

Energetic Electron Events Upstream of the Earth's Bow Shock

Early observations (mainly ions):

- Desai et al. 2000 (protons $< \sim 1$ MeV and electrons ~ 35 keV); Sanderson et al. 1996 (protons < 400 keV and electrons < 138 keV); Anagnostopoulos et al. 1999 (also electrons ≥ 220 keV, IMP-8, orbit=35 Earth's radii),
- Electrons: Scholer et al. (1981, ISEE-3, L1), $e < 115$ keV

Origin is explained:

- leakage of magnetospheric particles (ions +electrons)
- bow shock accelerated (ions)

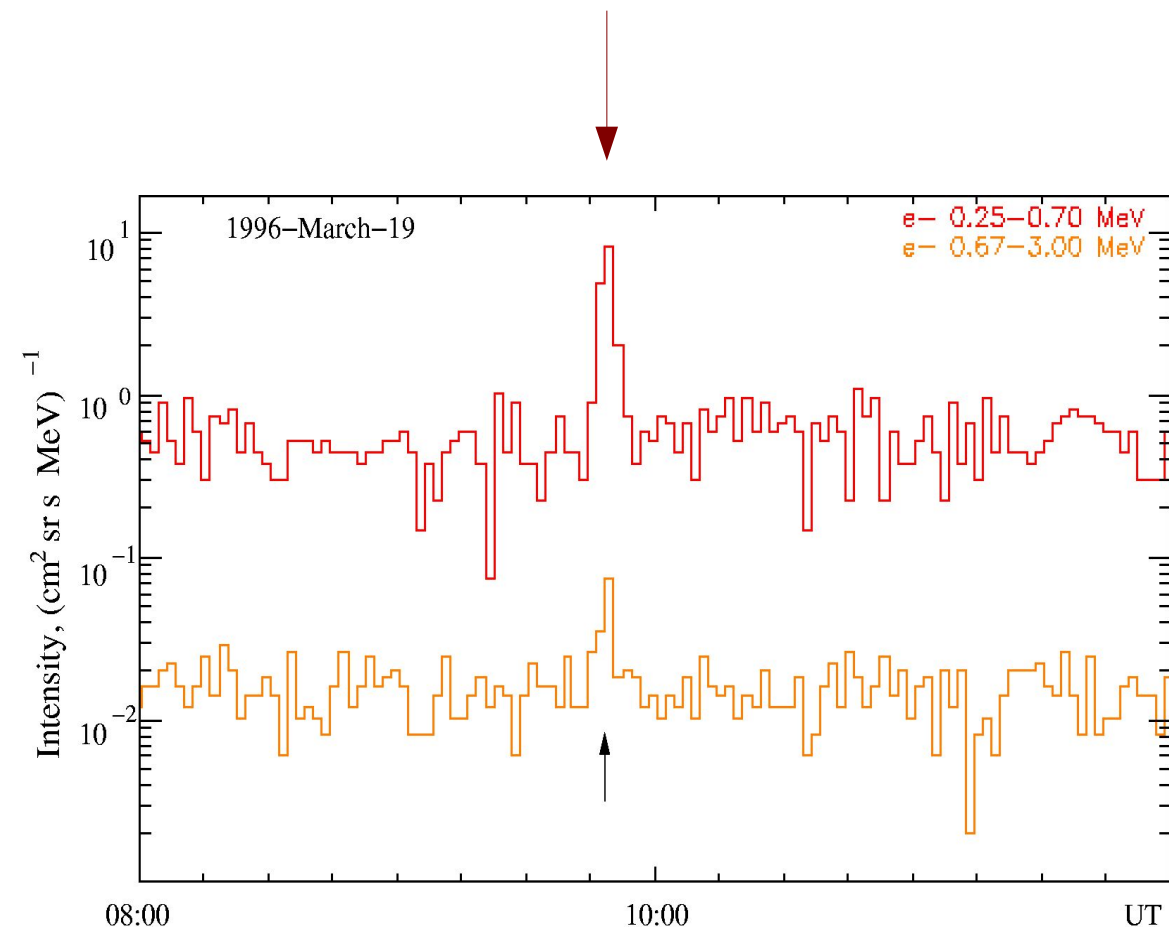
We have analyzed:

Number of events (124) from 1996 through 2005
-- selection criteria: 4 sigma over pre-event background;
: burst duration 2 min above 4 sigma.

Spatial distribution.

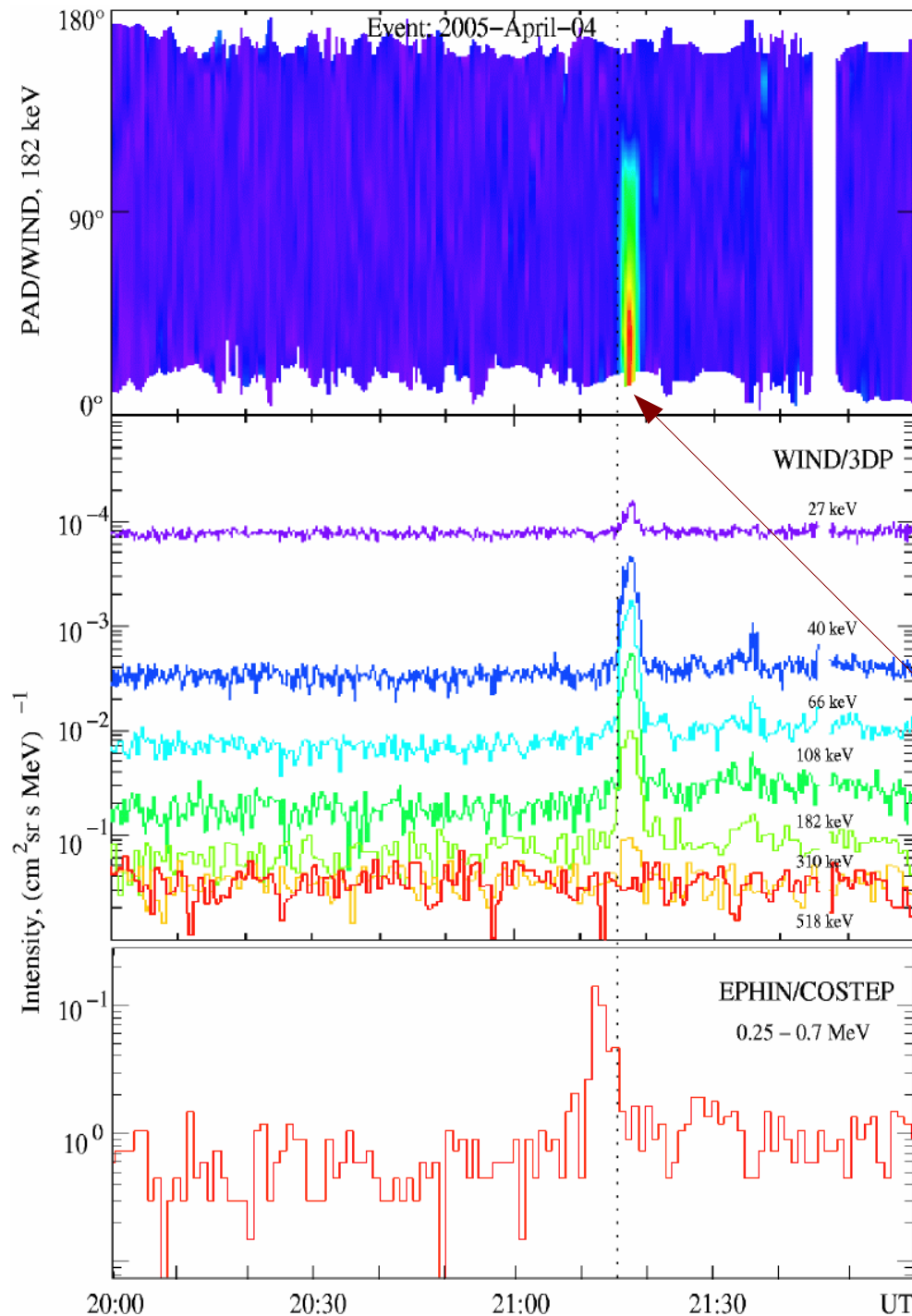
Association with solar wind & geomagnetic activity.

Seasonal variations.



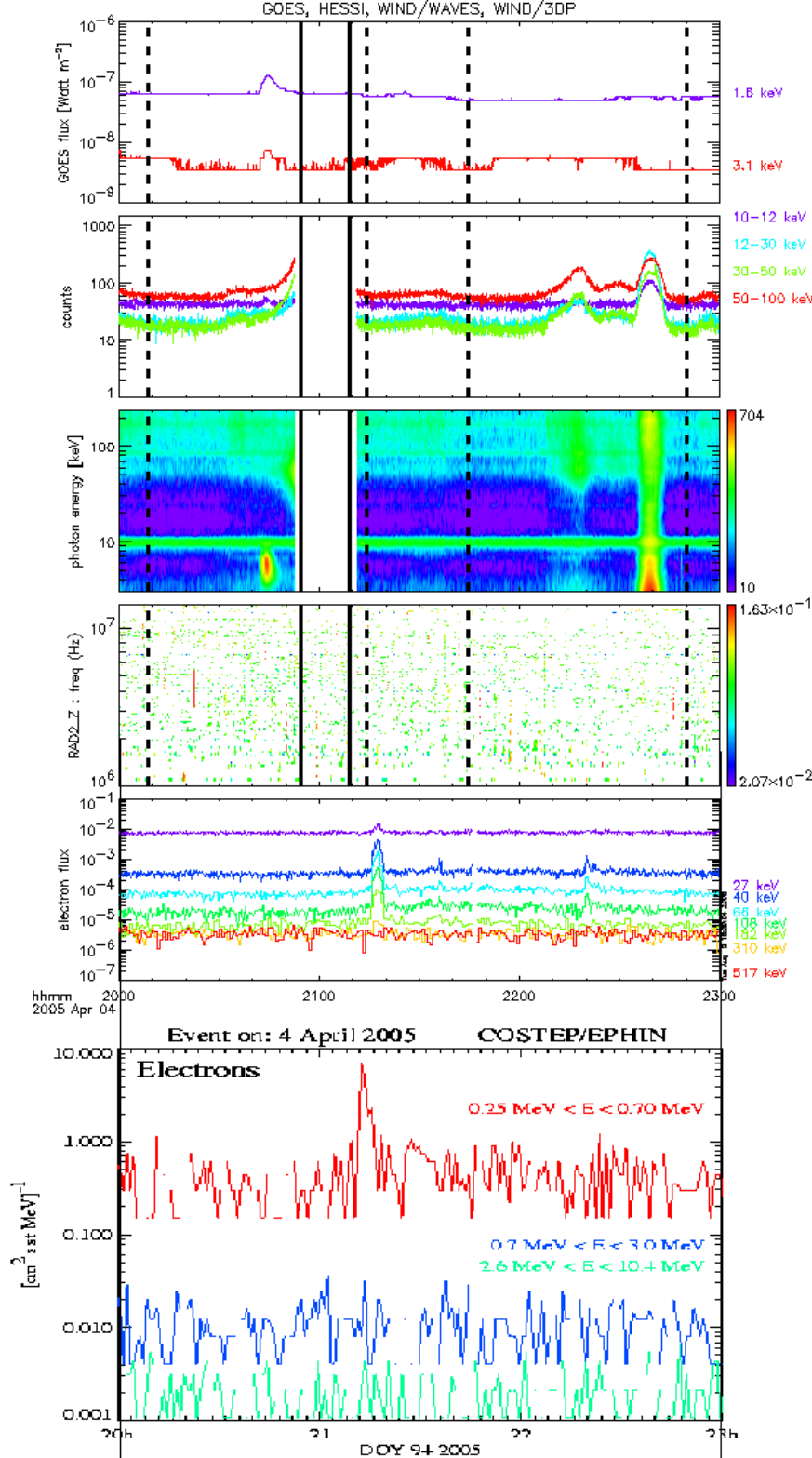
- Energy range: usually in 0.25-0.7 MeV channel.
- But 6% also in 0.7 – 3.0 MeV channel.
- Triangular pulse shape.
- No association with protons, helium, etc.
- No association with solar activity.

Event on 4 April 2005



- An event simultaneously observed by Wind.
- Time delay of 5 min.
- Square pulse shaped profile.
- PAD indicates a stream away from the Earth's magnetosphere.
- Burst without velocity dispersion.

Event on 4 April 2005



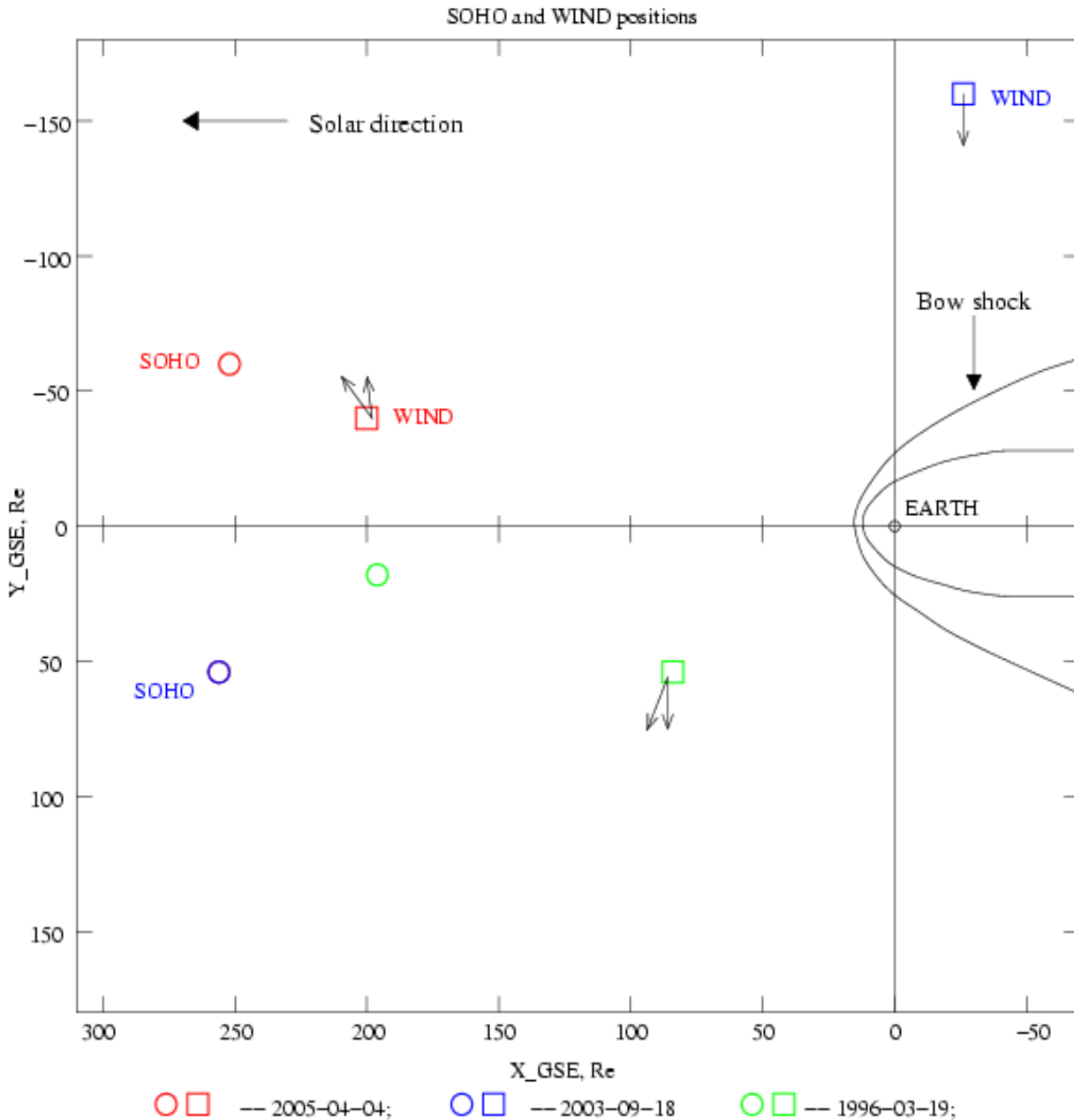
- Overview :
- GOES,
- RHESSI,
- Wind-Radio,
- Wind-3DP (electrons),
- and EPHIN,
- ACE, no burst observed.

Bursts characteristics:

- spiky structure;
- square/triangular pulse shape profiles;
- no velocity dispersion (for EPHIN time resolution =1 min);
- duration between 1 and 30 minutes (mean 10.3 min);
- PADs indicate flow from the anti-Sun direction;
- energy range: 0.25 –0.7 MeV & 0.7 -3.0 MeV;

Comparison with 3-DP/Wind observations:

- 50% of EPHIN bursts were also observed by WIND;
- time delay between EPHIN & WIND bursts and vice versa, usually (+- 2 - 10 min);



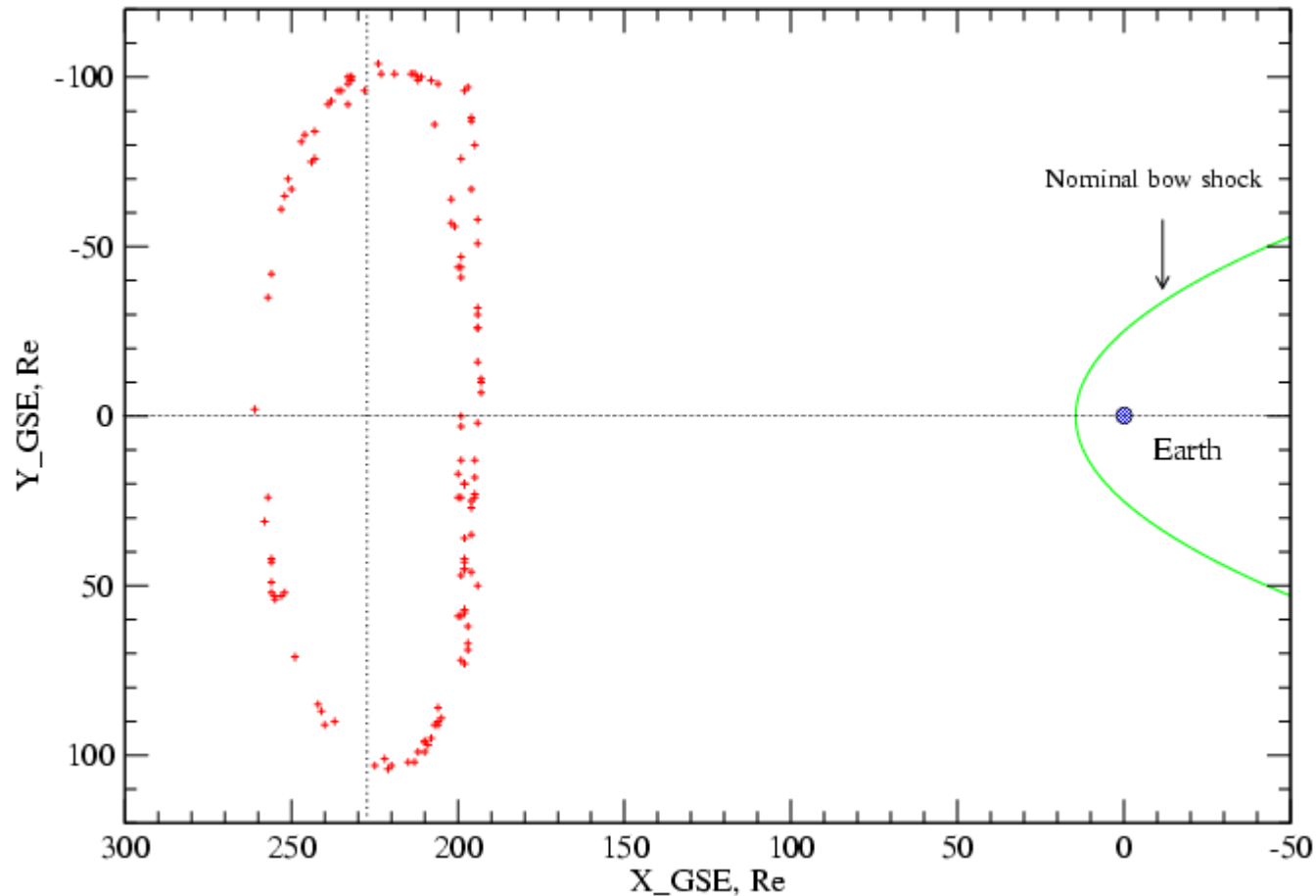
Relative positions of SOHO and WIND.

Red – 4 April 2005

The IMF projection is indicated by arrows.

→ During some events the IMF is not radial.

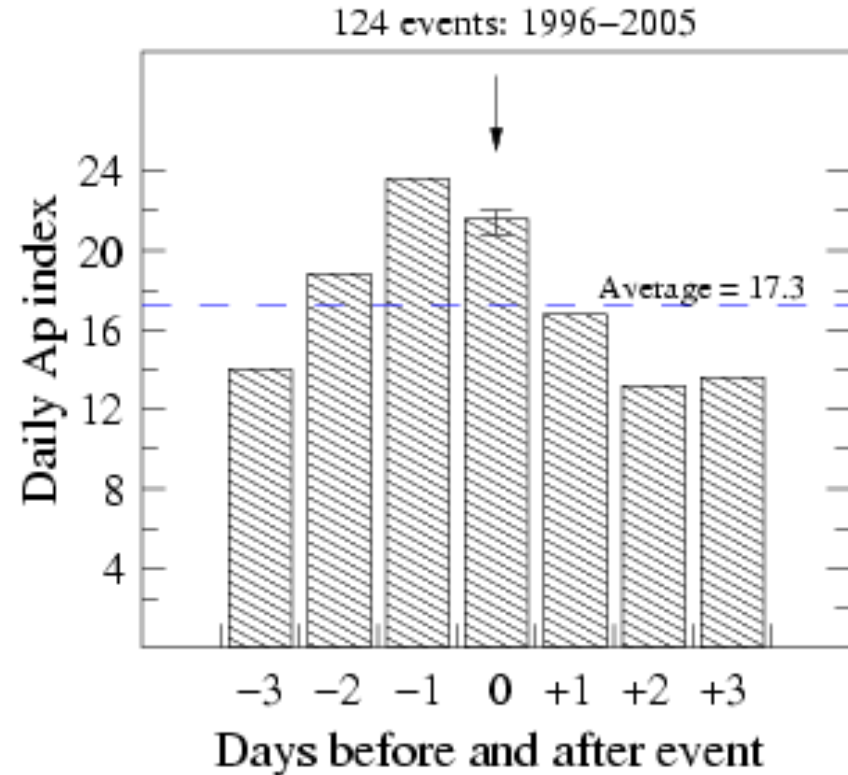
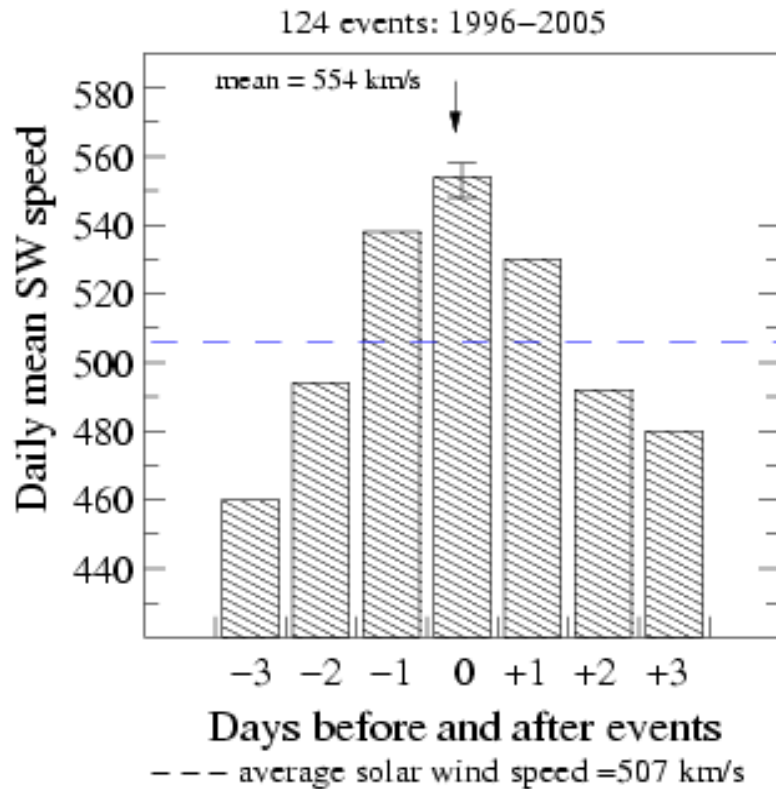
Spatial distribution of upstream events along the SOHO orbit



Each burst is indicated by a **red** cross.

- The most events (70%) occur at ≤ 228 Re.
- Distance dependency?

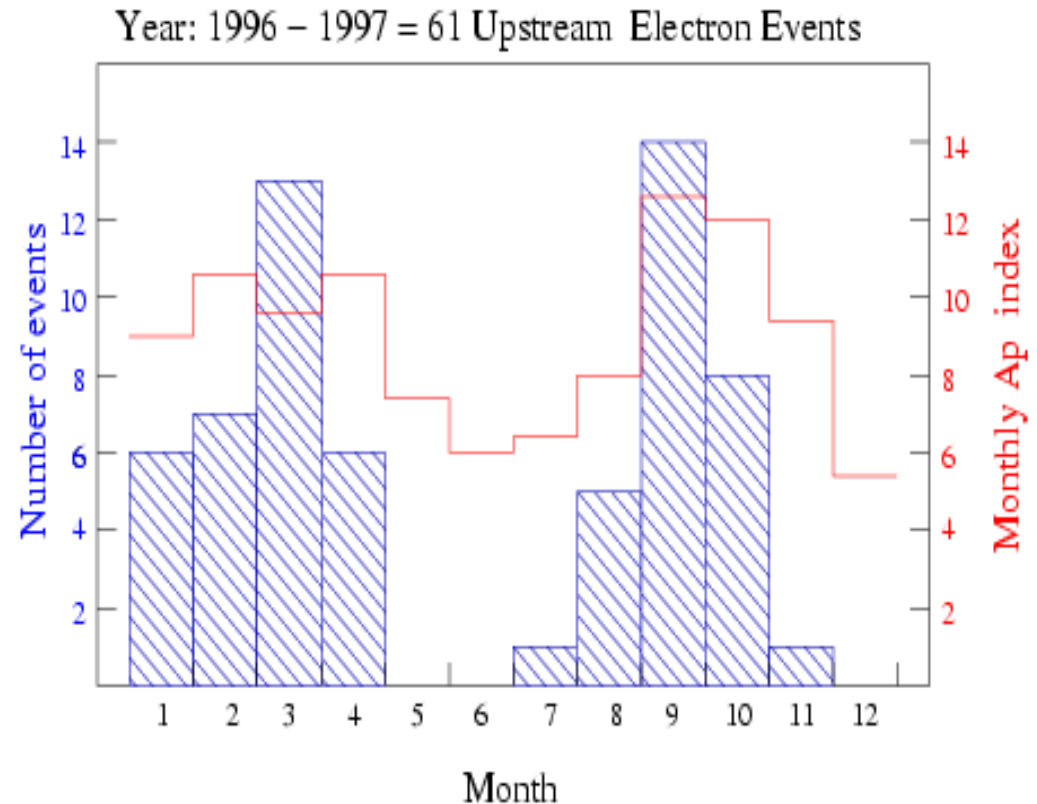
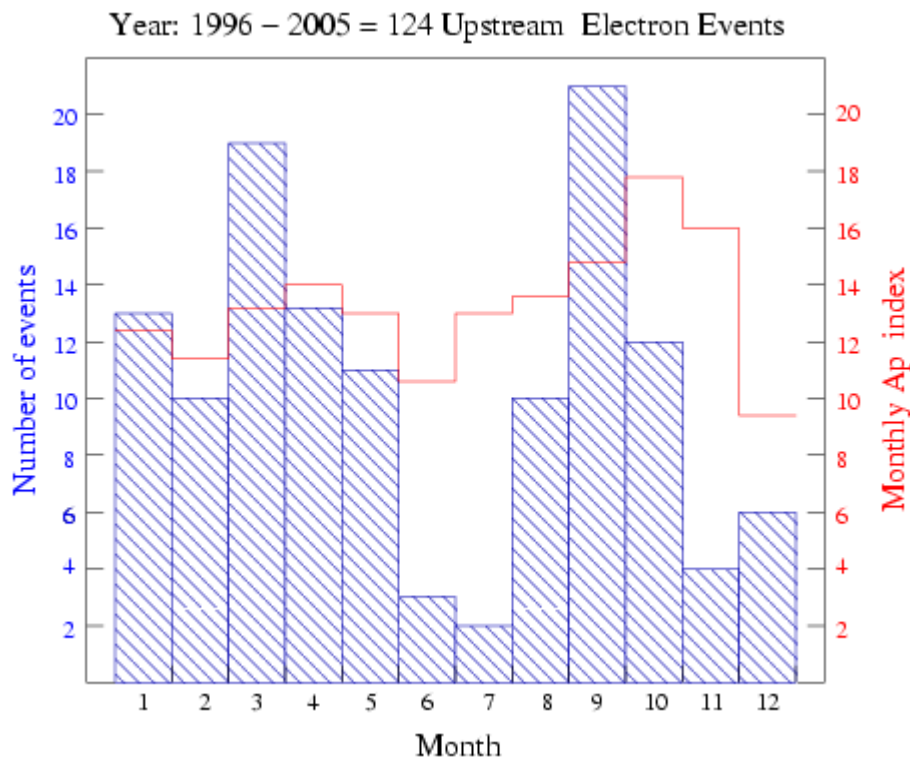
Superposed epoch analysis



Distribution of the daily Ap index and solar wind speed around the upstream events onset.

→ Upstream events occur during the maxima of Ap & Vsw

The occurrence number of **upstream events** and the geomagnetic activity **Ap index**



The events are nonuniformly distributed over the year.

- seasonal variation of number of upstream events in comparison with **Ap index**;
- during solar minimum the seasonal variation is more pronounced;

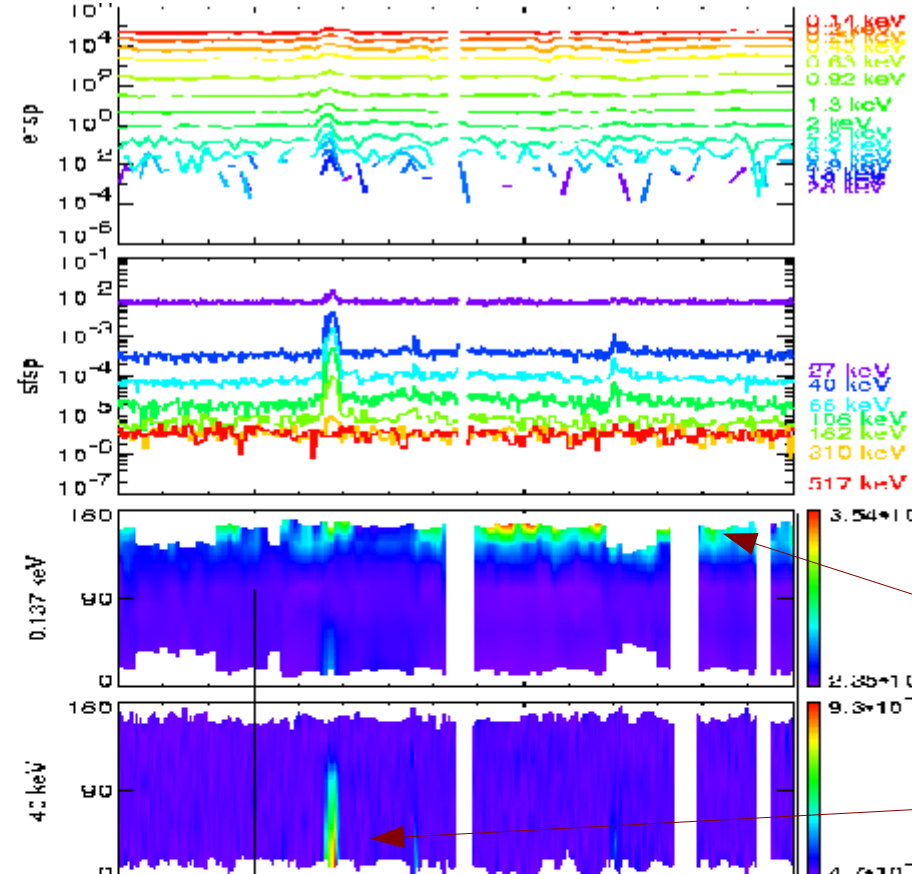
Results:

Association with other observations :

events occur without association with solar activity;
during incremented solar wind speed (352 – 815 km/s, mean = 509 km/s);
during enhanced geomagnetic activity (seasonal variation);
during some events the IMF is nonradial;

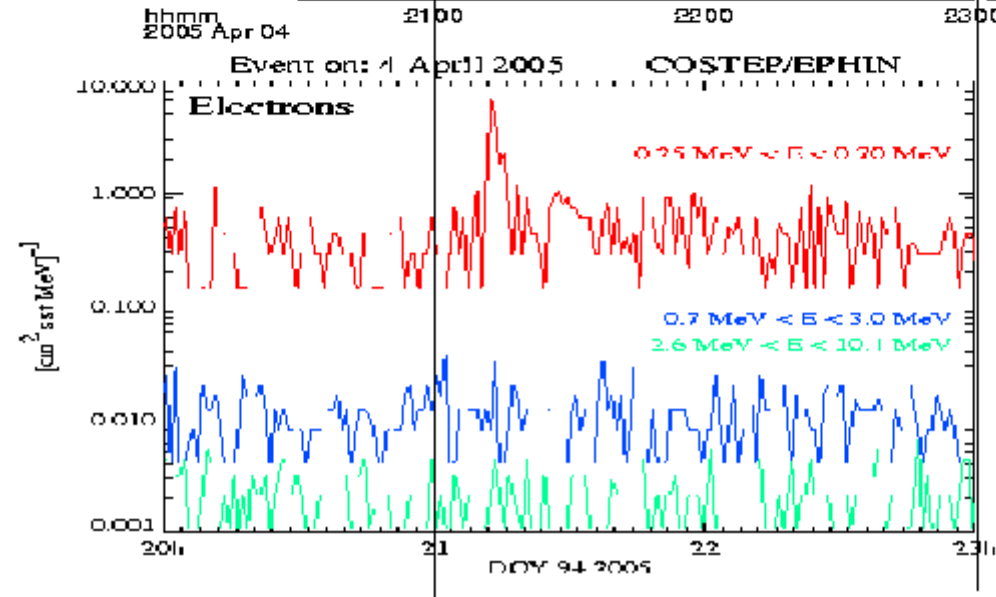
The strong seasonal variation of the number of upstream electron events and of the A_p index suggest that the observed events are rather of magnetospheric origin than bow shock accelerated electron beams.

The burst show no velocity dispersion

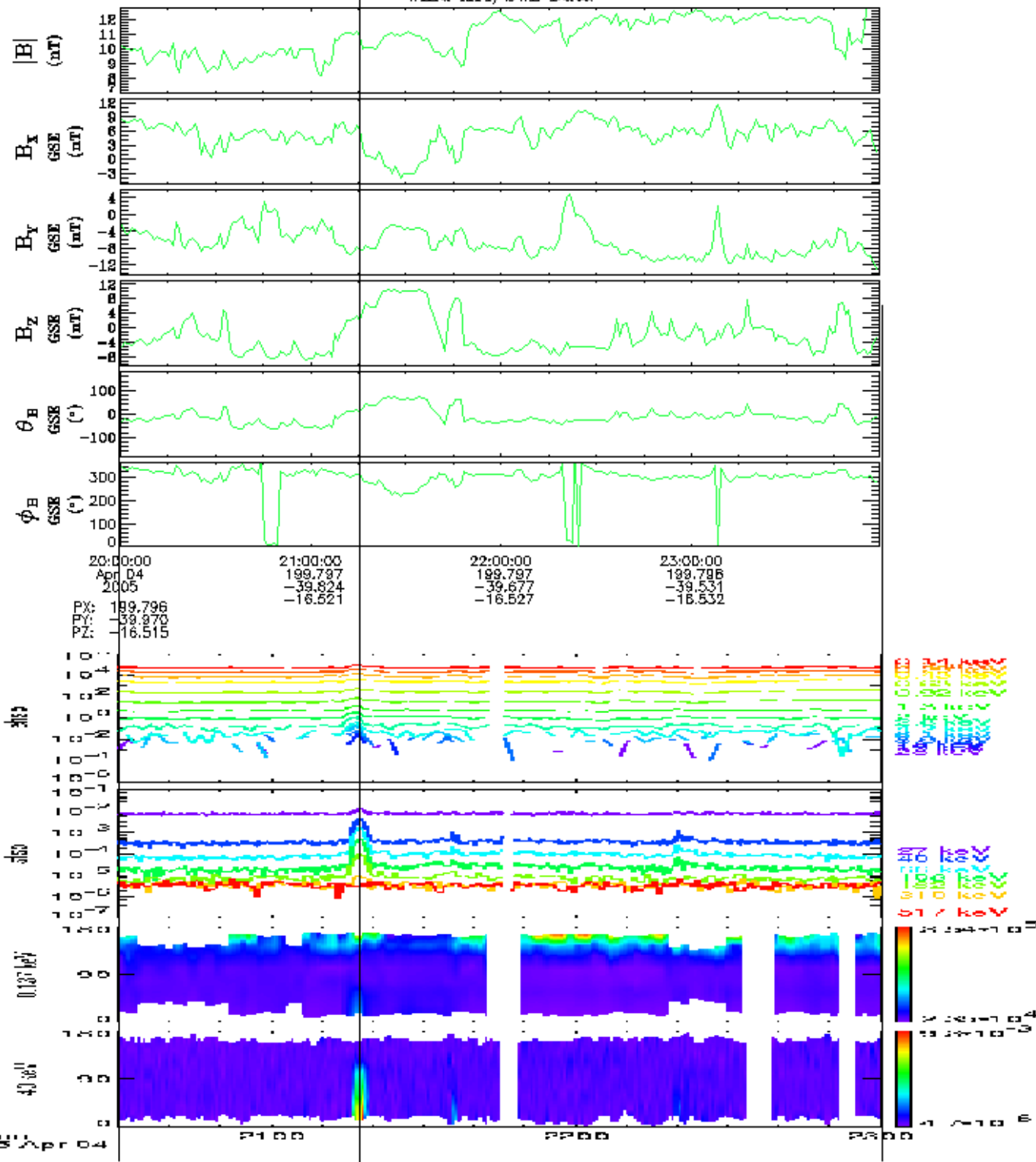


PAD_WIND
Strahl-Sun direction

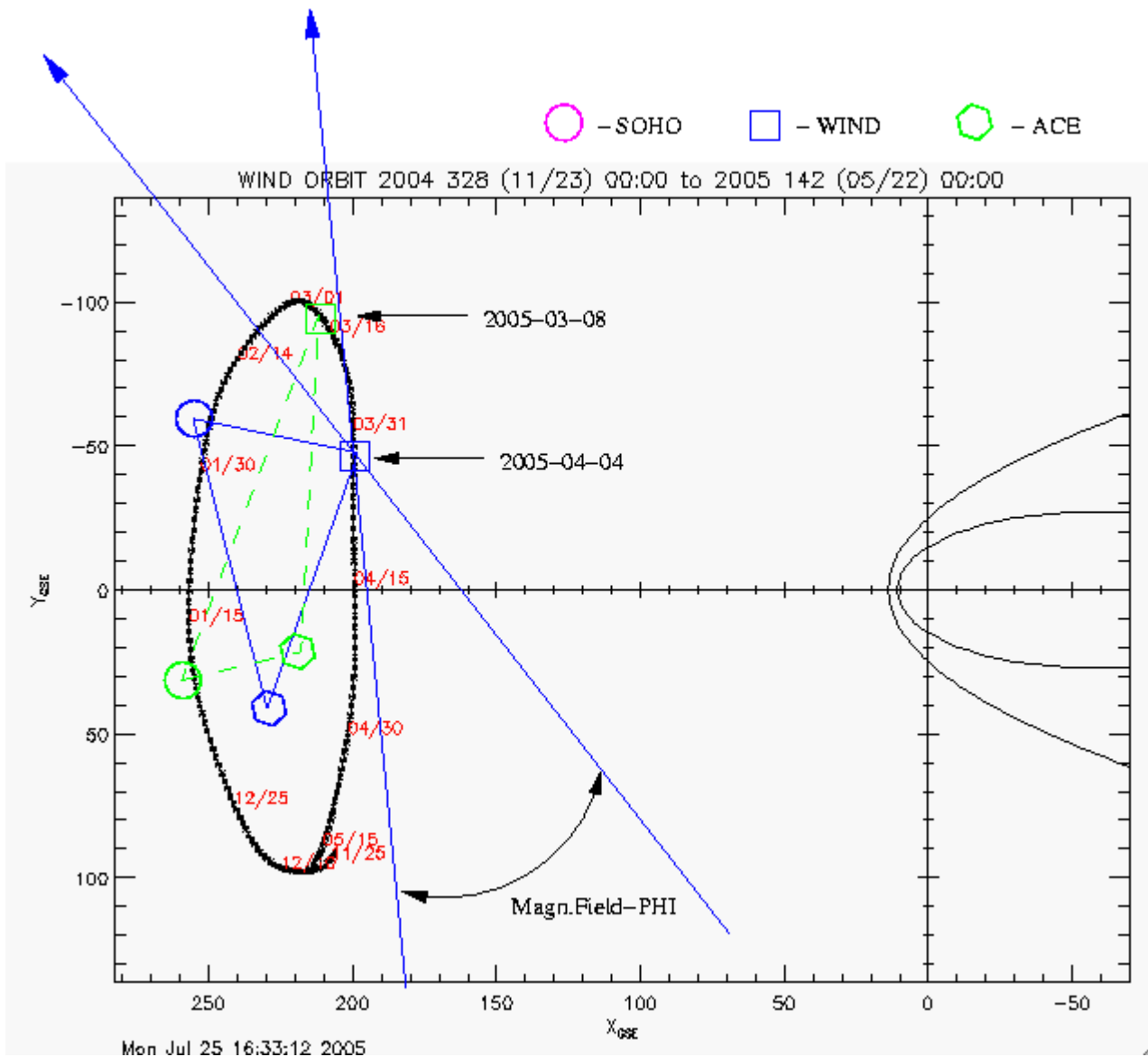
Burst - Anti-Sun
direction



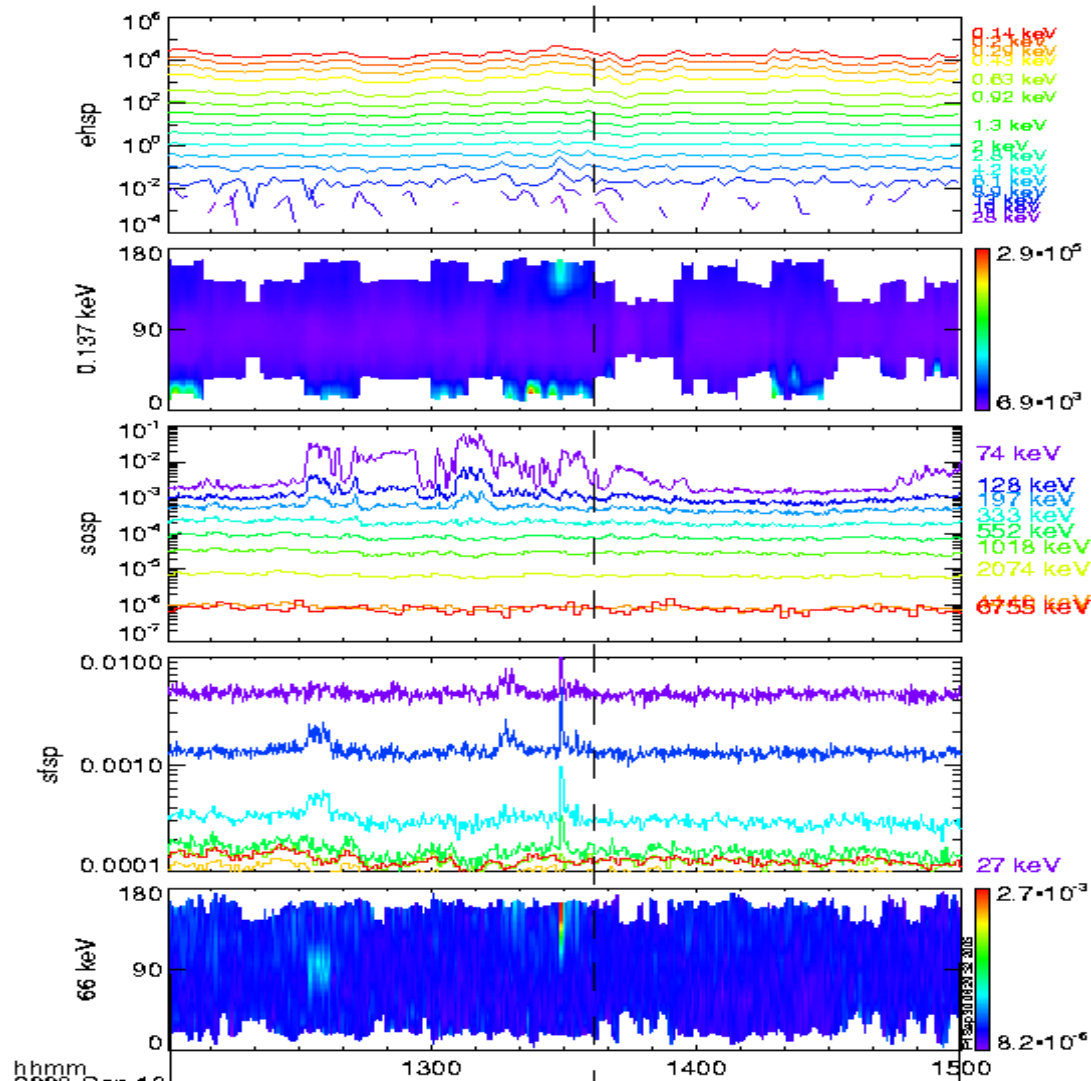
Wind MFI/SWE Data



- IMF parameters during an upstream event

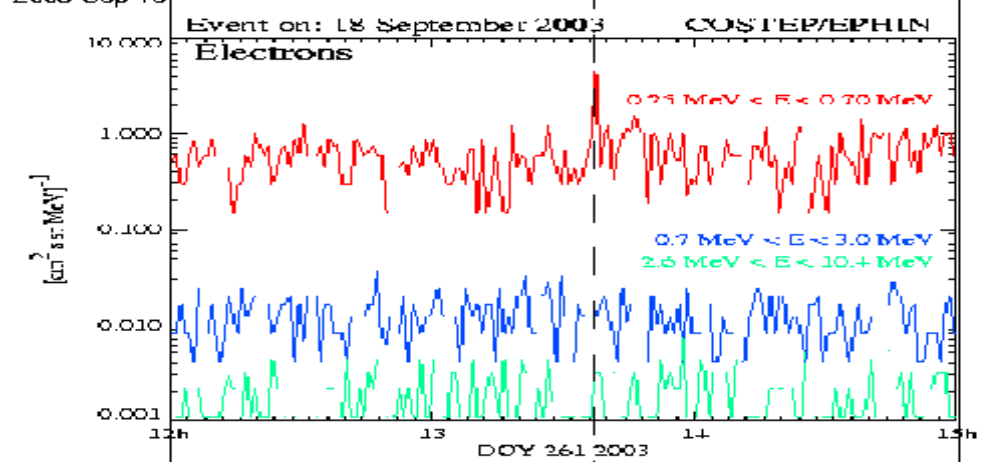


Positions of SOHO, WIND, ACE spacecraft and the IMF orientation.



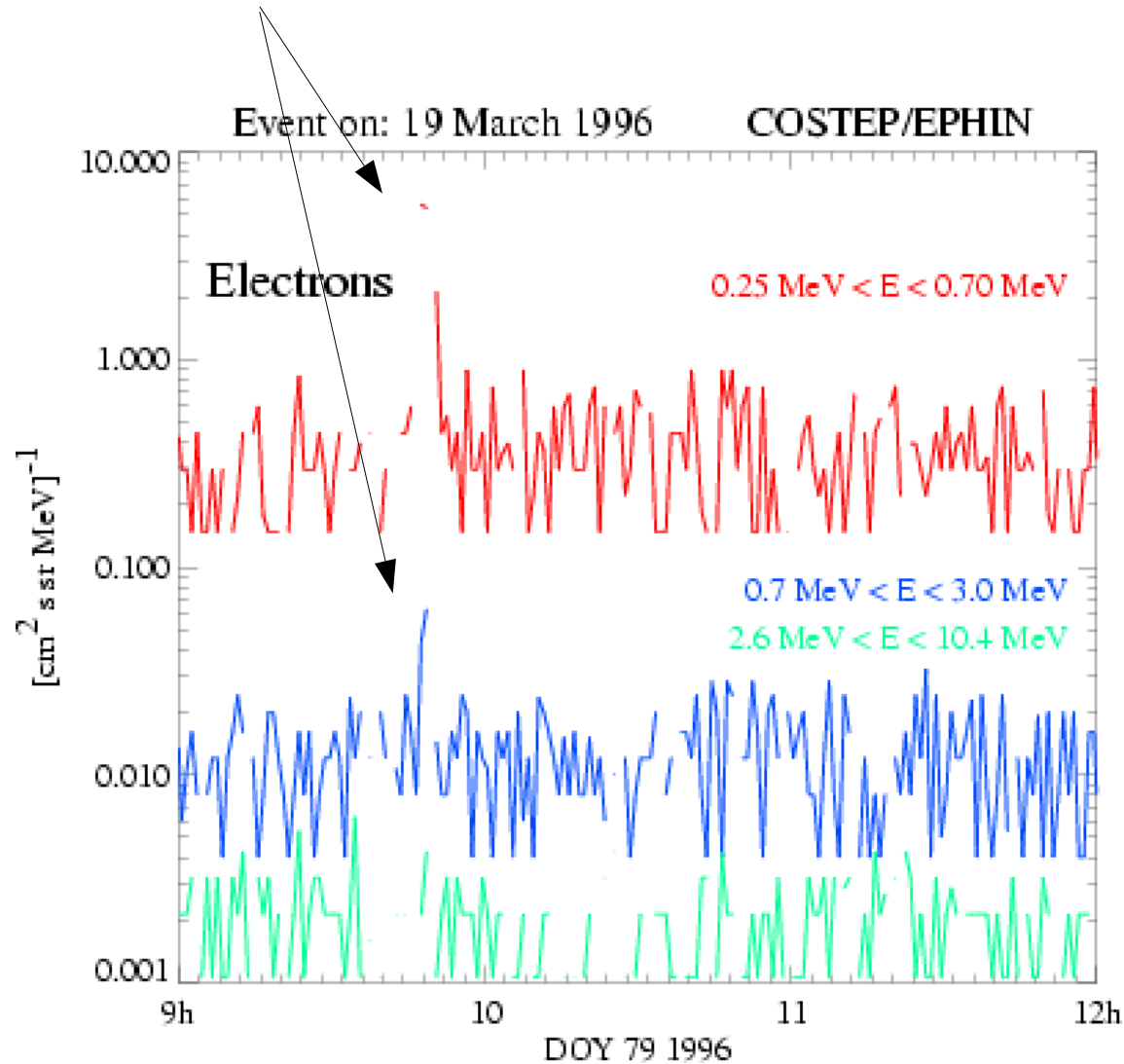
← WIND

'Short' duration event =< 4 min.



← EPHIN

Energy range: usually in 0.25-0.7 MeV channel, but ...
an event with some counts in 0.7 – 3.0 MeV channel, too.



Preliminary Results:

- Bursts characteristics:
 - spiky structure;
 - no velocity dispersion;
 - duration between 1 and 30 minutes;
 - PADs indicate flow from the anti-Sun direction;
- Association with observations at other satellites:
 - not all EPHIN bursts are observed by WIND & ACE;
 - time delay between EPHIN & WIND bursts and vice versa;
- Association with other observations :
 - some events are associated with low energy upstream protons (< 1 MeV);
 - events occur without association with solar activity;
 - during incremented solar wind speed (352 – 815 km/s, mean = 509 km/s);
 - during enhanced geomagnetic activity (seasonal trend!?);
 - during some events the IMF is not radial;