

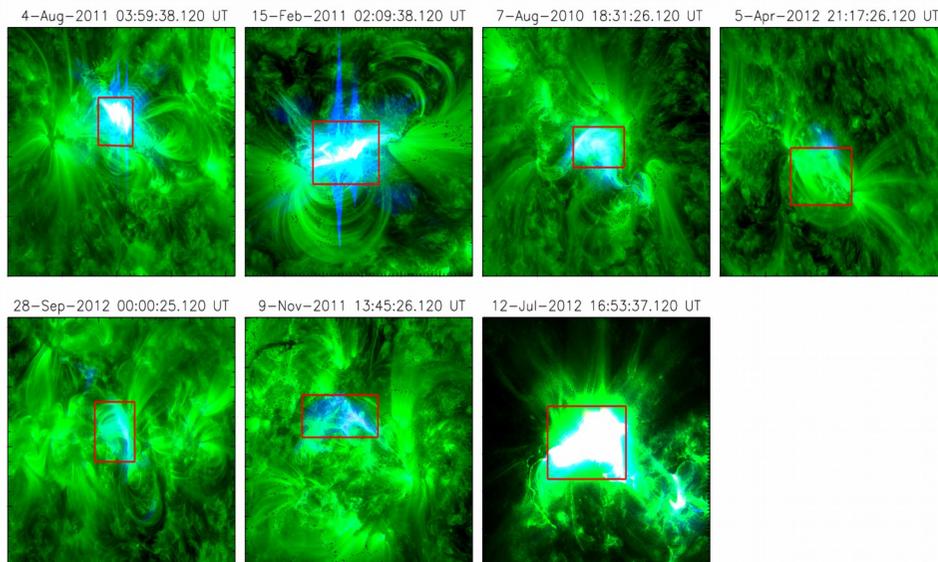
# Hard X-ray, EUV, and radio signatures in relation to solar energetic particles

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*We report analysis of observed electromagnetic signatures related to solar energetic particles (SEPs). We selected cases with simultaneous observations in hard X-ray, EUV and radio wavelengths of the SEP-related solar flares and analysed the properties of the emission. The results are compared with the outcomes when using GOES soft X-ray flare class.*



Composite images from three AIA/SDO channels: 94 Å, 171Å and 131Å, showing the studied events in the moment of their peak intensity.

## Observations:

We analyzed 7 solar flares which were observed in hard-X-ray, EUV and radio wavelength.

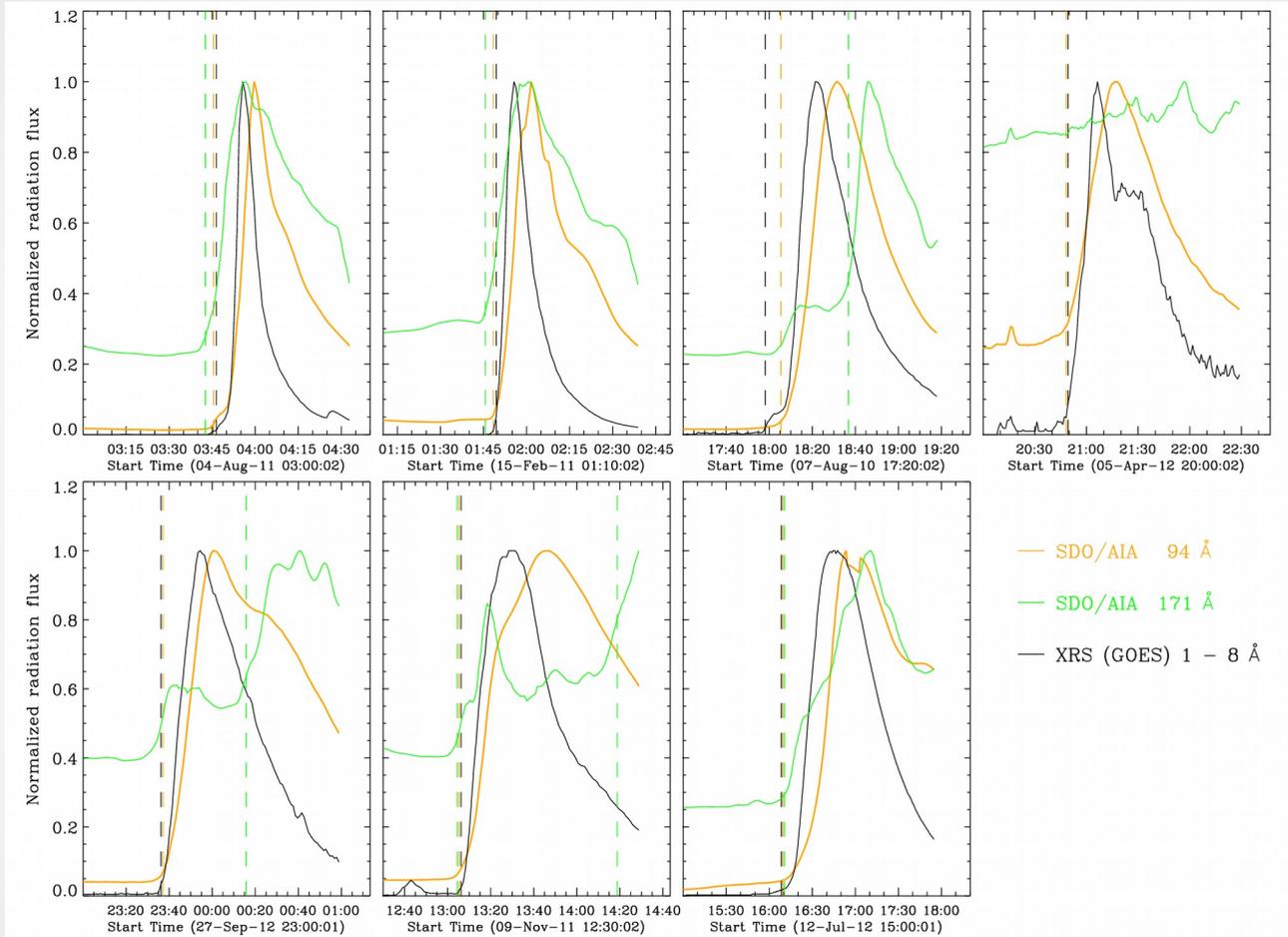
The flare behaviours in EUV (light curves and temporal evolution) are considered by using images obtained in the Fe IX 171 Å and Fe XVII 94 Å channels of AIA/SDO.

We used data from RHESSI to trace the flare properties in hard X-rays.

High-energy particles related to the studied events are analysed in different energy channels using proton data from SoHO/ERNE instrument. EUV waves' kinematics were estimated using off-limb observations from SDO/AIA, with the CASHew framework (Kozarev et al. 2017).

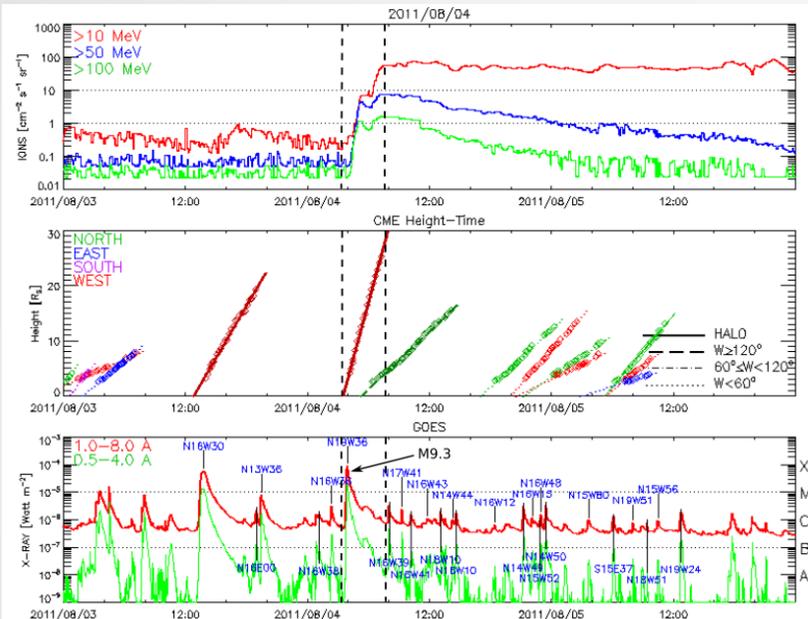
The radio signatures are deduced from dynamic spectrum obtained by Wind/WAVES RAD1 (20-1040 kHz) and RAD2 (1.075-13.825 MHz) receiver.

In order to search for a possible association with CME, data from LASCO/SoHO CME catalog ([https://cdaw.gsfc.nasa.gov/CME\\_list/](https://cdaw.gsfc.nasa.gov/CME_list/)) were also used.

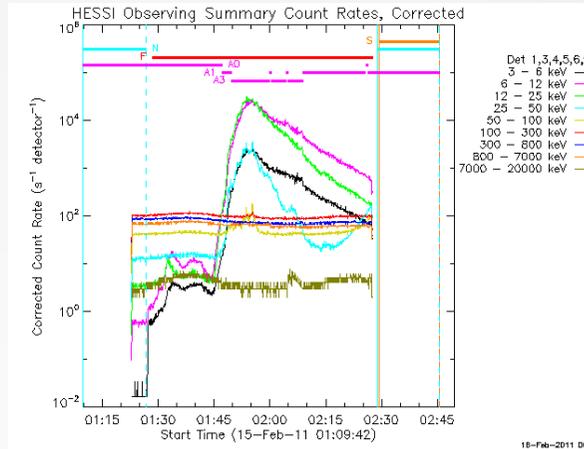


Flares light curves in soft X-ray from XRS (GOES) 1. - 8. Å channel and in two EUV wavelengths with different temperature formation: 94 Å (Fe XVIII;  $\log T=6.8$ ) and 171Å (Fe IX;  $\log T=5.8$ ), obtained from the red boxes overplotted in Fig.1. The vertical dashed lines mark the start of flares in different channels.

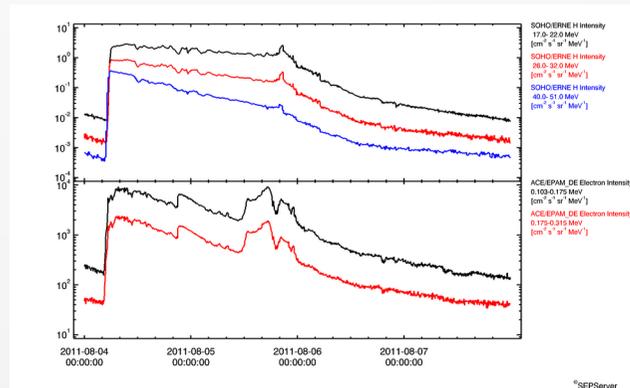
# SEPs:



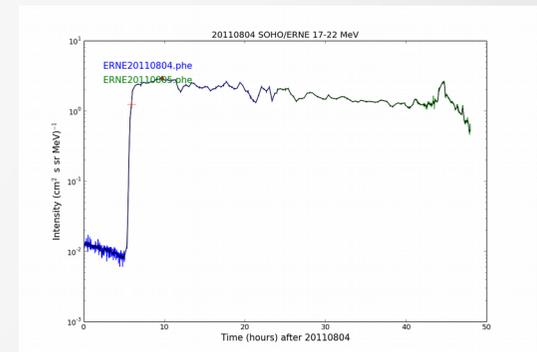
An example of SEP event on 04 Aug 2011: the time variation of SEP intensity in three energy channels (first panel); the CME height-time plot (second panel); and the soft X-ray flare light curves in two energy channels (third panel). The vertical dashed lines outline the impulsive flare phase.



Light curves of RHESSI count rates for the event on 04 Aug 2011.

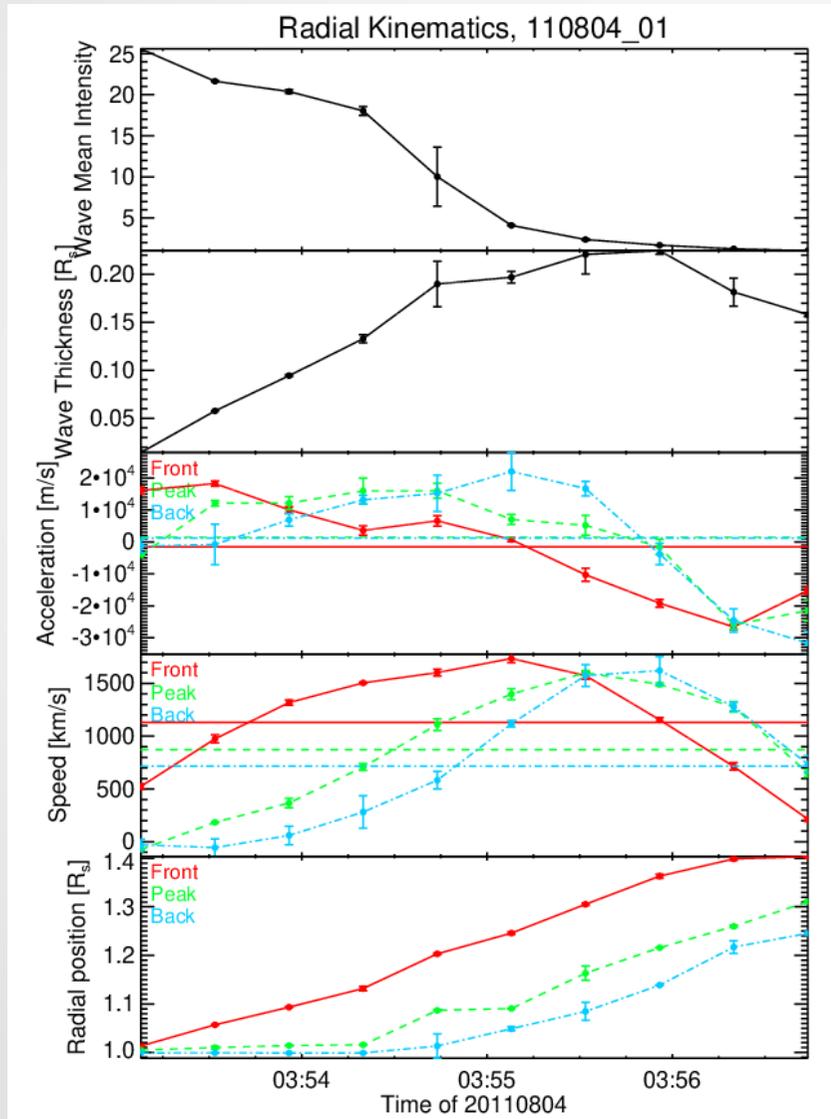


Proton (top panel) and electron (bottom panel) intensities, obtained from SoHO/ERNE and ACE/EPAM DE, respectively, in different energy channels for the event on 04 Aug 2011.



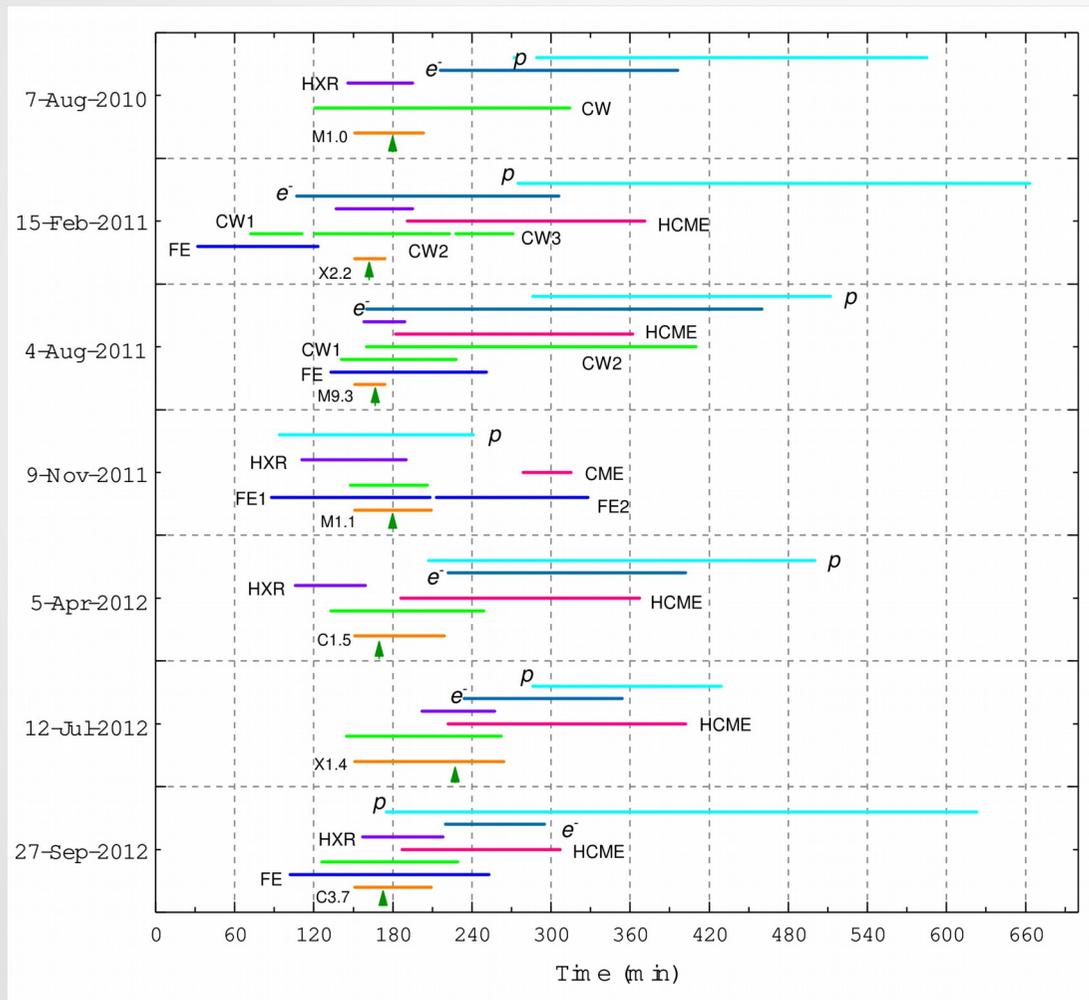
SoHO/ERNE proton intensities on 04 Aug 2011 in 17–22 MeV energy range

# *EUV Waves:*



Radial kinematic properties of the EUV wave, associated with the event on 04 Aug 2011. The front, intensity peak, and back of the wave time-dependent velocity and acceleration are from Savitsky-Golay fits.

## Some preliminary results:



Time lines for solar activity involved in each of 7 events. The durations of activities from the onset to the end are indicated by solid lines: flares - orange, filament eruption (FEs) - dark blue, coronal waves (CWs) - green, CMEs - purple (in LASCO C2 field-of view), hard X-ray - violet and electron and proton intensities enhancement - light blue and cyan. The peak's times of the GOEs SXR flux are also indicated with green arrows.

The time of 150 minutes before the flares onset is selected as a start point.