

^3He -rich SEPs from a Nearly Quiet Sun in 2007-2008

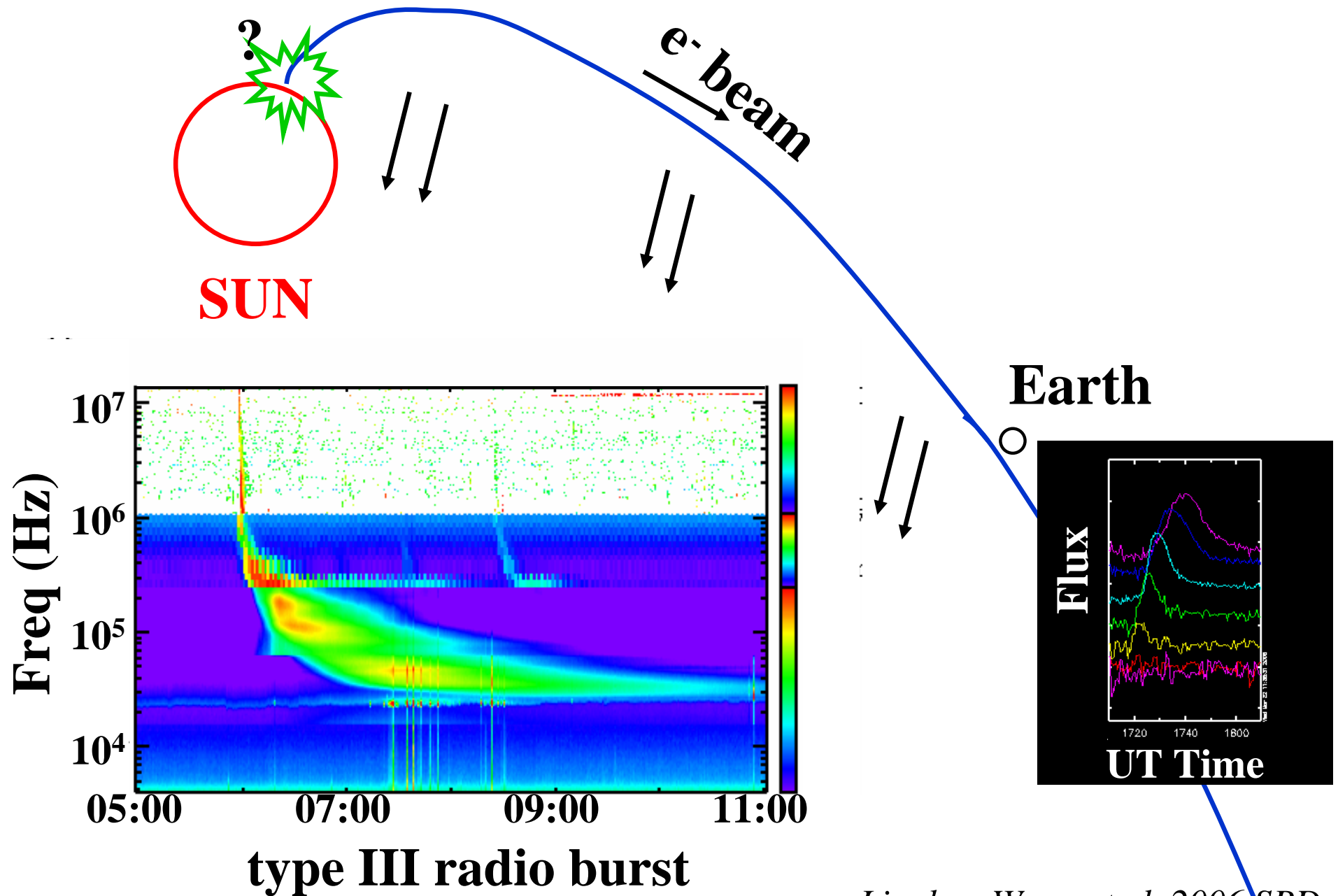
G. M. Mason, N. V. Nitta, C. M. S. Cohen
and M. E. Wiedenbeck

STEREO SWG #19
Pasadena, CA Feb. 3-5, 2009

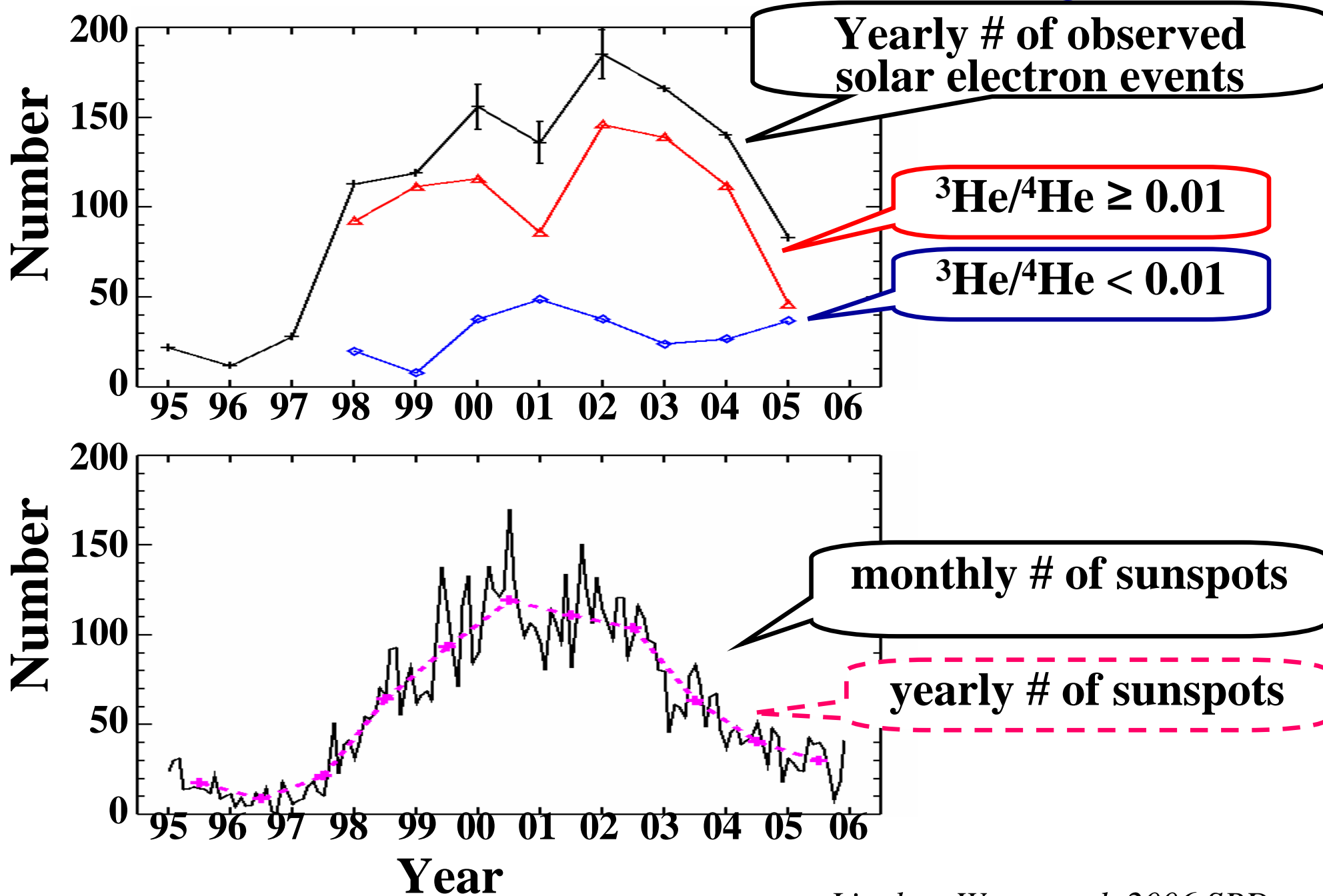
^3He -rich SEP ions outline --

- Brief history
- Spectral forms
- Composition
 - Models
- Source identification
 - Future outlook

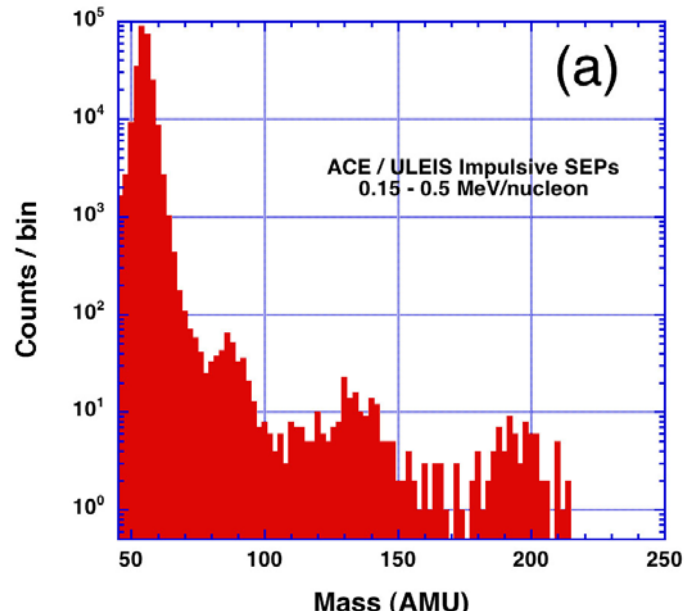
Injection study of impulsive electrons



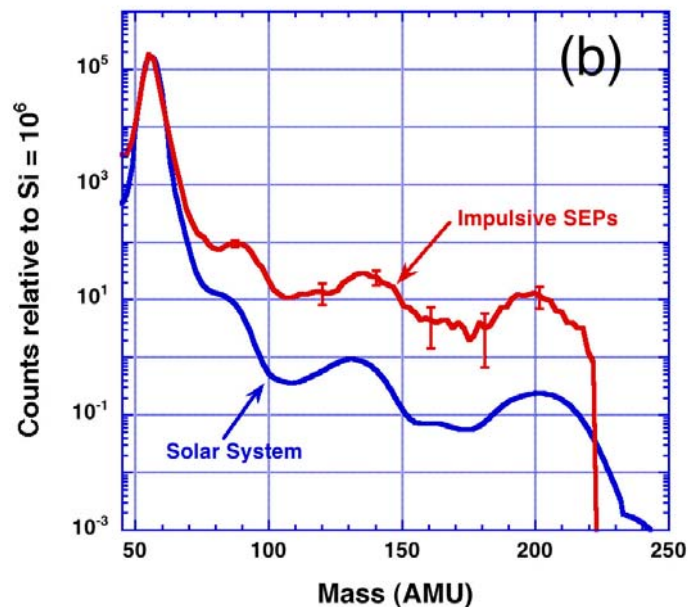
Time distribution over one solar cycle



UH nuclei in ^3He rich flares --

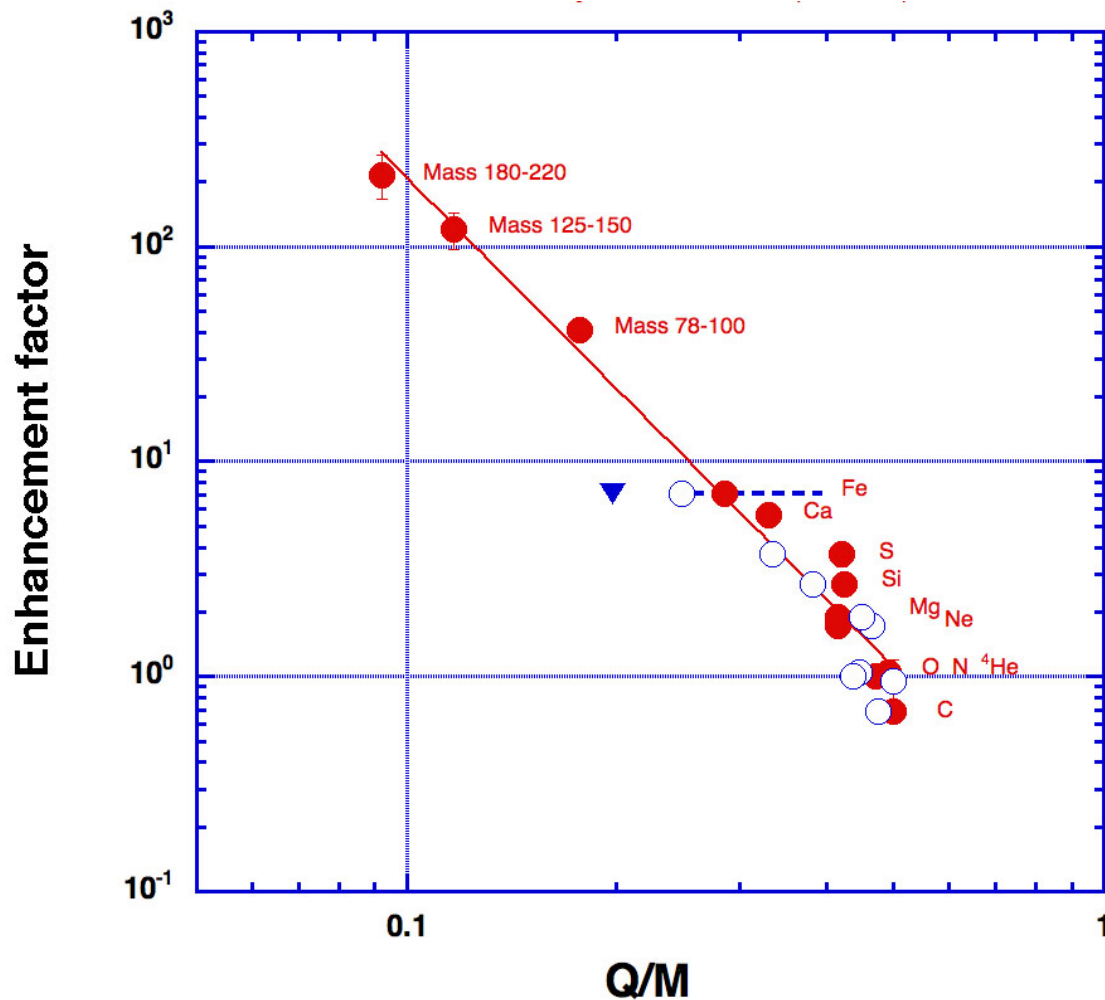


Mass histogram of events showing Fe peak and range out to ~220 AMU; note structure



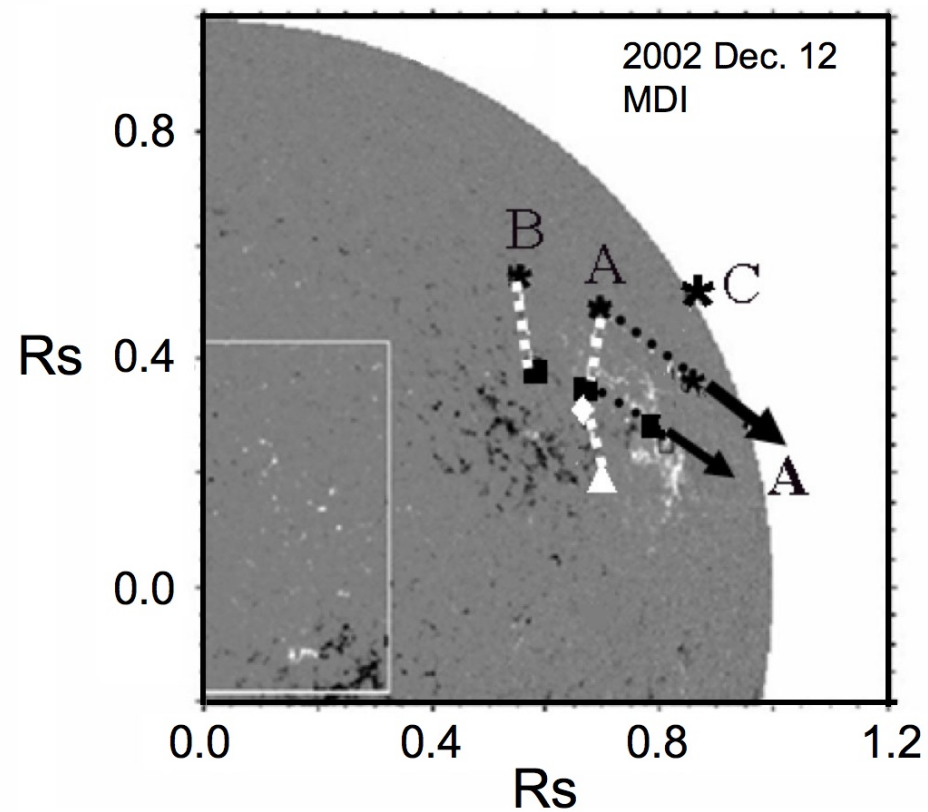
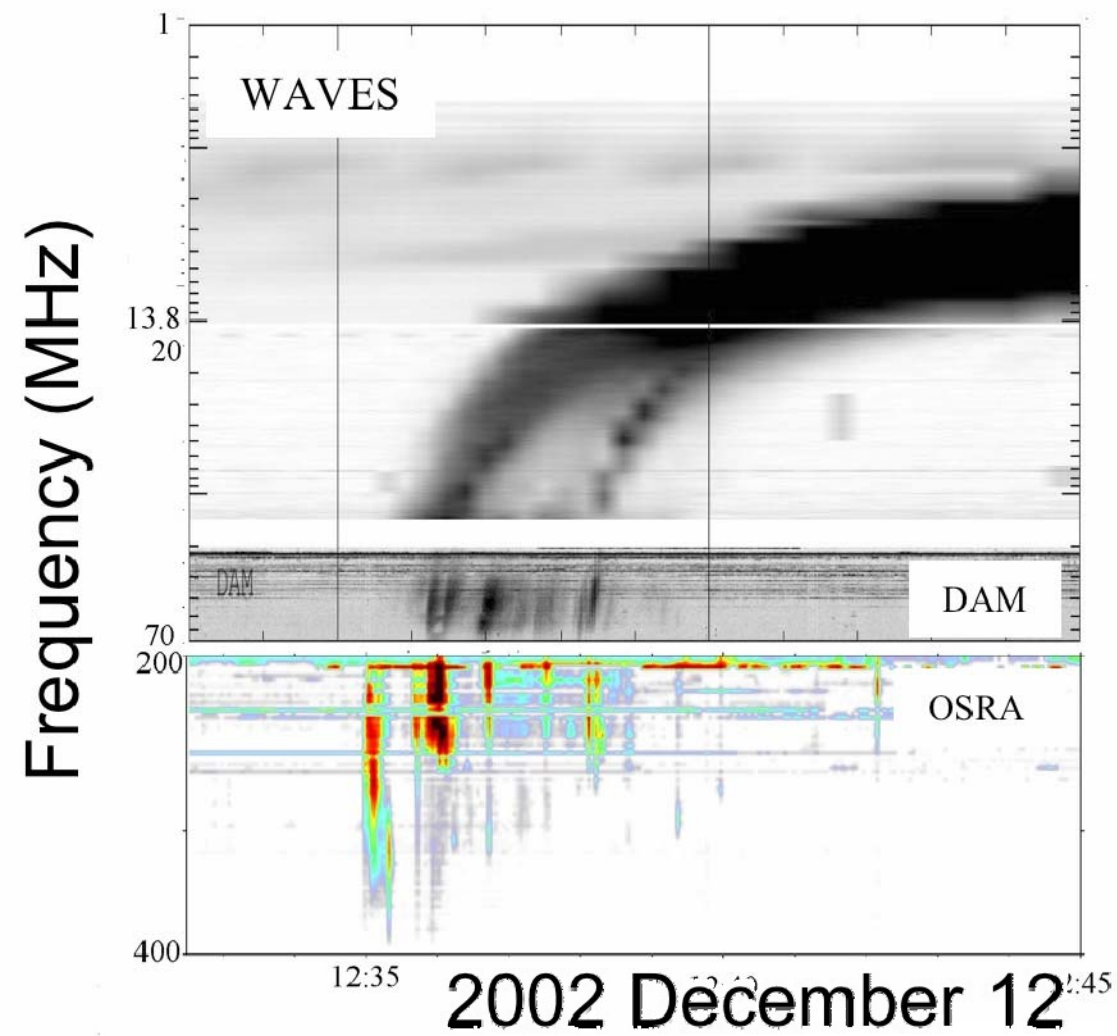
Smoothed ULEIS distribution (red) compared with smeared solar system abundances: enhancement increases with mass

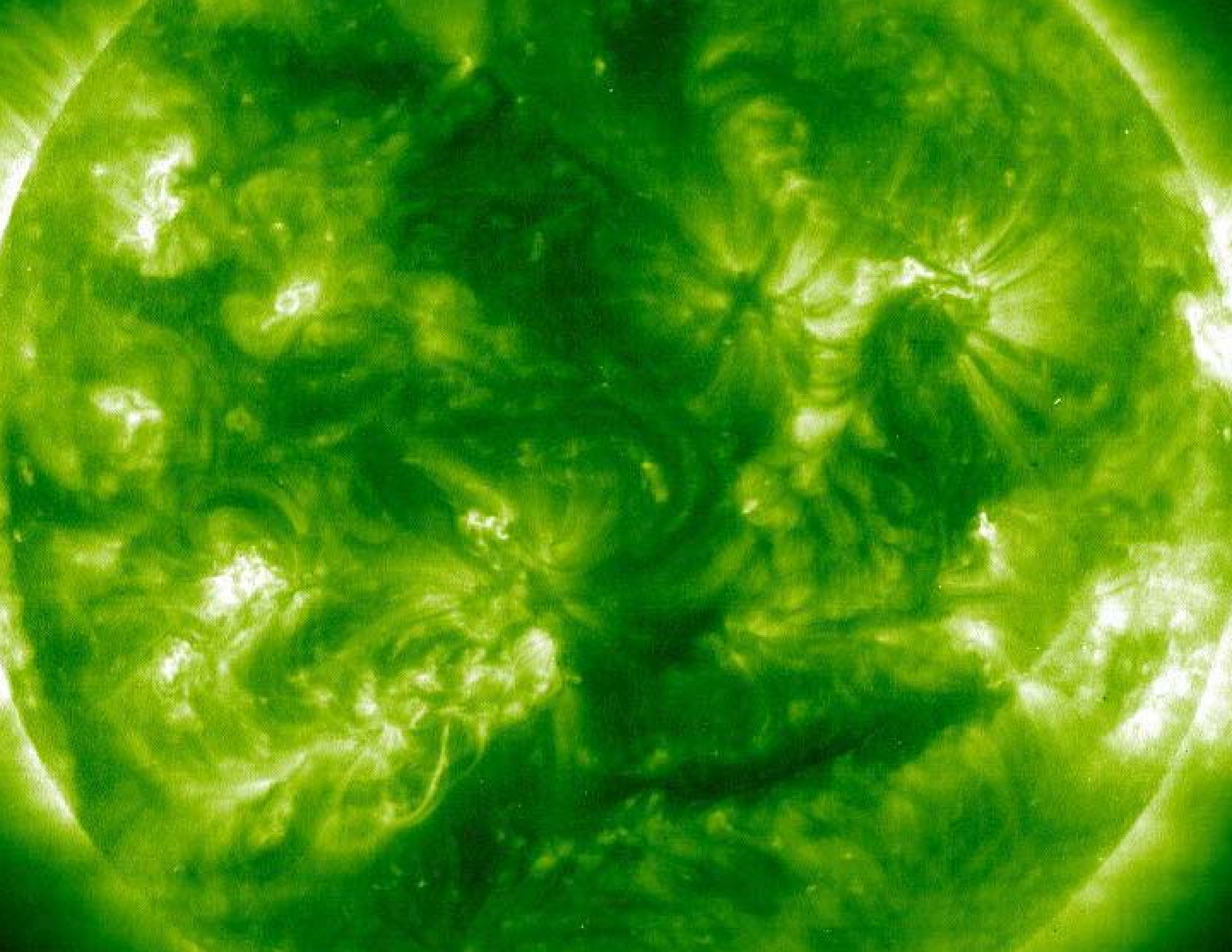
UH nuclei in ^3He rich flares --

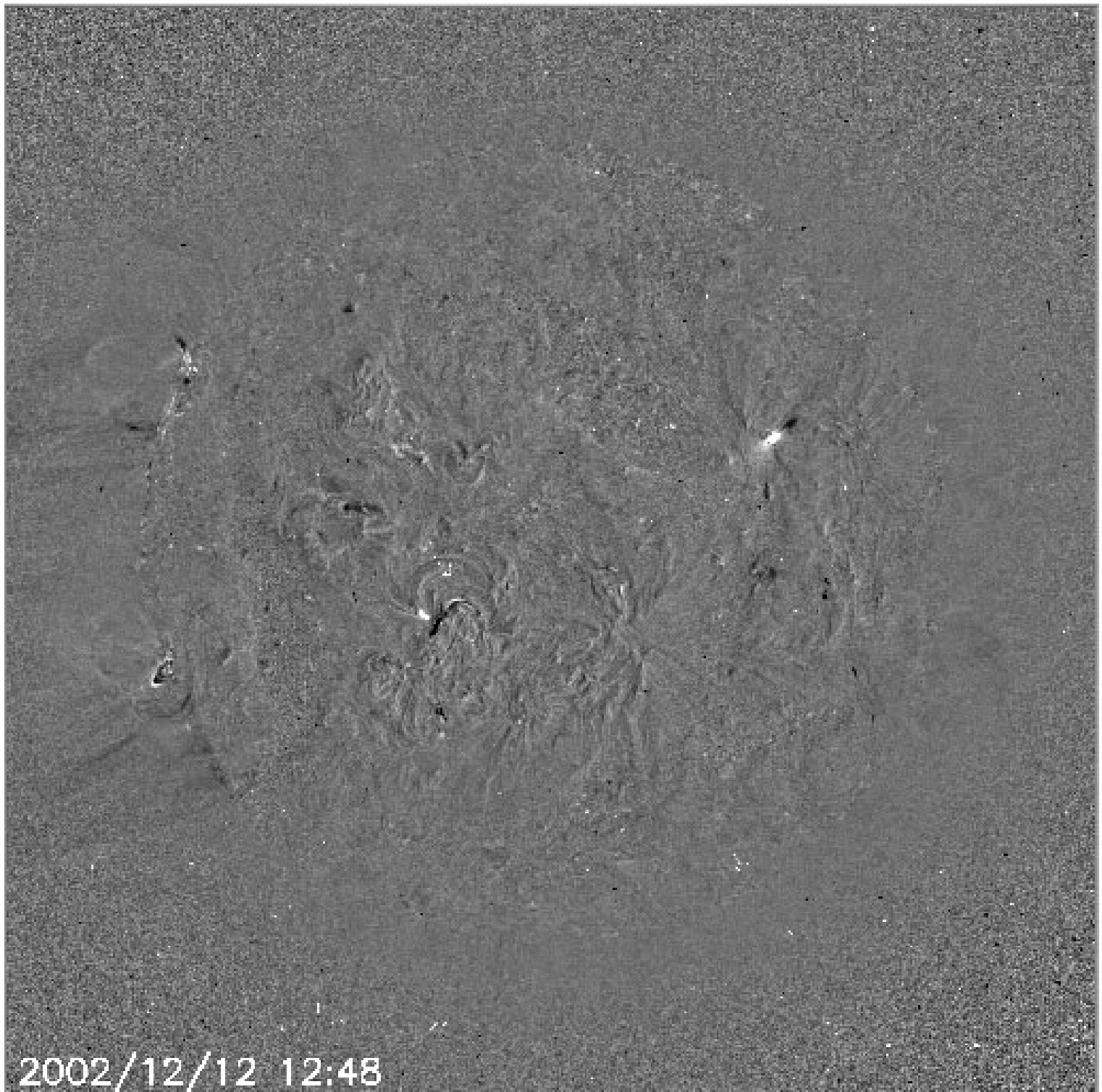


Enhancement also shows a general ordering by Q/M ratio, as seen by Breneman & Stone in large, gradual SEP events.

However, it is not clear what Q states we should use & if stripping occurs during acceleration, the Q s are ambiguous







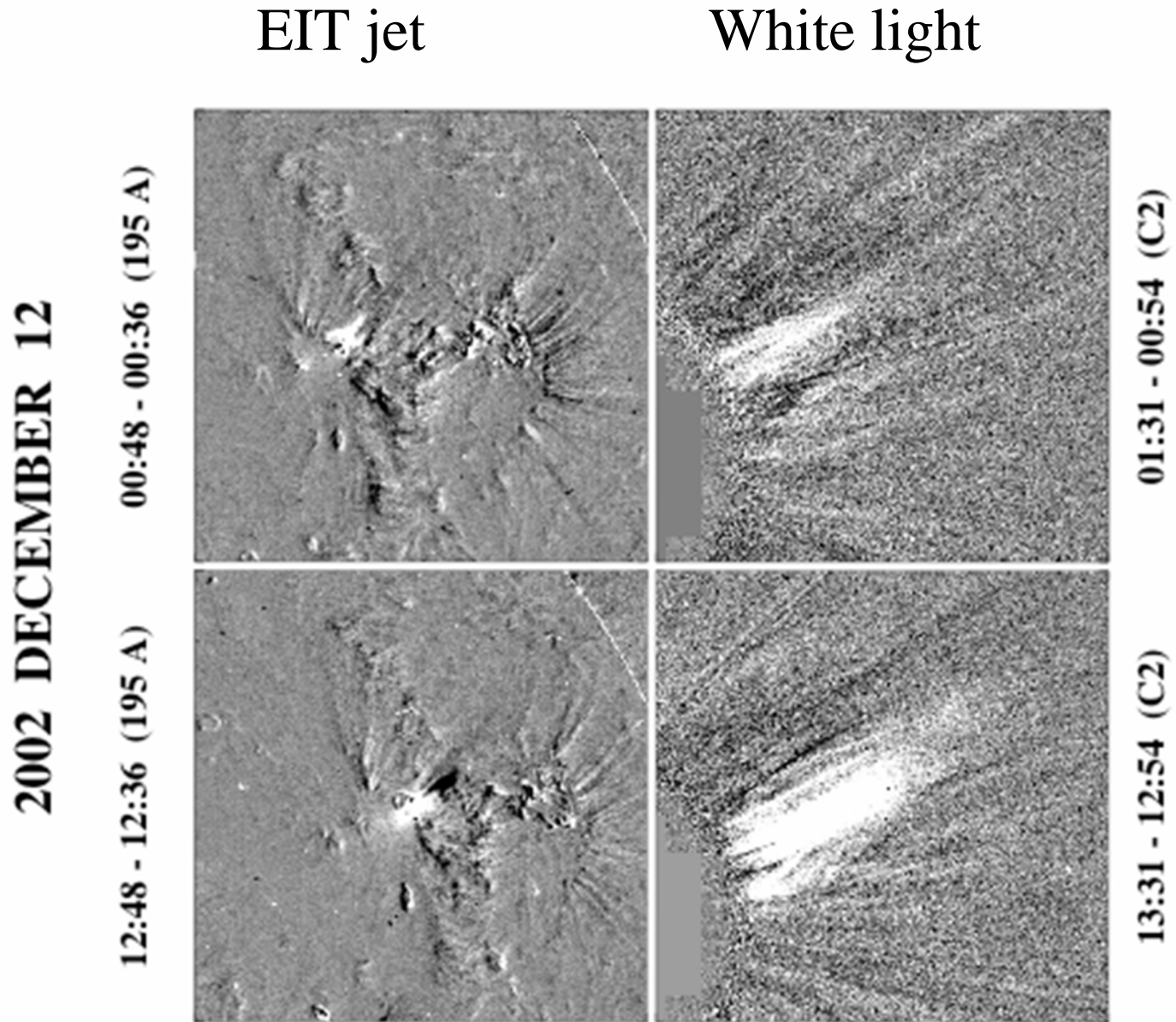
SOHO

EIT-dit

195

2002/12/12 12:48

Fig. 12



Two EUV jets emitted by same active region; 2nd, brighter, one is 12 hr after the first, and is associated with one of the SEP events in table 1; Note the “wishbone” shape in the event at 00:48 UT

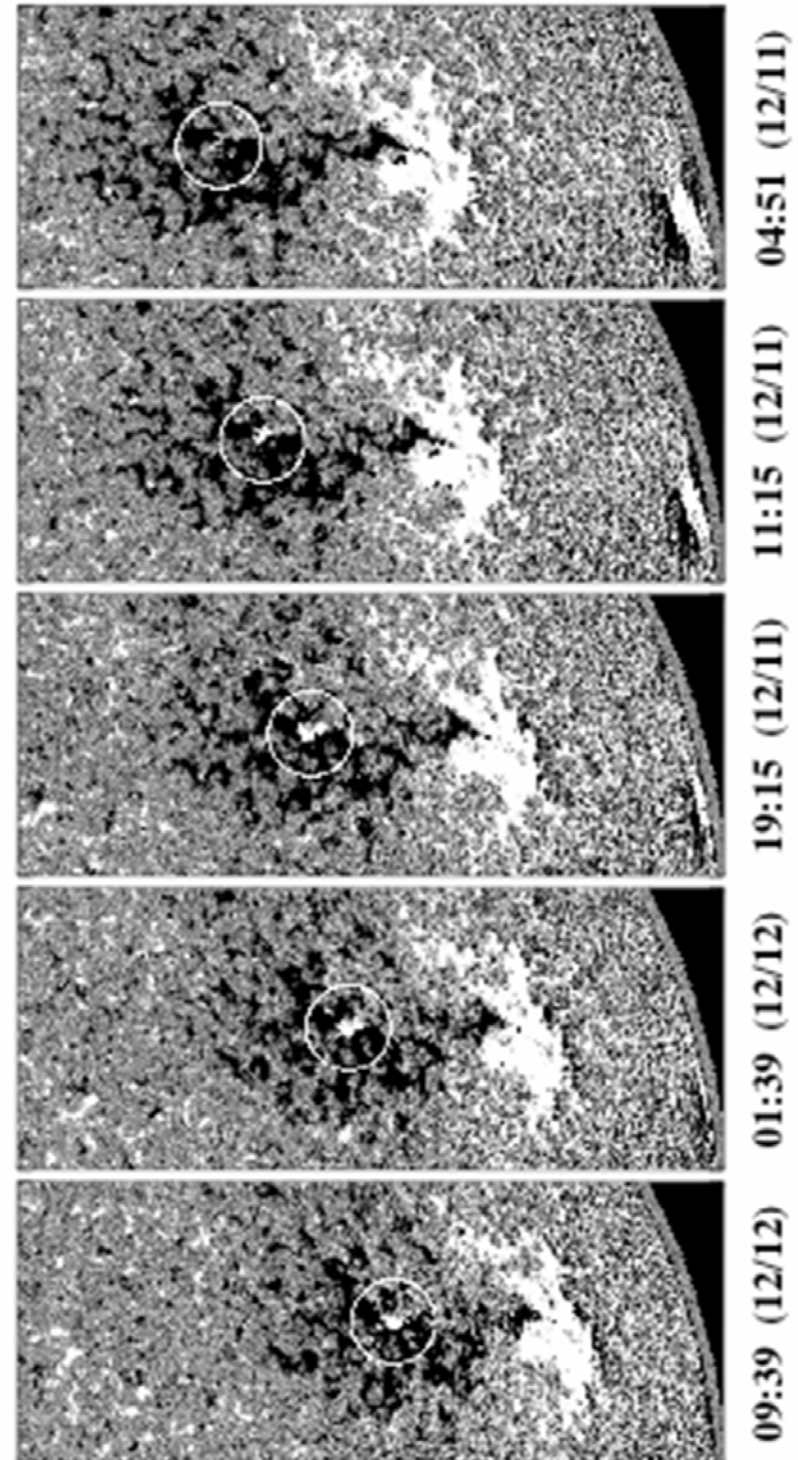
Fe XII L195 jets are commonly observed when magnetic bipoles emerge inside or near coronal holes, which in turn are embedded inside large unipolar regions (Wang et al. 1993; Wang & Sheeley 2002)

Fig. 13 Sequence of MDI Ni I 16768 magnetograms showing emergence of positive polarity flux within a large negative-polarity area during the day preceding the LASCO/EIT ejections of 12/2/02. The eruptions were centered about the newly emergent bipole.

Grey scale: $B_{\text{los}} < -20$ G (black) to $B_{\text{los}} > 20$ G (white)

Wang, Pick, & Mason, *ApJ*, 639, 495, 2006

2002 DECEMBER 11 - 12



Yohkoh images of an x-ray jet

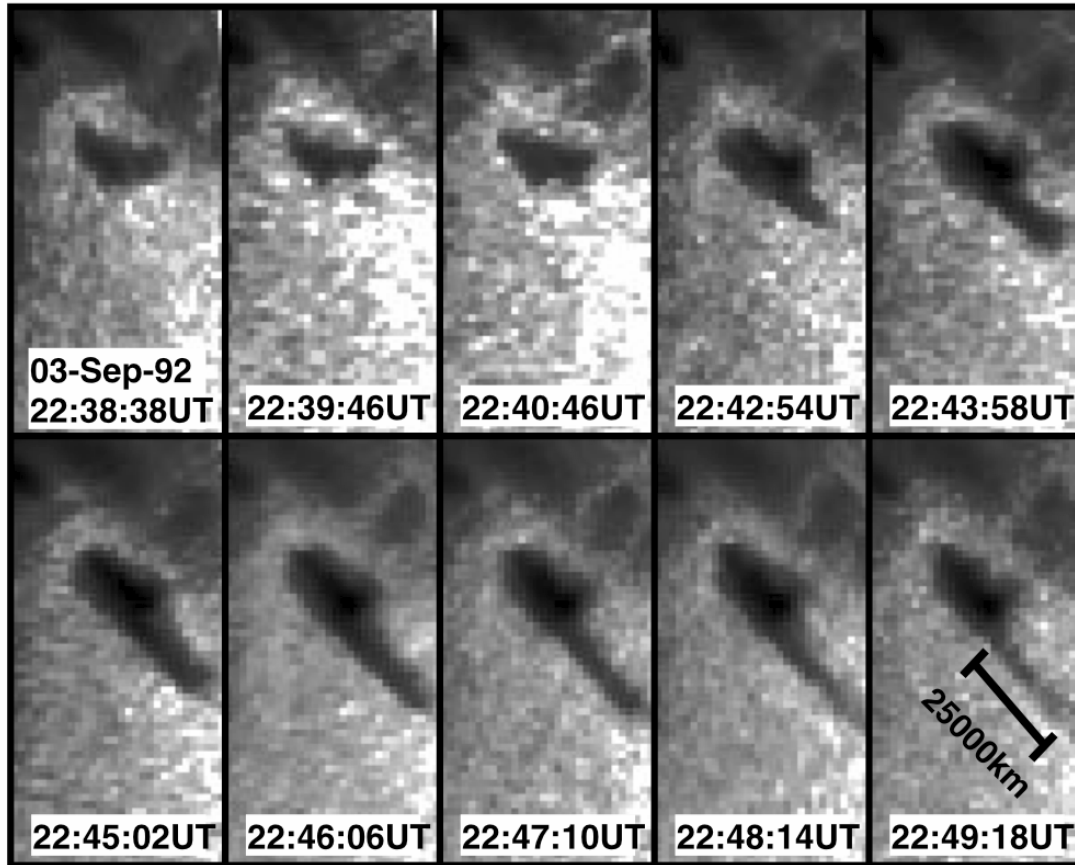


FIG. 1.—Example of an X-ray jet (1992 September 3 event)

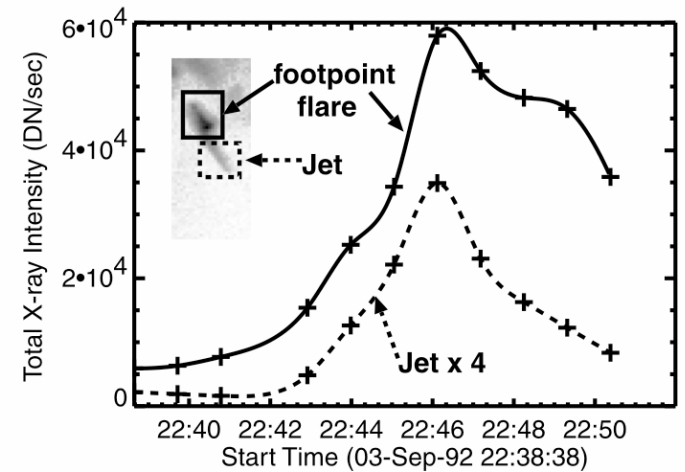


FIG. 2.—Time profile of X-ray intensity of the jet and the footpoint flare.

Wavelength 3-40 Å

$\sim 1.5 \times 10^6$ - few $\times 10^7$ K

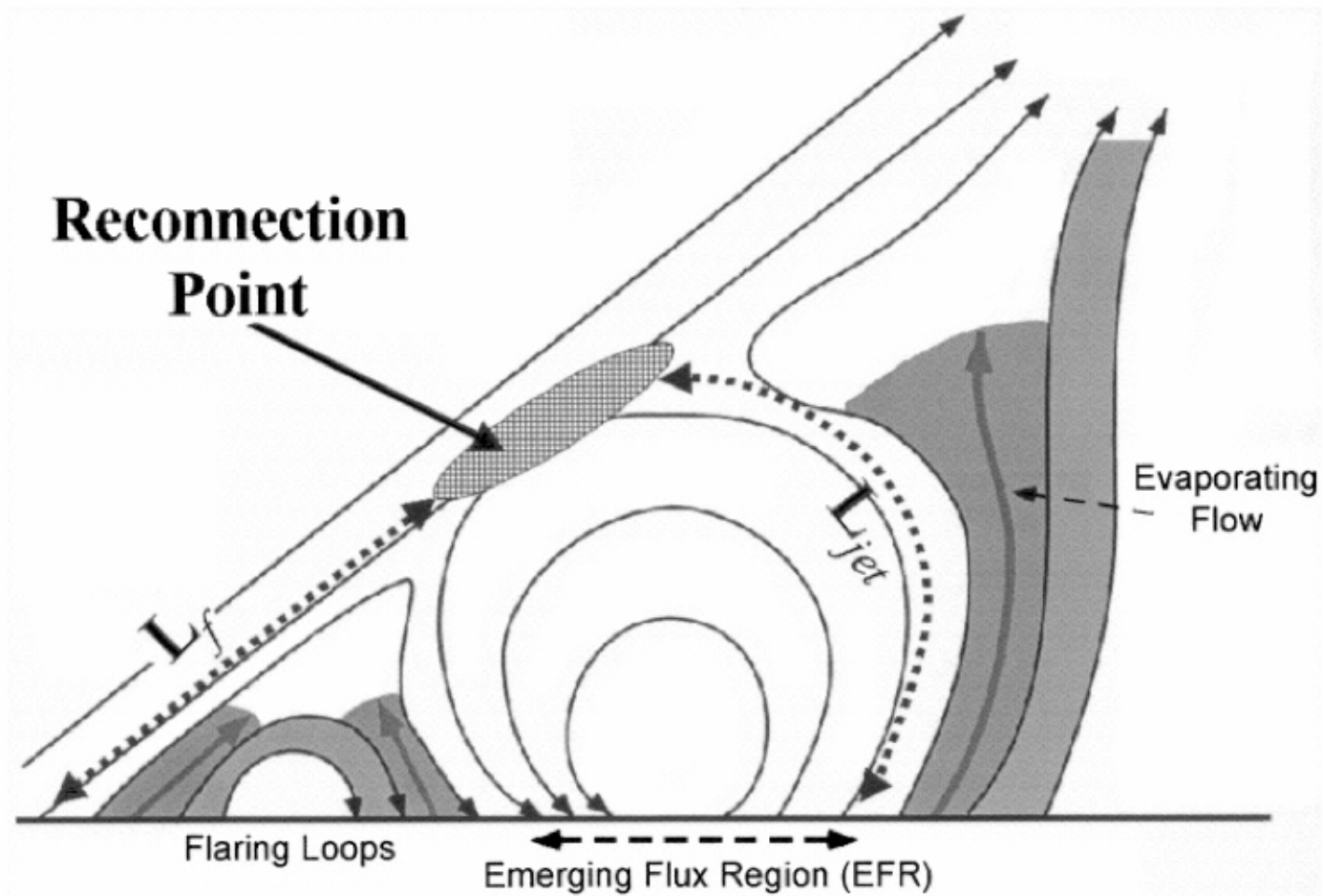
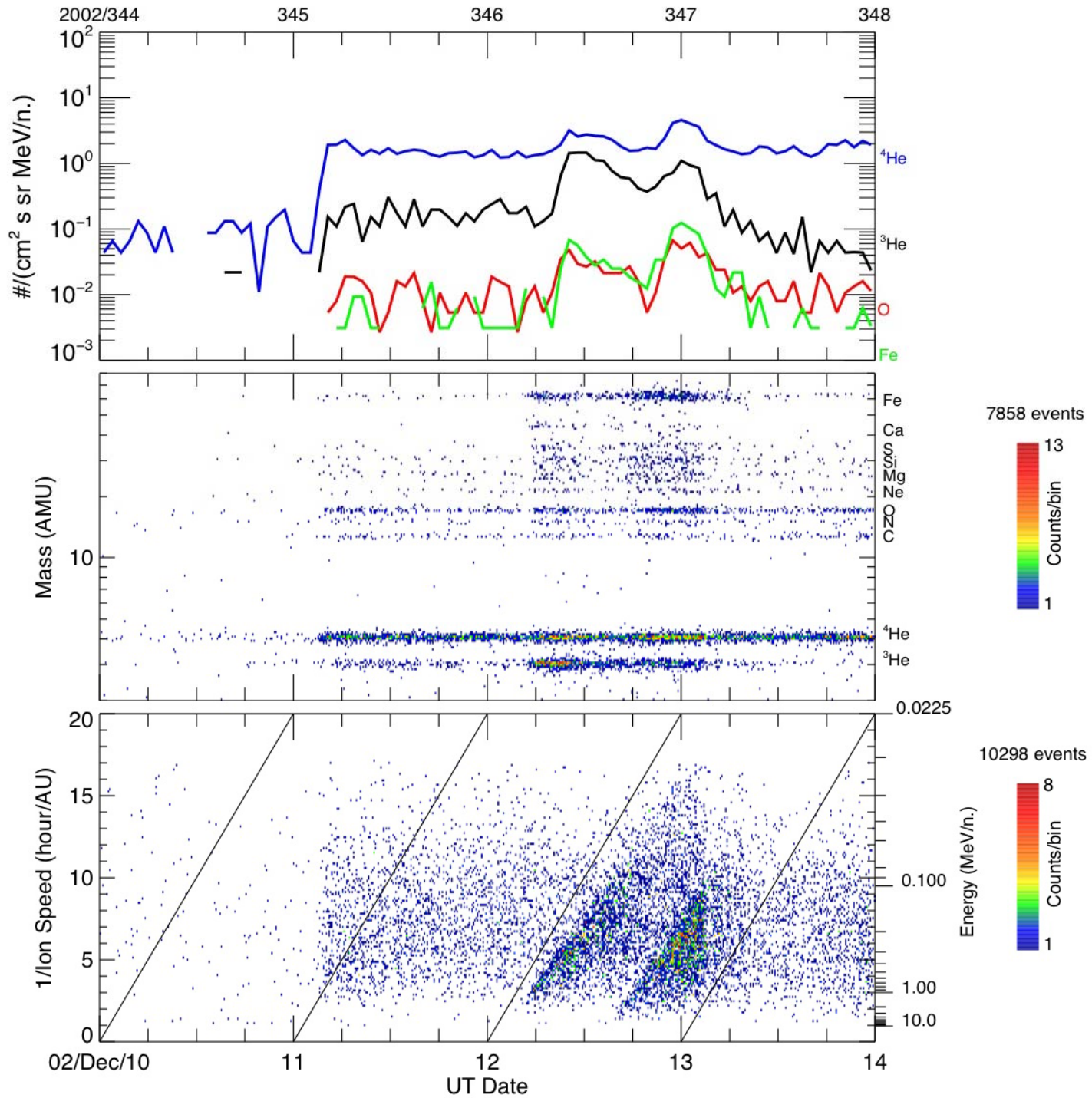


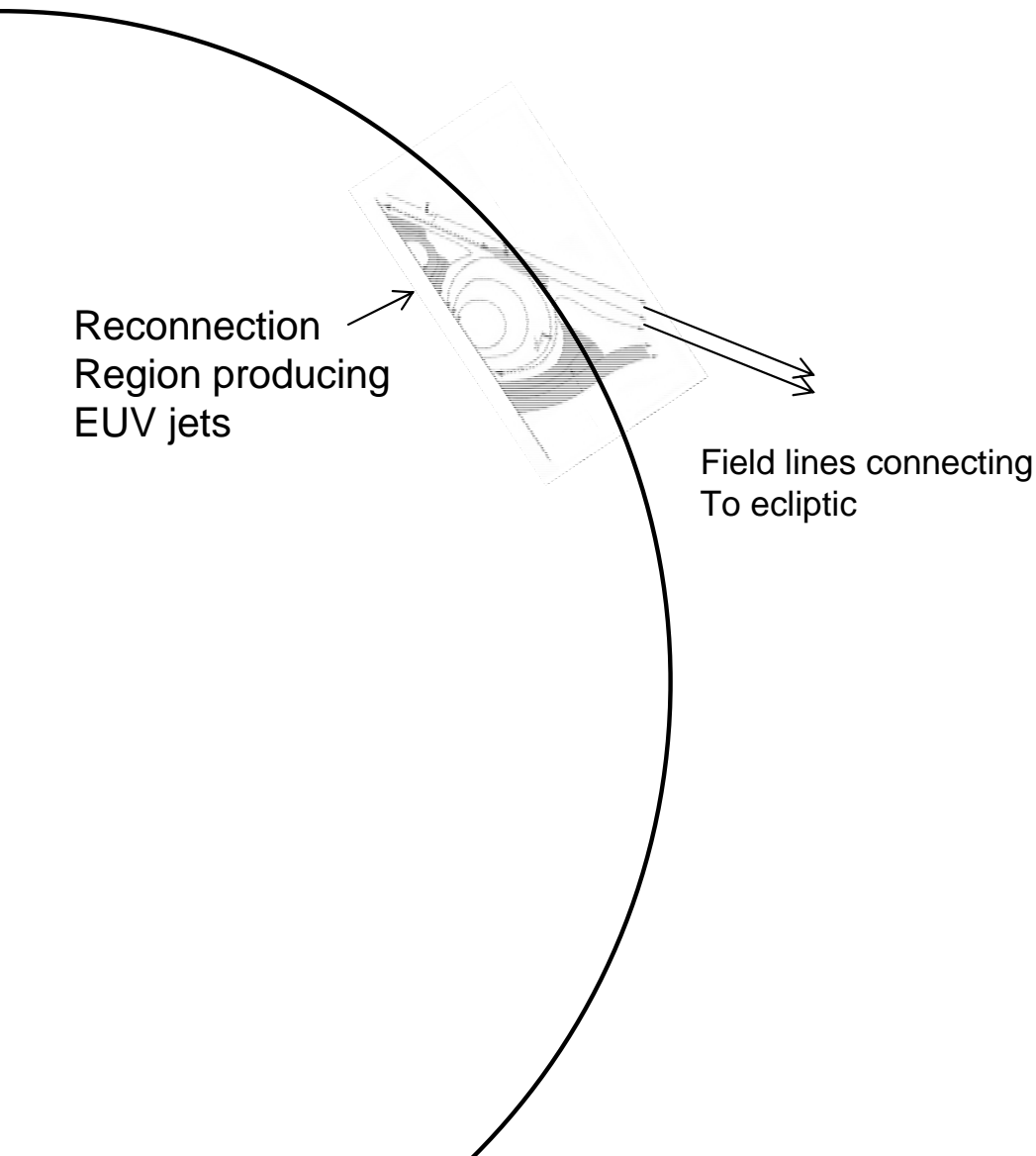
FIG. 7.—Reconnection jet model from Shimojo & Shibata (2000), based on magnetic reconnection and a jet. L_{jet} and L_f are the distances from the reconnection region to the flare and associated jet.

Shimojo and Shibata 2000 model for Solar X-ray jets (ApJ, 542, 1100)

Also used by Kahler et al. 2001 (ApJ 562, 558); Reames 2002 (ApJ 571, L63)

Top: 0.23–0.32 MeV/n. Intensity; Middle: Energy range = 0.4–10 MeV/n.; Bottom: Mass Range = 10–70 AMU





Open questions:

- do ions get accelerated in the reconnection region?
- or are they accelerated in connection with the jet and possible CME?
- are ions present during all the reconnection activity, and only seen at Earth when field lines open up to the ecliptic?
- are the ions accelerated at low coronal heights, as suggested by charge state measurements?
- Or
- are they accelerated high in the corona as suggested by electron spectra and timing studies of electron vs ion injection times?

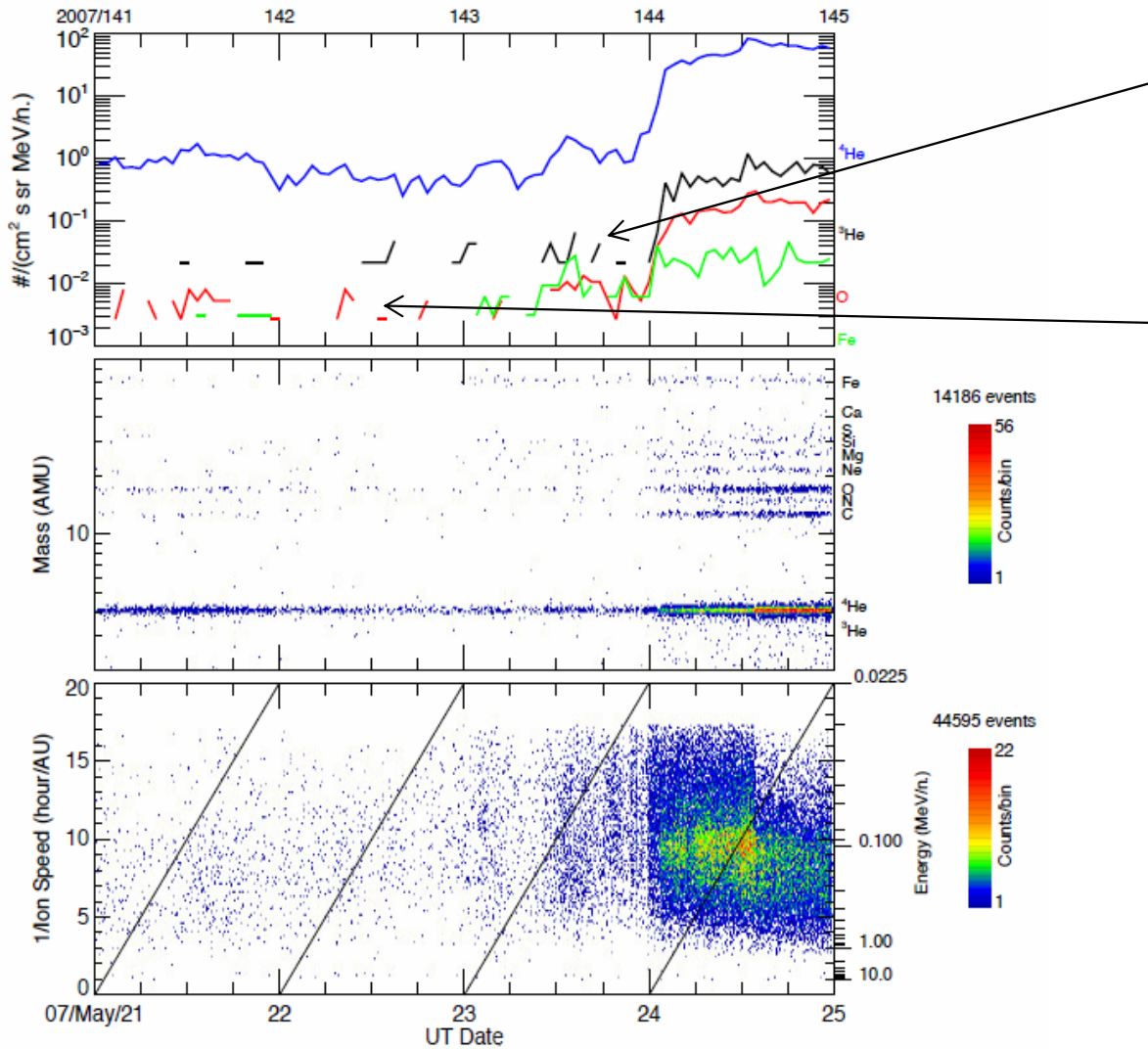
This survey–

- *most ^3He -rich events take place during active periods*
- *many things going on at roughly same time*
- *in 2007-2008 very low levels of solar activity*
- *search for ^3He -rich events on nearly quiet Sun, where chances for source confusion and multiple events is reduced*
- *surveyed ACE/ULEIS data for 2007-2008 following the ^3He -rich event in Jan 2007.*
- *4 events found, all smaller than events typically published in prior surveys: May 23, 2007; Feb 5, 2008; June 16, 2008; Nov 4, 2008*

May 23, 2007 event

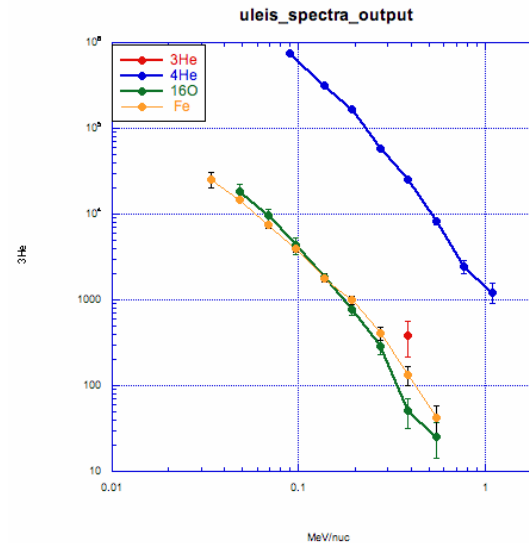
Created-Fri Sep 26 11:47:57 2008

Top: 0.23–0.32 MeV/n. Intensity; Middle: Energy range = 0.4–10 MeV/n.; Bottom: Mass Range = 10–70 AMU

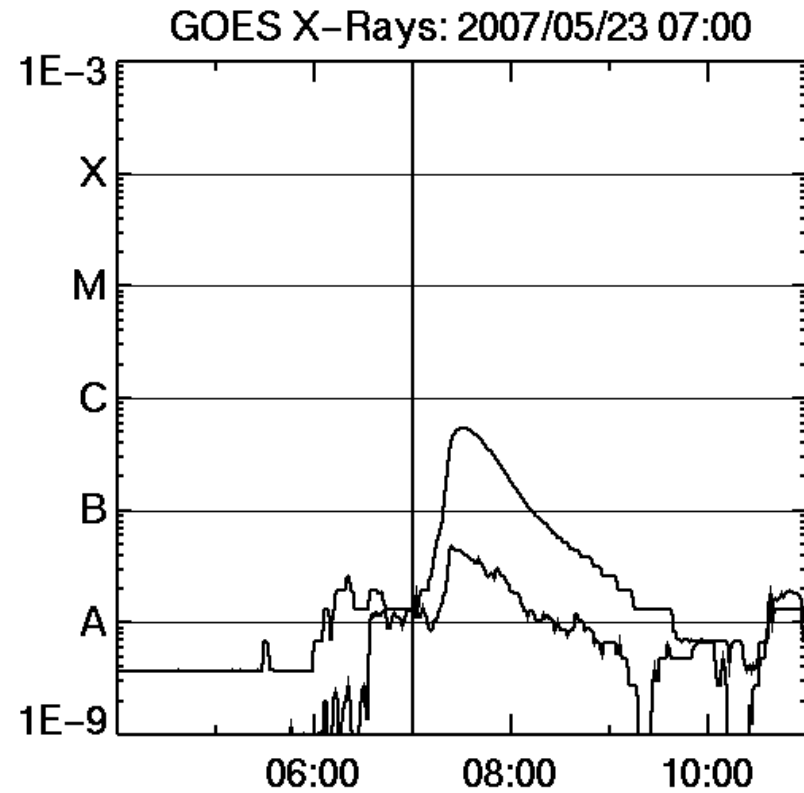


ACE/ULEIS data:

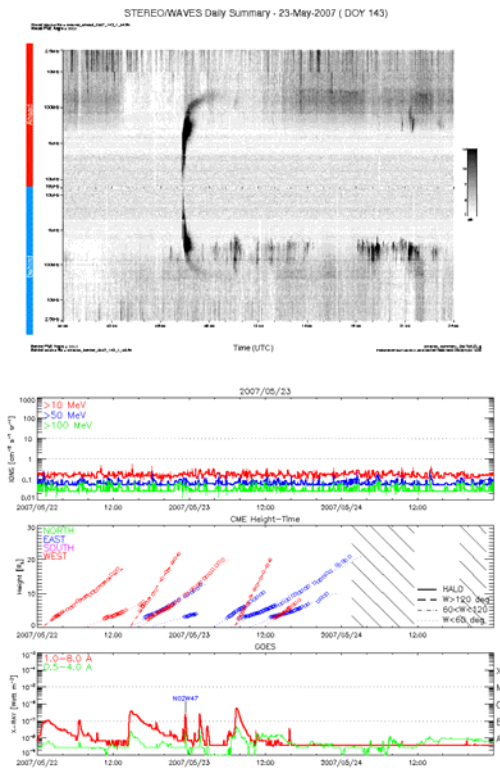
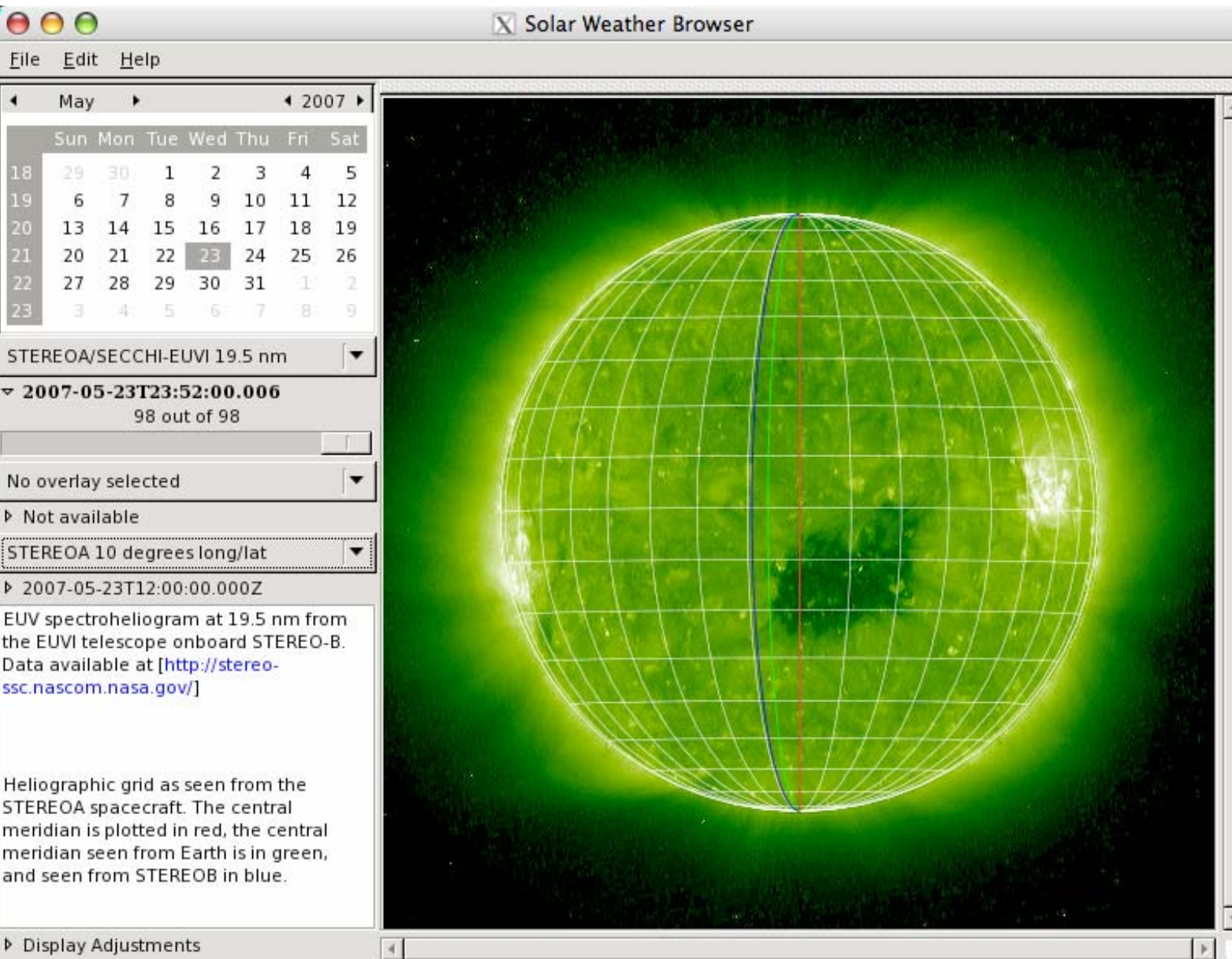
- 3He present
- Fe/O ~ 1, typical
- occurred just before a CIR (high speed solar wind stream), typical
- note slight presence of 3He and enhanced Fe/O for 2 days before event



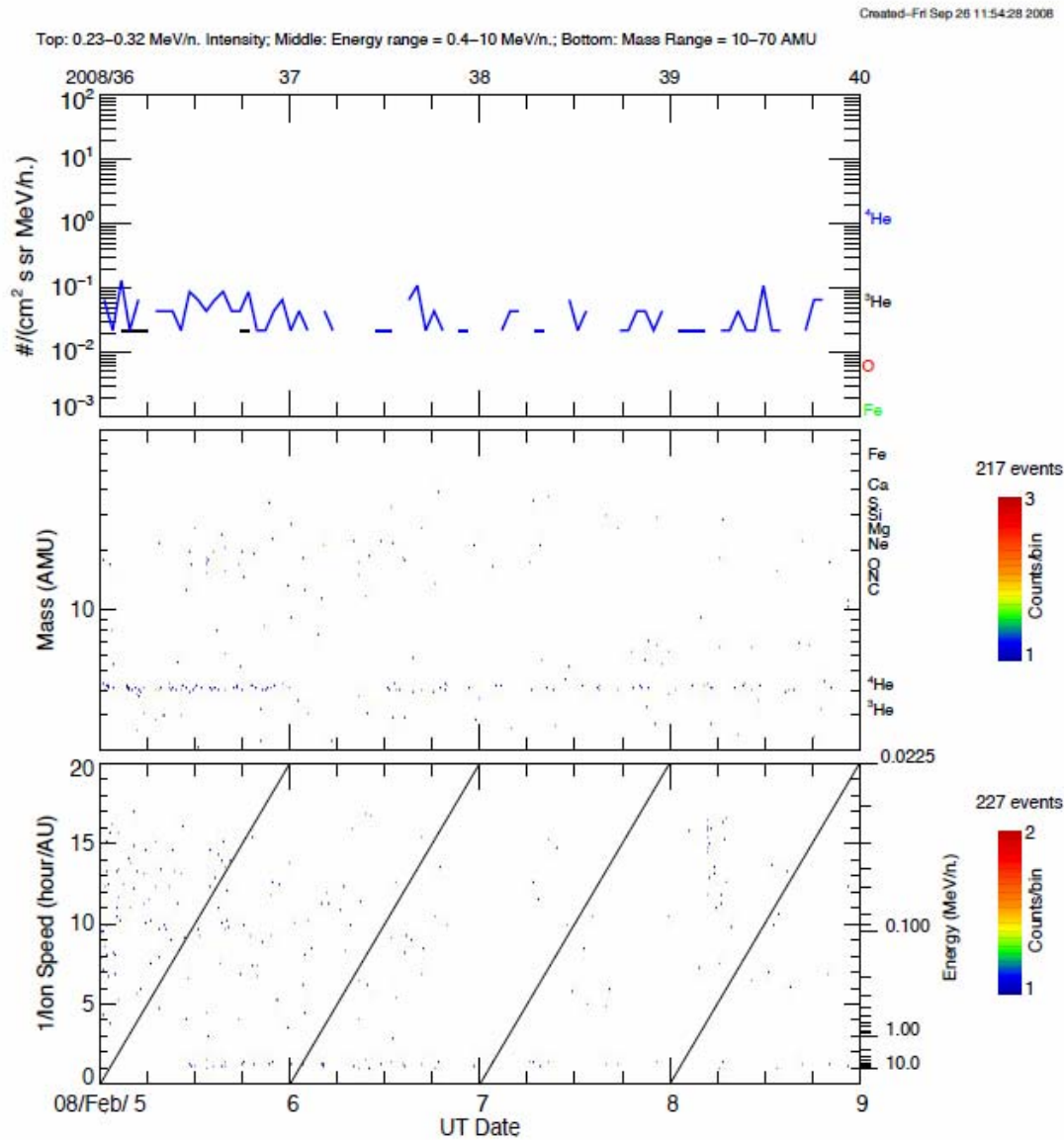
May 23, 2007 event



May 23, 2007 event

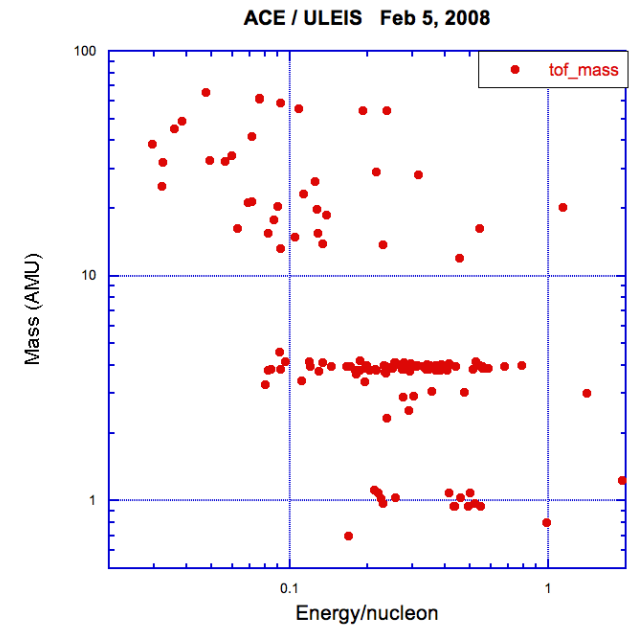


Feb 5, 2008 event

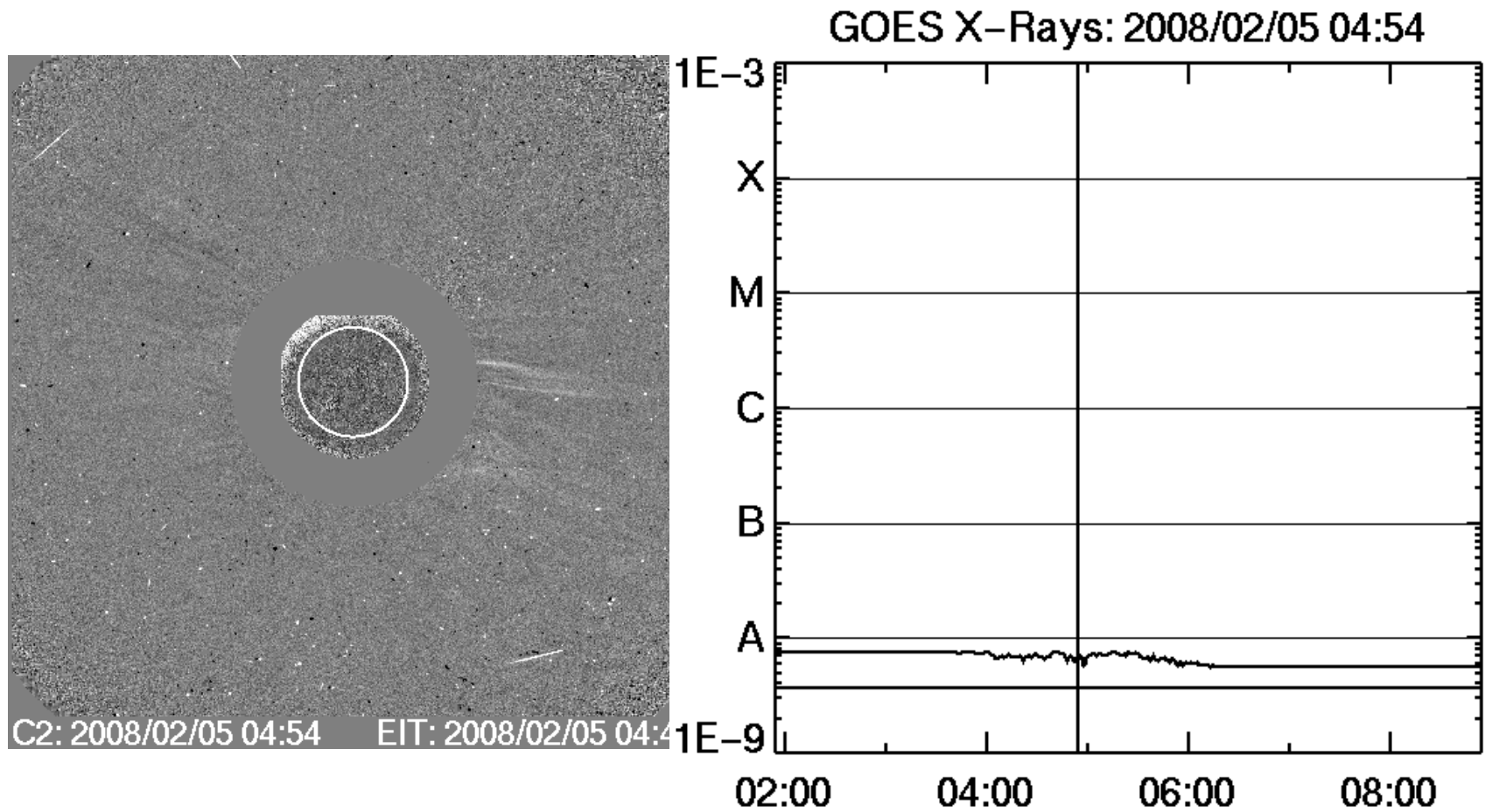


ACE/ULEIS data:

- ^3He present
- Fe/O ~ 1 , typical
- barely at the level of detectability



Feb 5, 2008 event

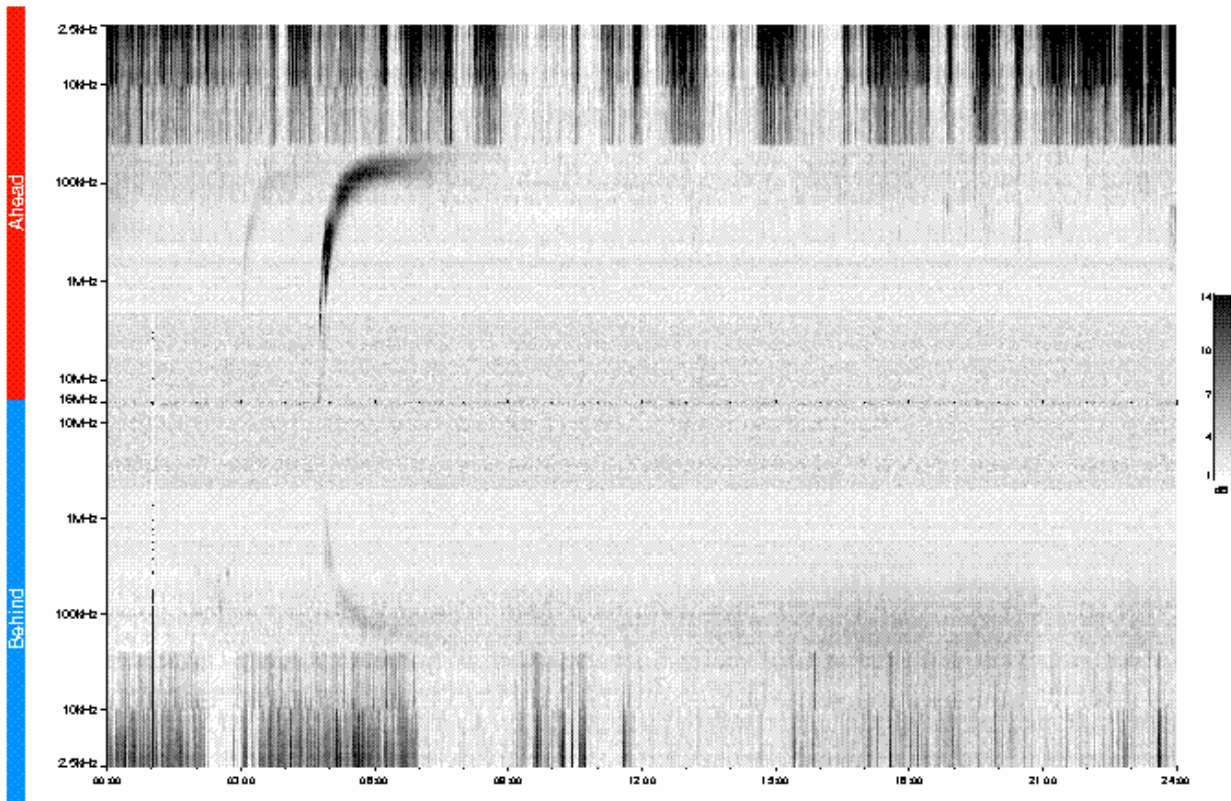


CME observed, but note GOES X-rays below class A

Feb 5, 2008 event

STEREO/WAVES Daily Summary - 05-Feb-2008 (DOY 036)

Ahead source file = swwaves_ahead_2008_02_05_1_07.fn
 Ahead PSE Angle = 3000K



Behind PSE Angle = 3000K
 Behind source file = swwaves_behind_2008_02_05_1_07.fn

Time (UTC)

swwaves_summary_20080205_07
 PSE Angle = 3000K

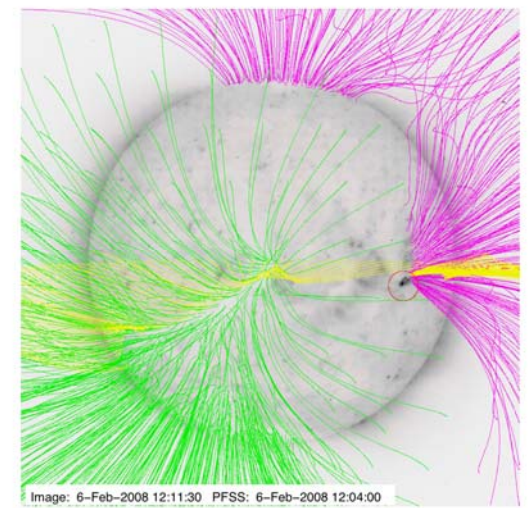
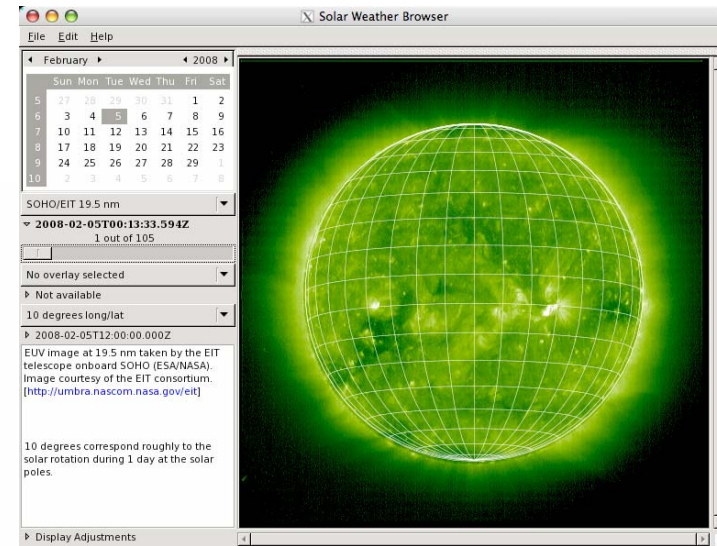
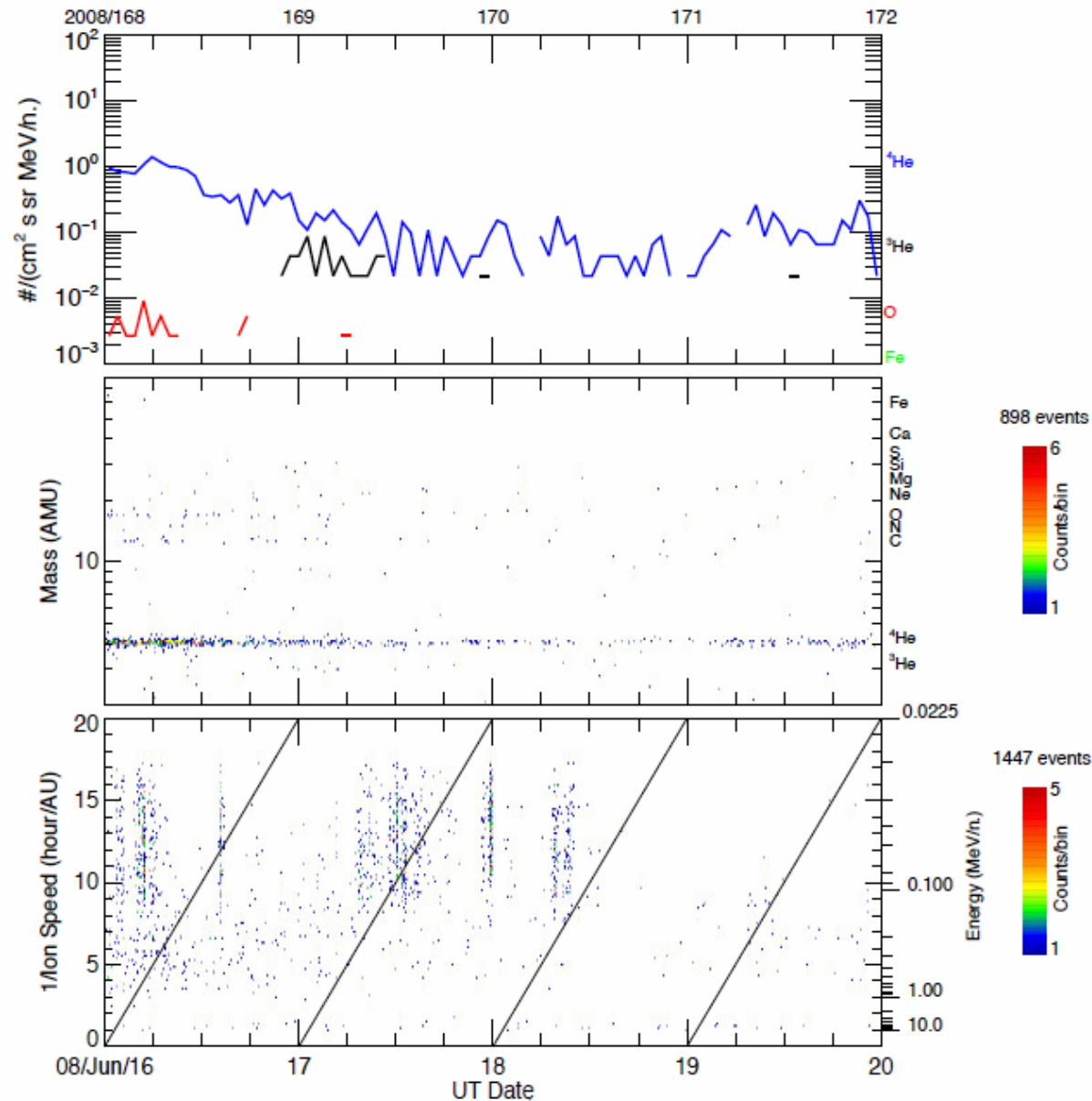


Image: 6-Feb-2008 12:11:30 PFSS: 6-Feb-2008 12:04:00

June 16, 2008 event

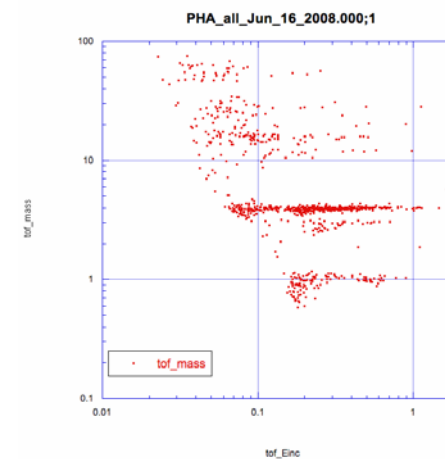
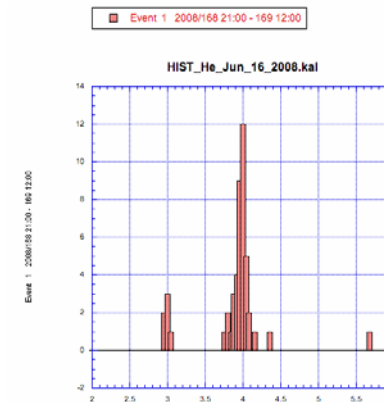
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Top: 0.23–0.32 MeV/n. Intensity; Middle: Energy range = 0.4–10 MeV/n.; Bottom: Mass Range = 10–70 AMU

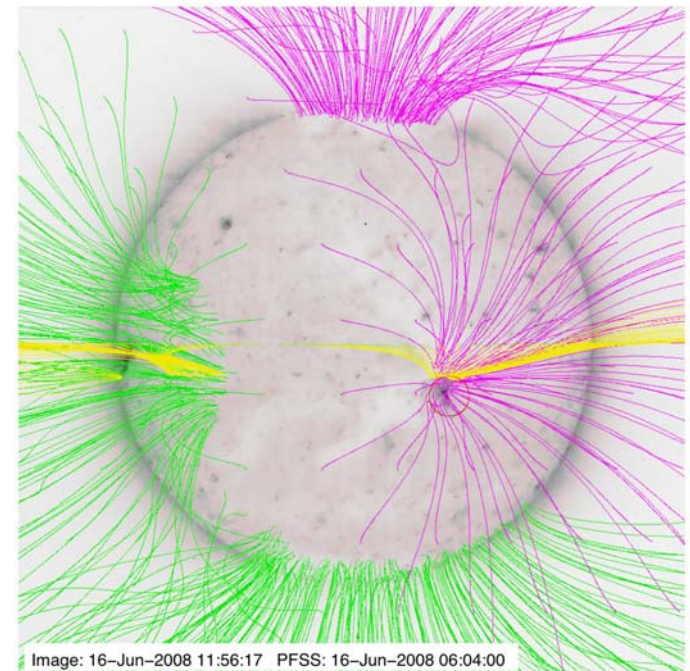
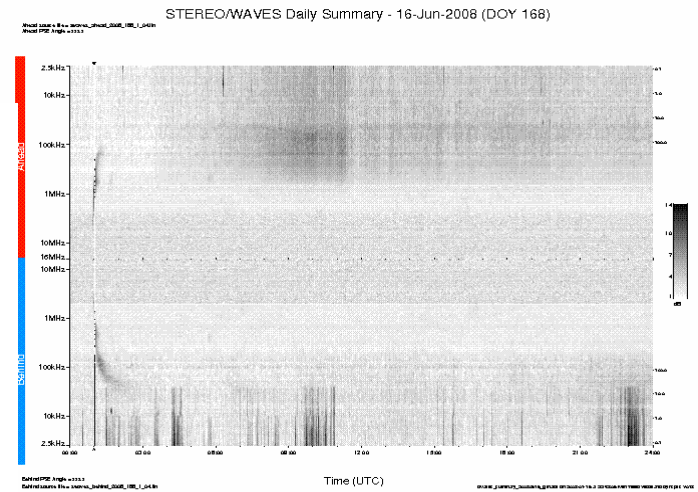
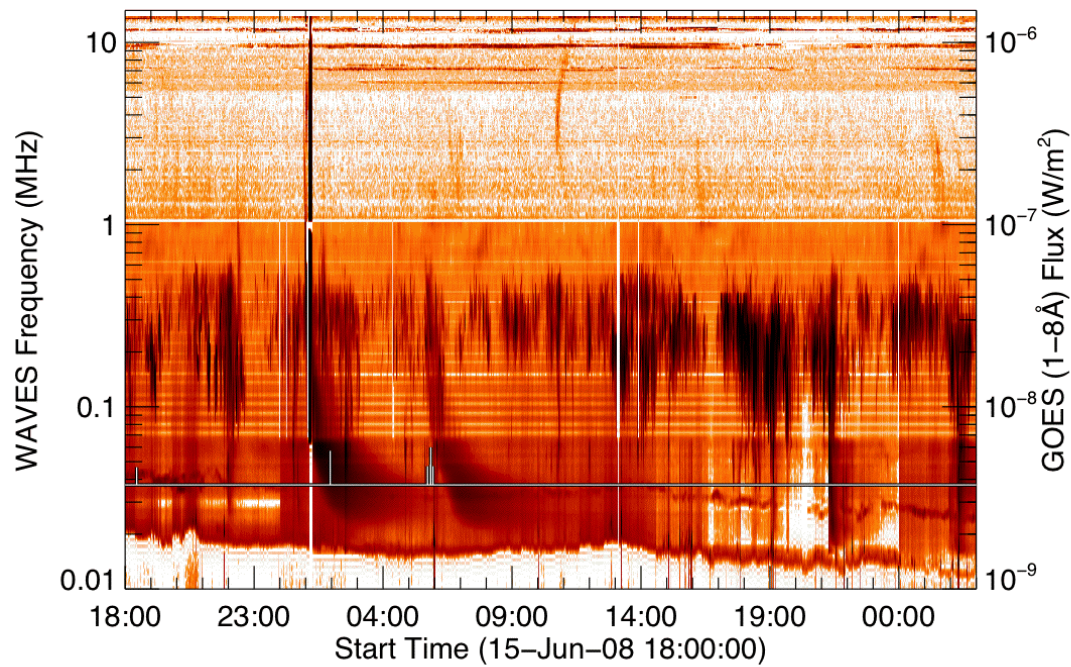


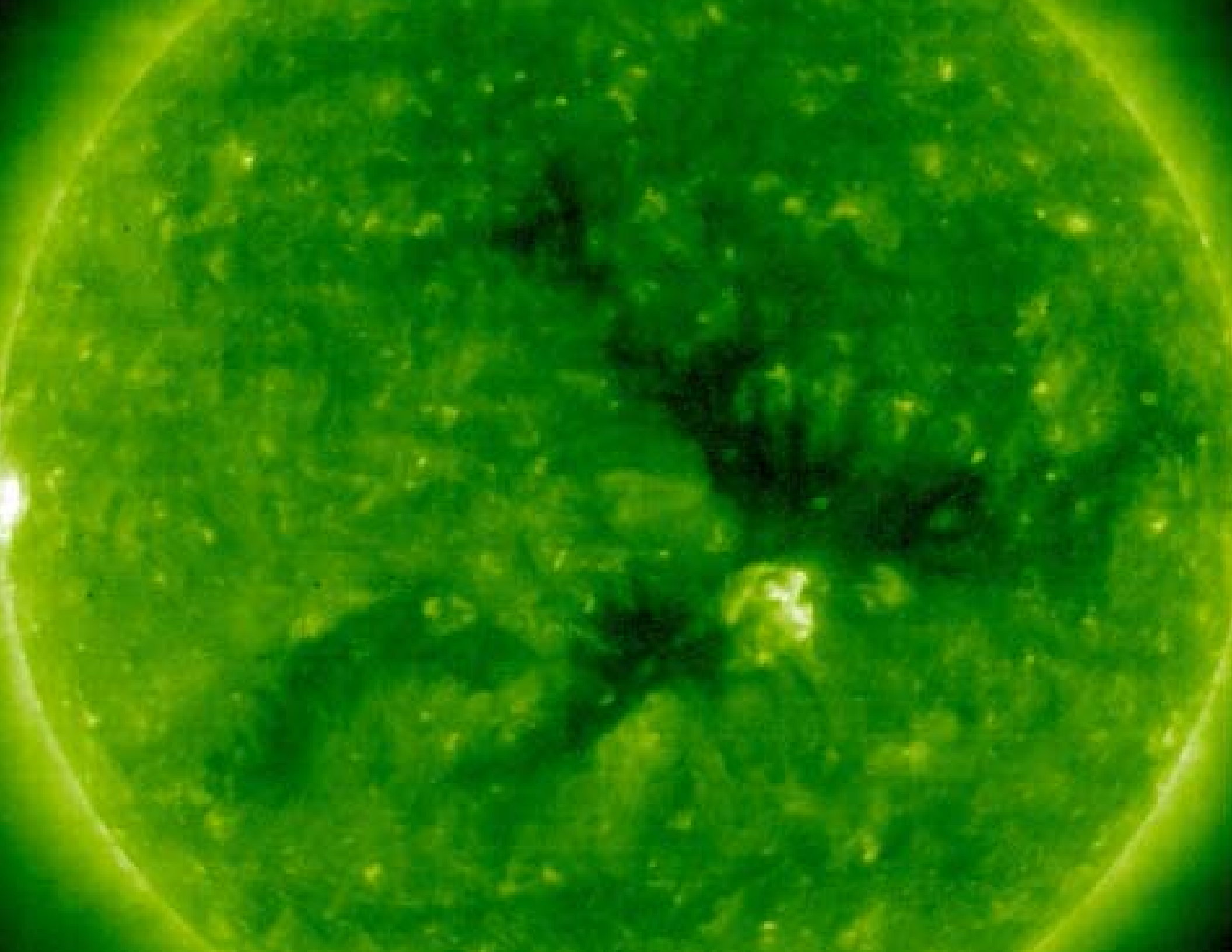
ACE/ULEIS data:

- 3He present
- Fe/O ~ 1, typical
- followed a small CIR

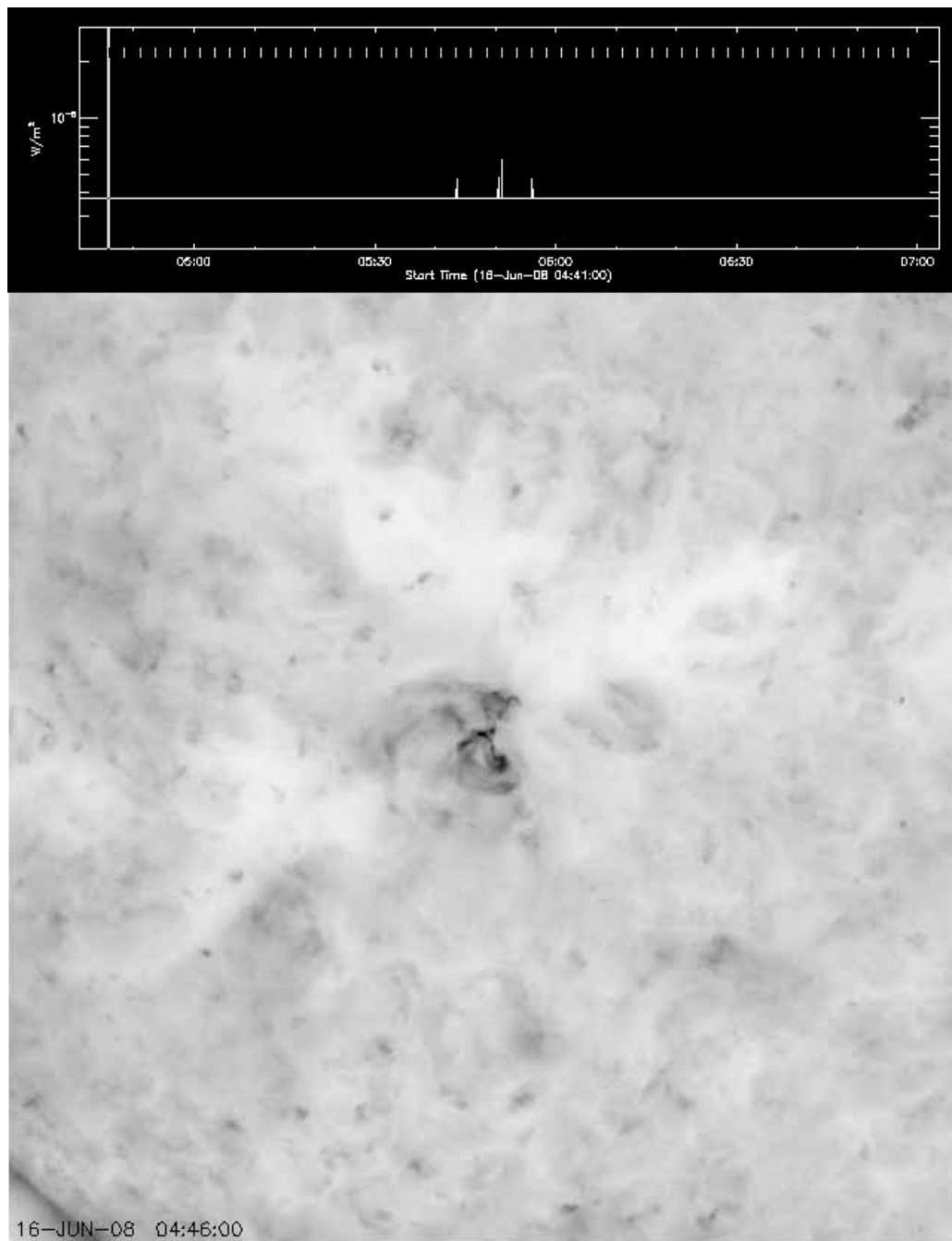
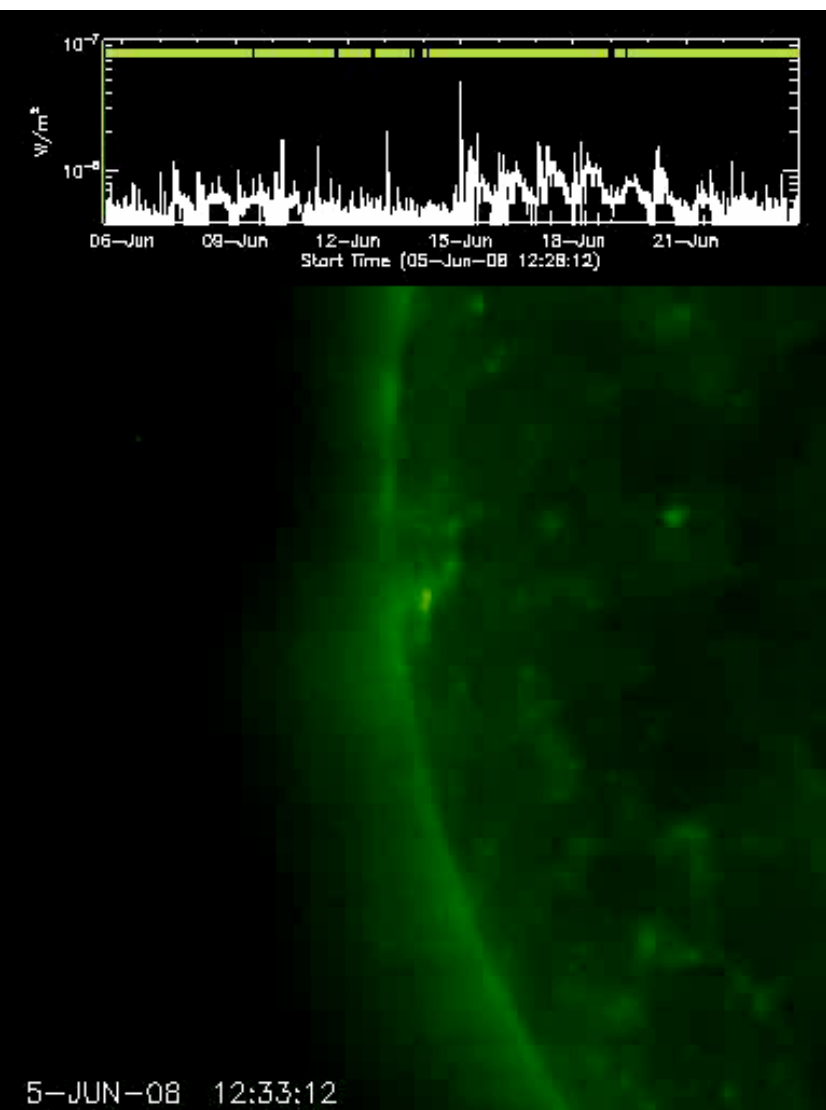


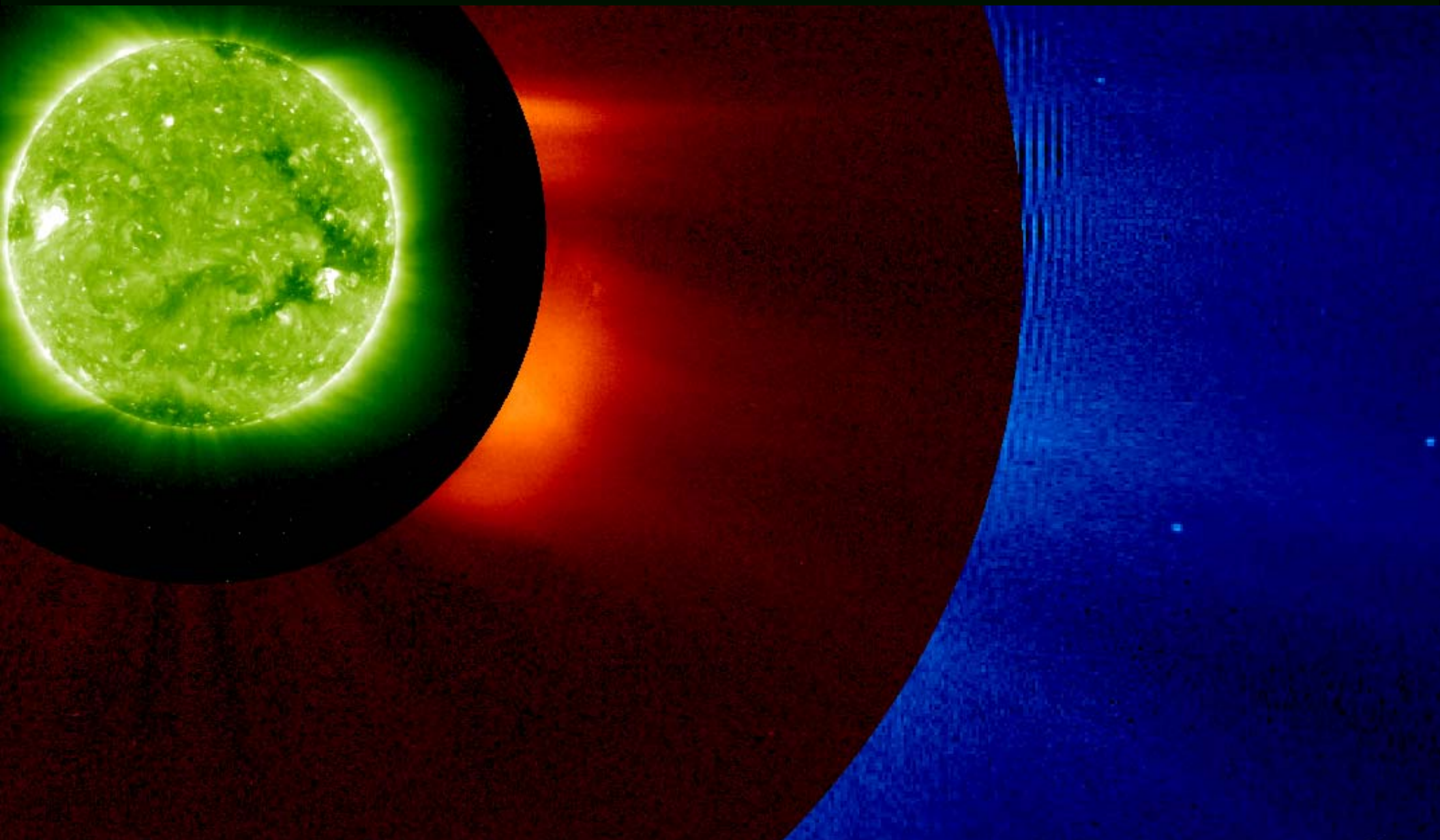
June 16, 2008 event





June 16, 2008 event





FESTIVAL

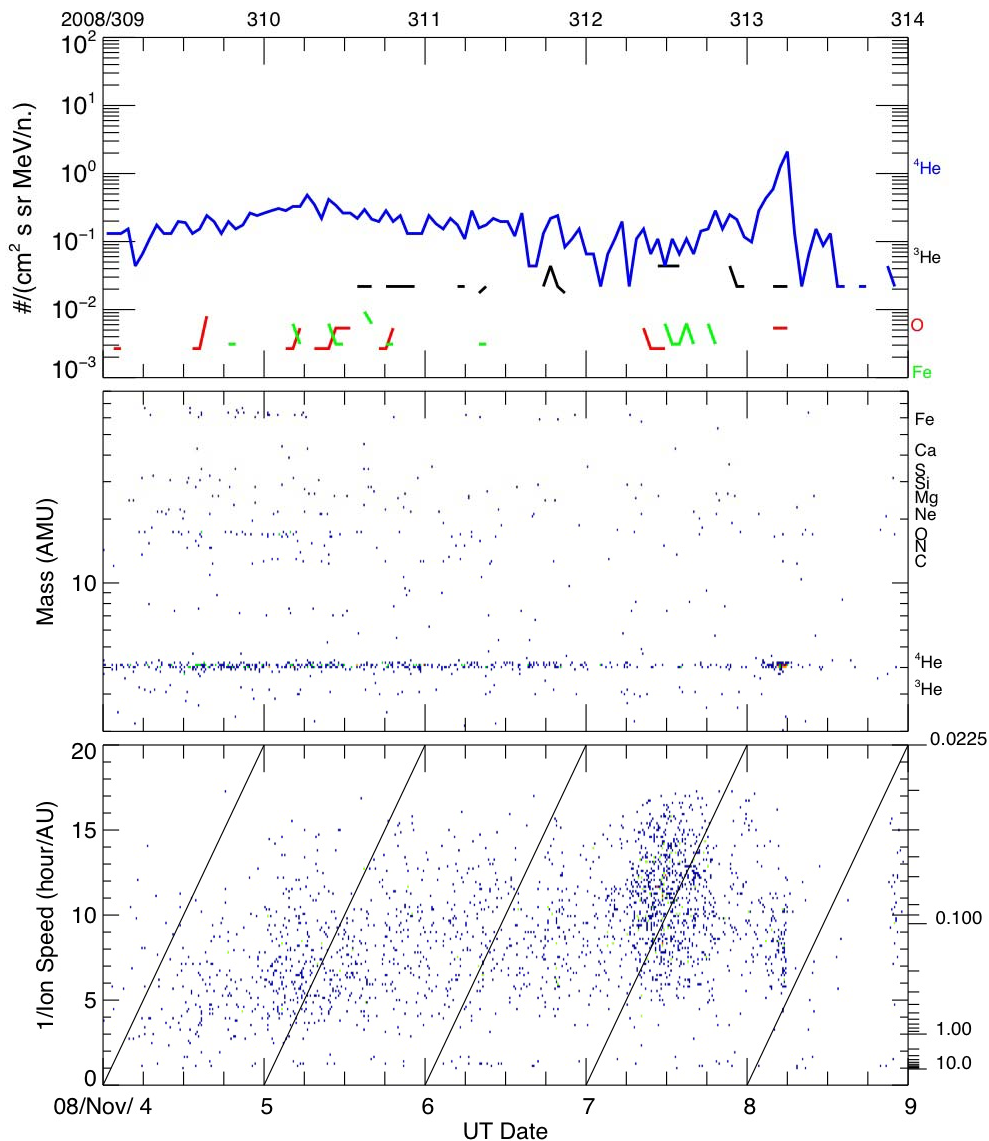
EUVI (195 A): 05:36:21, COR1: 05:45:51, COR2: 05:52:51

SECCHI

Nov 4, 2008 event

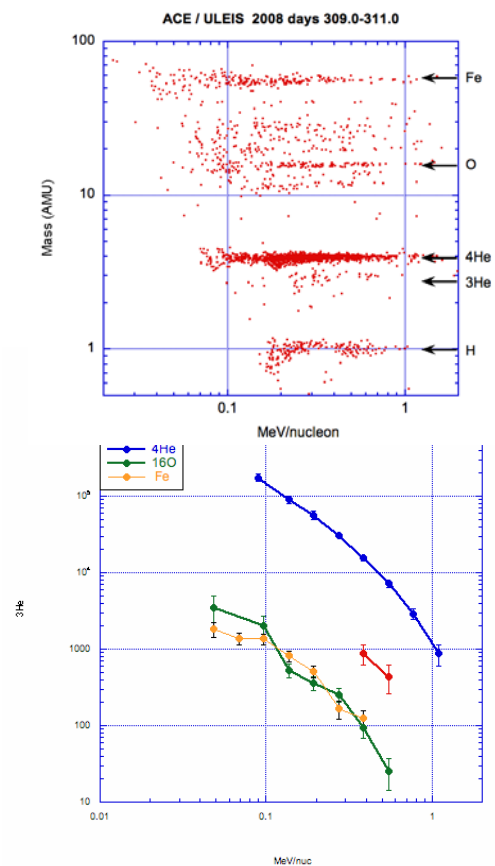
Created-Fri Jan 30 16:55:04 2009

Top: 0.23–0.32 MeV/n. Intensity; Middle: Energy range = 0.4–10 MeV/n.; Bottom: Mass Range = 10–70 AMU

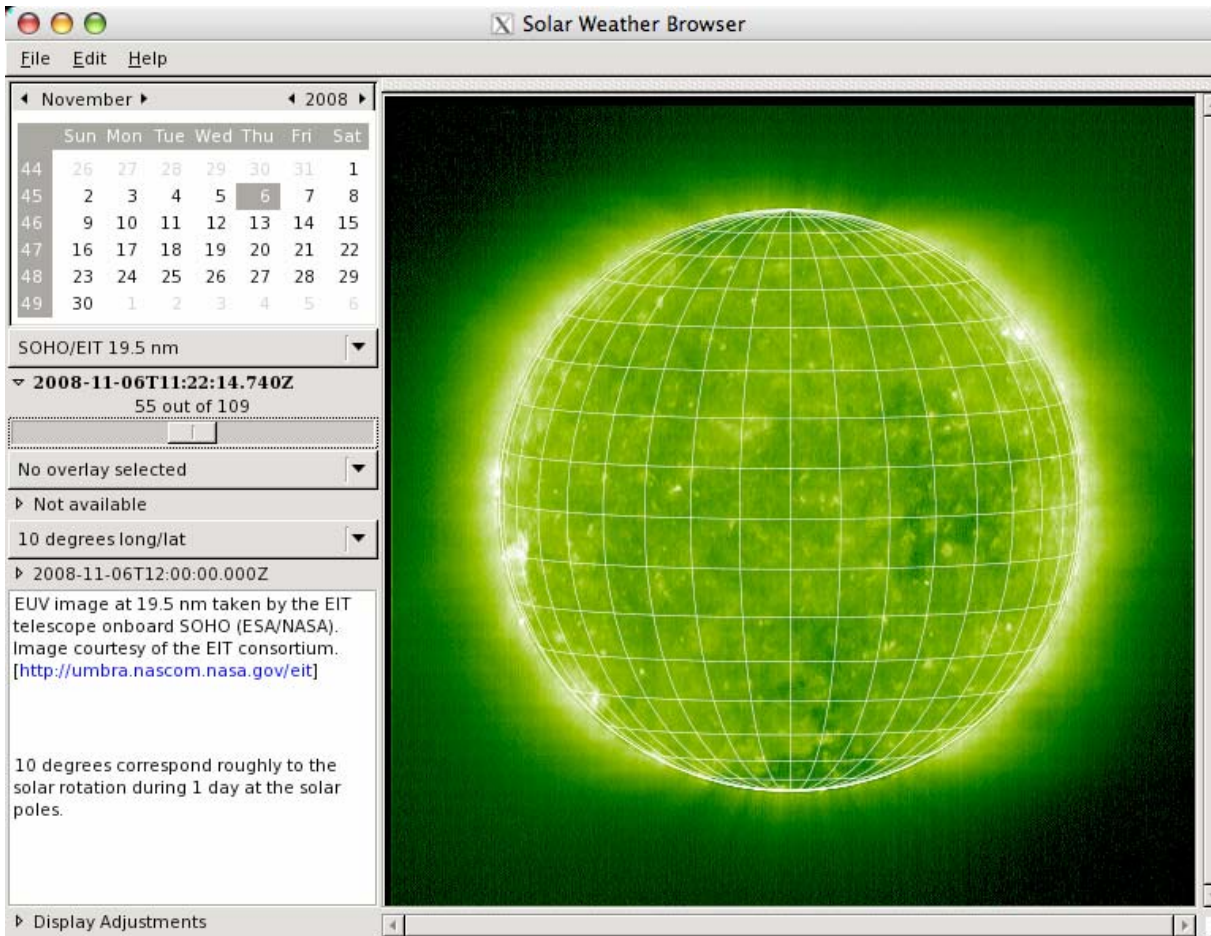


ACE/ULEIS data:

- 3He present
- $Fe/O \sim 1$, typical
- note slight presence of 3He and enhanced Fe/O persists for days before event

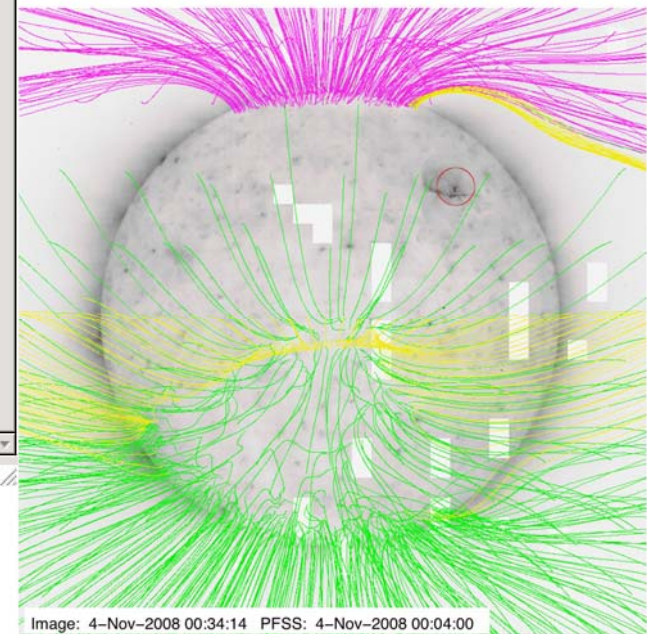


Nov 4, 2008 event

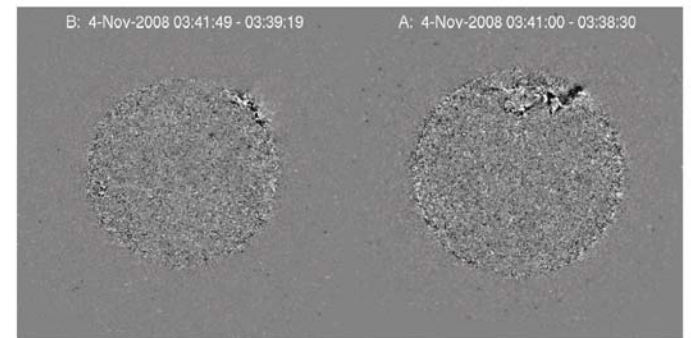
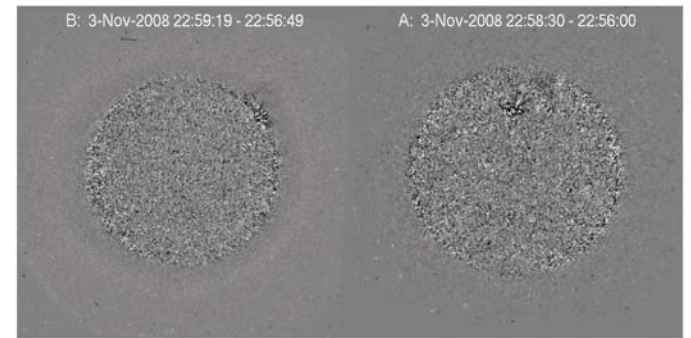
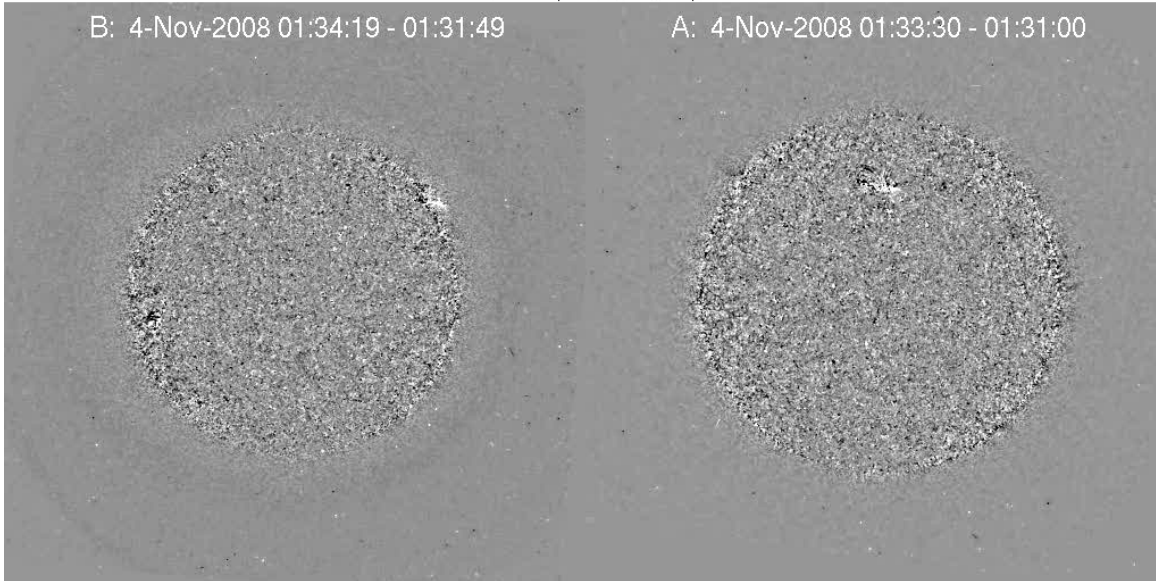
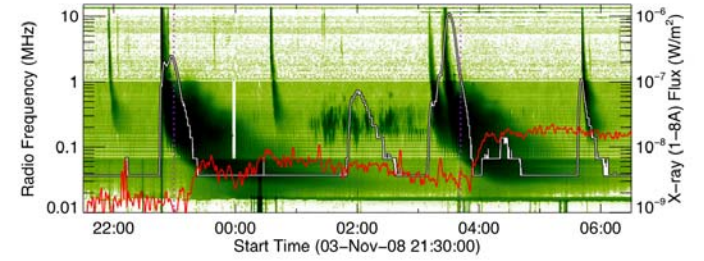
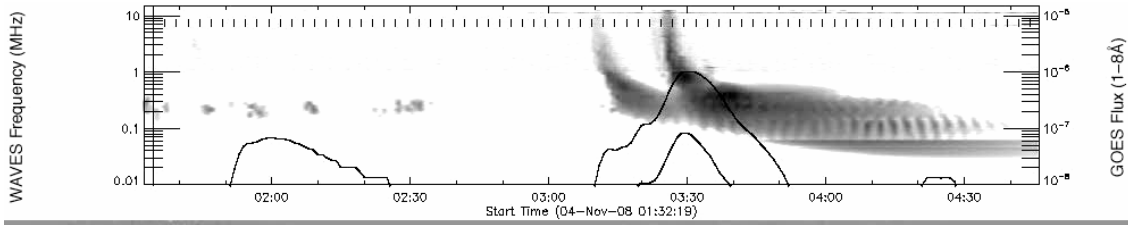


active region on west limb shows some transients near time of type III

PFSS model does not show any field line connections to ecliptic



Nov 4, 2008 event



STEREO-B & A

Summary—

- *We have surveyed the period 2007 Feb – 2008 Dec for ^3He -rich ion events during solar minimum*
- *4 events were found, close to the threshold of detectability. These events were all smaller than ion events published in prior surveys.*



Summary— solar sources of ^3He rich SEP events

- The events showed characteristics similar to those identified in the study by Yi-Ming Wang et al (2006) in that they were in active regions with reasonable connection to the ecliptic - however conspicuous jets were not seen*
- in one case, June 16, 2008, there was no X-ray signature, and a Type III burst early in the day was several hours earlier than would be expected given the roughly measured particle onset; there was no obvious CME, but there may have been a dimming.*
- Two of the events showed presence of impulsive material for more than one day, even though the activity outbursts were small and did not last long.*
- This might suggest that activity in the reconnection region is associated with an initial stage of ion acceleration, including enhancements with mass; additional activity, if it occurs, further energizes these ions.*