

# SEPT/STEREO Observations of Upstream Particle Events: Almost Monoenergetic Ion Beams

A. Klassen, R. Gomez-Herrero, R. Mueller-Mellin and SEPT Team,  
G. Mason and SIT Team

Upstream particle events ( $E < 1$  MeV) stream from the Earth's magnetosphere towards the upstream region of the bow-shock (Asbridge et al. 1968)

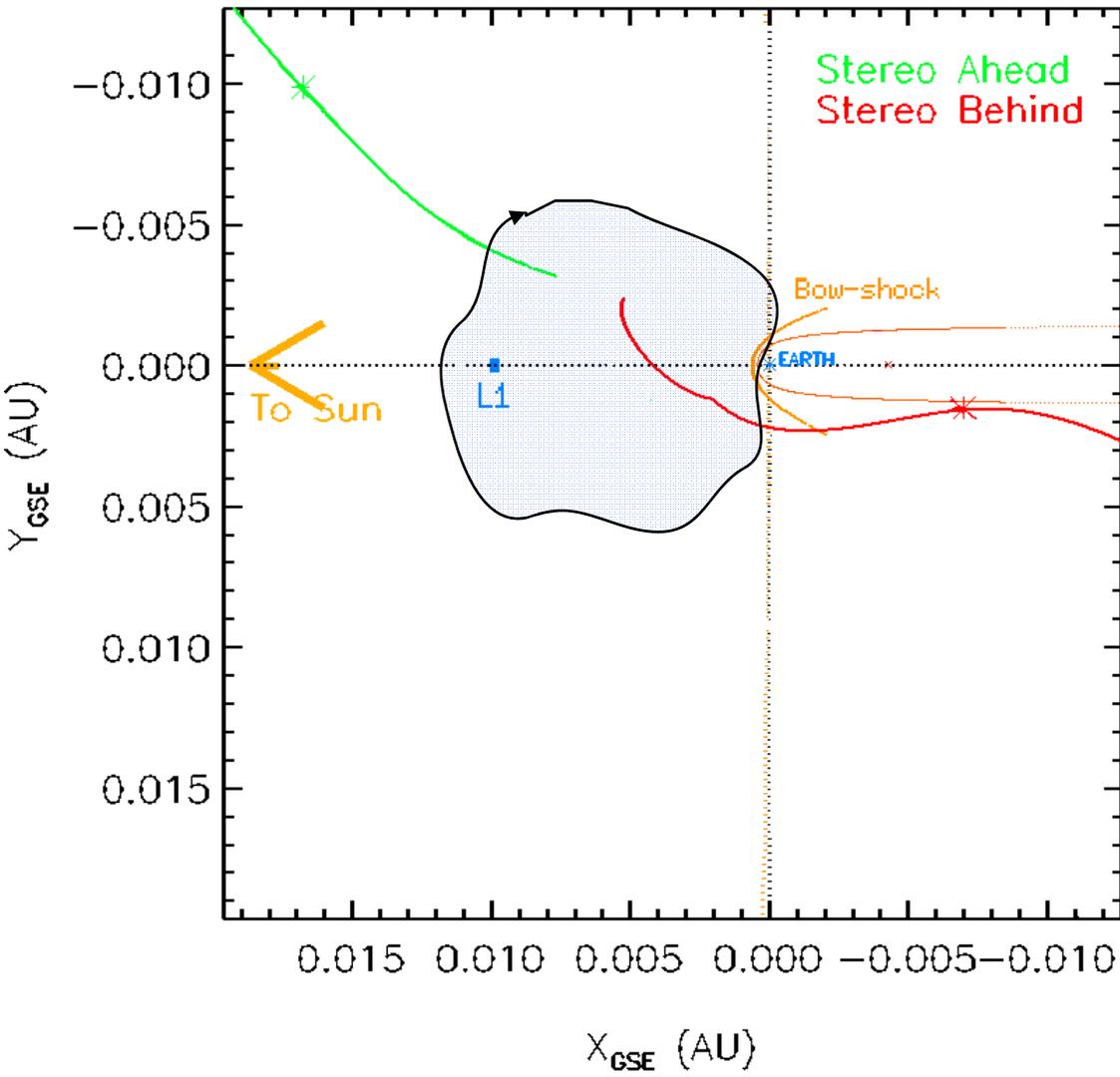
The origin was explained in two ways:

- acceleration at the bow-shock (e.g. Fermi or shock drift mechanisms)
- leakage of magnetospheric particles accelerated within the magnetosphere

All these mechanisms predict **power-law** energy spectra.

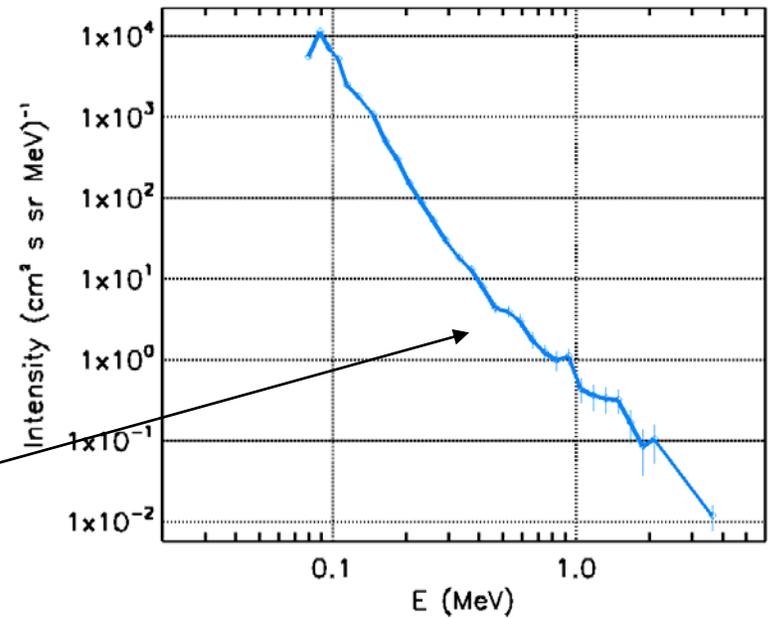
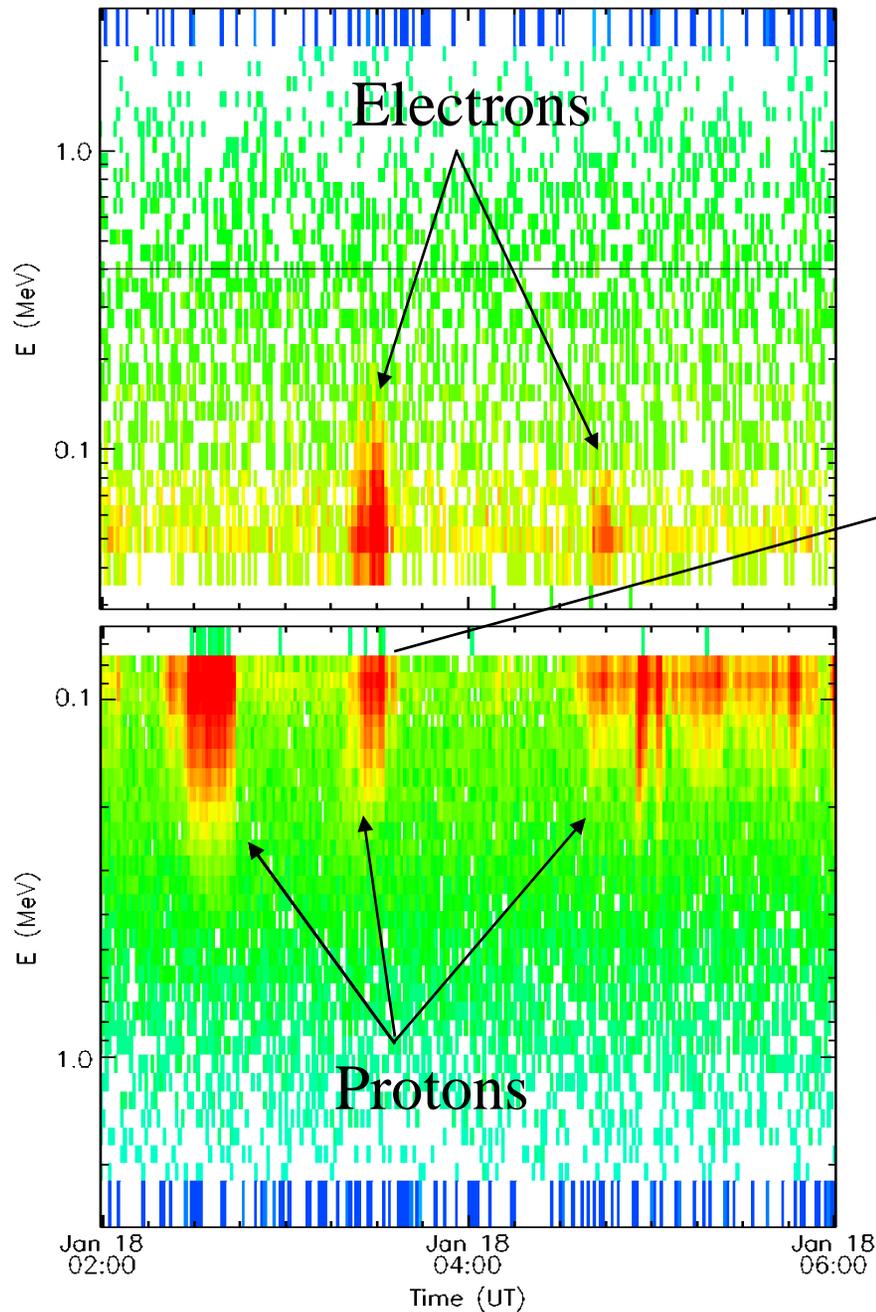
Indeed, such spectra were observed by different space missions during the last 40 years.

STEREO ORBIT (Feb 8, 2007 00:00:00 – Feb 9, 2007 00:00:00)



- In the past most of the upstream events were observed in the region between the Earth's bow-shock and the L1 point (ISEE-3, ACE, Wind, SOHO etc).

# SEPT-A/AntiSun telescope (STEREO-A)

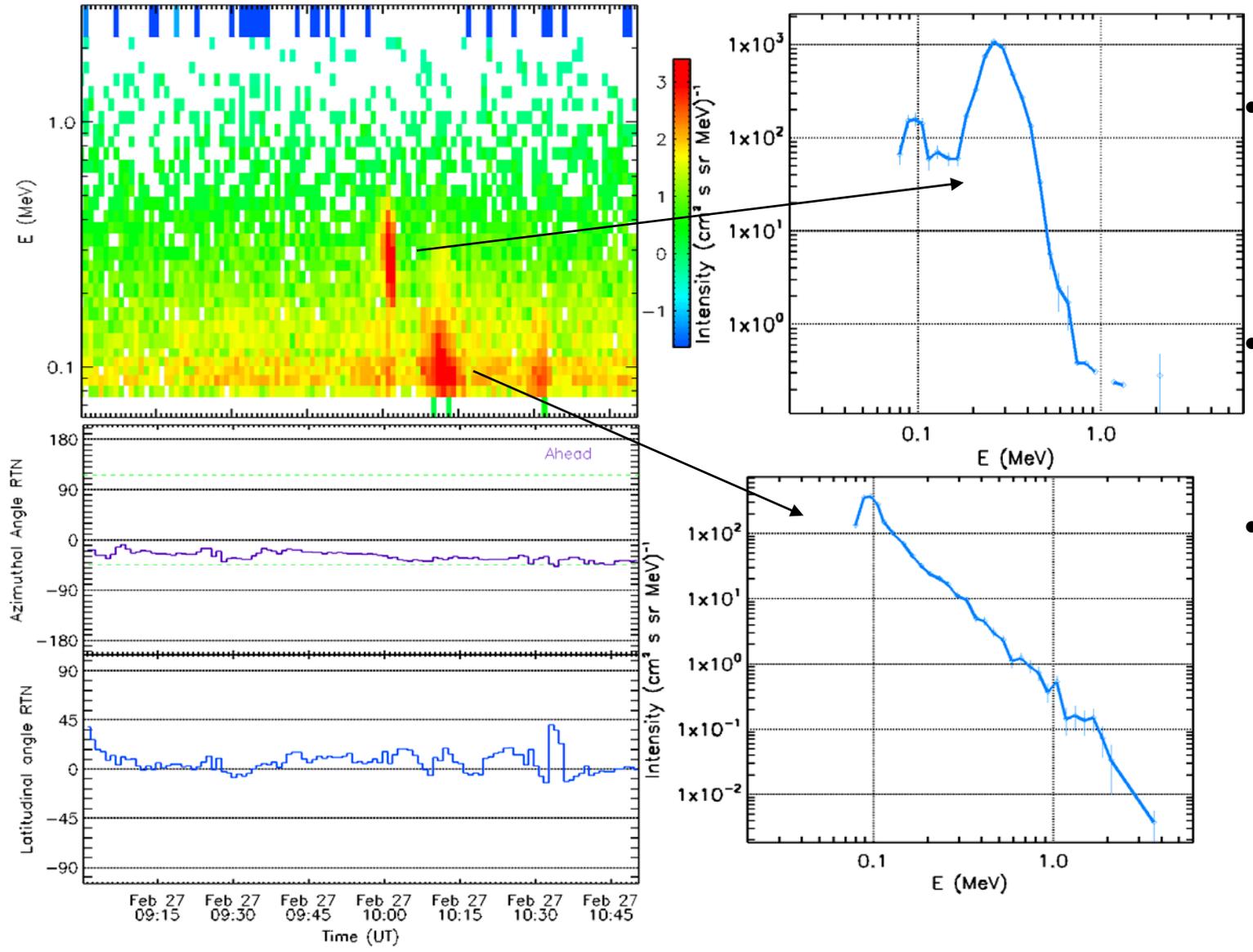


Energy spectrum of protons is a power-law.

A sequence of upstream proton & electron events. The first proton event was not accompanied by electrons.

## ”Almost Monoenergetic Ions” (AMI) Events

- about 10 years ago Lutsenko & Kudela (1999) reported detection of narrow lines ( $E_{\text{FWHM}}/E_{\text{max}} \sim 0.15-0.30$ ) in the energy spectra (50-1000 keV) of upstream events using observations with the Interball-1 spacecraft. These ion events have been called ”Almost Monoenergetic Ions” (AMI) and were observed close upstream of the Earth's bow-shock and in the magnetosheath, only.
- these observation were not confirmed, before the launch of STEREO.
- using the Solar Electron Proton Telescope (SEPT) aboard STEREO-A&B we detected about 60 AMI events close to the bow-shock and to the magnetopause as well as far away from the Earth at distances up to 0.27 AU (6000 Re).

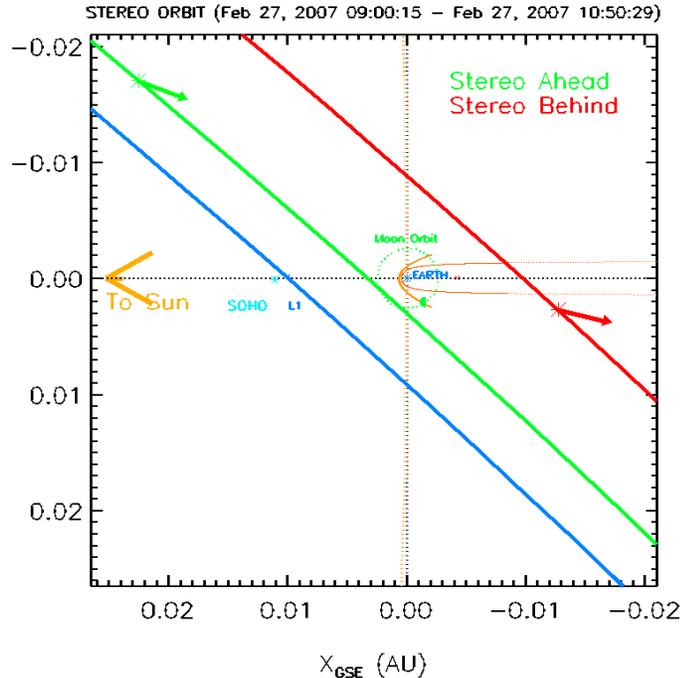
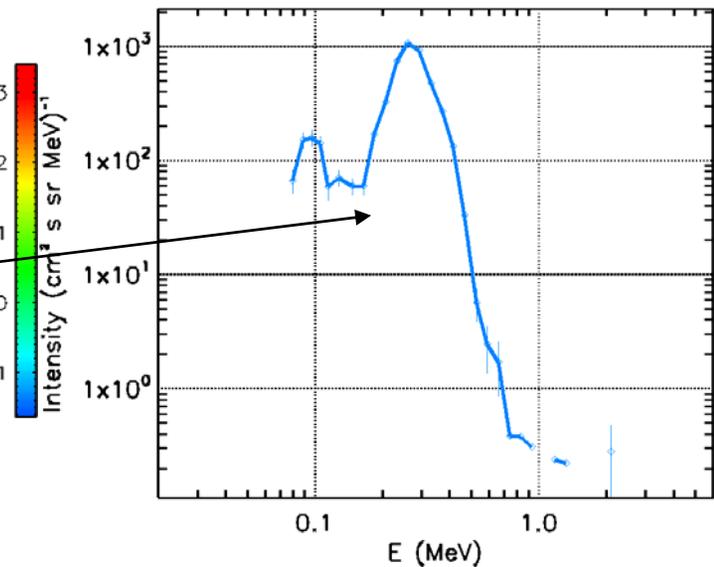
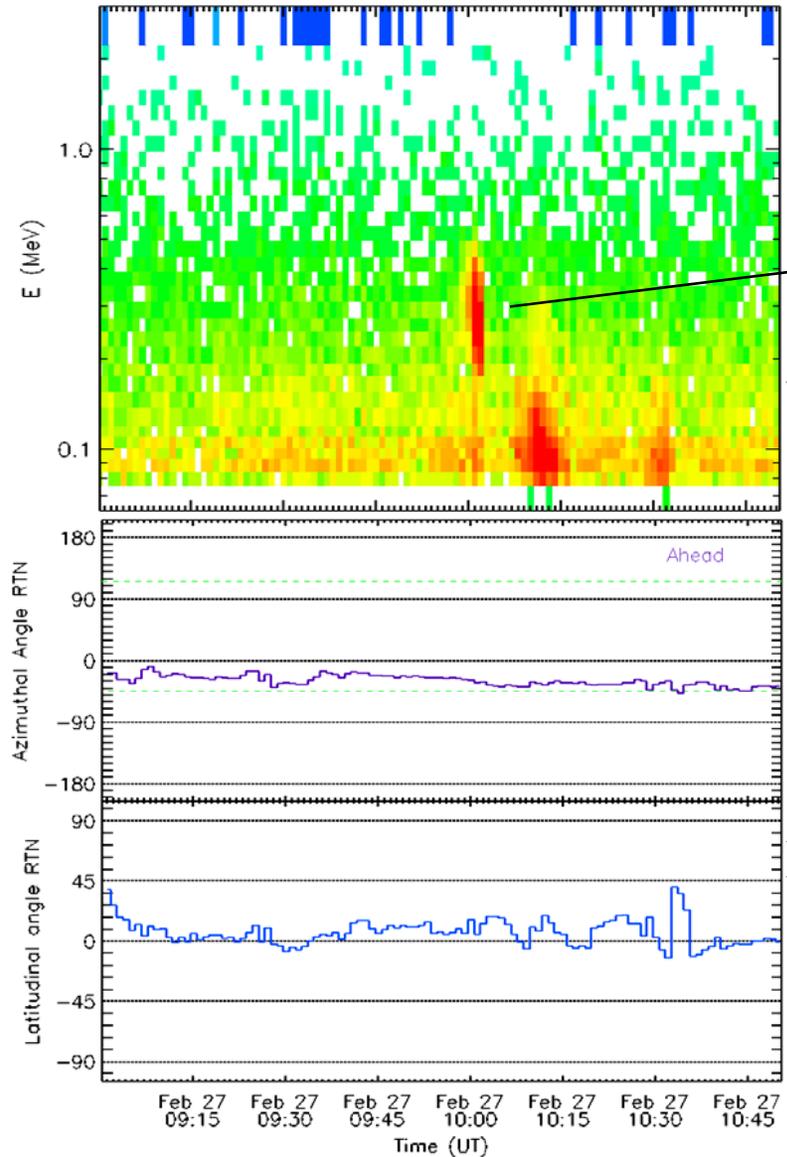


- the first event shows a monoenergetic line at 260 keV with FWHM=130 keV

- second and third events show “normal” power-law spectra

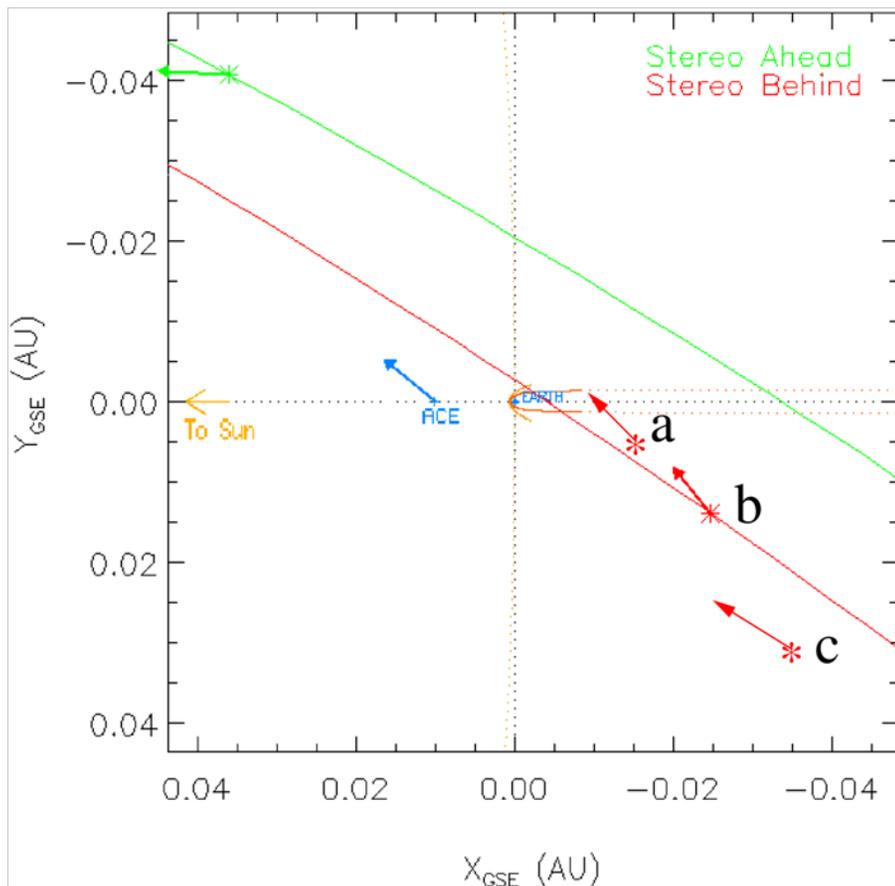
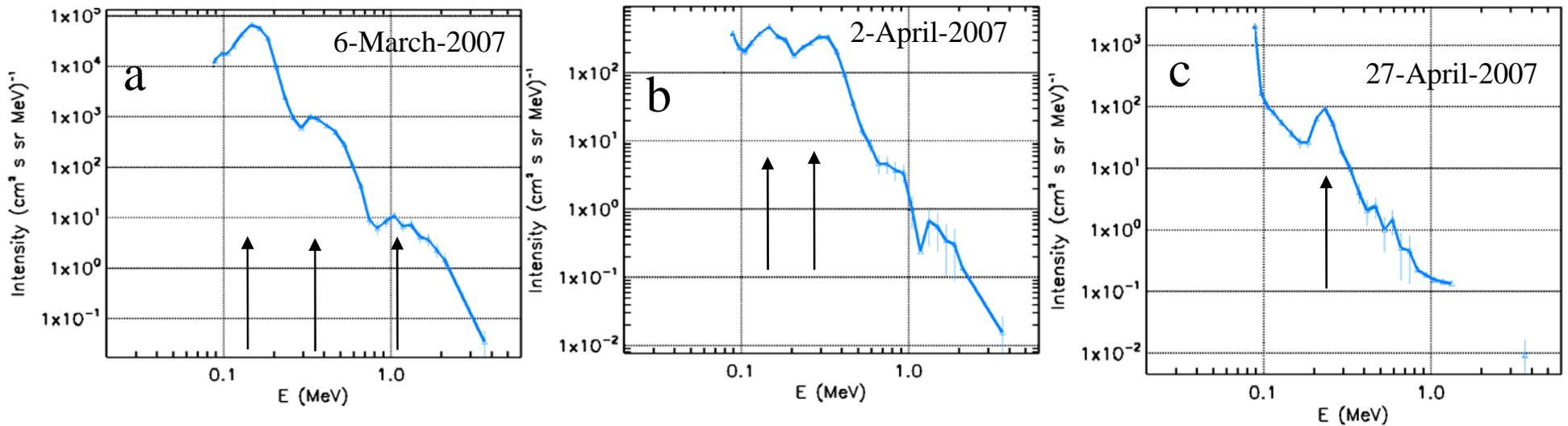
- no changes in IMF during and before the events

# Almost Monoenergetic Event on 27-February-2007 (STEREO-A)



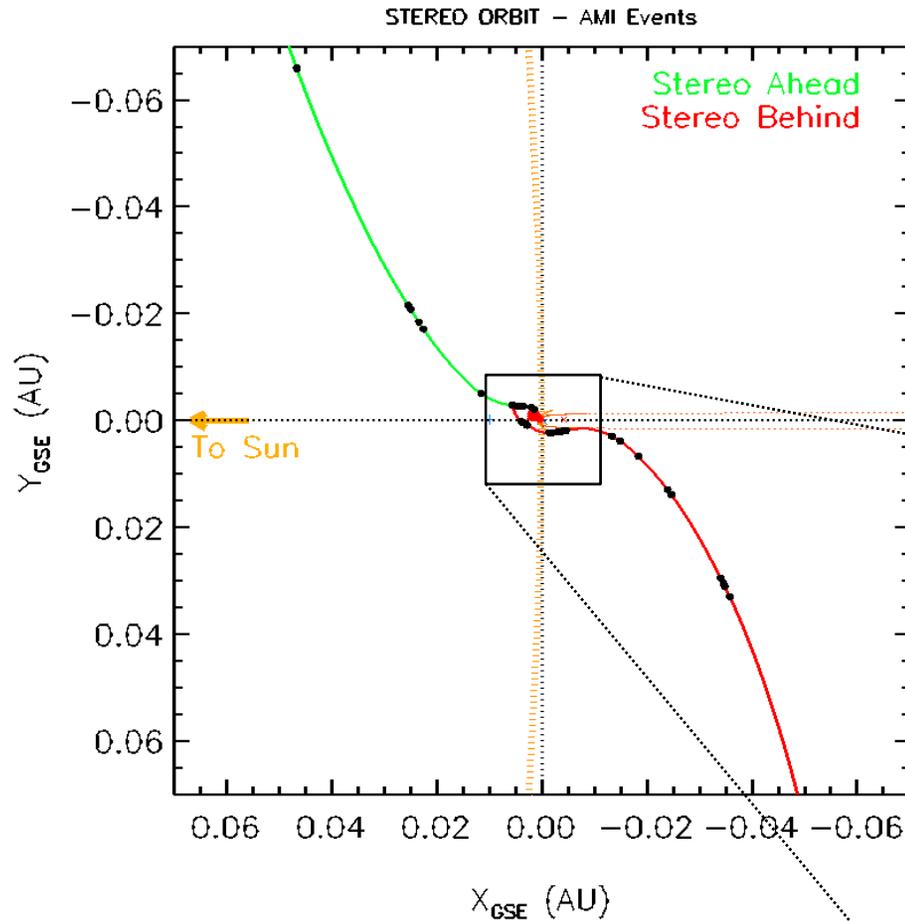
- STEREO-A: distance to Earth=0.028AU=659 Re
- the ecliptic IMF component (green arrow) is directed towards the magnetosphere
- the Parker spirals are drawn according to  $V_{sw}$  (ST-A&B, ACE)

# Three, two & one line spectra (STEREO-B)

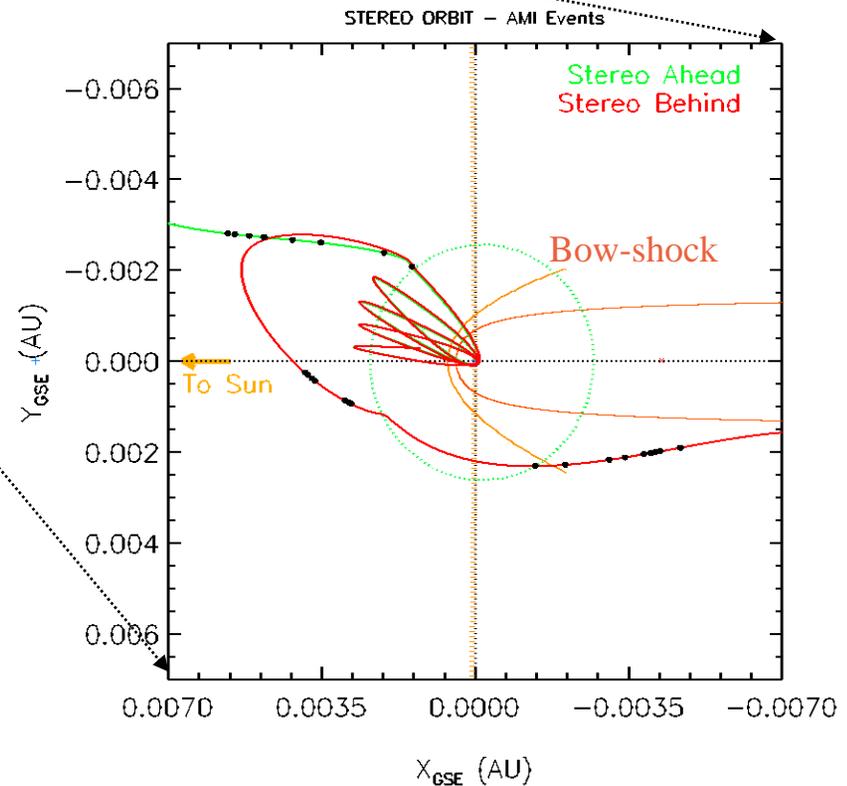


- AMI events far away from the Earth.  
Distance to Earth: 351, 656 & 1150 Re
- the ecliptic IMF component (red arrow) is directed towards the magnetotail (a&b) or towards the bow-shock (c)

# Spatial distribution of AMI events



- the AMI events (diamonds) were detected not only close to the bow-shock and close to the magnetopause, but also far away from the Earth up to distances of 0.27 AU (not in figure)



# Main properties of AMI events

- AMI events show **one**, **two** or **three** narrow lines in the energy range from 120 to 1200 keV with a mean width ( $E_{\text{FWHM}}/E_{\text{max}} = 0.40 \pm 0.02$ )
- almost all events show a strong anisotropy streaming from the Earth direction
- the energy peak ratio is 1:2 by two lines, and 1:2:(5-6) by three lines
- AMIs were observed close to the bow-shock and close to the magnetopause as well as far away from the Earth ( $\leq 0.27$  AU)
- mean duration time is 4 minutes
- only ~20% of 60 AMI events were associated with electron events
- normally the AMI events occur during high SW speed and when the  $B_z$  component of the IMF is negative

# Possible sources of AMIs

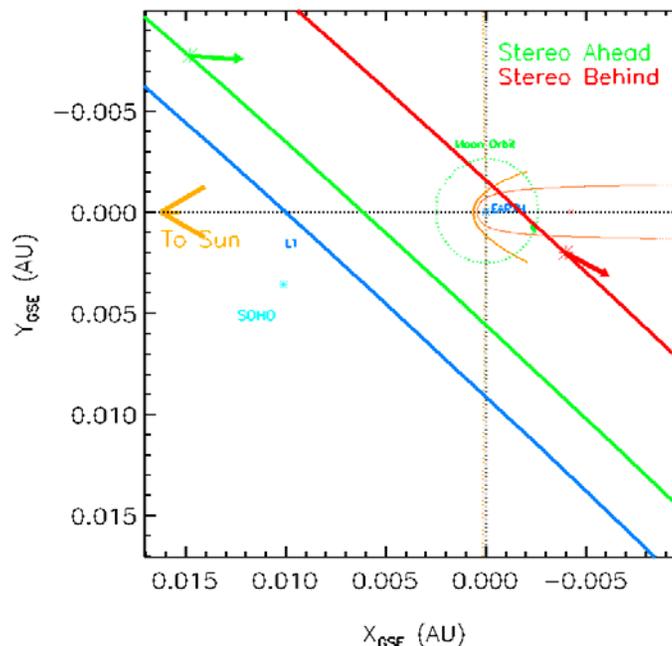
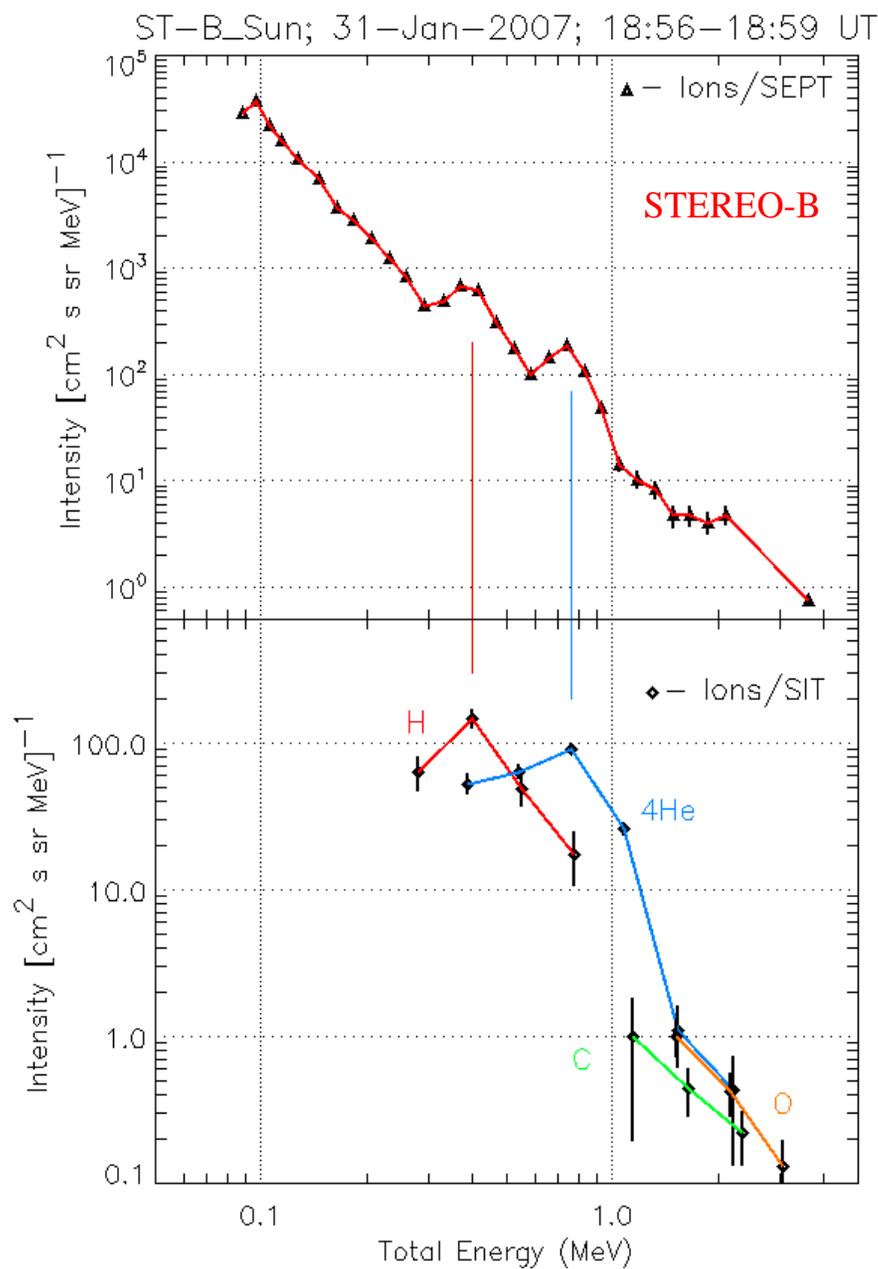
- A lot of AMI events were detected when **STEREO-B** was connected to the magnetopause, therefore it is plausible that the magnetopause is the best candidate for an AMI acceleration source
- the Earth's bow-shock and the CIR shocks cannot be excluded, because **STEREO-A** was also well connected to these structures
- We suggest like Lutsenko & Kudela (1999) that the narrow lines (AMI) may be explained as  $H^+$ ,  $He^{++}$  and  $CNO^{+(5-6)}$  ion beams accelerated in an electrostatic field proportional to their charge  $Q$ , because the energy peak ratio in three line spectra is 1:2:(5-6), i.e.:

$$E_{ion} = Q \cdot F_{estat} \cdot d$$

where  $d$  is the size along the electrostatic field  $F_{estat}$



# Comparison of energy spectra obtained with the SEPT and SIT instruments



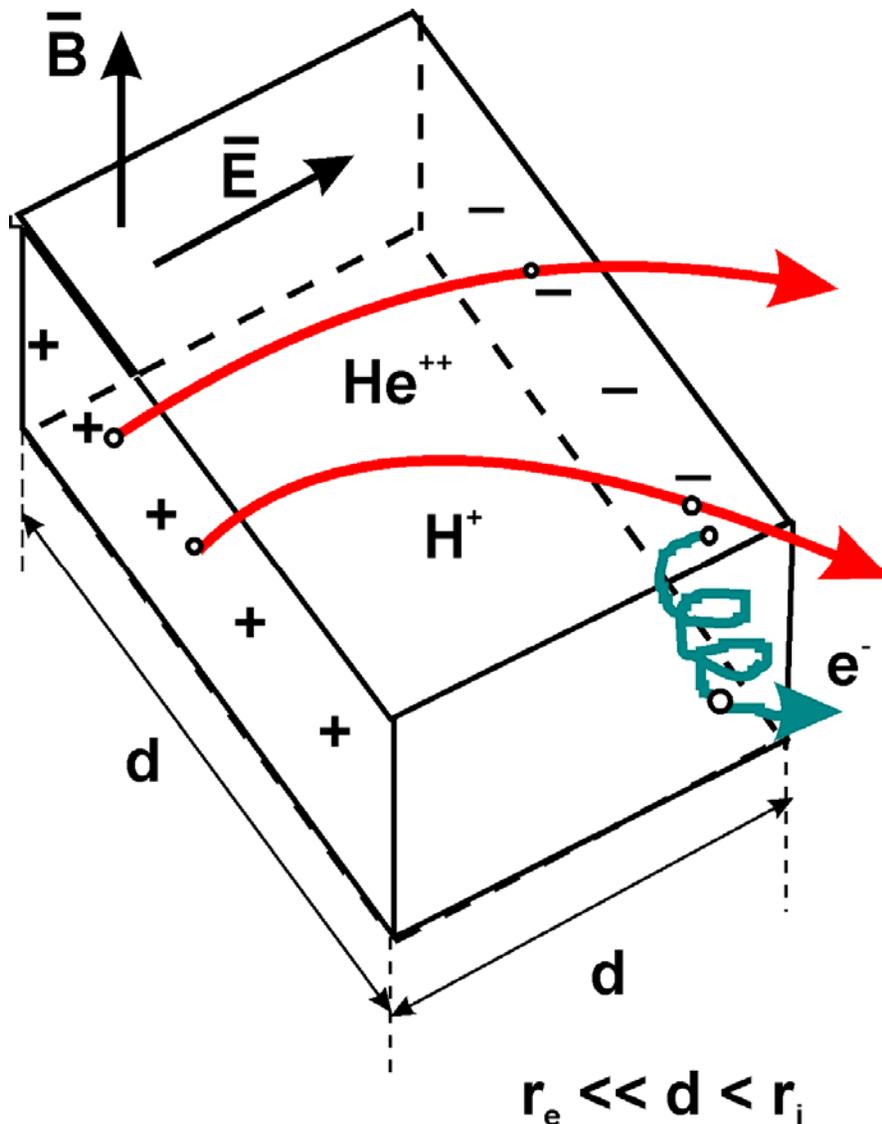
- two lines by SEPT
- two lines by SIT: first due to  $\text{H}^+$ , second due to  $\text{He}^{++}$
- energy peaks match each other very well
- in both spectra the peak ratio is 1:2
- these observations support the idea that AMI events are due to  $\text{H}^+$  and  $\text{He}^{++}$  beams accelerated in an electrostatic field

# Conclusions

- Using **SEPT/STEREO-A&B** we detected narrow energy lines (AMI) in the spectra of upstream events close to the Earth's bow-shock and along the STEREO trajectories up to distances of 0.27 AU from the Earth
- Multiline spectra show energy peak ratio of 1:2:(5-6)
- It is suggested that these lines occur due to acceleration of **protons**, **He<sup>++</sup>** and **CNO<sup>+(5-6)</sup>** in a burst of strong electrostatic fields at the magnetopause or/and at the bow-shock/CIR shock

## Lutsenko (2001) hypothesis on the AMI origin:

Acceleration must take place in a region with  $\mathbf{E} \perp \mathbf{B}$  and dimensions  $d$  lower than ion and much greater than electron gyroradii. The potential drop  $\Delta V$  must be of 50-150 keV



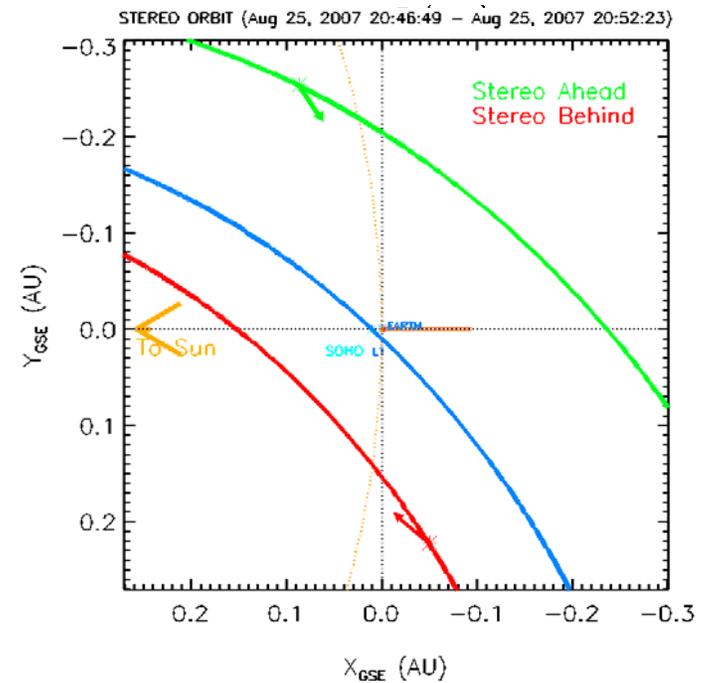
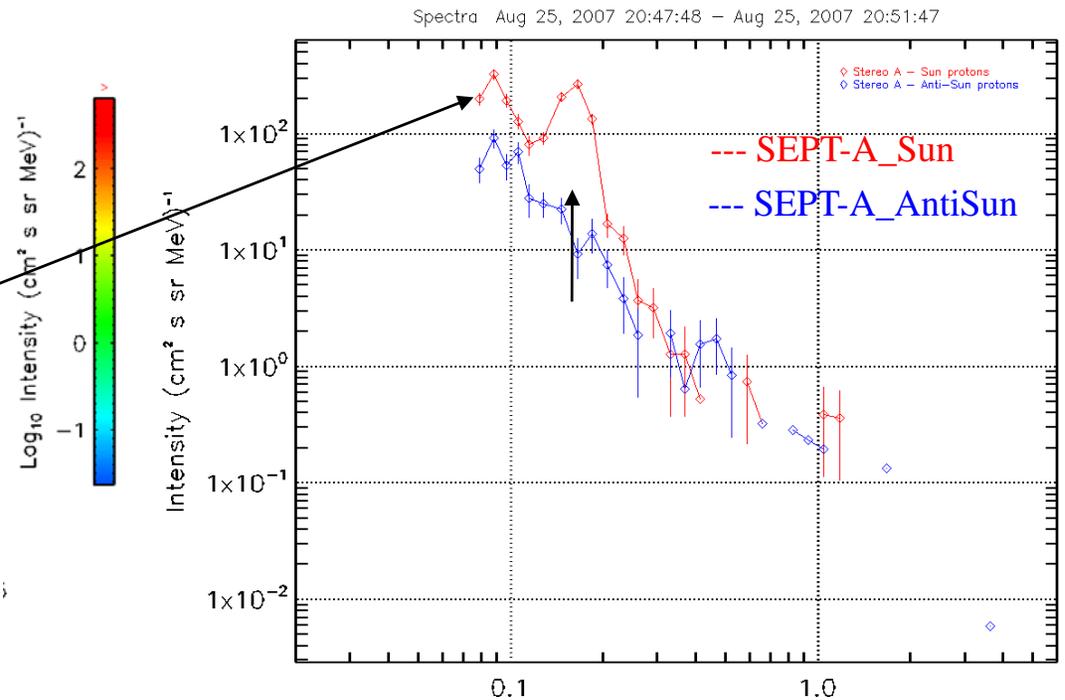
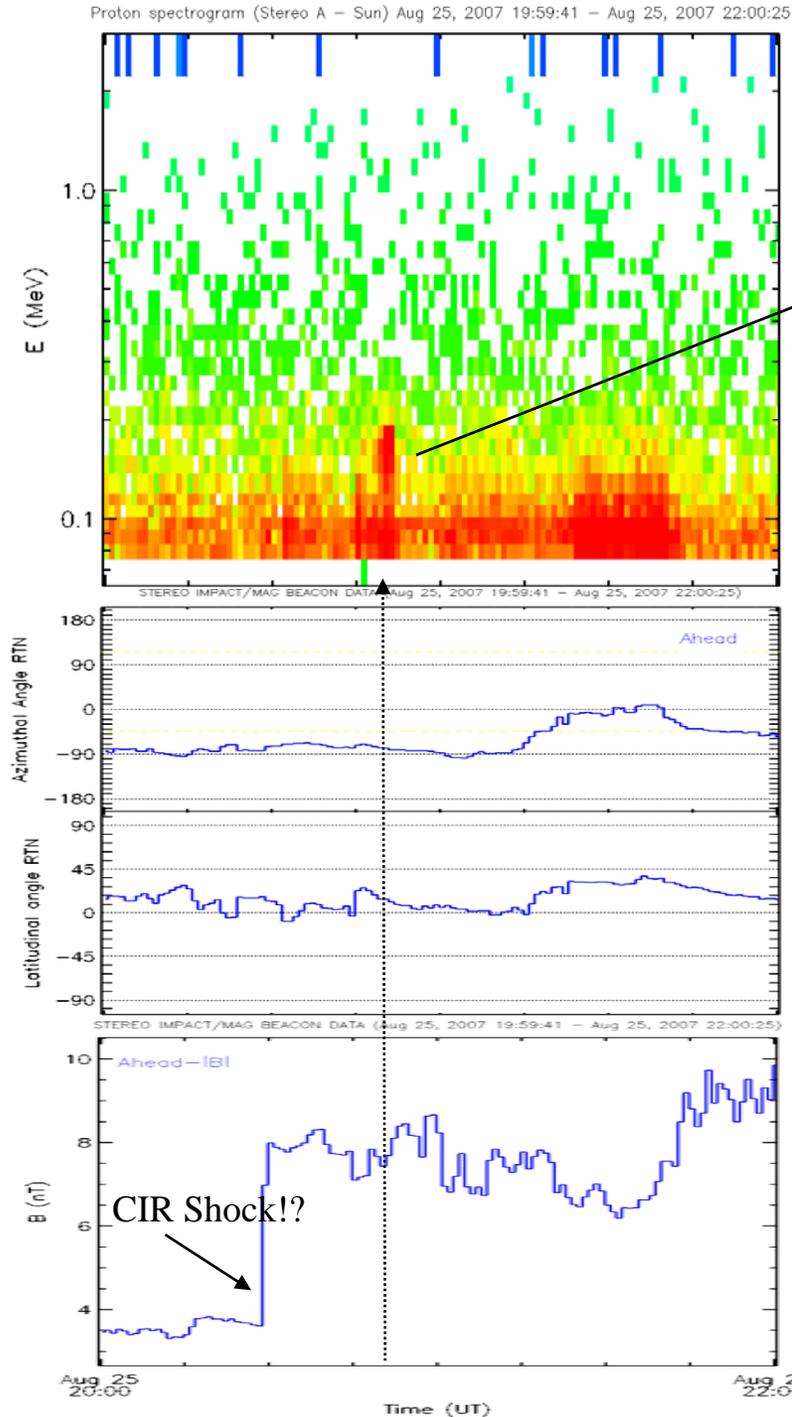
Acceleration of plasma ions in such a region must give 2 narrow lines in the spectrum with energy ratio of 1:2 ( $\text{H}^+$ ,  $\text{He}^{+2}$ ) and a broader peak ( $\text{C,N,O}^{+(5-6)}$ ) with energy 5-6 times that of  $\text{H}^+$ . This indeed was observed. The intensity ratio, too, corresponds to the known solar wind composition.

Electrons cannot be accelerated (only swept out by  $\mathbf{E} \times \mathbf{B}$  drift).

**BUT, at STEREO we detected also AMI events associated with electrons.**

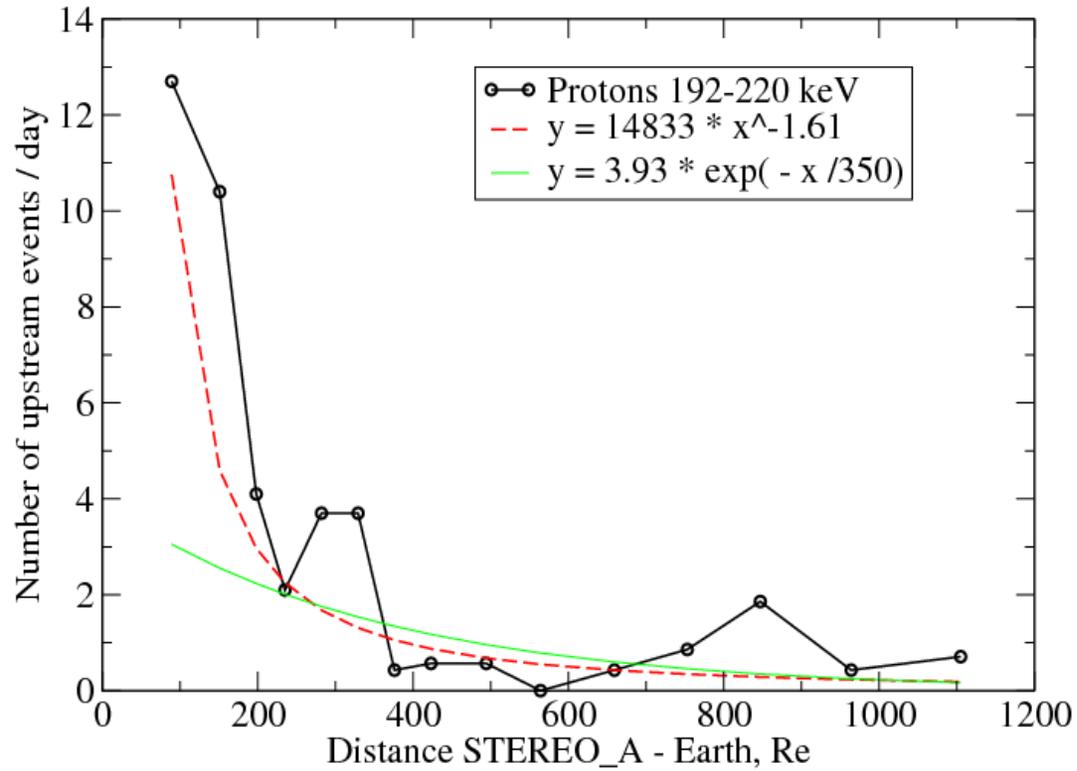
# AMI event streaming from the Sun direction!

## Is it accelerated at the Sun or by the CIR shock?



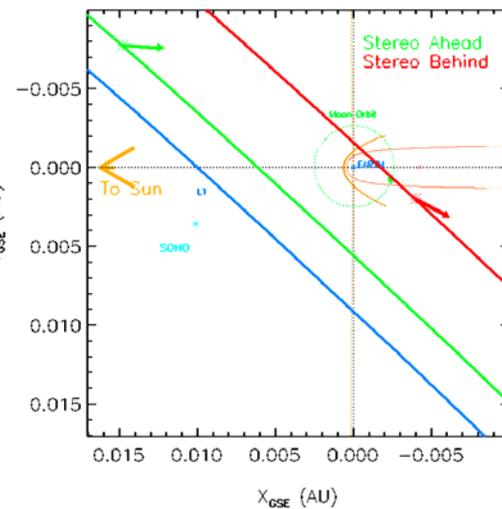
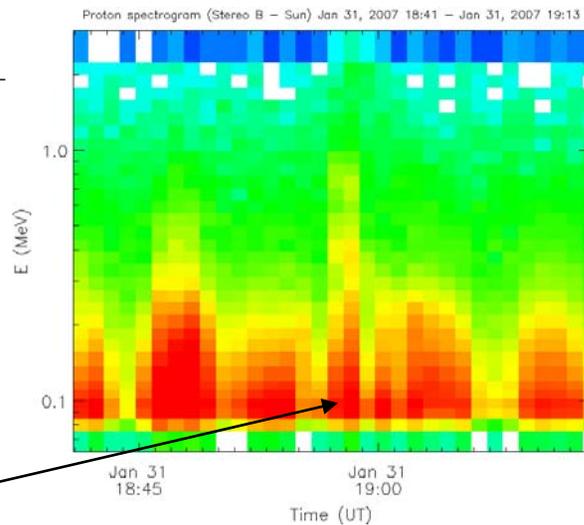
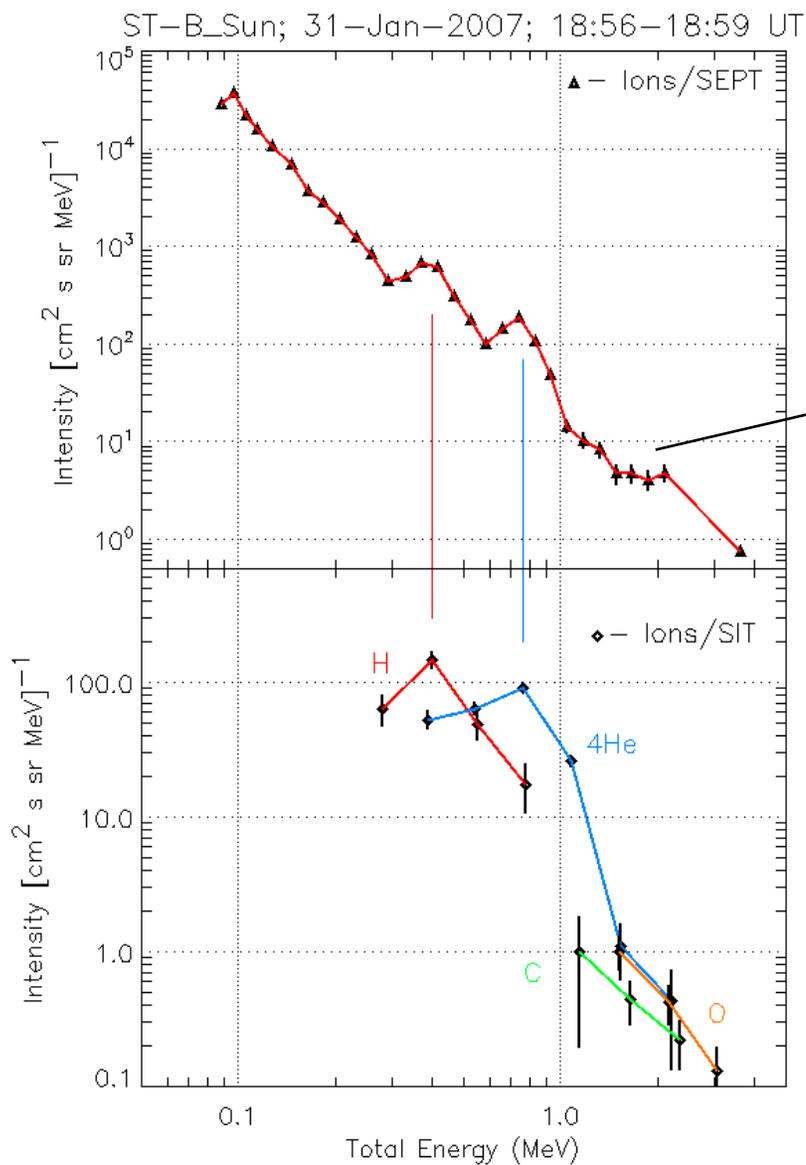
The End

# Upstream proton events vs. distance from the Earth



# Comparison of energy spectra obtained with the SEPT and the SIT instruments

## STEREO-B



# Stereo-B, dist. to Earth=0.054 AU=126 Re

