Recurrent CIR-accelerated ions observed by STEREO/SEPT

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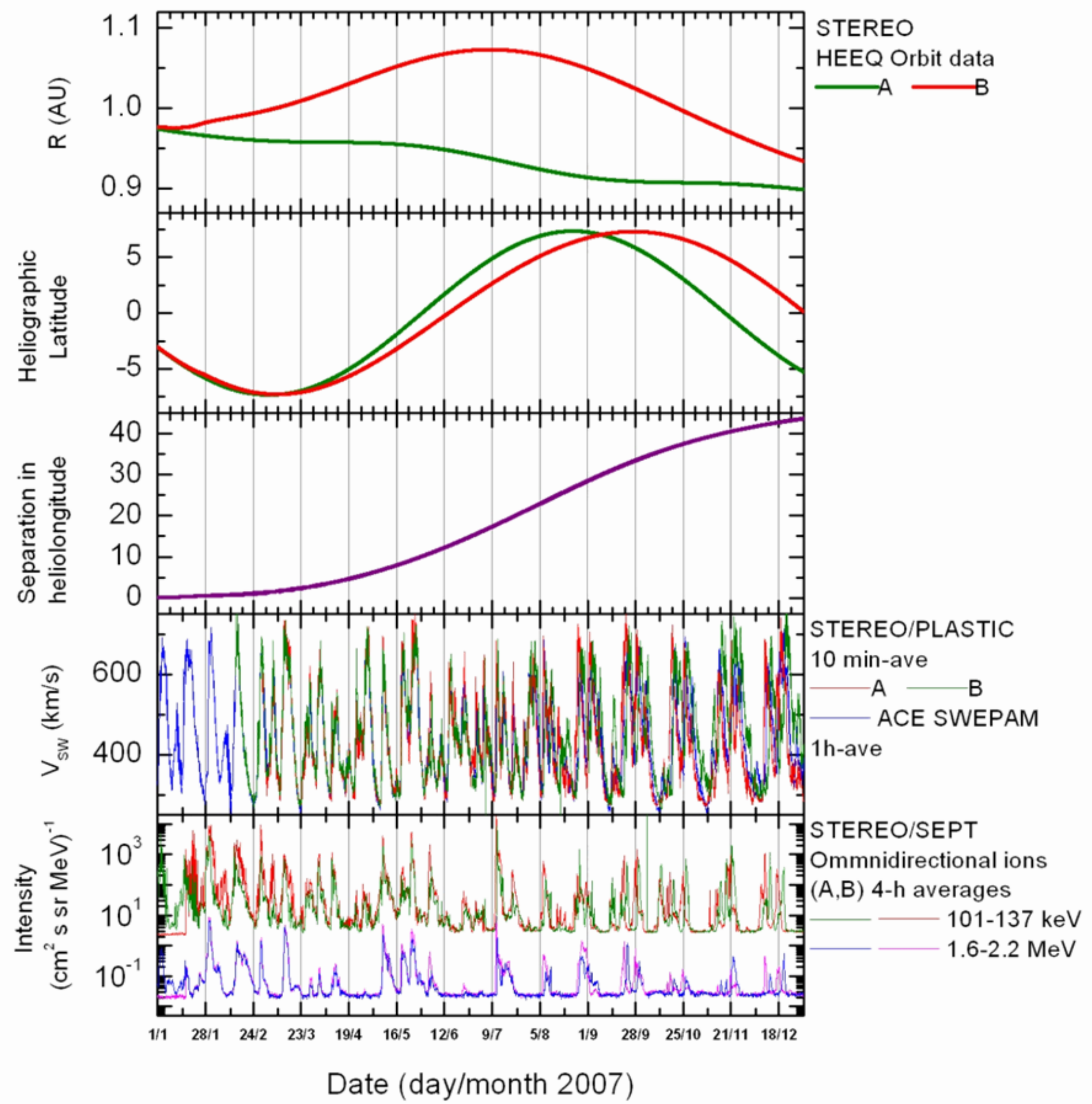
STEREO SWG #18, Meudon April 20-22, 2008

Solar Wind and Energetic Particles during 2007



Radial separation < 0.2 AU

Heliographic latitudinal separation < 5 degrees

Azimuthal separation between STEREO A and B increasing by ~44 º/year

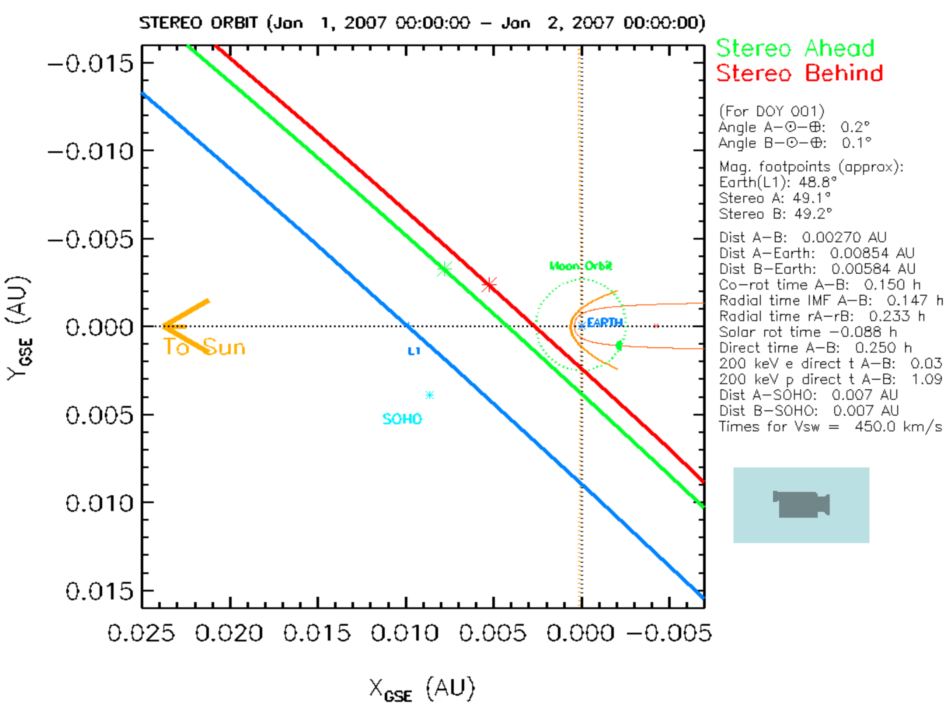
High speed solar wind streams

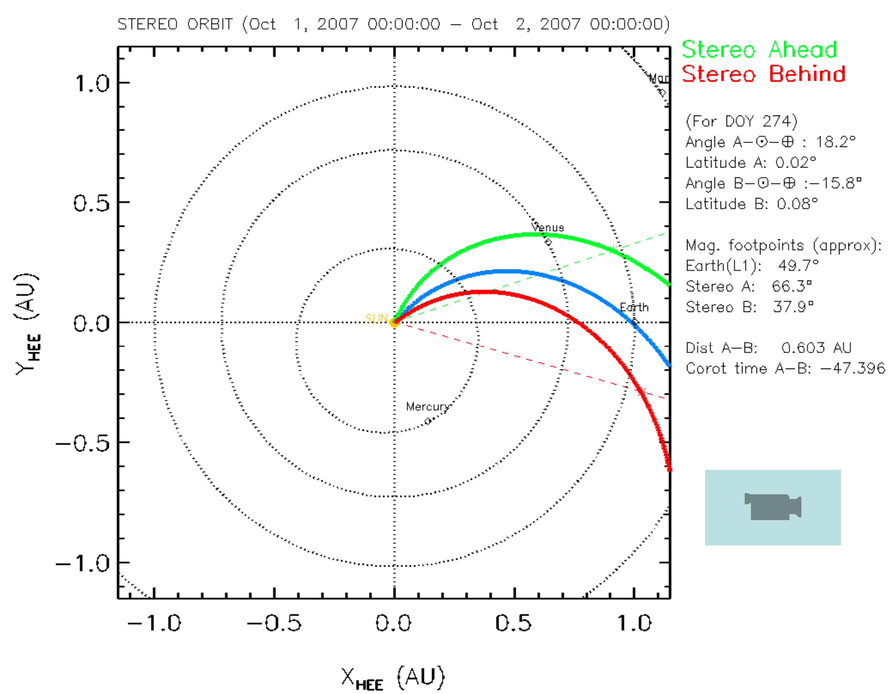
Energetic ion intensities are dominated by CIR-accelerated recurrent events

CIR signatures in solar wind and energetic particles show progressive time delay

STEREO orbit and nominal magnetic connection

- Magnetic footpoints for STEREO A and STEREO B vary due to changing solar wind velocity and orbital motion
- The time lag during CIR ion events is caused by the corotating nature of the events.
- Early in the mission STEREO A can be first to see the event, depending on the solar wind speed.
- Later, STEREO B is always first to see the event.





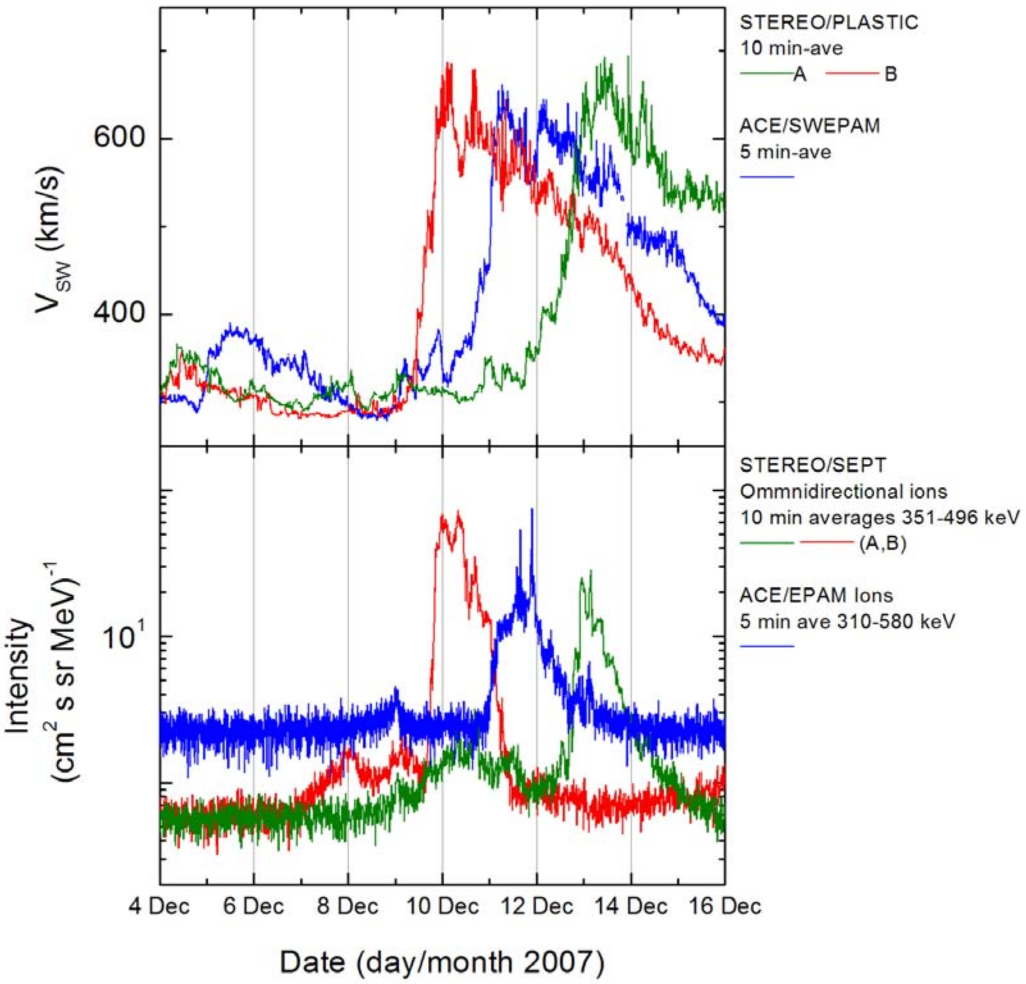
Before Ballistic backmapping

- Corotation time between STEREO-A (Φ_A, r_A) and STEREO-B (Φ_B, r_B):

$$t_B - t_A = \frac{\phi_B - \phi_A}{\Omega_{SUN}^{S}} + \frac{r_B - r_A}{V_{SW}}$$

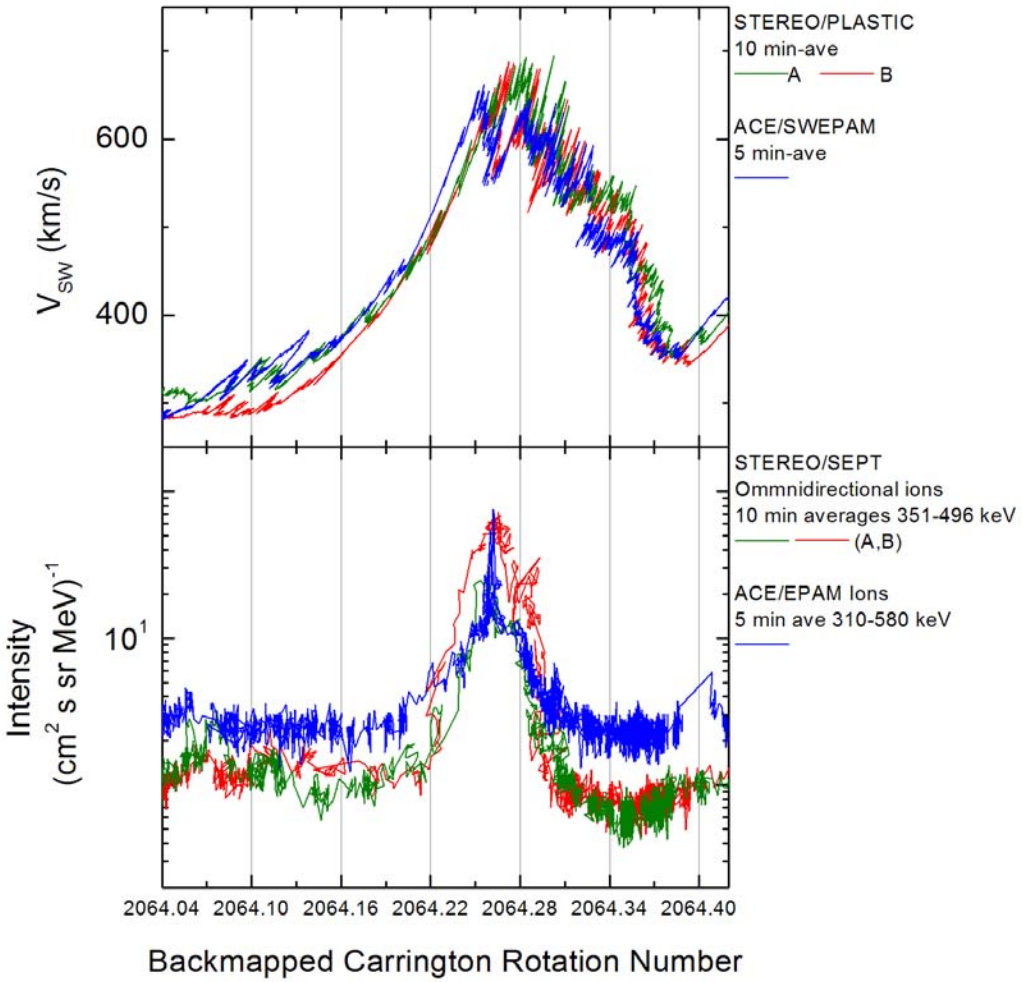
- Sun rotation angle $\Delta\Phi$ relative to sub-satellite point during transit time from source surface to STEREO:

$$\Delta\phi = \frac{\Omega_{Sun}(r - r_{Source})}{V_{SW}}$$

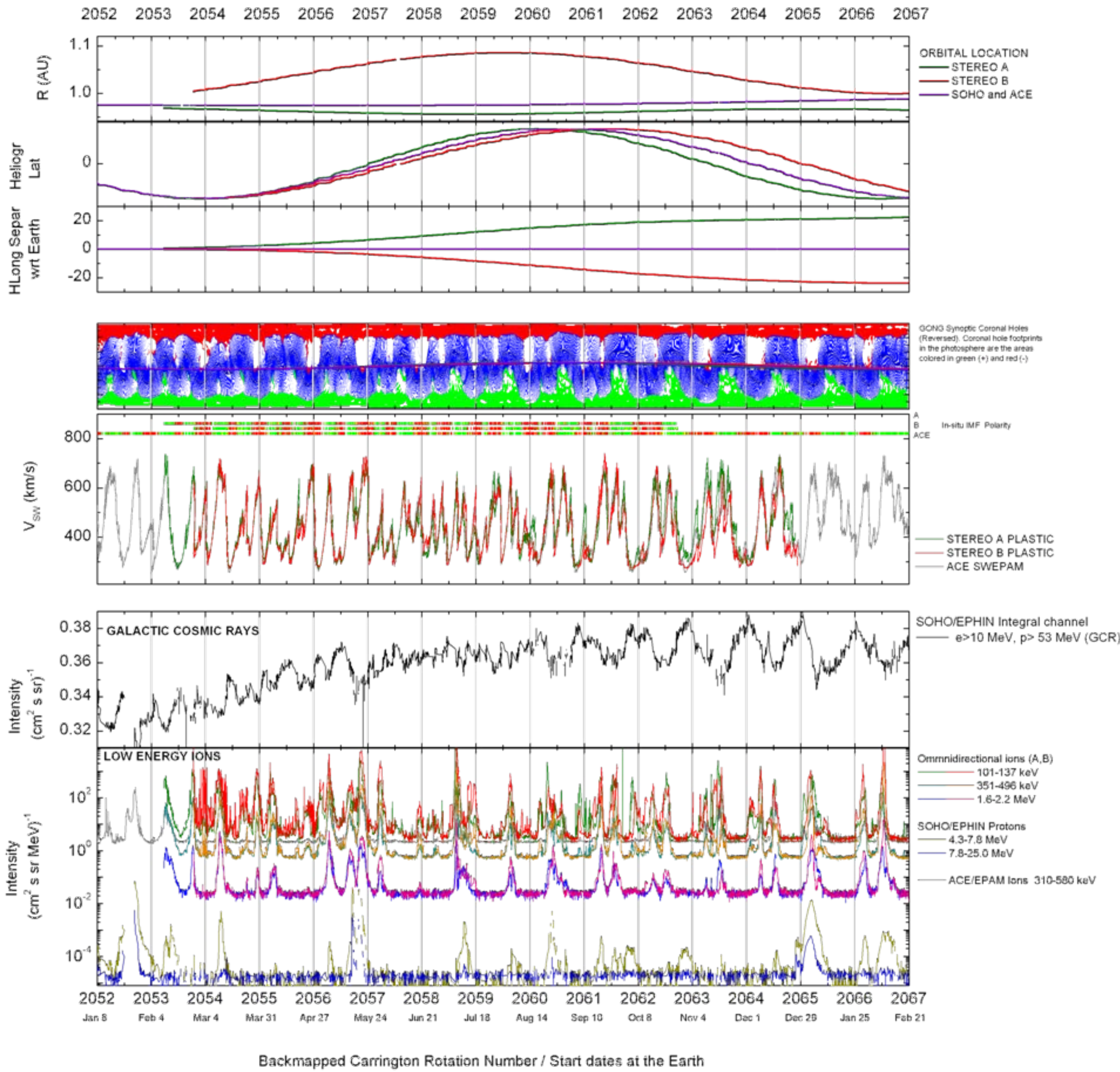


After Ballistic Backmapping

- Replace time scale by the magnetic footpoint of STEREO
- This simple backmapping offers good overall reconstruction of the observed delays
- This technique allows direct comparison with coronal maps for the identification of parent coronal holes



Coronal Holes, Solar Wind, Energetic Particles (Jan 2007 – Feb 2008)



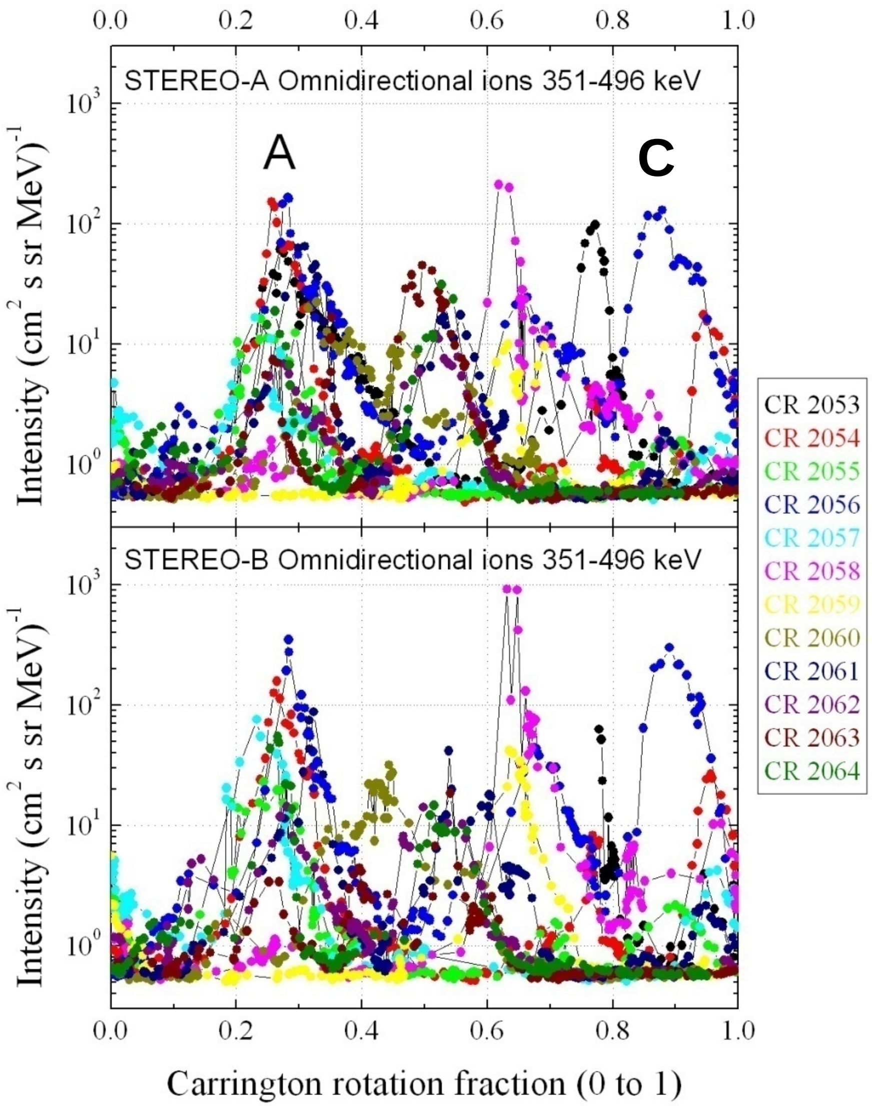
Backmapping permits:

- direct comparison with synoptic coronal hole maps provided by GONG
- identification of parent coronal hole for each stream

We find evidence for:

- agreement between in-situ magnetic field polarity and polarity at the source
- Recurrent modulation of galactic cosmic rays
- Evolution of CIR structures with coronal hole contours and orbital motion

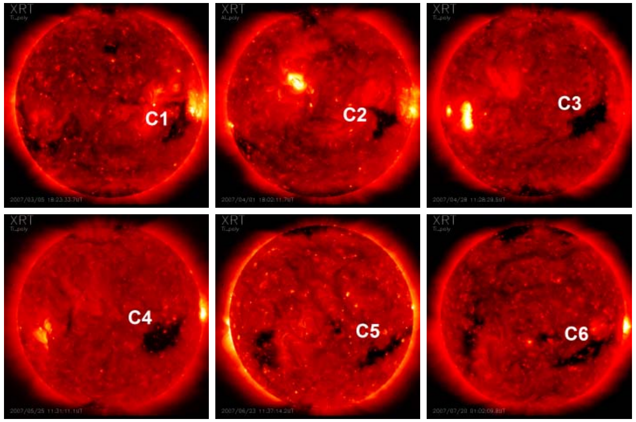
Temporal variations



CIR particle events associated to the same stream show significant variations between consecutive rotations.

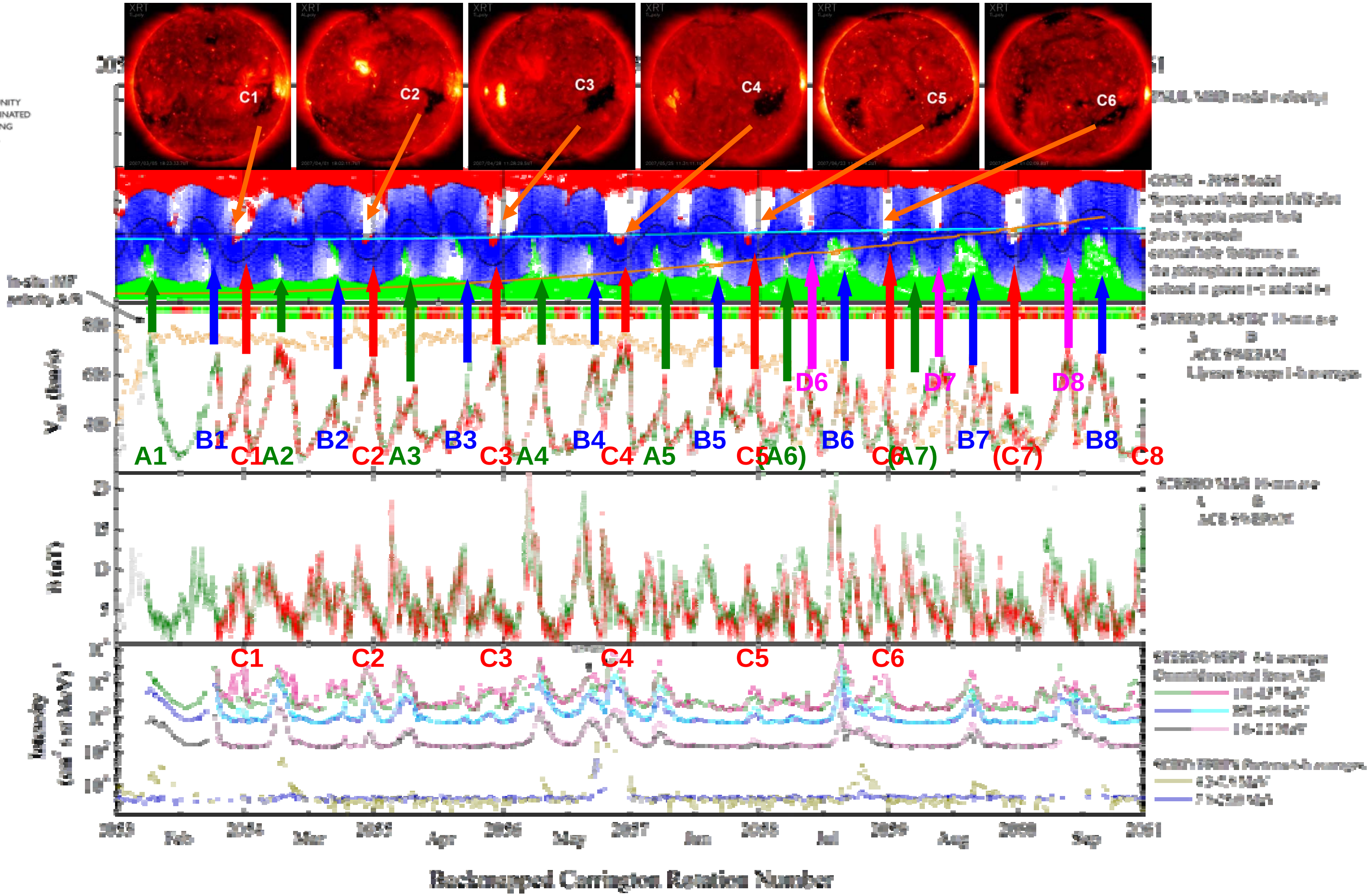
Explanation:

Coronal hole changes with time.
But there must be more !



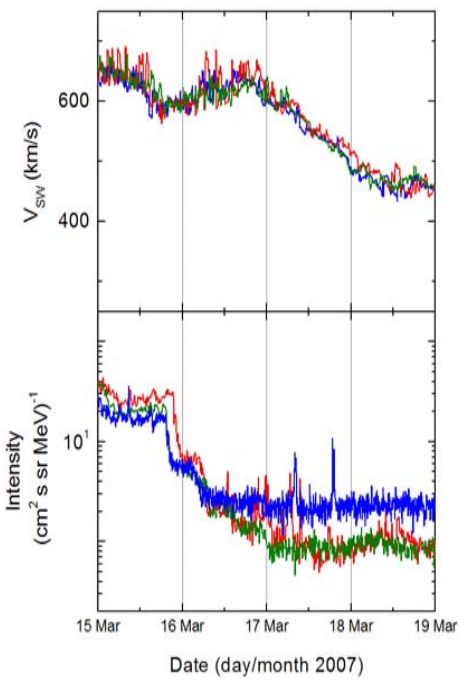
Hinode XRT images

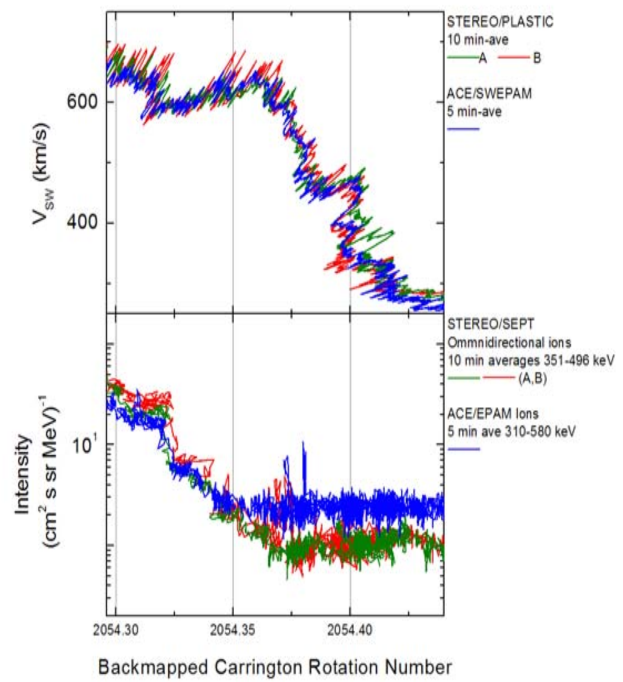
Backmapped in-situ data vs synoptic maps

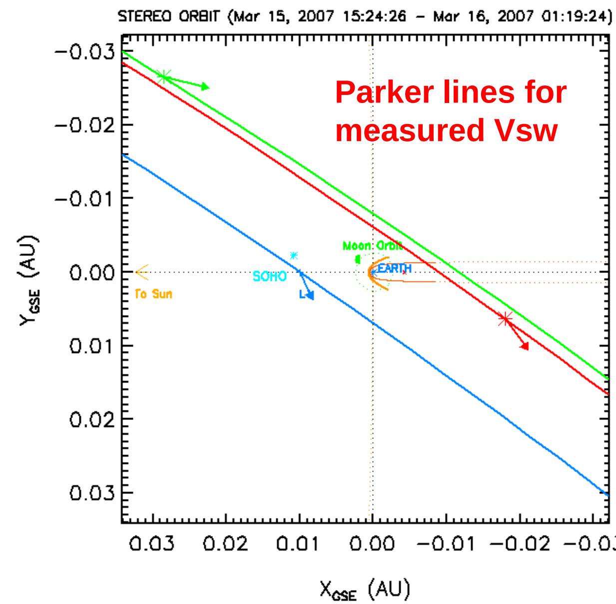


Deviations from the ideal co-rotation

- Frequently particle events associated with the same stream show significant variations between two consecutive rotations.
- Even during the co-rotation transit from STEREO-B to STEREO-A sometimes fine scale differences arise
- Small scale deviations from the expected co-rotation delays are also observed





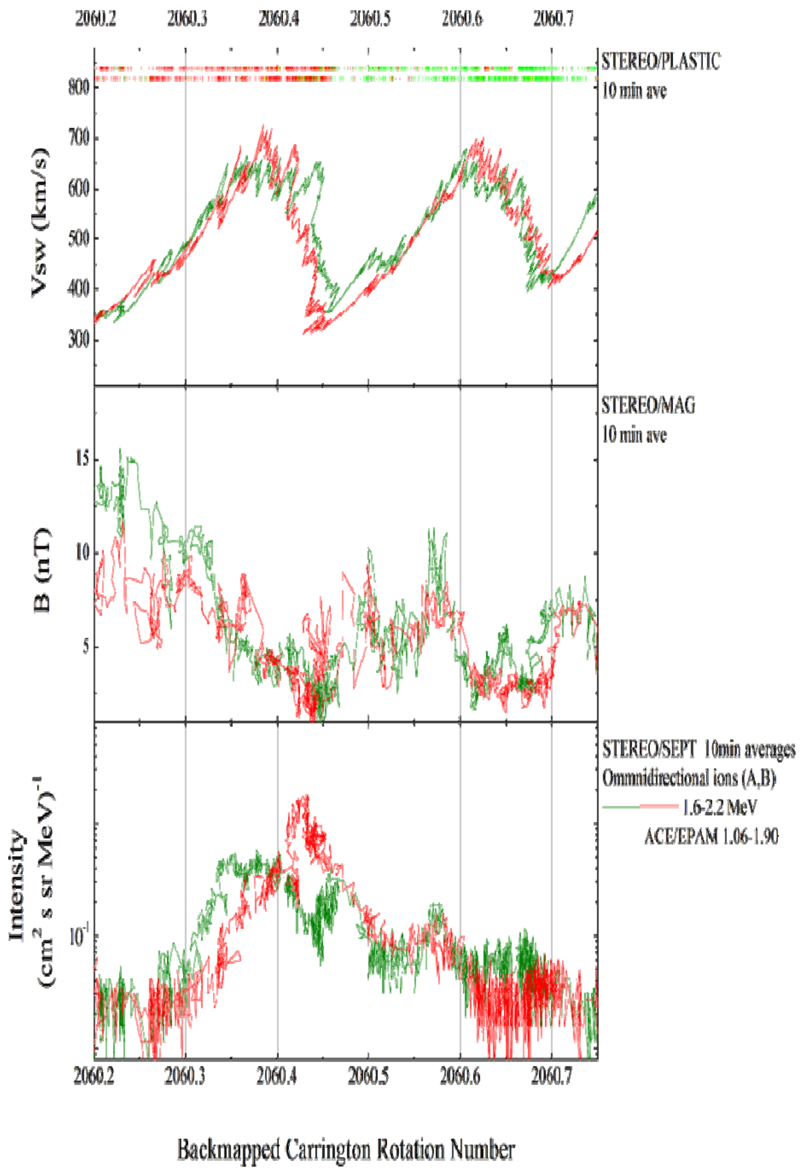


March 15, 2007
(sudden drop during event A2 decay)

Behind expected first for $V_{SW} \in$ [570-700] but observed 2.25 h after Ahead!

	BEHIND	EARTH	AHEAD
Heliographic Latitude	-7.25	-7.16	-7.20
Heliographic Longitude	-0.36	0.00	1.59

Deviations from the ideal co-rotation



Maximum radial separation

Small latitudinal separation

Aug. 2007, CR2060

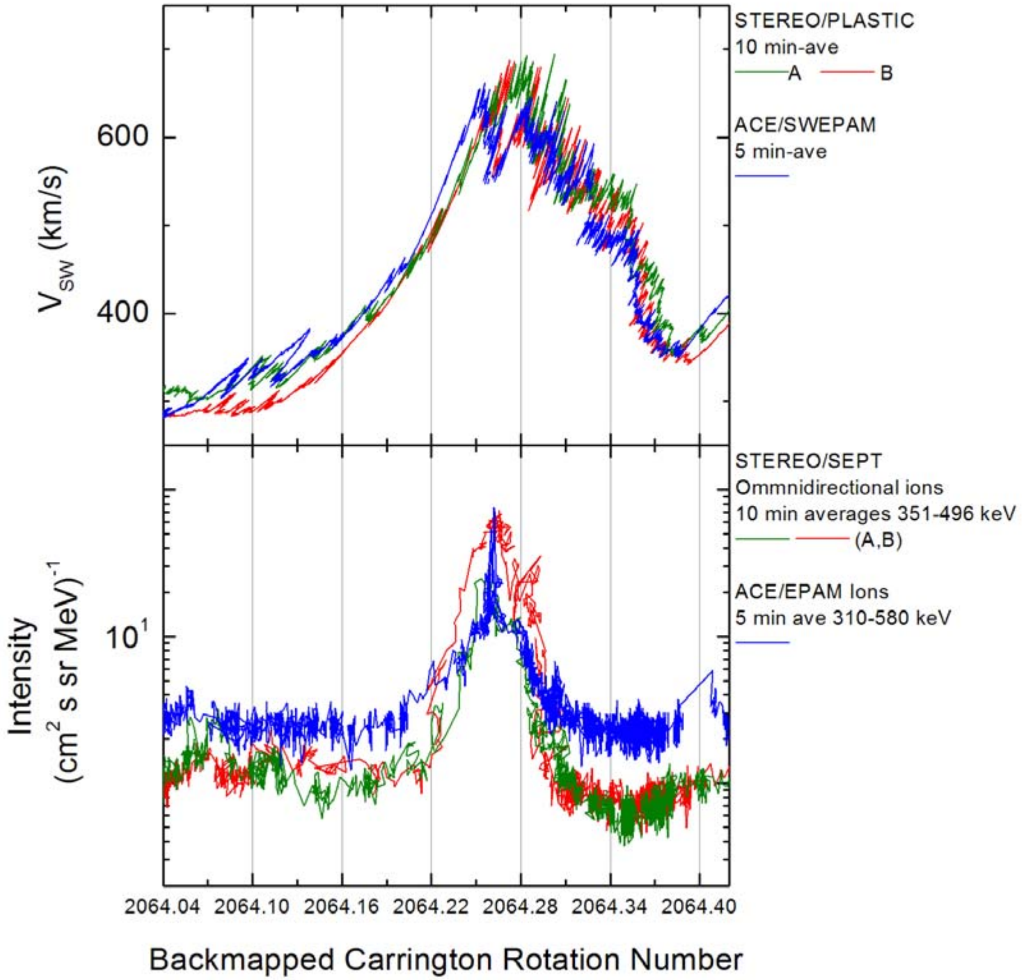
Solar wind and magnetic field show nearly perfect backmapping

• Energetic particles don‘t

Explanation:

No changes at the Sun, but possibly in interplanetary space at 4 AU where CIR particles are accelerated ?

Deviations from the ideal co-rotation



Maximum latitudinal separation, small radial, large azimuthal separation
Dec. 2007, CR2064

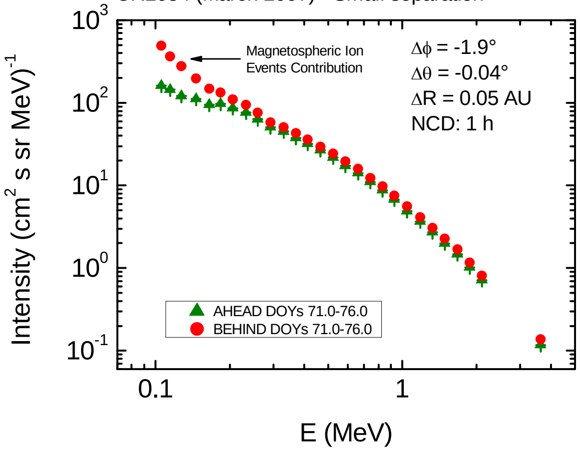
Surprise!!!

No deviations, instead perfect backmapping

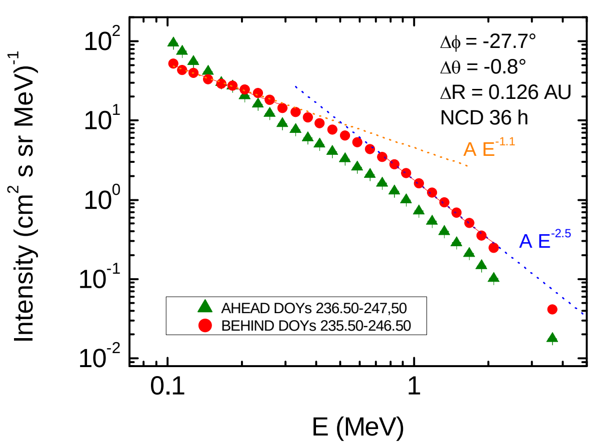
although we know from Helios measurements, how sharp latitudinal boundaries can be.

Spectral evolution

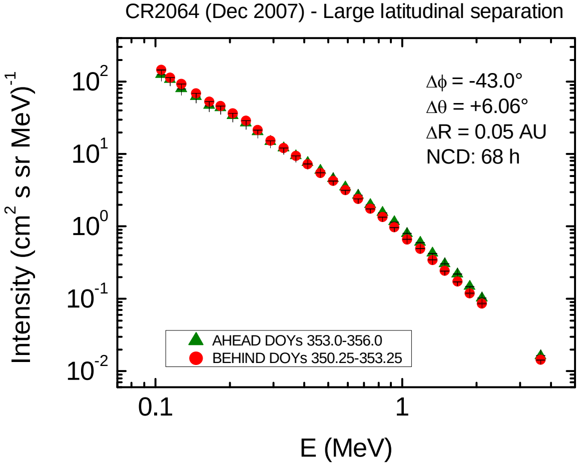
CR2054 (March 2007) - Small separation



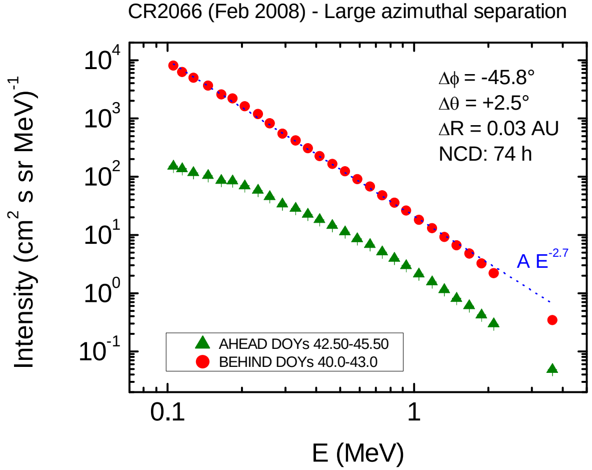
CR2060 (Aug 2007) - large radial separation



CR2064 (Dec 2007) - Large latitudinal separation



CR2066 (Feb 2008) - Large azimuthal separation



Event averaged spectra

- good agreement at small separation (difference in low energy part caused by upstream events)
- deviations more pronounced with increasing separation

But exception:

- perfect agreement in Dec 2007 inspite of latitudinal and azimuthal separation

Summary

- Coronal holes are long-lived structures, hence CIR-accelerated ions related to the same high speed stream reappear for several consecutive solar rotations.

- Significant evolution is observed after several rotations. Sometimes this evolution becomes evident even in the short co-rotation time from STEREO B to STEREO A.

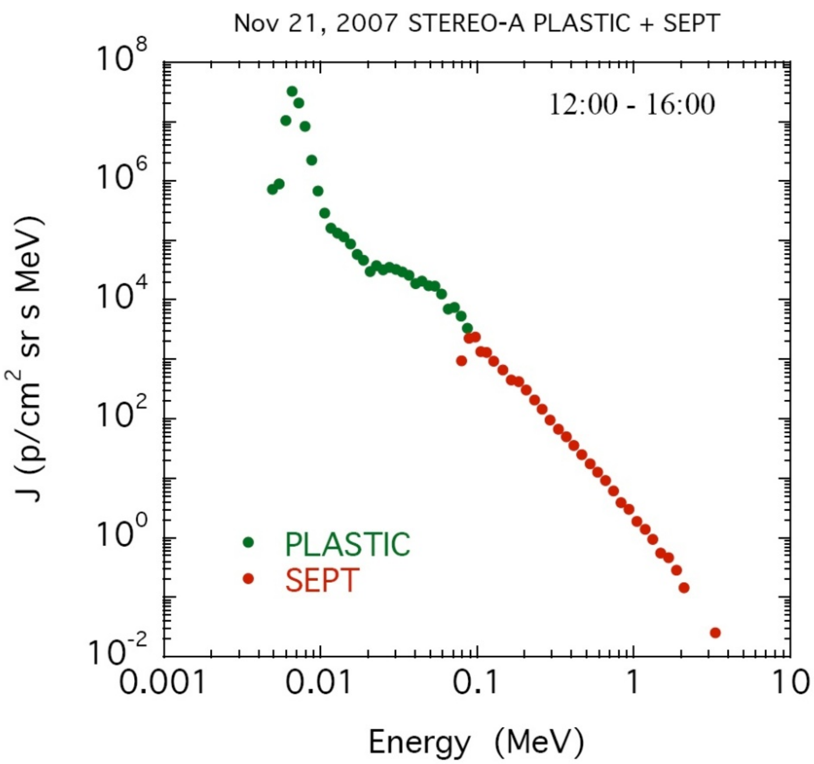
- Possible contributions to the observed variations:
  - **Temporal variation** of the **coronal hole contours** and coronal magnetic field structure (spacecraft magnetic connection)
  - **Temporal evolution** of the distant **CIR shocks**
  - Effects due to small **latitudinal variations** (e.g. Schwenn, 1981)
  - Effects due to **radial evolution**
  - **Contributions from local particle acceleration** superposed on the main flux from the distant CIR-shock (e.g. Richardson, 2004)
  - Short-time scale **deviations from the nominal Parker spiral** changing the magnetic connection

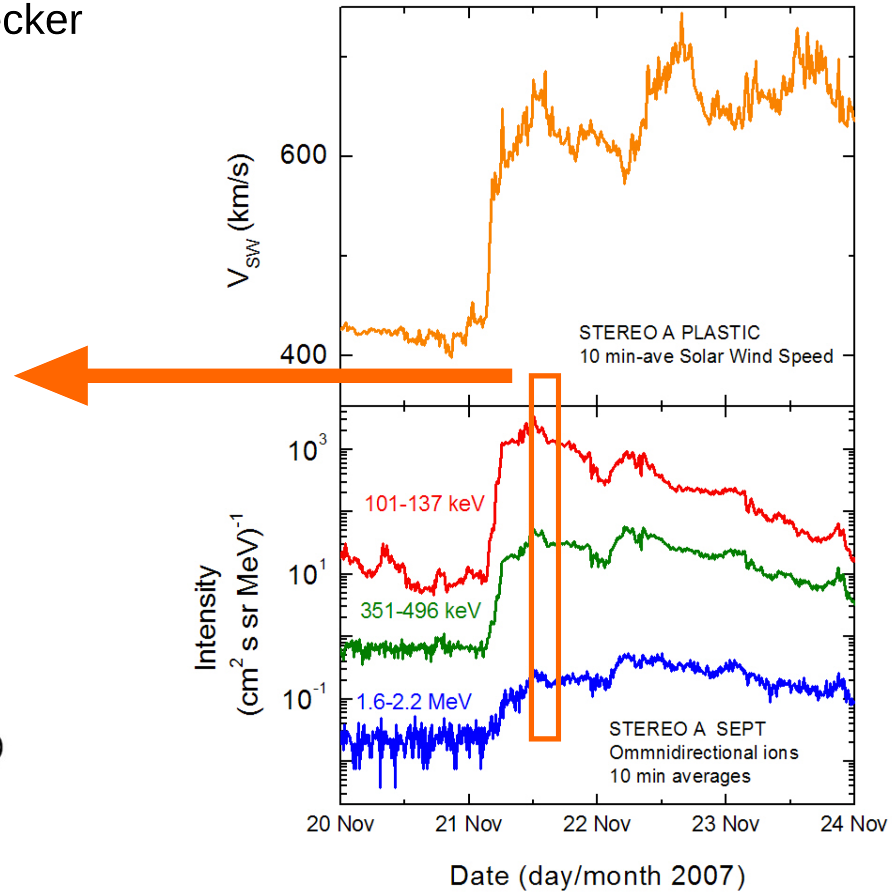
Backup

SEPT energy spectra – comparison with PLASTIC

- Comparison interval: Nov 21, 2007 12:00-16:00 UT (near the maximum of CIR event) SEPT and PLASTIC sensors pointing sunward

Compiled by B. Klecker





SEPT energy spectra - comparison with SIT, LET, ULEIS

Compiled by R. Leske