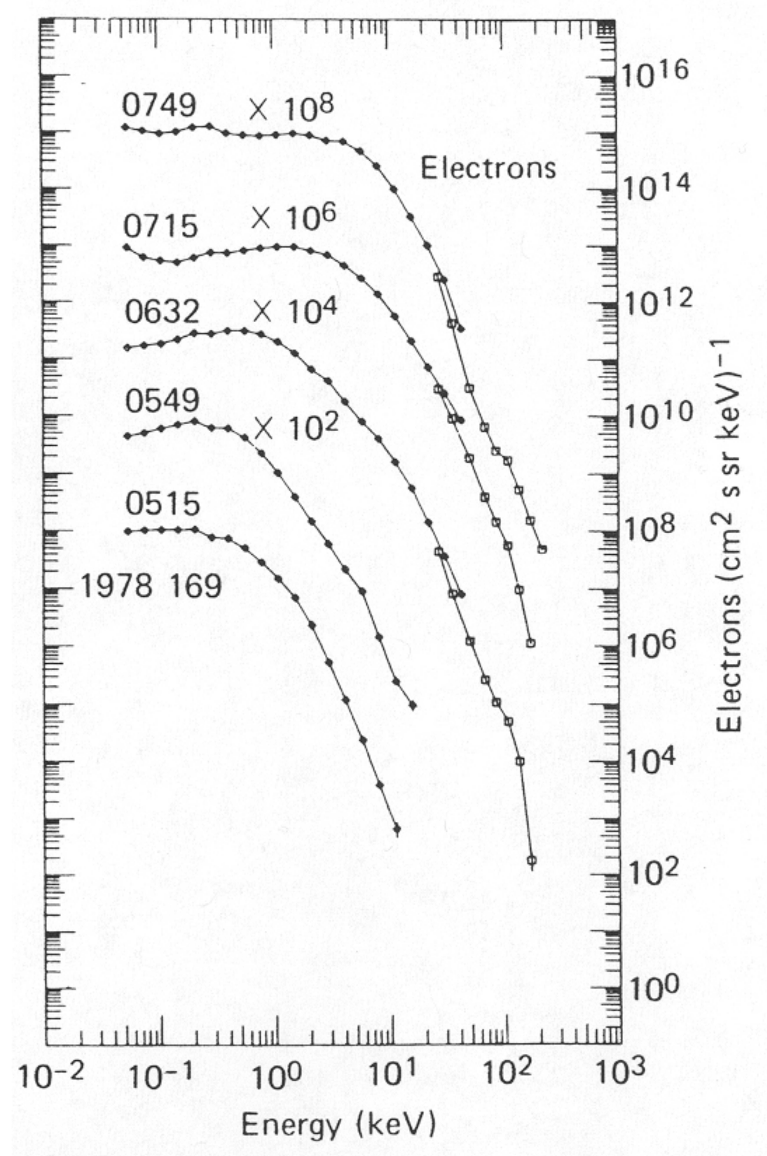
# Electron Spectral Changes in the PS

Example from *Christon et al.* [1988]

- Slow transition in temperature ($E_o$) $\kappa \sim$ constant (in this case)

- Lower kT, higher κ during quiet intervals (AE < 100 nT);
- Higher kT, lower(?) κ during active intervals (AE > 100 nT) [*Christon et al.*, 1991]

**Ambiguity:** Spatial or temporal?

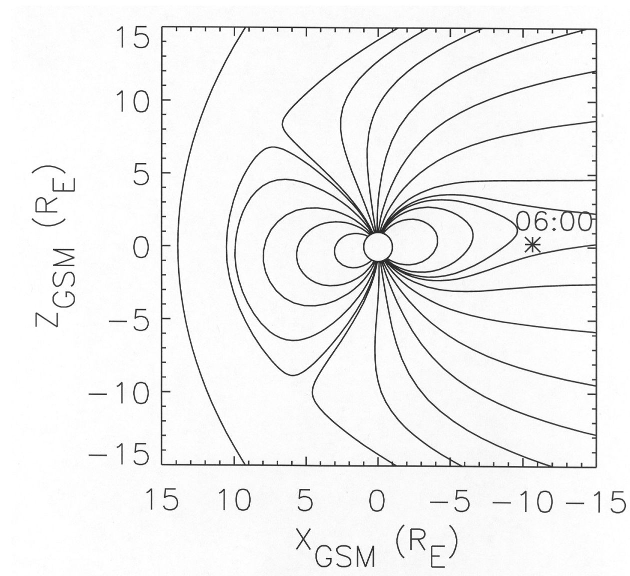


# Instrumentation

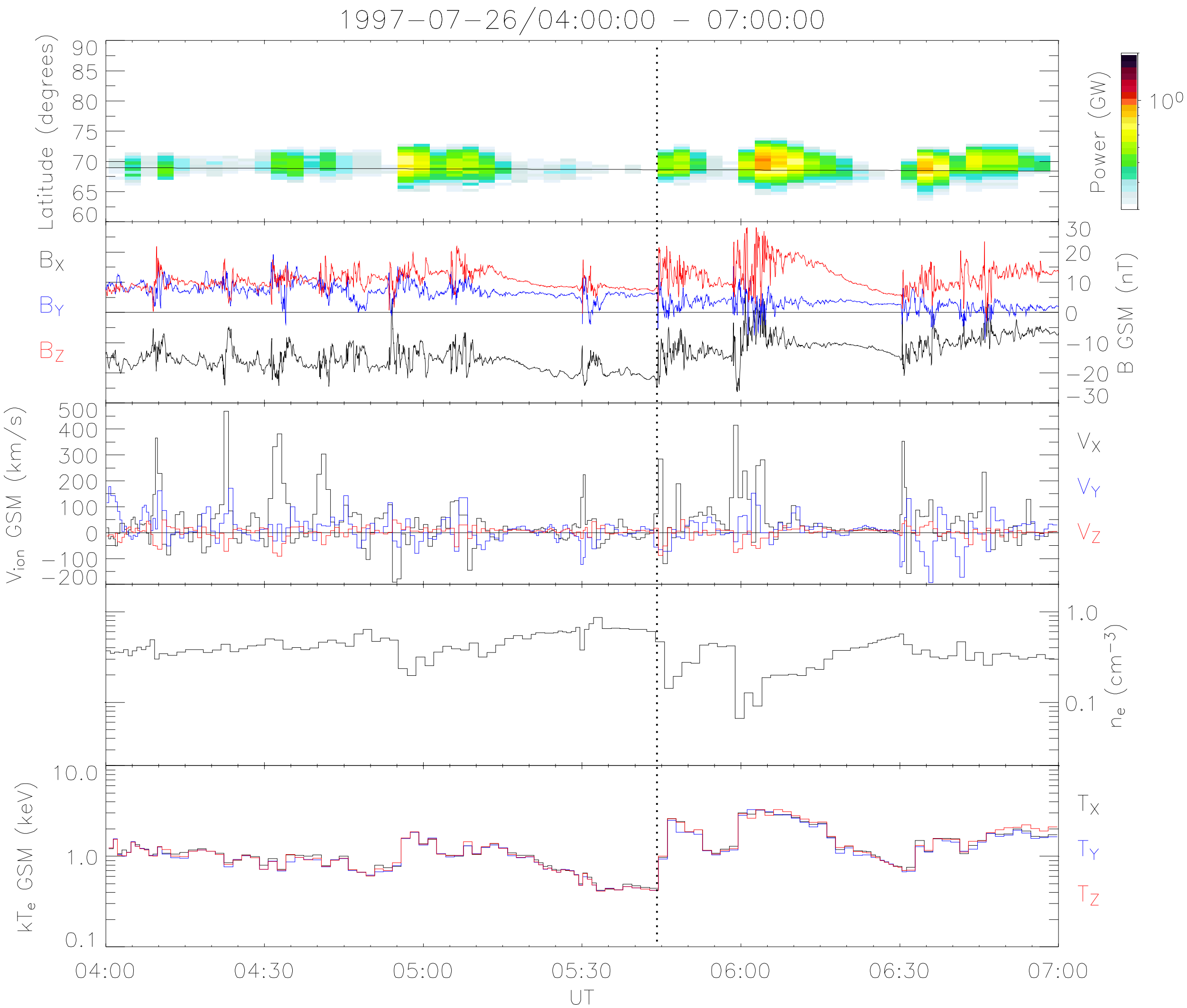
Wind 3DP

- EESA-High
  - Energy range: 100 eV – 30 keV
  - Time resolution: 3 sec (1 s/c spin) every ~ 100 seconds
- SST-Foil
  - Energy range: 25 keV – 600 keV (> 1 MeV)
  - Time resolution: 12.5 sec for 25 keV; 50 sec for 600 keV

At 06 UT on 1997-07-26, Wind was located in the plasma sheet at [-11, 3, 0] $R_E$ GSM



# Overview of PS Electron Observations




During intervals of auroral brightening,

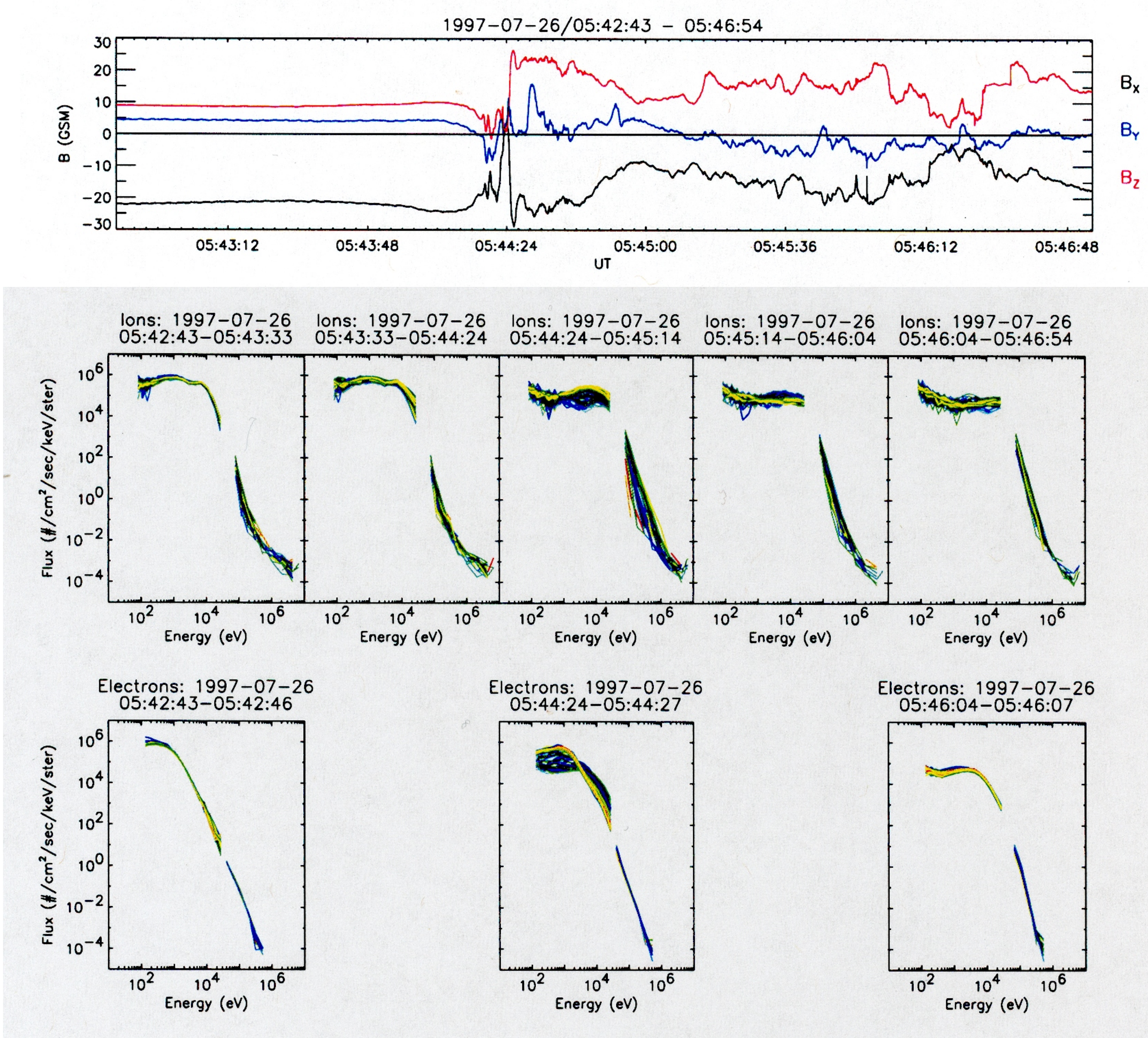
large **B** fluctuation,

high ion velocity;

- $n_e$ decreases,
- $kT_e$ increases

⇒ electron spectral change

# Electron Spectra

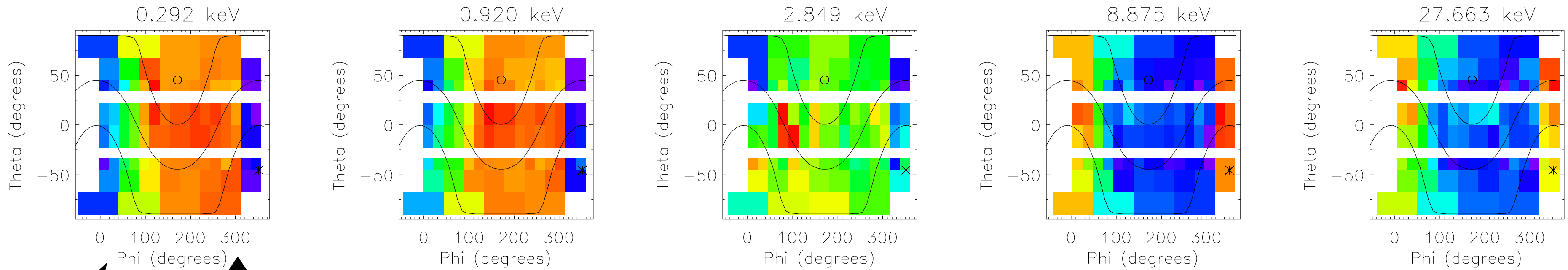



05:42:43 UT
smooth **B**,
isotropic ions,
cold, isotropic $e^-$

05:46:04 UT
fluctuating **B**,
hot ions, hot $e^-$

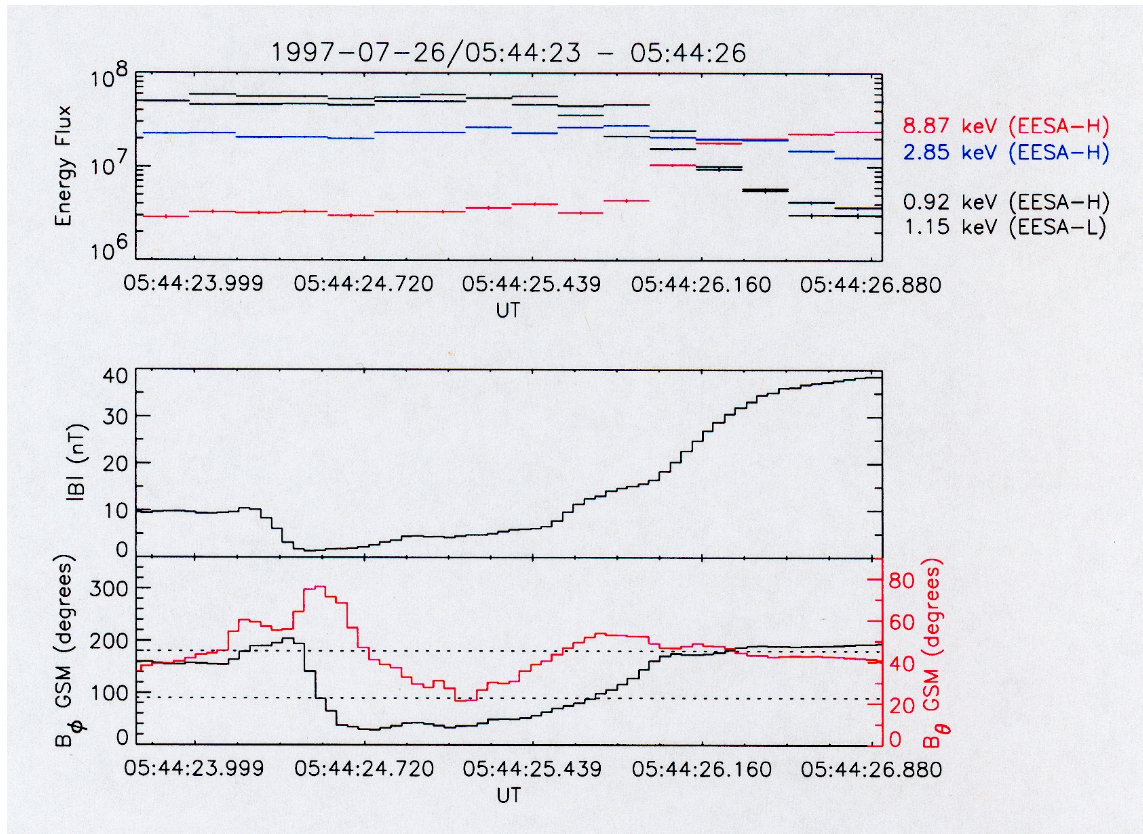
05:44:24
fluctuating **B**,
dynamic ions
??? $e^-$

# Sub-Spin (200 ms )Resolution



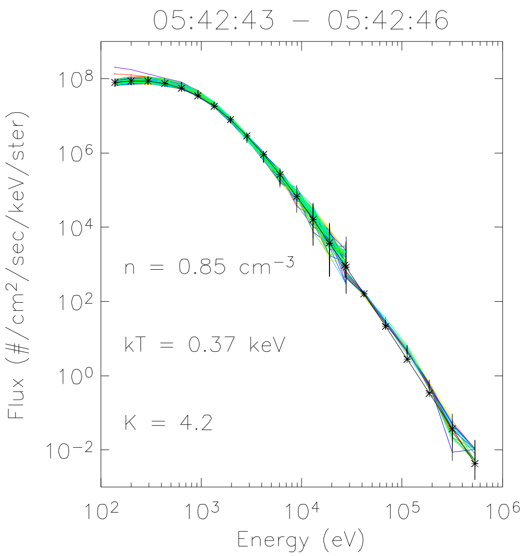

Spin
Start

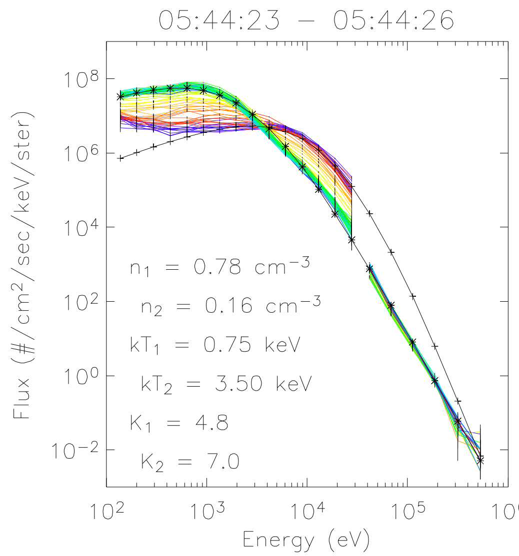
1 keV flux decreases
(in all directions),
3 keV flux ~ constant,
9 keV flux increases,
in ~ 1 second;

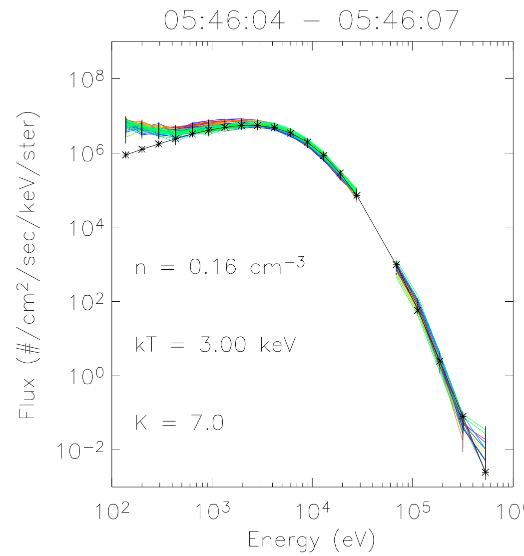



**B** increases from 1.5 to
40 nT in ~ 2 sec (≥ 20x)

# Spectral Fits: Before and After




| Before | | After |
|---|---|---|
| $n = 0.85$ cm$^{-3}$ | $n_1 = 0.78$ cm$^{-3}$ | $n = 0.16$ cm$^{-3}$ |
| | $n_2 = 0.16$ cm-3 | |
| $kT = 0.37$ keV | $kT_1 = 0.75$ keV | $kT = 3.00$ keV |
| | $kT_2 = 3.50$ keV | |
| $\kappa = 4.2$ | $\kappa_1 = 4.6$ | $\kappa = 7.0$ |
| | $\kappa_2 = 7.0$ | |

# In-situ Acceleration?

Non-adiabatic in fluid sense:

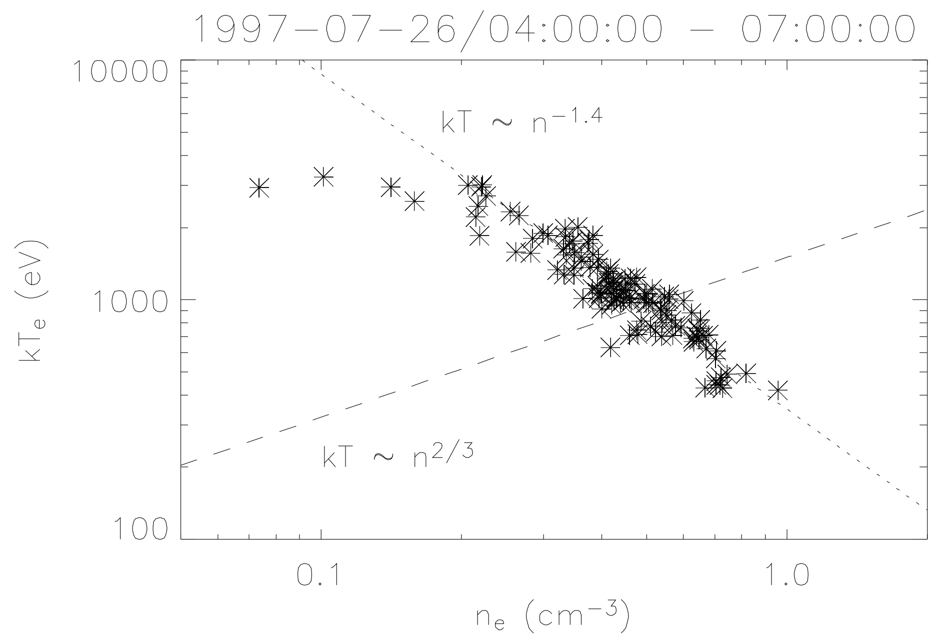
$P = \alpha n^{\gamma}$, $P = nkT$

$\Rightarrow kT = \alpha n^{\gamma-1}$

$\alpha$ = specific entropy

$\gamma$ = polytropic index

= 5/3 $\Rightarrow$ adiabatic




Non-adiabatic in kinetic sense:

$\mu = E_{\perp}/B = \text{constant} \Rightarrow \delta E_{\perp}/E_{\perp} = \delta B/B$ (e.g., betatron)

Expect translation in energy with constant spectral index (slope)

Not observed; $\kappa = 4.2 \rightarrow 7.0$

Also, $B_{initial}$ (05:42) and $B_{final}$ (05:46) approx. equal (~ 20 nT)

# Propagating particle boundary?

- $\rho_e \sim 100 \sqrt{E_\perp}$ [keV]/B [nT] km
  For B = 10 nT, $E_\perp = 25$ keV, $\rho_e \sim 50$ km
  $E_\perp = 600$ keV, $\rho_e \sim 250$ km
  For B = 40 nT, $E_\perp = 25$ keV, $\rho_e \sim 12.5$ km
  $E_\perp = 600$ keV, $\rho_e \sim 62.5$ km
- $\langle v_i \rangle \sim 300$ km/s
- In 1 second, traverse few $\rho_e$ for $E_\perp \sim 600$ keV
  few 10s of $\rho_e$ for $E_\perp \sim 25$ keV
  $\sim 100\ \rho_e$ for $E_\perp \sim 1$ keV (thermal $e^-$)
- In this case, don't expect adiabatic behavior:
  ⇒ not following plasma element; inhomogeneities in $\alpha$
  [cf., *Baumjohann and Paschmann*, 1989]

# Summary

We have presented high-time resolution (200 ms) observations of a rapid (~ 1 second) electron spectral change in the plasma sheet during an "active" period (aurora, large $\Delta B$, large $\langle v_i \rangle$)
$\Rightarrow$ $n_e$ decrease, $kT_e$ increase, $\kappa$ increase (softening of spectrum)

Inconsistent with ***local*** adiabatic (fluid or kinetic) acceleration
Consistent with crossing a boundary several energetic $\rho_e$ thick

Ambiguity remains:

- local non-adiabatic process (temporal), or
- sampling different plasma populations (spatial) (simplest interpretation)