

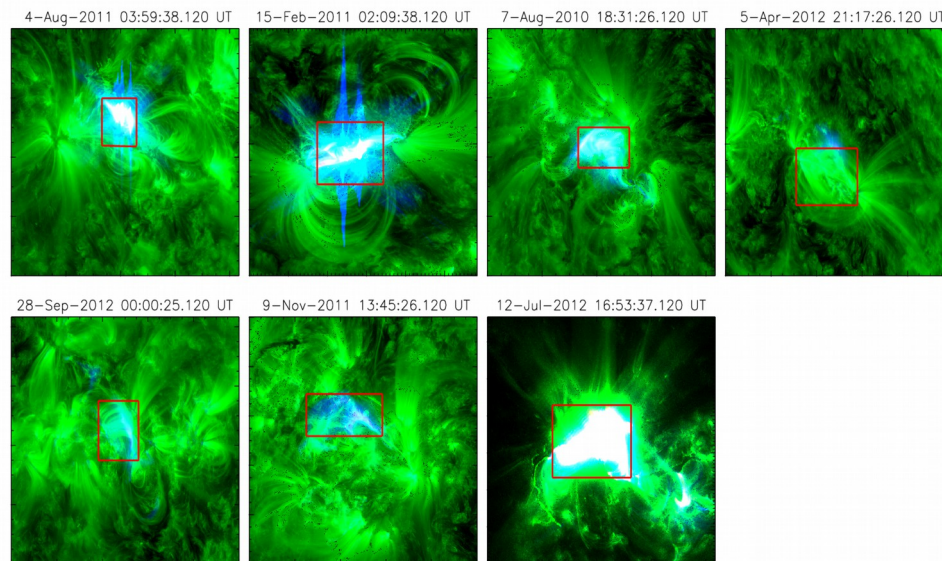
# Hard X-ray, EUV, and radio signatures in relation to solar energetic particles

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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.:

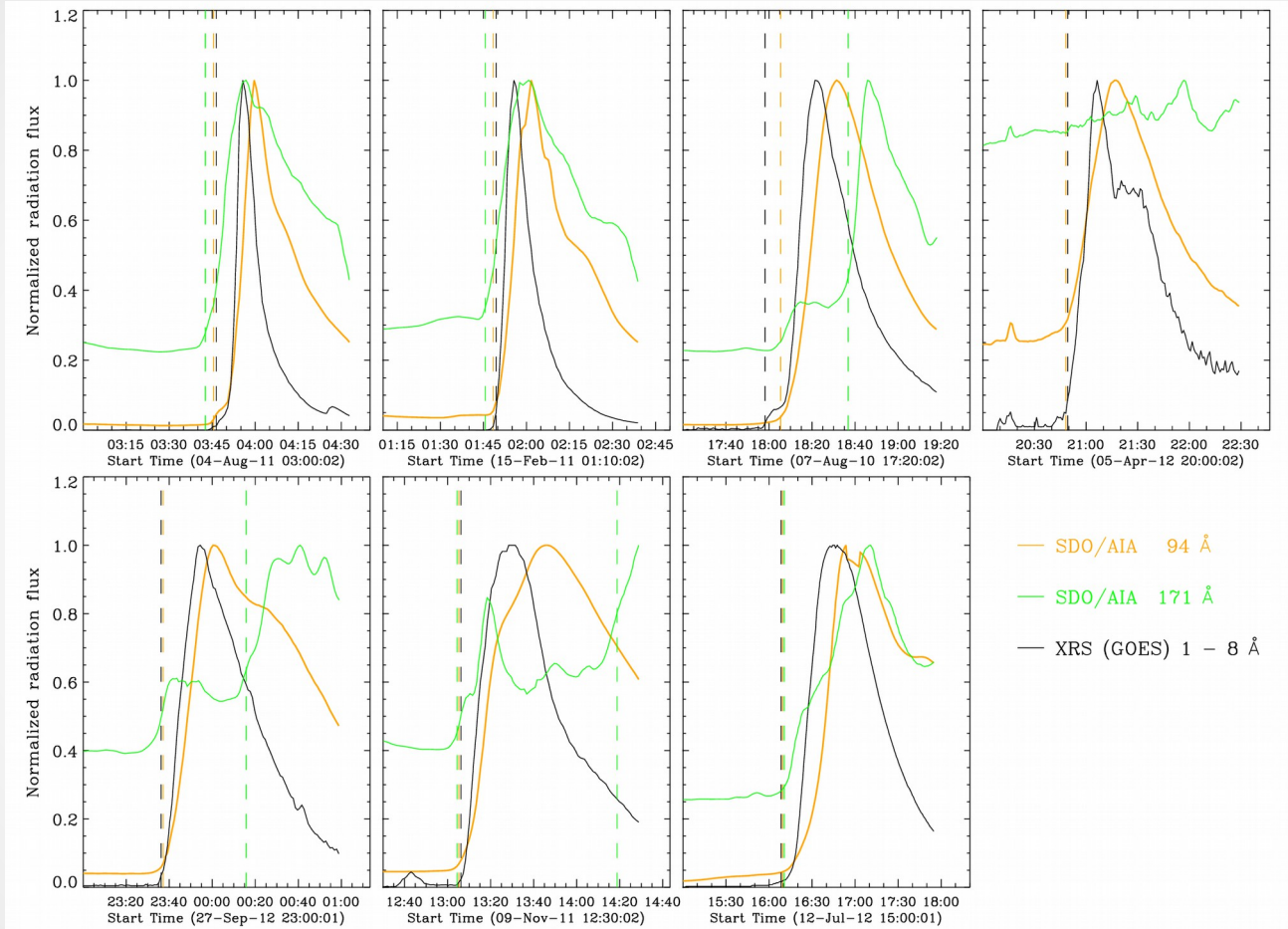
The flare behaviours in EUV (light curves and temporal evolution) are considered by using images obtained in the Fe IX 171Å and Fe XVII 94Å channels of AIA/SDO.

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.

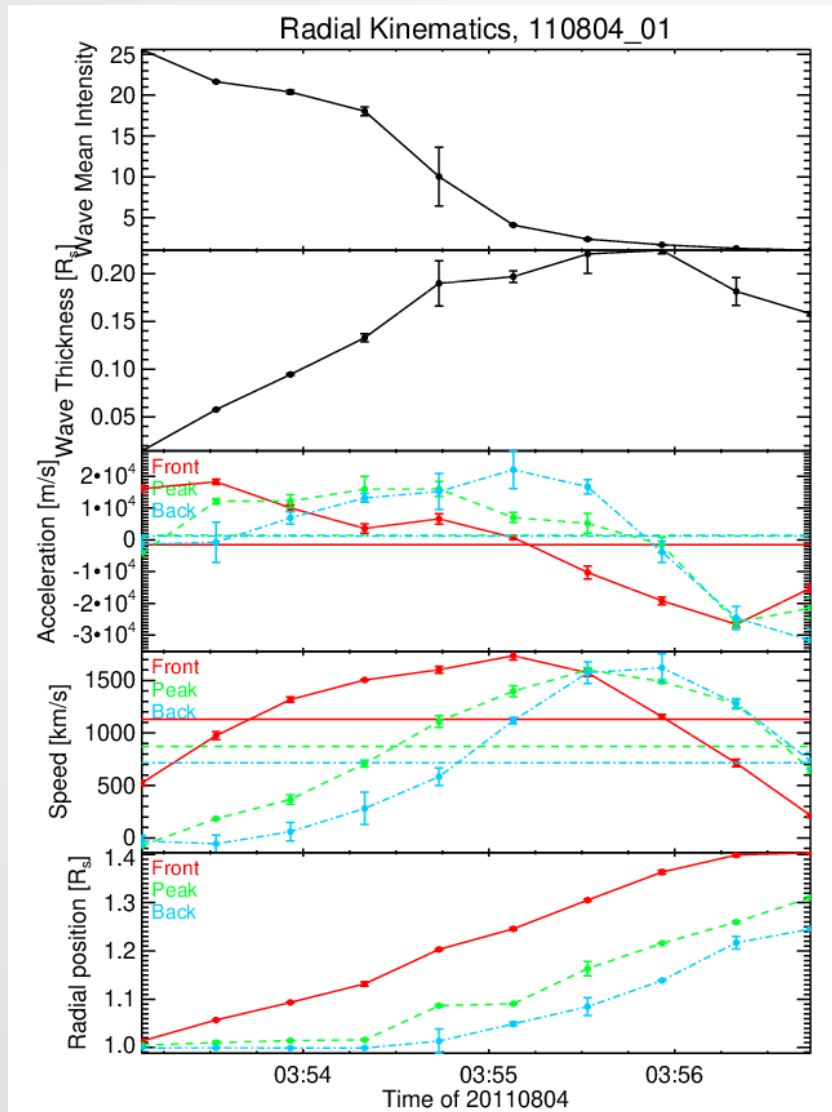
In order to search for a possible association with CME, data from LASCO/SoHO CME catalog ([https://cdaw.gsfc.nasa.gov/CME\\_list/](https://cdaw.gsfc.nasa.gov/CME_list/)) were also used.



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 171 Å (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.



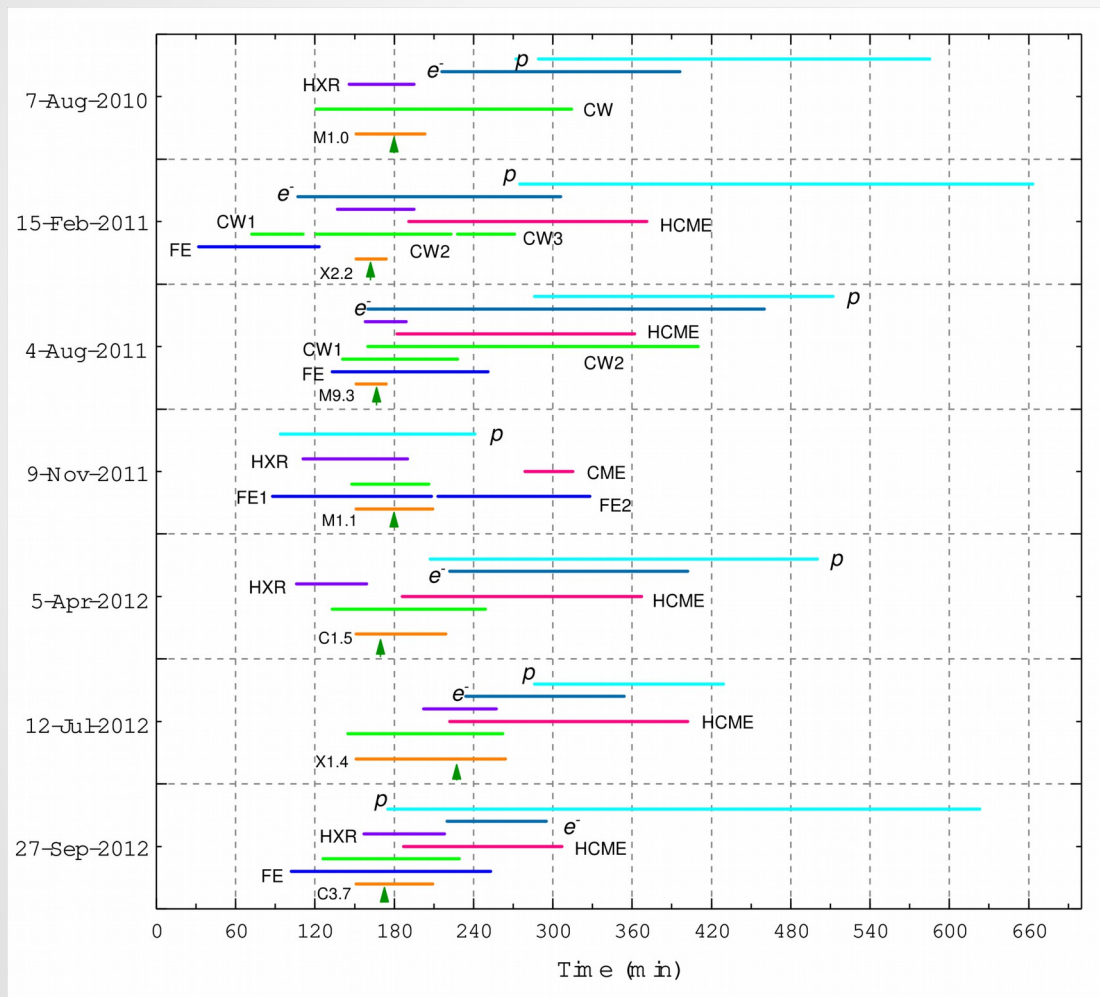
# *EUV Waves:*



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.