Multi-point observations of CIRs by STEREO and ACE

during the extended solar minimum of solar cycle 23

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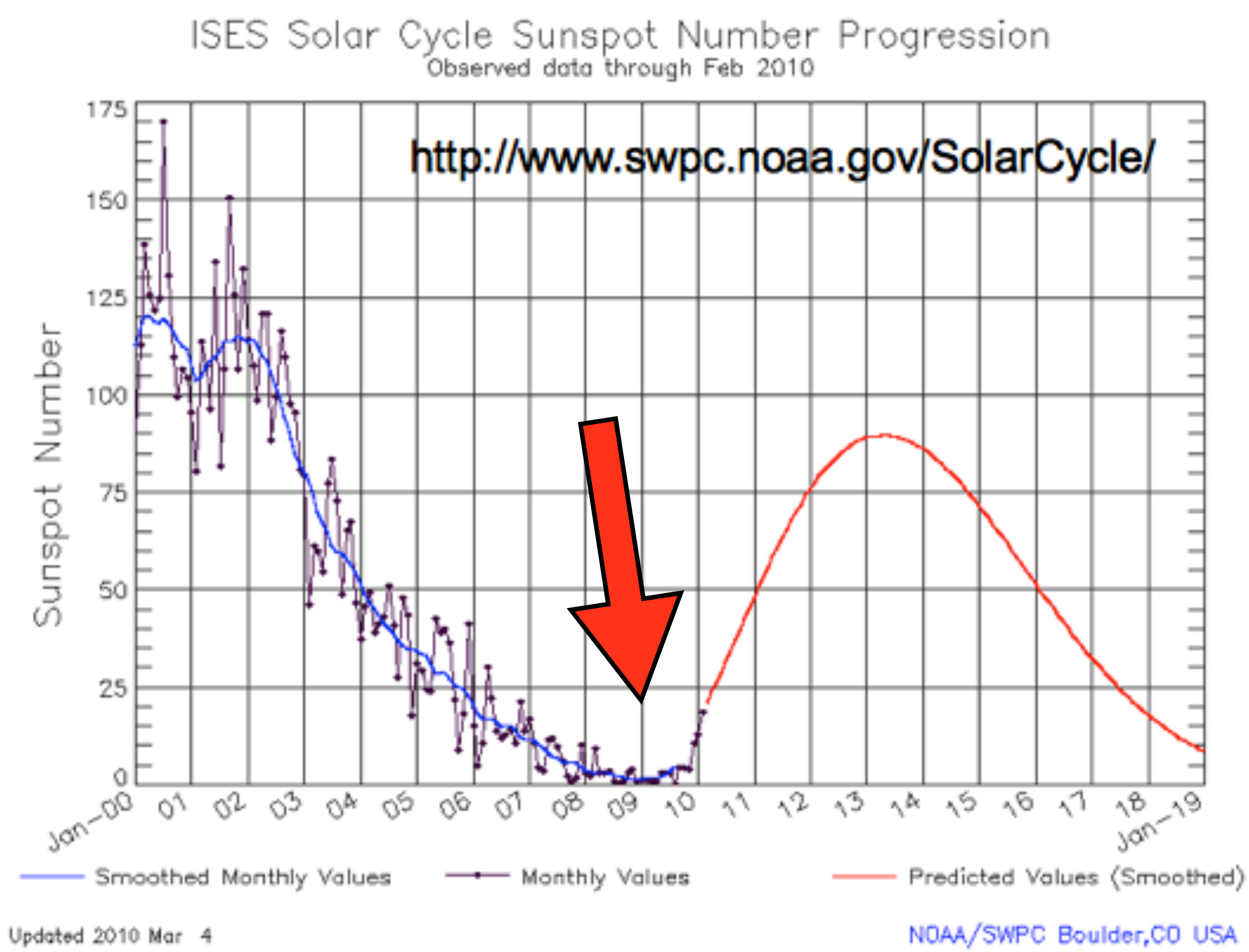
Observation Period

- Period under study: CR 2067.0-2082.0 (Feb 21, 2008 - April 5, 2009)
- Solar minimum between solar cycles 23 and 24. Very low solar activity. 2008 and 2009 are the quietest years since 1913
- Few (<10) SEP events (minor)
- Optimal conditions for the study of SIR/CIR-associated energetic ions



Multi-point in-situ observations

Goal: Comparison of STA and STB (and ACE) in-situ observations of the **same CIR** by

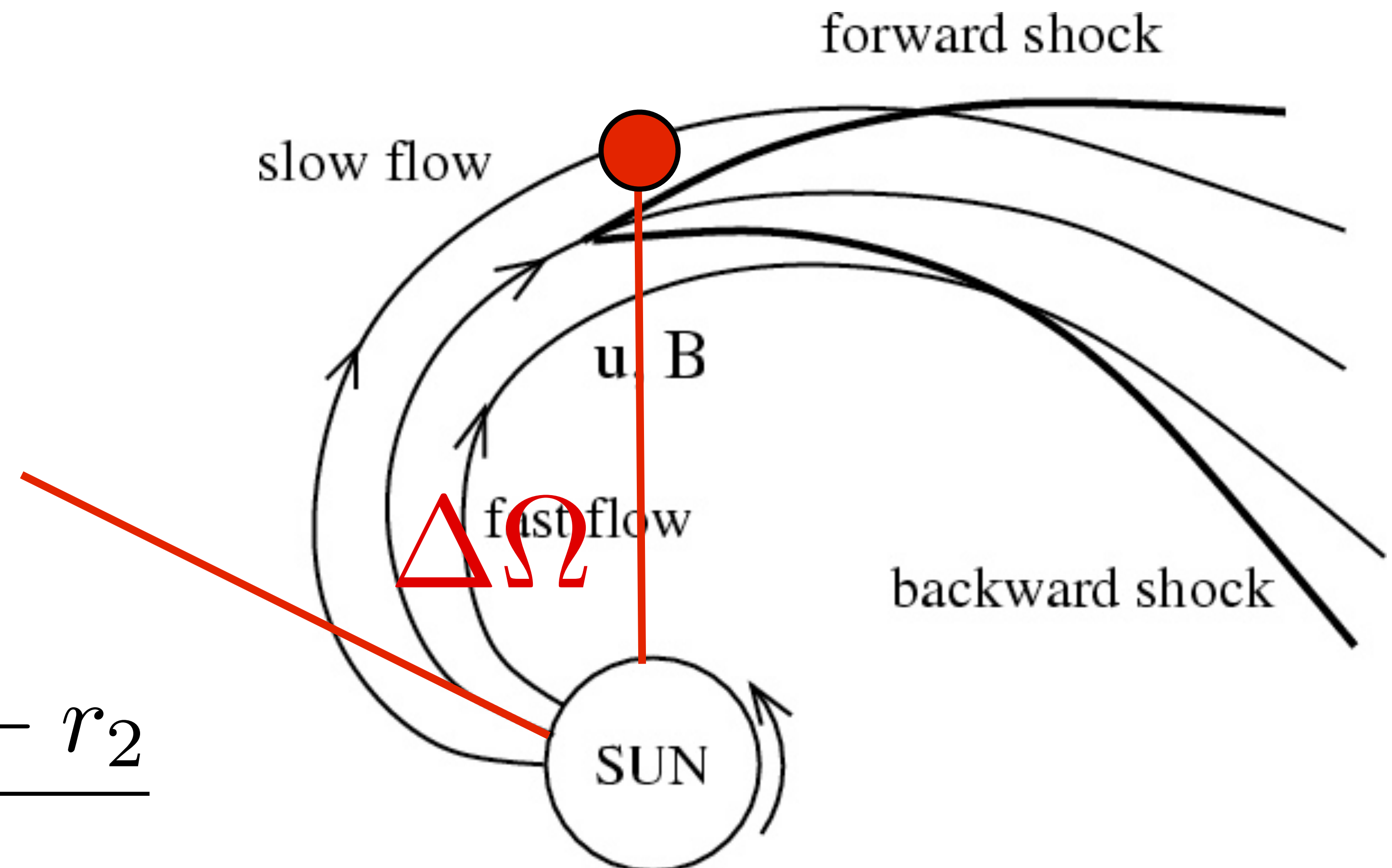
- correlating with remote sensing observations of the corona
- focussing on energetic ion increases
- identifying causes of discrepancies (spatial/ temporal)

Multi-point in-situ observations

Basic tools:

Ballistic back-mapping:

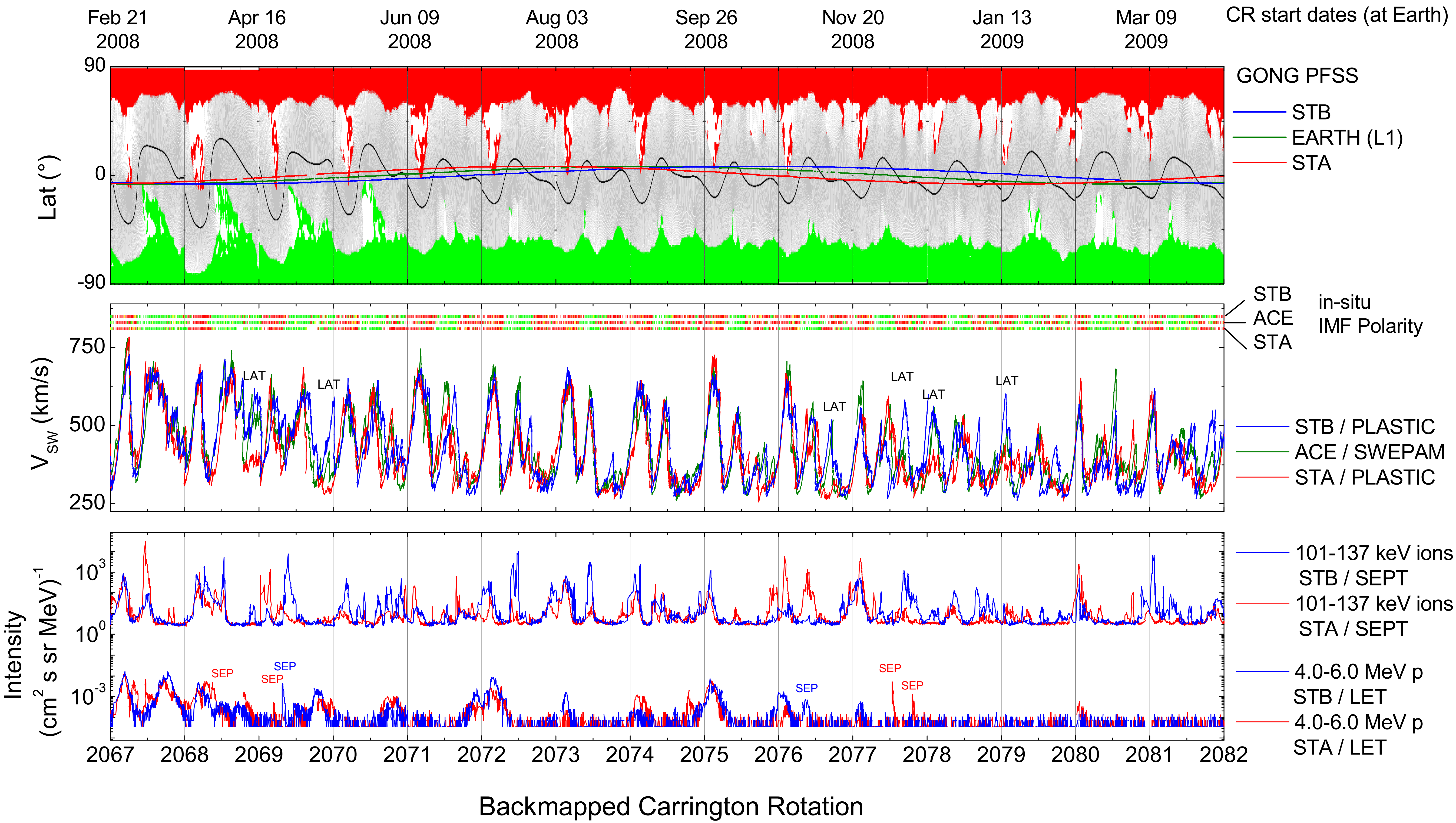
$$\Delta\Omega = \frac{\Omega_S (r - r_0)}{v_{sw}}$$



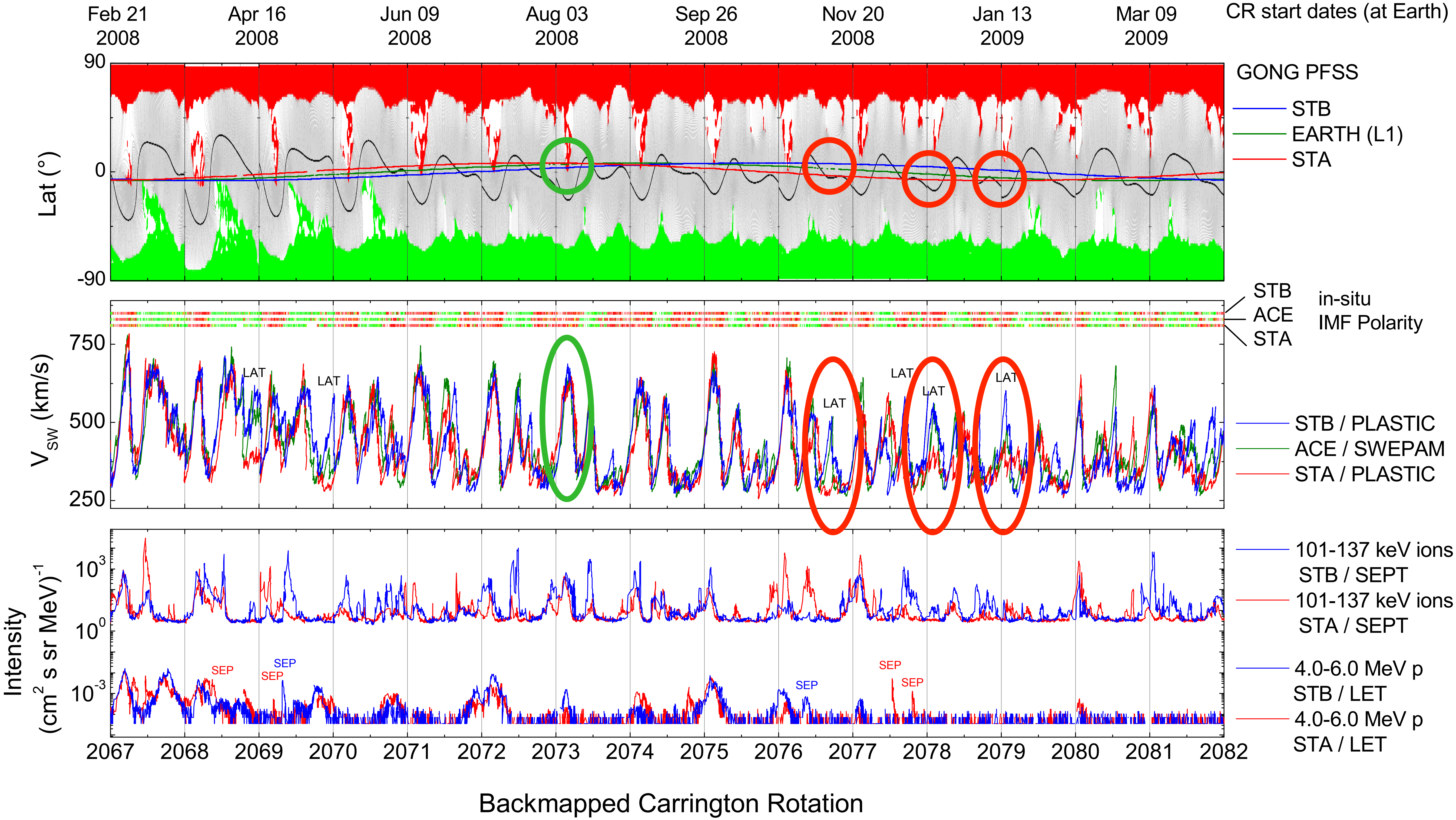
Time-shifting:

$$t_1 - t_2 = \frac{\Phi_1 - \Phi_2}{\Omega_S} + \frac{r_1 - r_2}{v_{sw}}$$

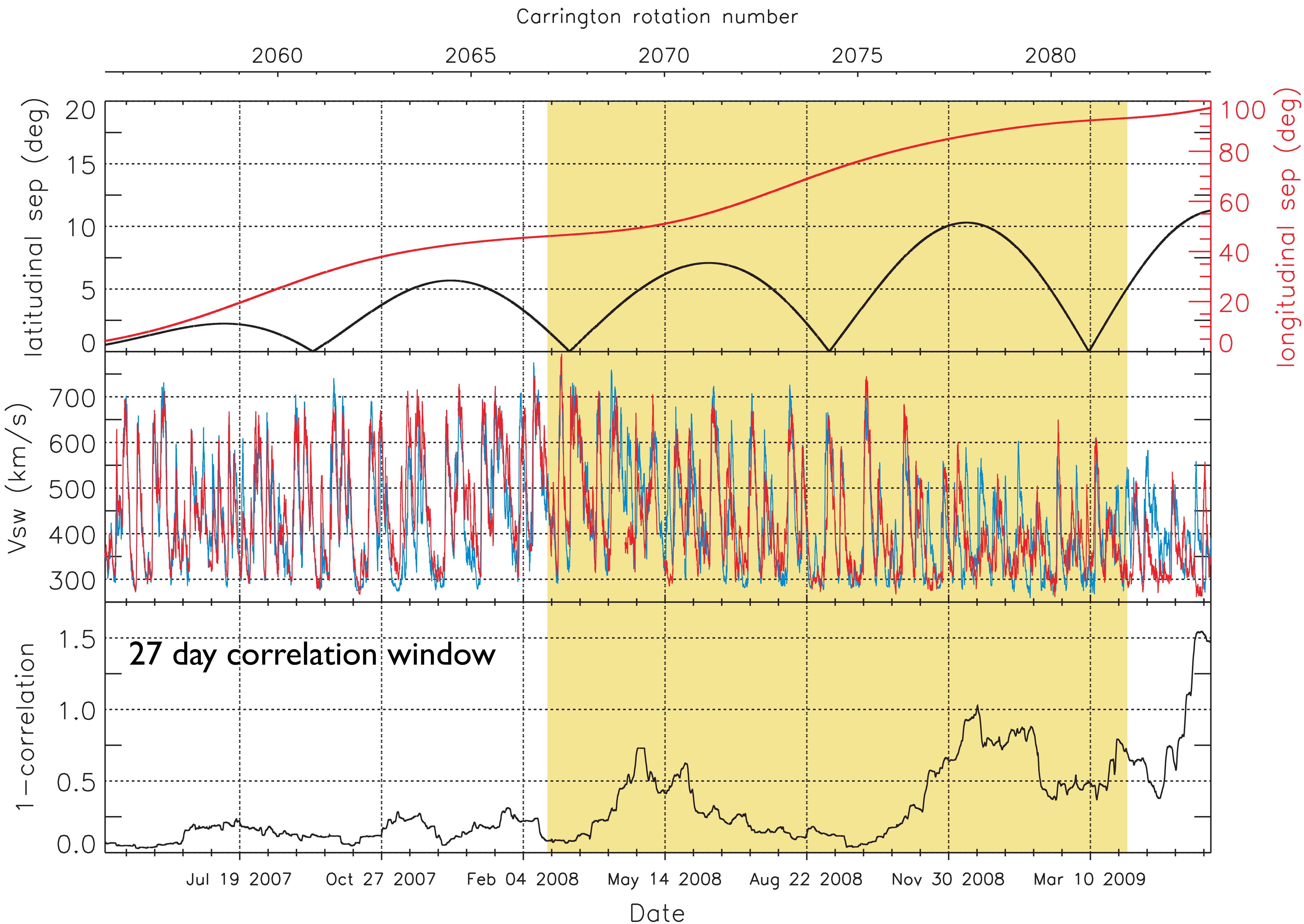
Overview of backmapped observations



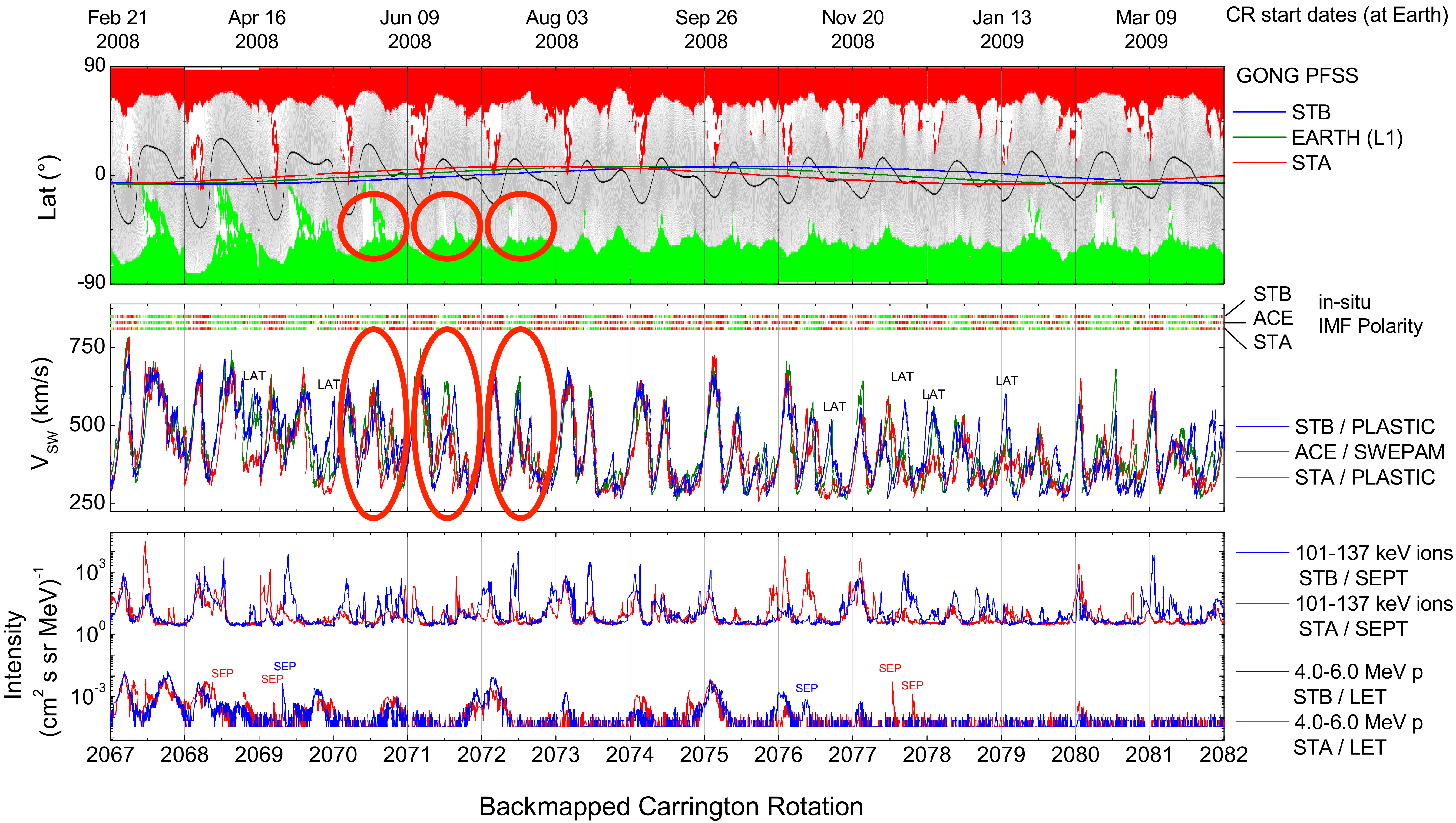
Importance of latitudinal separation



Importance of latitudinal separation



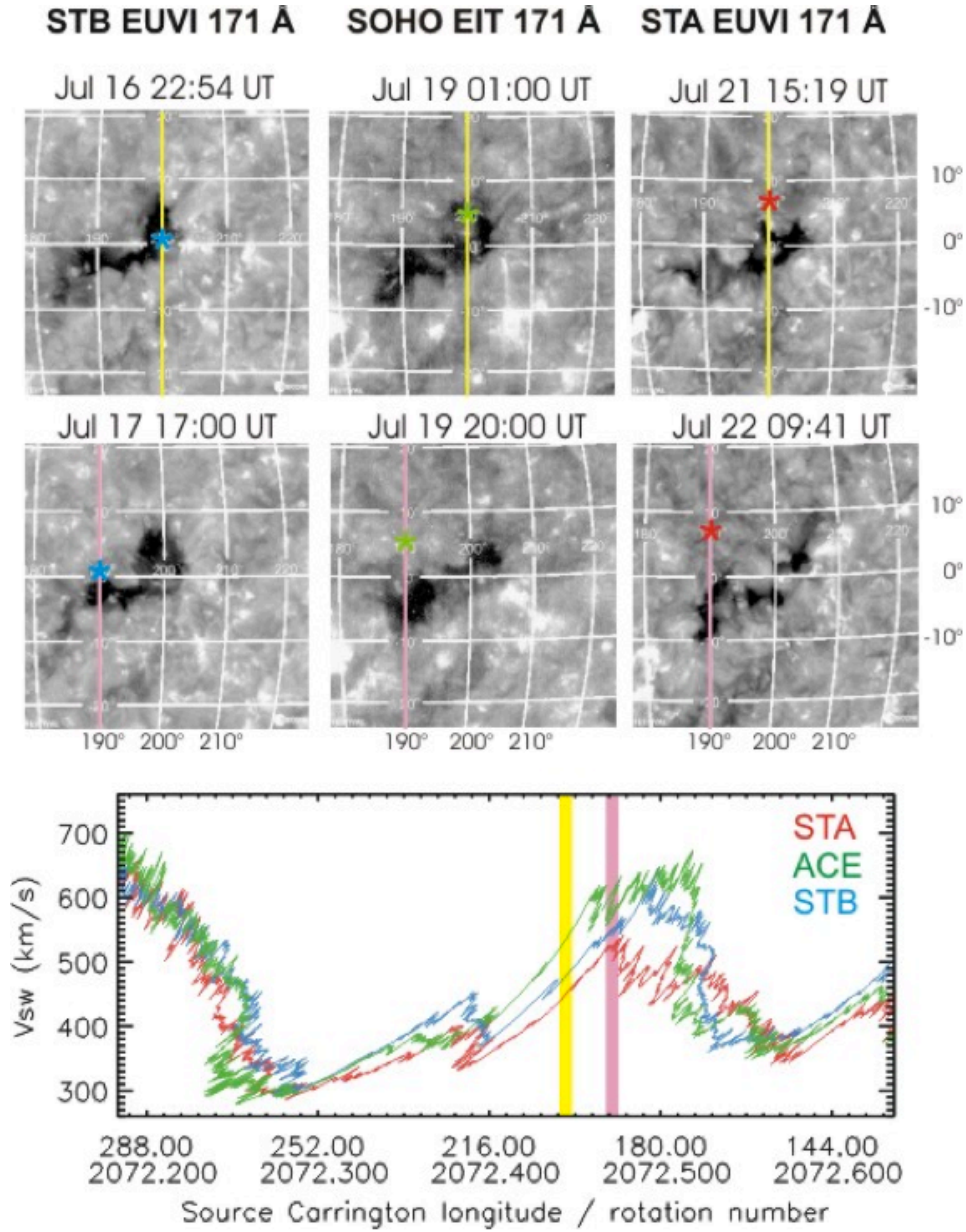
Coronal hole changes



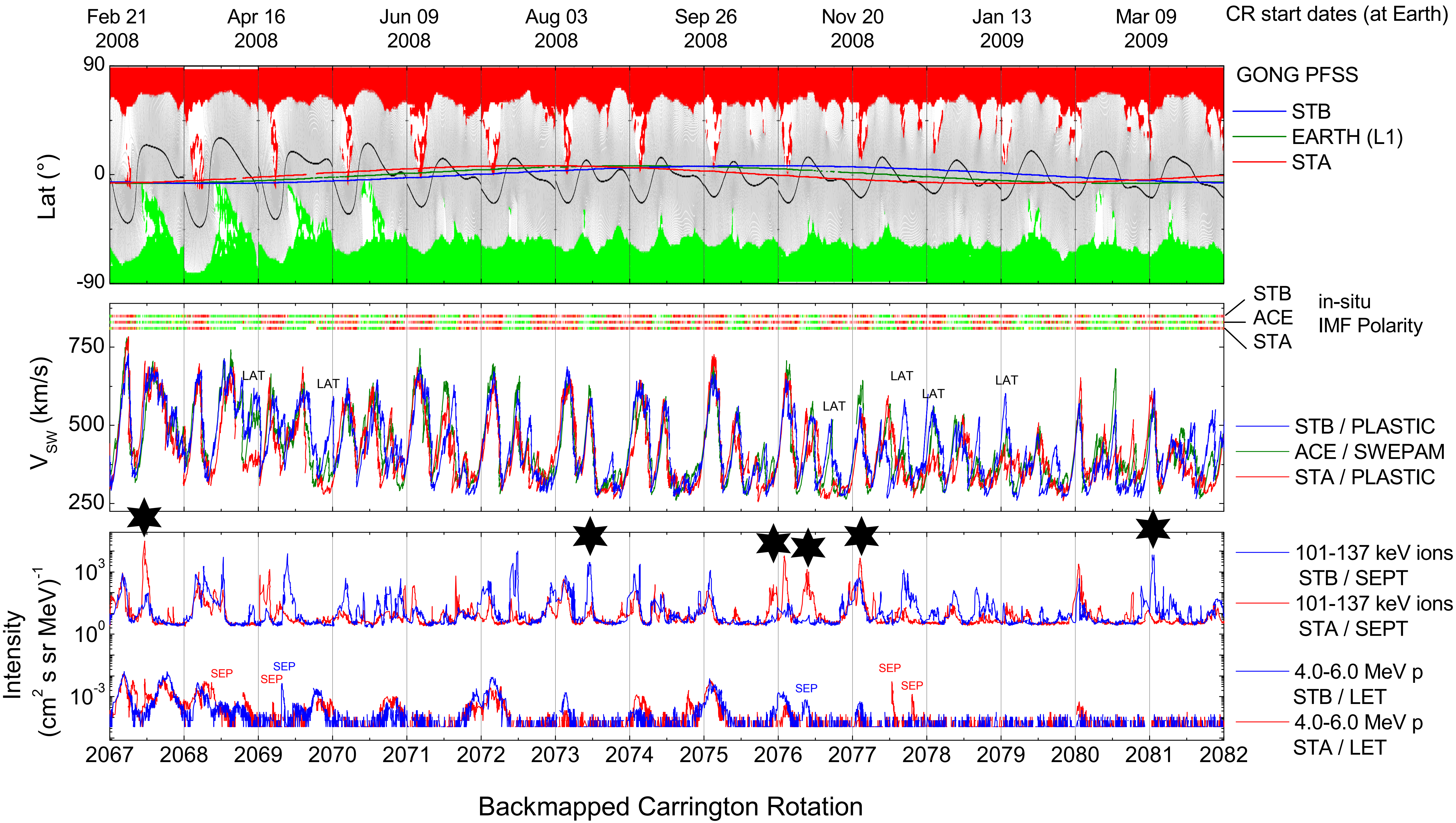
Changes in the shape or magnetic topoligy of coronal holes give rise to changes in the SIR structure at 1AU

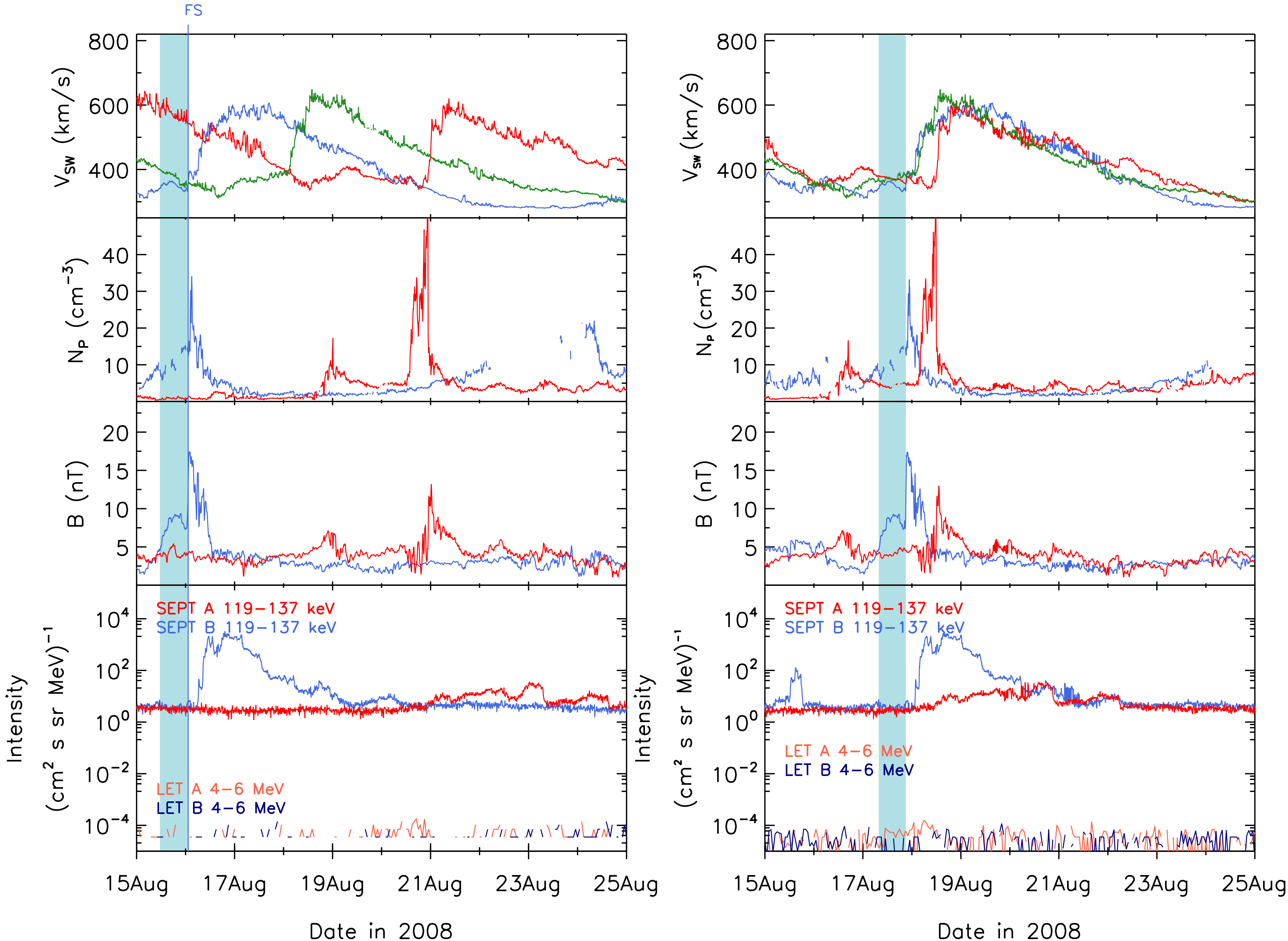
This effect is easy to track in the long term
(> 1 CR), e.g. CR 2070,
but difficult to study in the short term (< 1 CR) using multi-s/c data

Example: CR 2072 (July 2008). Event associated with a near- equatorial coronal hole extension with positive polarity

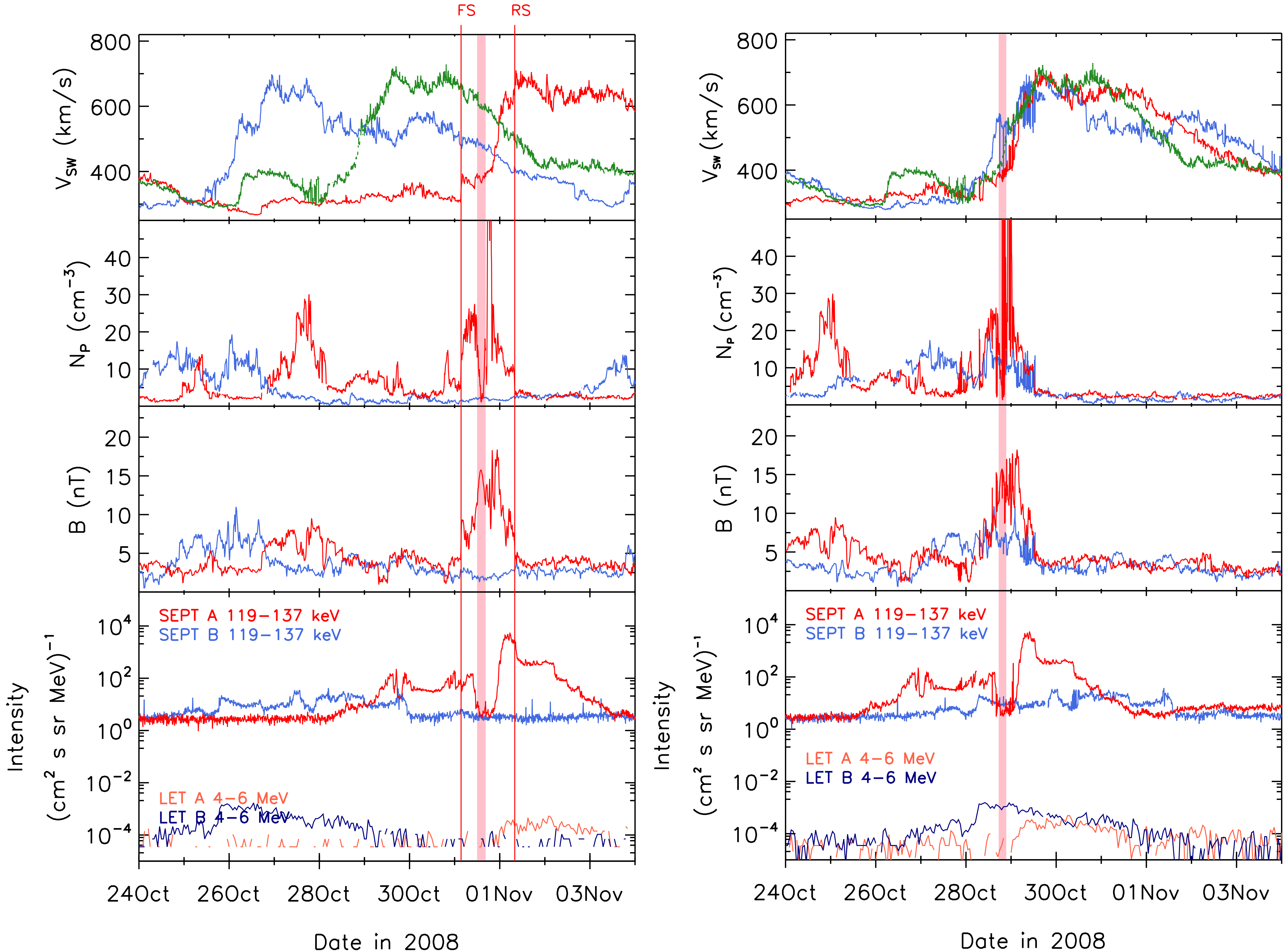


A search for ICME effects on CIR ion increases





FS
800
600
400
V_{SW} (km/s)
40
30
20
10
N_P (cm^{-3})
20
15
10
5
B (nT)
SEPT A 119–137 keV
SEPT B 119–137 keV
LET A 4–6 MeV
LET B 4–6 MeV
10^4
10^2
10^0
10^{-2}
10^{-4}
Intensity
(cm^2 s sr MeV)$^{-1}$
15Aug
17Aug
19Aug
21Aug
23Aug
25Aug
Date in 2008



FS
RS
V_{SW} (km/s)
N_P (cm^{-3})
B (nT)
Intensity
(cm^2 s sr MeV)$^{-1}$
SEPT A 119–137 keV
SEPT B 119–137 keV
LET A 4–6 MeV
LET B 4–6 MeV
24Oct
26Oct
28Oct
30Oct
01Nov
03Nov
Date in 2008

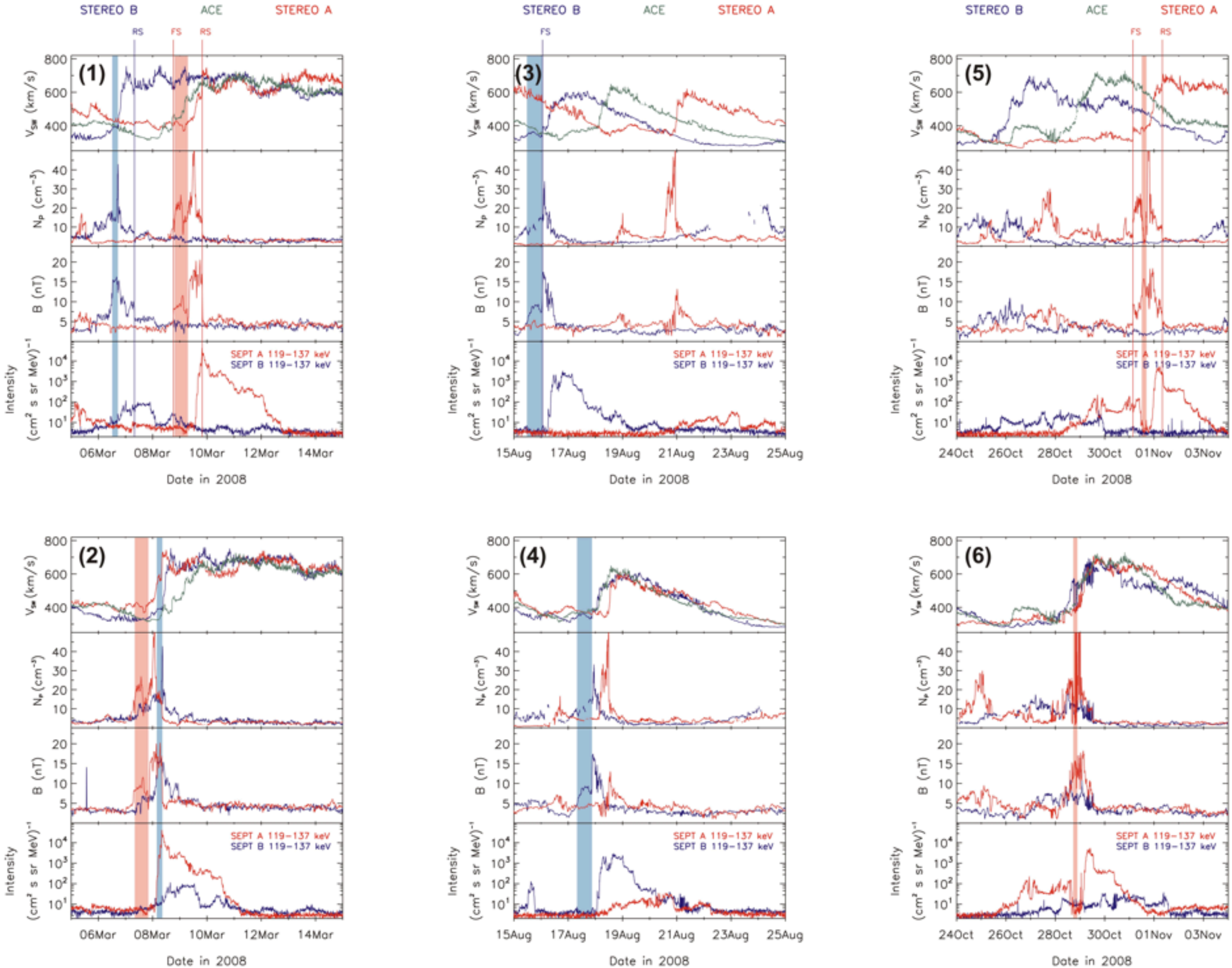
Conclusions

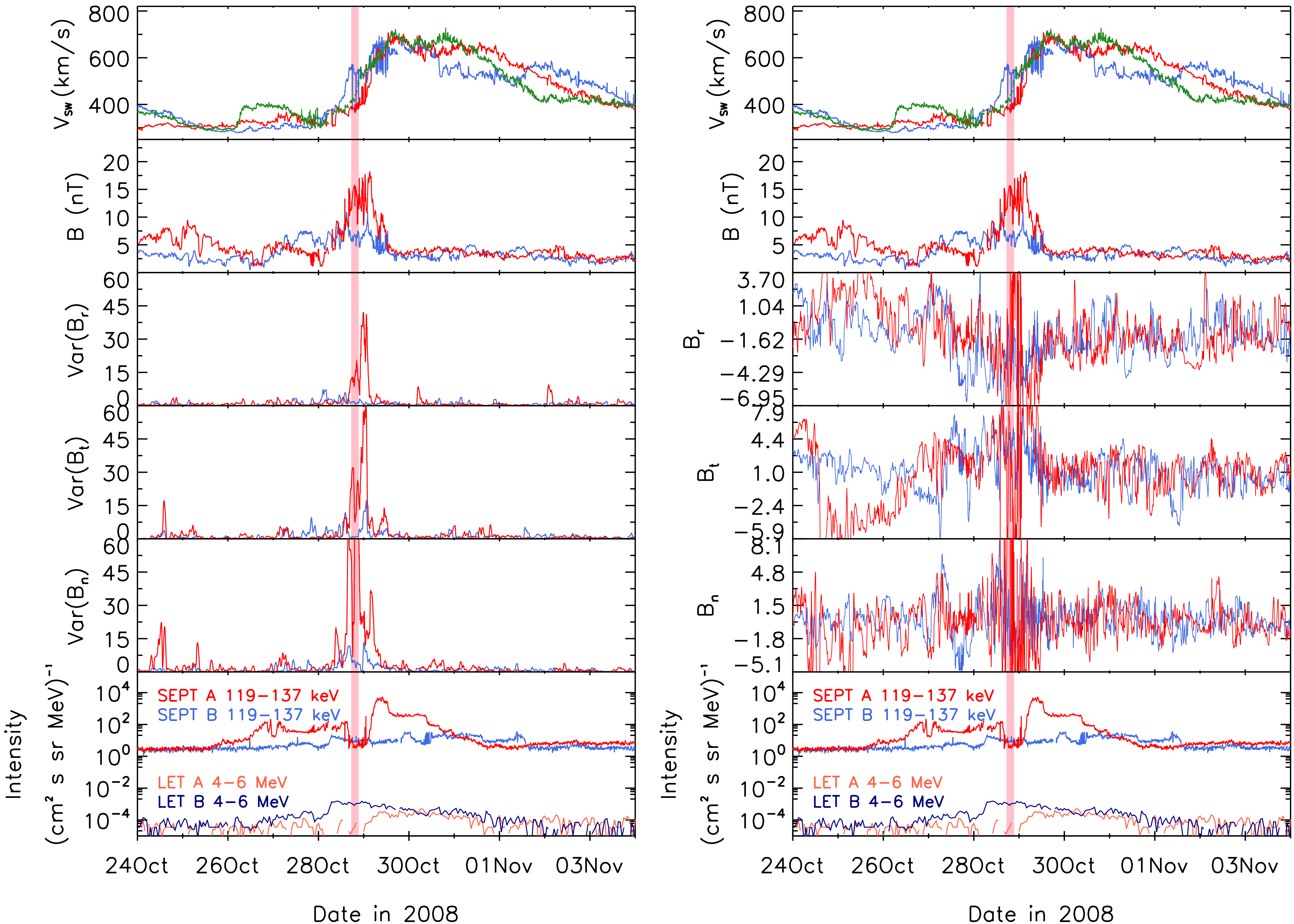
Heliographic latitudinal separation is a common source of discrepancies in the CIR structure observed by different spacecraft. This effect can be significant even for separations of a few degrees but its importance varies from case to case depending on the proximity to the latitudinal boundaries and also on the morphology of the coronal hole.

Discrepancies can be still present excluding pure spatial effects (latitudinal effects, radial gradients) **CIRs are not ideal stationary structures showing identical characteristics at two spacecraft** separated by co-rotation times of several days. The sources of temporal variations can be found at the Sun (coronal hole evolution) or in the interplanetary medium (possible interaction with transient structures in the slow wind).

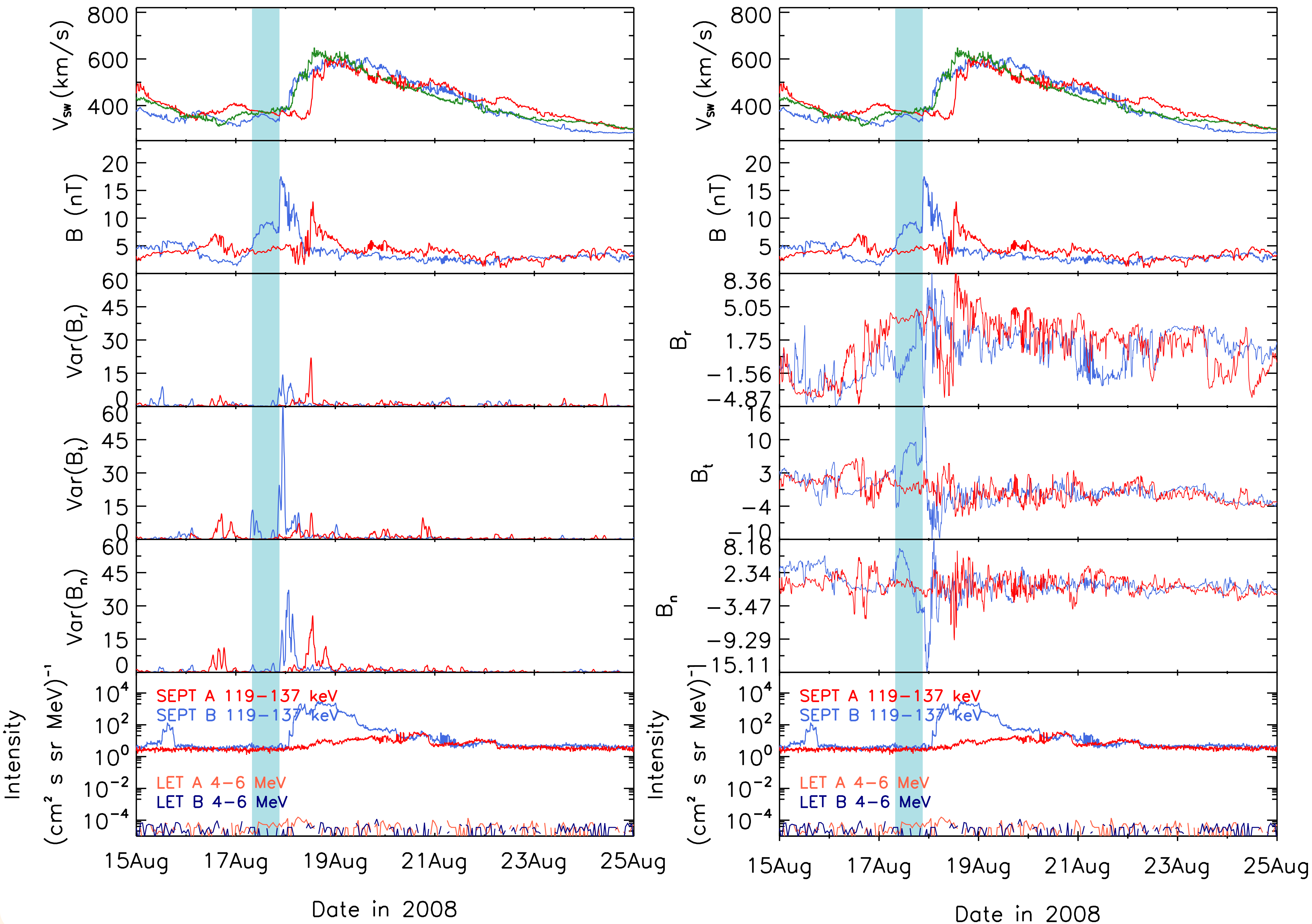
We presented **cases where the presence of an interplanetary transient in the vicinity or embedded in the CIR for one spacecraft is accompanied by enhanced ~100 keV ion acceleration**.

Theoretical modeling approach for ICME+CIR regions would allow further progress.


STEREO B
ACE
STEREO A
RS
FS
RS
(1)
(2)
(3)
(4)
(5)
(6)
FS
FS
RS
V_SW (km/s)
N_p (cm^-3)
B (nT)
Intensity (cm^2 s sr MeV)^-1
SEPT A 119–137 keV
SEPT B 119–137 keV
06Mar
08Mar
10Mar
12Mar
14Mar
15Aug
17Aug
19Aug
21Aug
23Aug
25Aug
24Oct
26Oct
28Oct
30Oct
01Nov
03Nov
Date in 2008



V_sw (km/s)
B (nT)
Var(B_r)
Var(B_t)
Var(B_n)
B_r
B_t
B_n
SEPT A 119–137 keV
SEPT B 119–137 keV
LET A 4–6 MeV
LET B 4–6 MeV
Intensity (cm² s sr MeV)⁻¹
24Oct
26Oct
28Oct
30Oct
01Nov
03Nov
Date in 2008



V_sw (km/s)
B (nT)
Var(B_r)
Var(B_t)
Var(B_n)
B_r
B_t
B_n
Intensity (cm² s sr MeV)⁻¹
SEPT A 119–137 keV
SEPT B 119–137 keV
LET A 4–6 MeV
LET B 4–6 MeV
15Aug
17Aug
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The SEPT instrument