Solar Sources of Impulsive SEP Events

Associated with

- type III bursts

  (Reames & Stone, 1986 ApJ, 308, 902)

- 2-100 keV electron events

  (Reames, von Rosenvinge & Lin, 1985 ApJ, 292, 716)

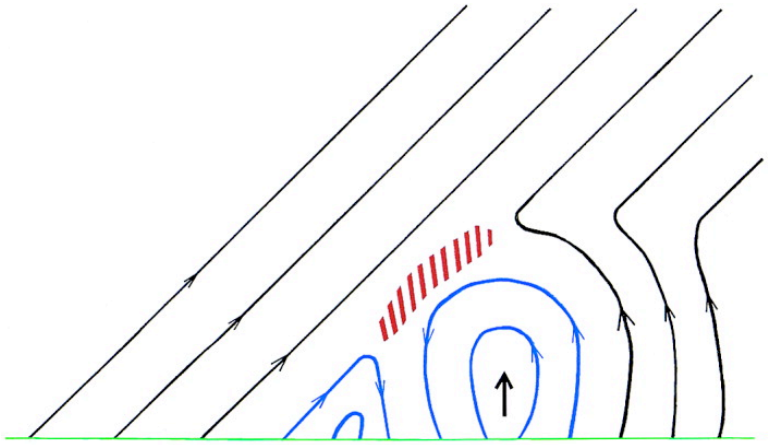
Nariaki Nitta

Lockheed Martin Solar and Astrophysics Laboratory

Origin of Impulsive SEP Events

Unlike gradual SEP events, they are thought to originate in flares, since acceleration at the CME shock alone does not seem to account for the pronounced abundance anomalies (esp. $^{3}He/^{4}He$).

Impulsive SEP events may result from impulsive solar flares that are well-connected. At least, they are hardly associated with gradual flares that often accompany CMEs.



Magnetic field topology of flares associated with impulsive SEPs proposed by Reames, 2002, ApJ, 571, L63

Questions

- Do the solar flares associated with impulsive SEP events have distinct characteristics? What constraints can we put on acceleration mechanisms?

  Long way to answer. Need imaging observations

- Why do impulsive SEP events tend to be associated with small flares?

  Not X-class flares or γ-ray line flares

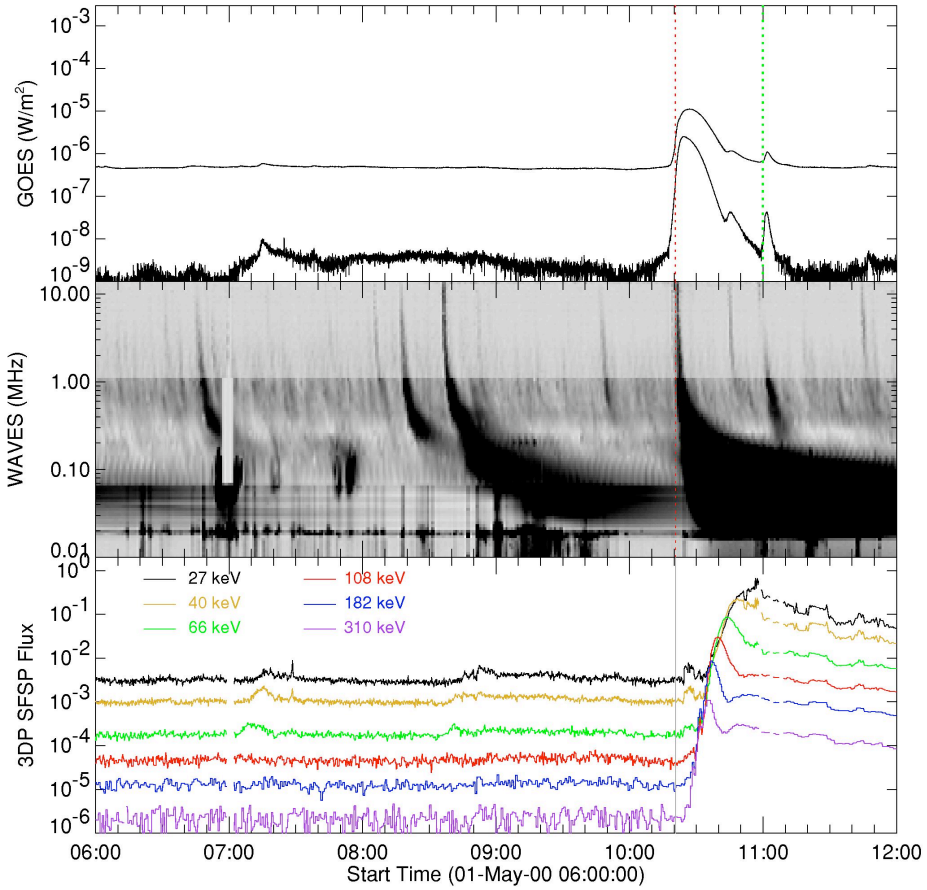
- To what extent are the different properties of impulsive SEP events attributable to different solar sources?

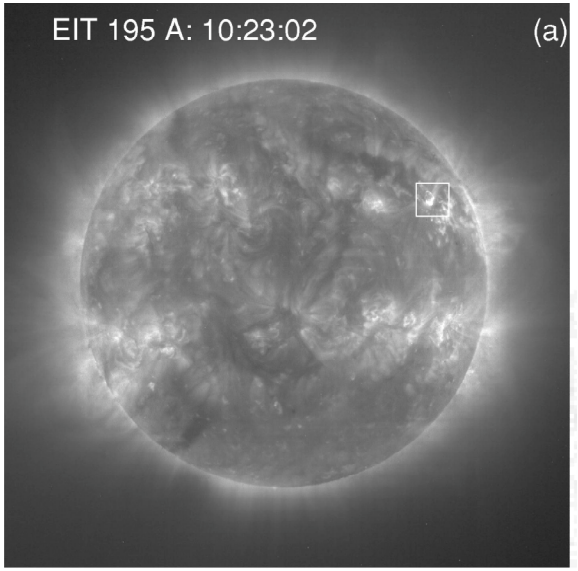
  Different types of energy release in the corona, but could be IP

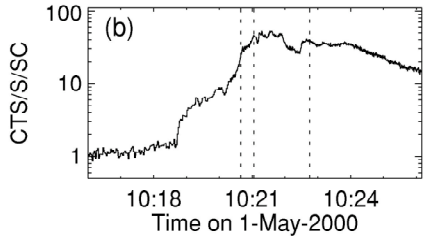
- Where are well-connected field lines anchored?

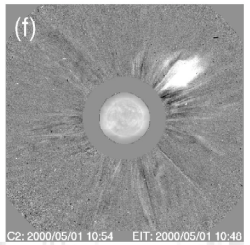
  Serve as a good test for magnetic field models

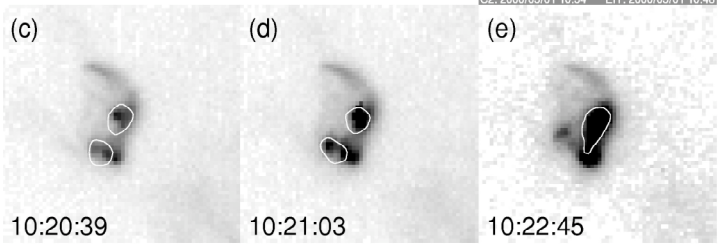
Identification of the Solar Source (I)





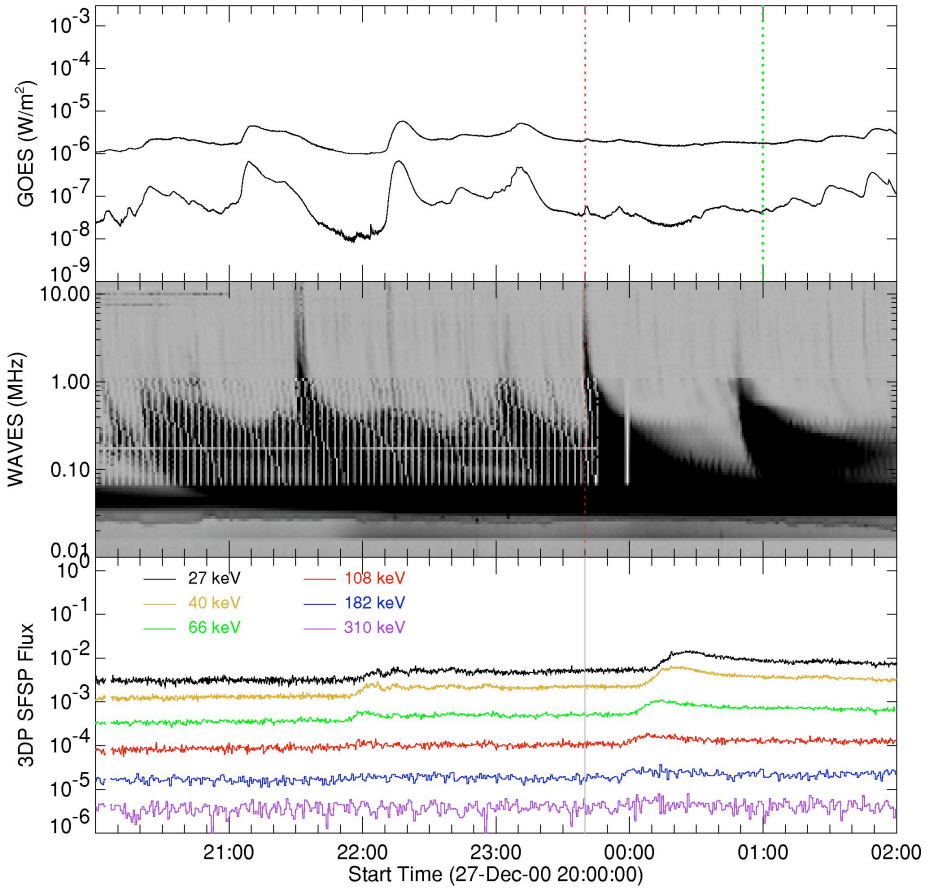


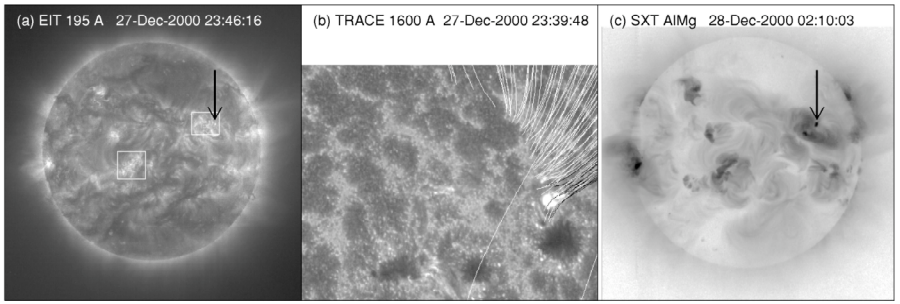




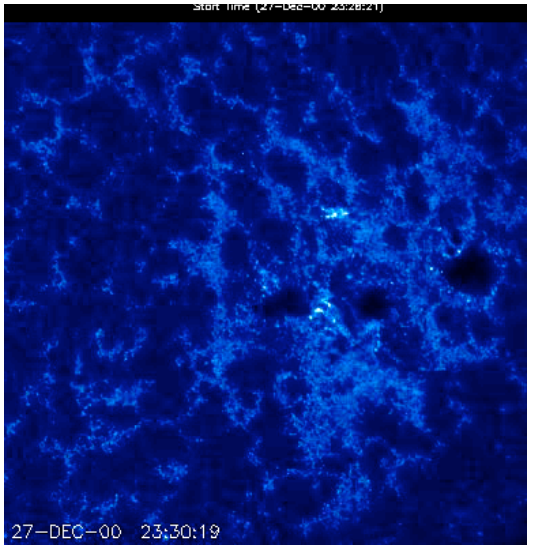
cf. Kahler, Reames, & Sheeley 2001, ApJ, 562, 558

Identification of the Solar Source (II)





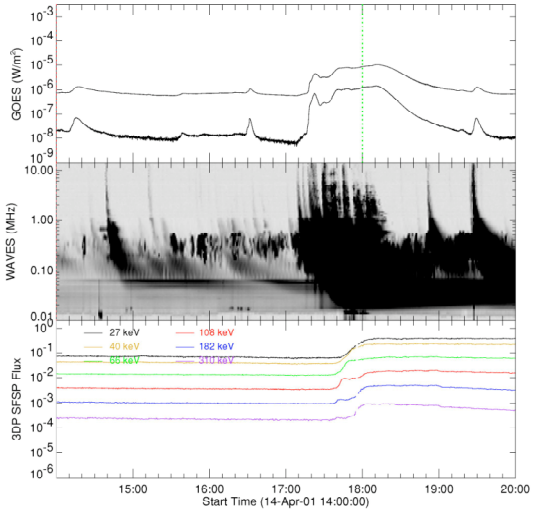
TRACE 1600 A movie shown with GOES and WAVES 10 MHz "light curves"



Combined with the electron data, the solar source seems to be not quite visible in GOES X-ray data.

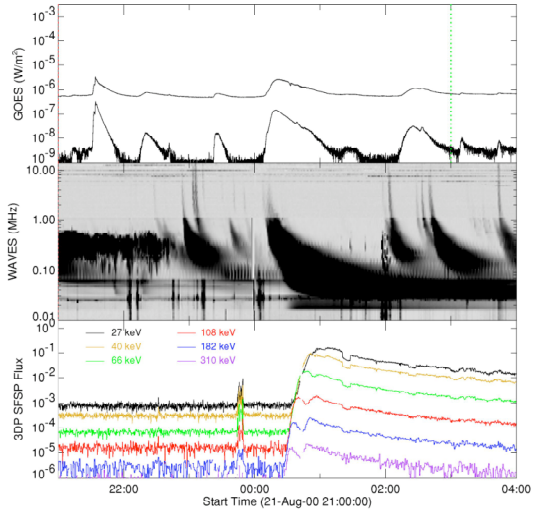
Identification of the Solar Source (III)

Identification is sometimes difficult or ambiguous.

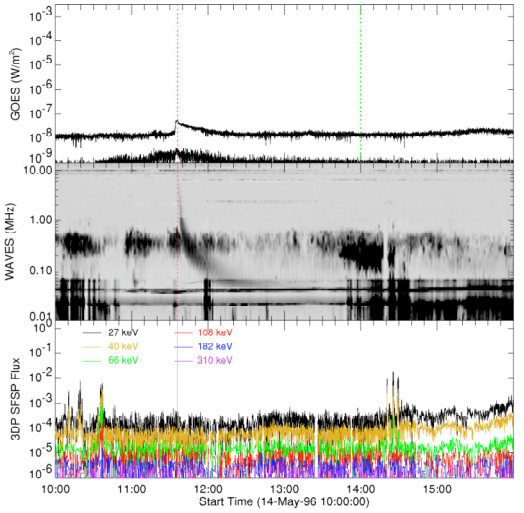


Multiple type III's

Multiple electron events?

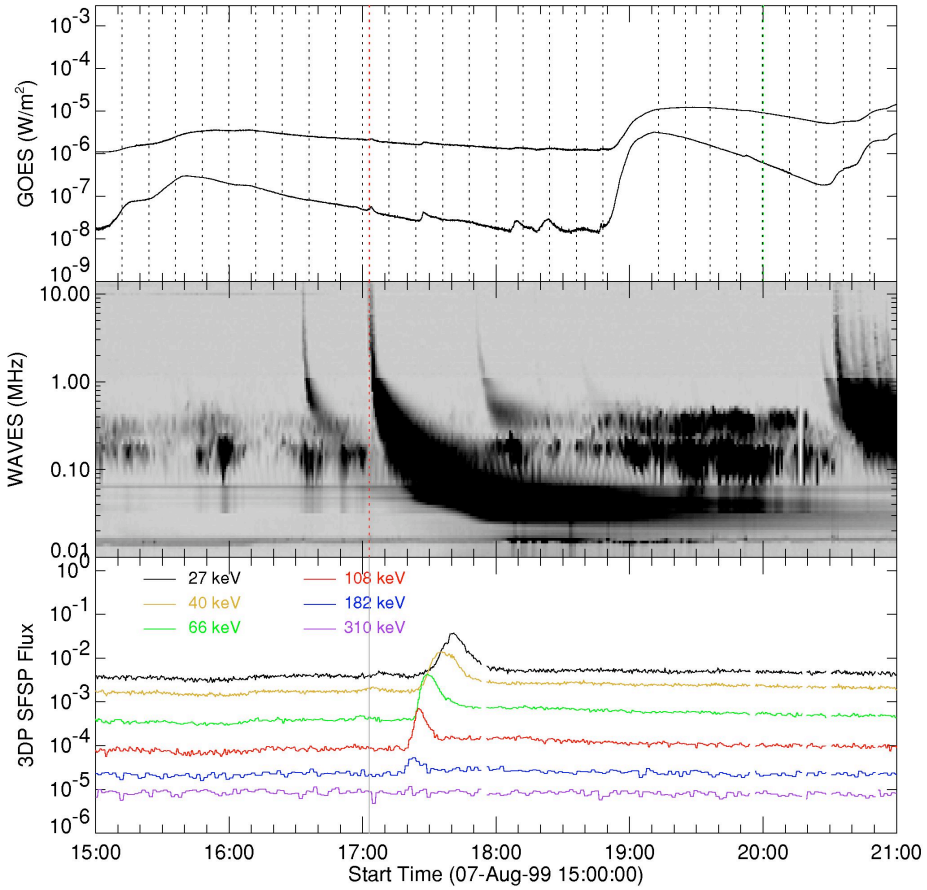


Weak type III above 1 MHz



No or slow electron event

Full-Disk Images



Correct identification of the solar source requires full-disk images at a high cadence.

SOHO/EIT, with a ~12 minute regular cadence, usually does a great job of locating a minor brightening. But we sometimes need a better cadence, as in this example.

Yohkoh/SXT captured some of the minor flares with a higher cadence, but data coverage was unsatisfactory.

Other resources include GOES/SXI, ground-based H observation networks (especially BBSO), and radio observatories (NRH, NoRH, etc.)

Closer Look at the Solar Sources

Once we locate the solar source in full-disk images, we examine it in high spatial and temporal resolution images.

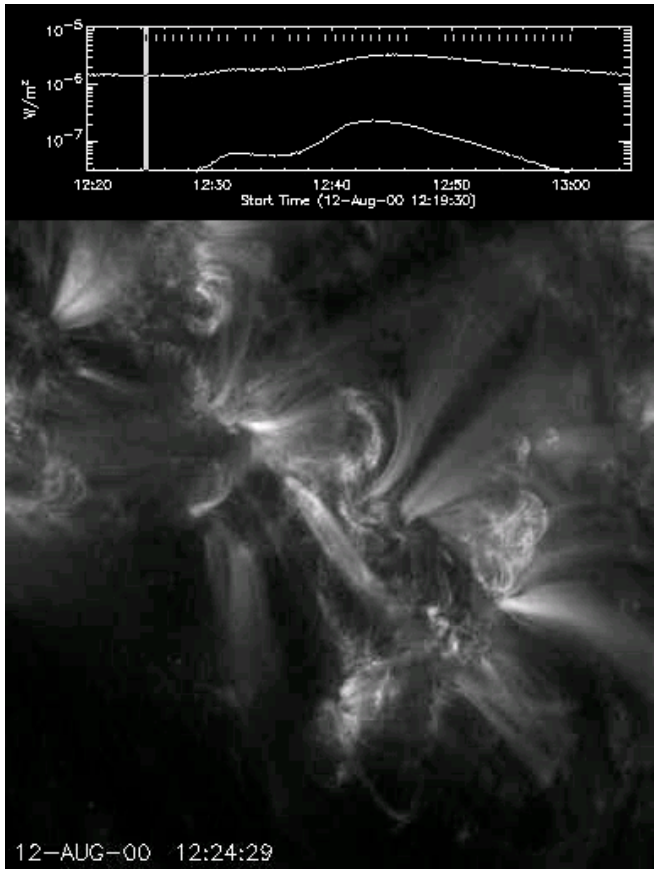
TRACE is an ideal instrument for this task, supplemented by SXT high-cadence images and high-quality Hα images.

For a number of the solar events associated with impulsive SEPs, the EUV/X-ray jet is a characteristic manifestation.

This may not be surprising, considering the association of (metric) type III bursts with jets (Kundu et al. 1995, ApJ, 447, L135).

It is speculated that the (narrow) CMEs associated with impulsive SEP events are jet materials rather than resulting from global magnetic field opening up.

TRACE 171 A movie



Magnetic Field Connectivity (I)

Solar origin of impulsive SEP events provides a direct test of our understanding of the Sun-Earth magnetic field connectivity.

-The simplest, but the only practical method to relate the solar photospheric magnetic field and the heliospheric magnetic field is the potential field source surface (PFSS) model. No current is allowed below the source surface (typically at 2.5 Rsun), from where the field is forced to be radial.

- This is of course not suitable for studies of the cause of flares and CMEs, but the PFSS model often reproduces the coronal hole boundaries and the IMF orientation reasonably well.

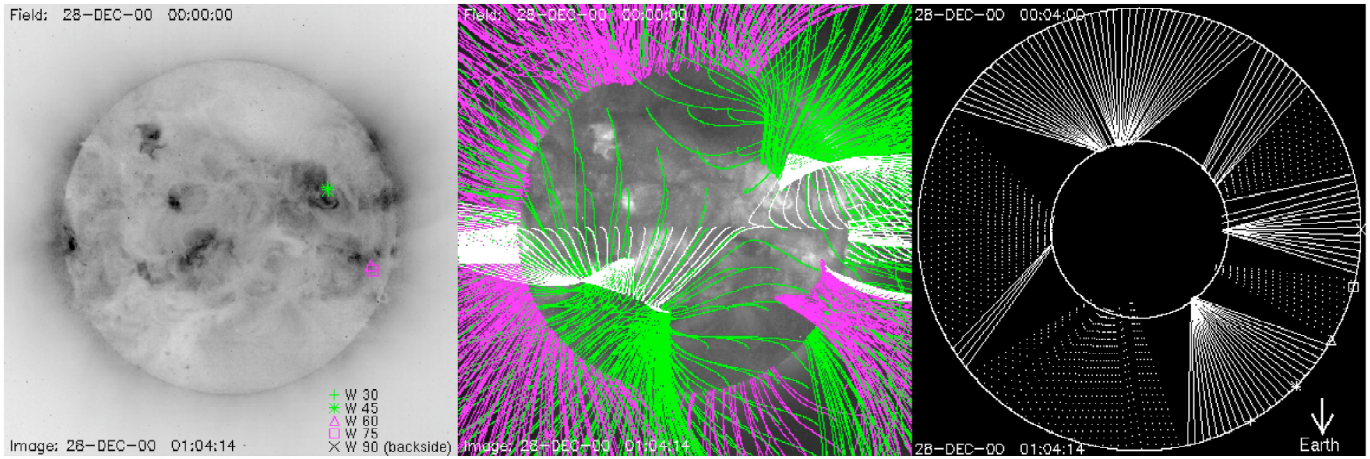
- The PFSS result is also used as an input to more complicated MHD simulations.

Magnetic Field Connectivity (II)

Coronal field is globally connected, so an extrapolation essentially requires **B** at the whole surface as the boundary condition. But we do not even have B_r at the moment, nor will we have in the foreseeable future.

Synoptic magnetograms that include a portion up to 14 days old are often used.

Here we use the PFSS model as implemented by Schrijver and DeRosa 2003, SP, 212, 165), which is built on MDI magnetograms assimilated into a flux dispersal model, combined with information of major flux emergence at the far side estimated from helioseismology. The location of the flare associated with the impulsive SEP event is compared with the computed foot-points of well-connected field lines.



Preliminary Results

We tried to identify the solar sources of the 38 impulsive SEP events (May 1996 – April 2002) as identified by D. Reames for the LWS CDAW (July 2002) using Wind/EPACT/LEMT data. We also compared their locations with the PFSS extrapolations, and studied their characteristics.

- The solar source was located for 30/38 events, using type III timing. Most (18) of them were C-class flares, only one M-class flare, and the others were B or smaller flares. Most (28/30) events were from the western hemisphere.

- The PFSS model was successful in 11/30 events.

- High resolution images were studied for 9 events. In 6 events, a jet was found. More events are likely to have been observed by TRACE.

- In 24/30 events, an electron event was found in Wind/3DP data.

Things To Do

- Identification of the solar source of more ^{3}He or UH-rich events

- Examination of more high-resolution data to characterize the solar sources

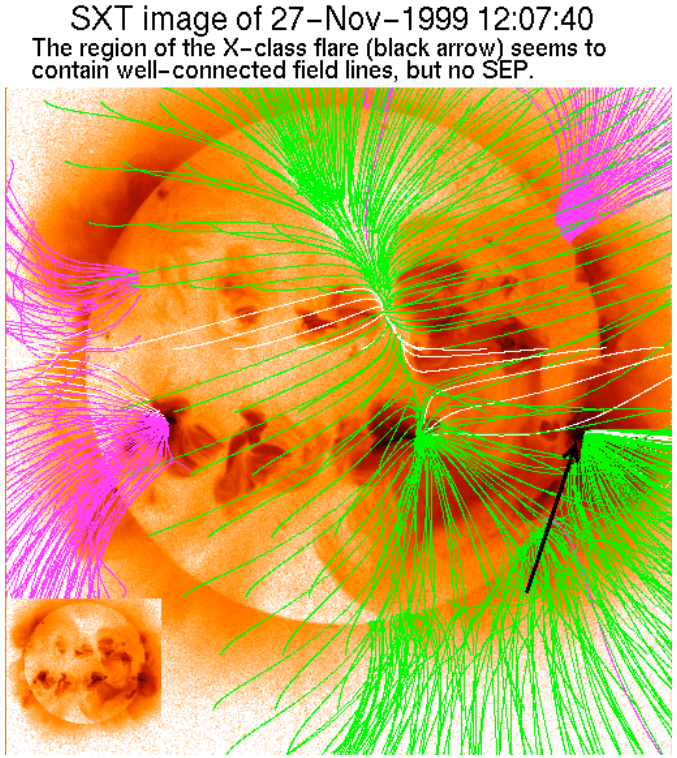
- Search of possible relation of different source characteristics with different impulsive SEP properties (abundance, spectrum, temporal variations, etc.)

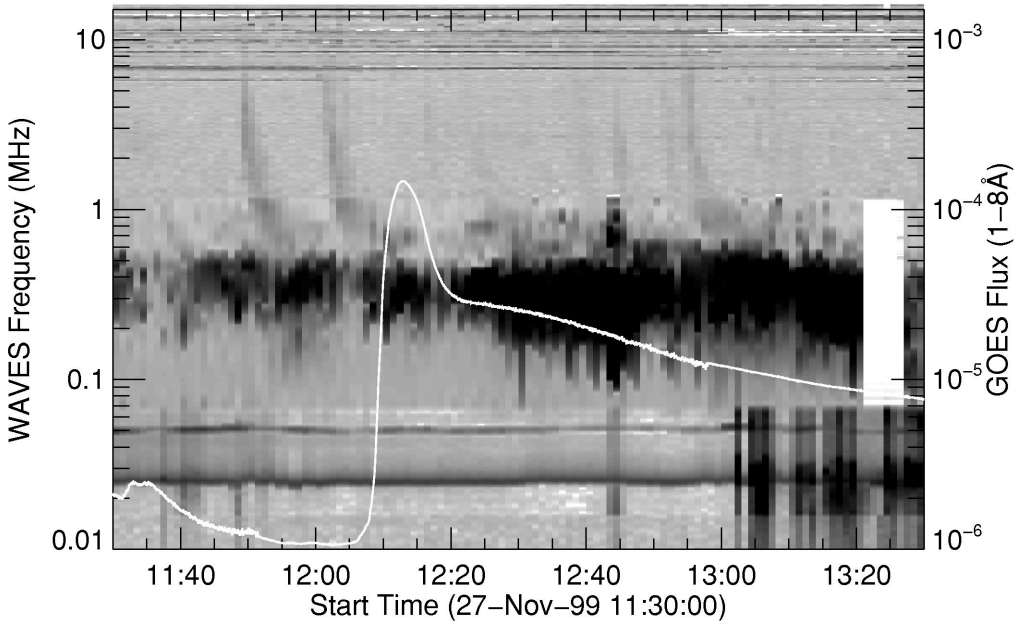
- Detailed study of flares in active regions (through their disk passages) that produced multiple impulsive SEP events and possibly some gradual SEP events, to better understand how the solar processes affect SEP properties and how important the magnetic field connectivity is for the detection of impulsive SEP events

- Exploration of the reasons the PFSS model does not work in many cases. Try different versions of PFSS. Are there open field lines in the flaring region? At what latitudes and longitudes do they reach the source surface? What effects do major regions coming form the east limb produce?

Major Flares without SEPs

Non-issue for SEP workers, but…..





No type II's or type III's in DH, and no type III's in metric, but there was a metric type II burst.

Why do we not observe impulsive SEP events associated with big flares? This flare is an X-class flare, impulsive and at a well-connected longitude, but no SEP was observed.