PROCEEDINGS OF SCIENCE

The Large Solar Energetic Storm Particle Event of September 18, 2017 Observed by STEREO-A

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Abstract: Solar Cycle 24 solar activity ended during September 2017 with a series of ”bangs” that included four X-Class flares, a record-breaking 3000 km/s CME, and a large ground-level event, all recorded by Earth-based observers. Less well known is the eruption of a far-side CME from the same active region on September 17, which resulted in a spectacular energetic storm particle (ESP) event observed on September 18-19 at STEREO-We report the time history, energy spectra, and composition of ~0.1 to 100 MeV/nucleon ions and 0.1 to 4 MeV electrons measured during this period by the SEPT, LET and HET instruments on STEREO-A. We also compare this event with the intense July 23, 2012 ESP event also observed by STEREO-A. The composition of ESP ions will be compared with possible seed-particle sources. Finally, these observations will serve as a basis for a modeling effort to be reported by Hu et al. at this conference.

There have been several studies of solar-maximum-ending activity during September 2017, including a special issue of Space Weather. With a few exceptions (e.g., Luhmann et al. (2018, Bruno et al. (2018) most of these have focused on activity observable from near-Earth spacecraft and ground-based facilities. This paper will focus on a far-side (eastern) 1380 km/s CME on September 18 that resulted in a spectacular energetic-storm-particle (ESP) event observed by STEREO-A. We report on the magnitude of the ESP enhancements of different species observed in this event. We have also measured the composition and energy spectra observed by instruments from the STEREO-IMPACT collaboration as well as solar-wind data from STEREO IMPACT & PLASTIC instruments. The observed properties of the 9/18/17 event will be compared with the large SEP/ESP event of January 23, 2012

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1. Introduction: Shown below are figures that provide an overview of solar proton intensities, X-ray flares, and interplanetary shocks during September, 2017.

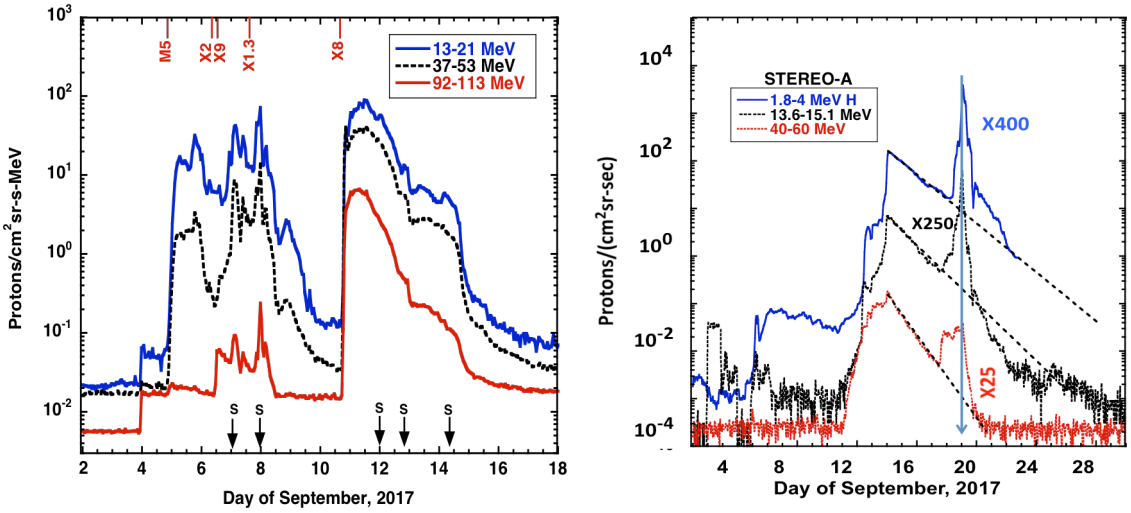

Figure 1 (left): The time history of near-Earth solar energetic particle (SEP) activity as seen by GOES-13. Also indicated are M and X-class flares, (top labels) and L1 interplanetary shocks (S). Some of this front-side activity is also observed at STEREO-A. The September 18 CME was aimed 15° to the west of STEREO-A. (right) As an illustration of the extreme "spike-like" nature of the September 2017 ESP event at STERREO-A, we show time histories of protons in three energy intervals from the Low-Energy Telescope (LET)[1]. [Note that the three narrow proton spikes stand out above the exponential decay of the September 10 event by factors ranging from ~25 to ~400! (measuring from the dotted line to the top of the spike). This shows that the Sept. 18 CME shock was a very efficient accelerator in spite of its 1380 km/s launch speed.

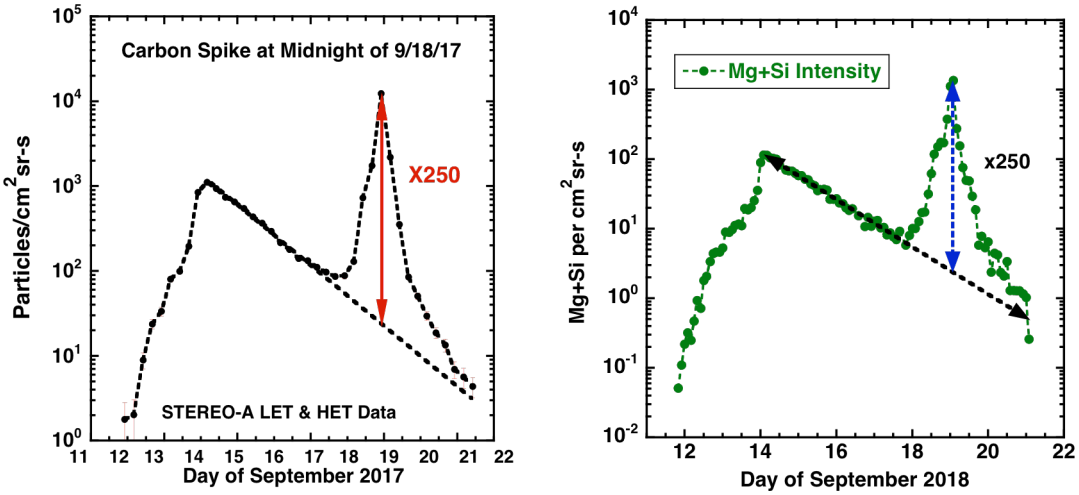

Figure 2: All heavy elements accelerated at this shock showed "spikes" extending ~250 times above the extrapolated decay profile of the pre-shock ion intensity. The heavy-ion profiles are all from the LET Telescope on STEREO-A.

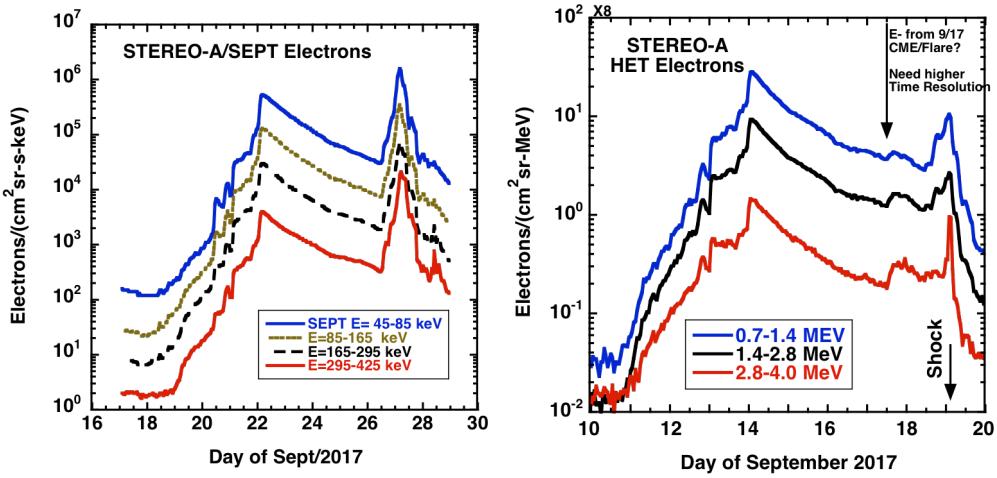

Figure 4a (left): Electron time histories from the STEREO-A Electron time histories from the STEREO-A Solar Electron and Proton Telescope (SEPT)[2] and HET [3]. The profiles are similar to those for ions (Figure 1 and 2) with elevated intensities from the earlier front-side events (especially Sept.10) followed by a significant response to the shock on late September 18-19.

The September 18 CME was also an efficient accelerator of electrons (Figure 4). It made a quasi-perpendicular shock, which is generally more efficient at accelerating electrons. In Figure 4 we show electron time histories measured with the Solar Electron and Proton Telescope (SEPT; Muller-Mellin et al., 2008)[2] and with HET [3]. These time profiles are remarkably similar to those for the ions.

2. Comparison with the July 23, 2012 ESP Event.

Cohen and Mewaldt [4] catalogued the largest SEP proton events of Cycle 23 and 24 on the basis of their >10 MeV proton fluences at 1-AU. The two largest were September 1, 2014 and July 23, 2012, both measured by STEREO-A. We choose to compare the September 18 and July 23 ESP events which both had very large ESP

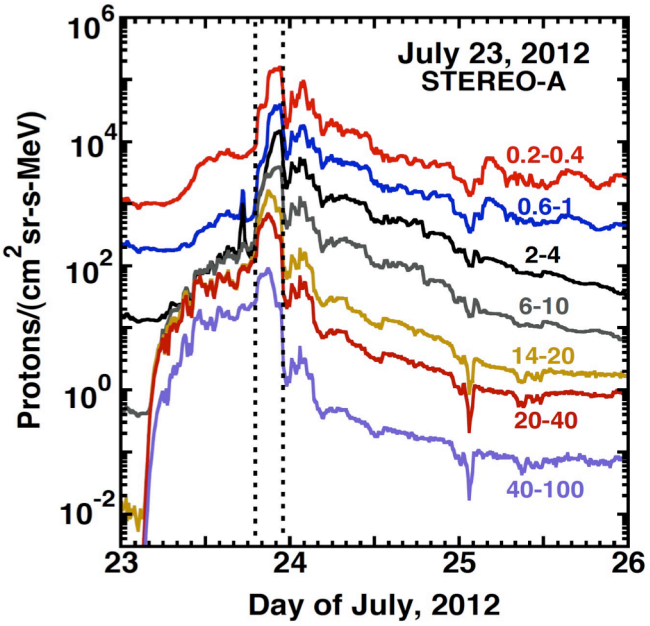

Figure 4: Protons from 0.1 MeV to 40-100 MeV showed a significant spike.

The July 23, 2012 event was outstanding in several ways (see Russell et al. 2013) [5]. It was driven by a 2000 km/s CME aimed almost directly at STEREO-A. The transit time to STEREO-A at 0.96 AU was only ~17 hours, with the result that the front-side arrival velocity was measured at >2000 km/s [3]). The magnetic field strength reached a maximum strength of 109 nT at STERREO-A[5]. Mewaldt et al. [6] reported a peak >10 MeV proton intensity of 35,800 protons/(cm^{2}sr-s). Finally Joyce et al. (2014)[7] considered the possible radiation effects had this CME been aimed at interplanetary space travelers.

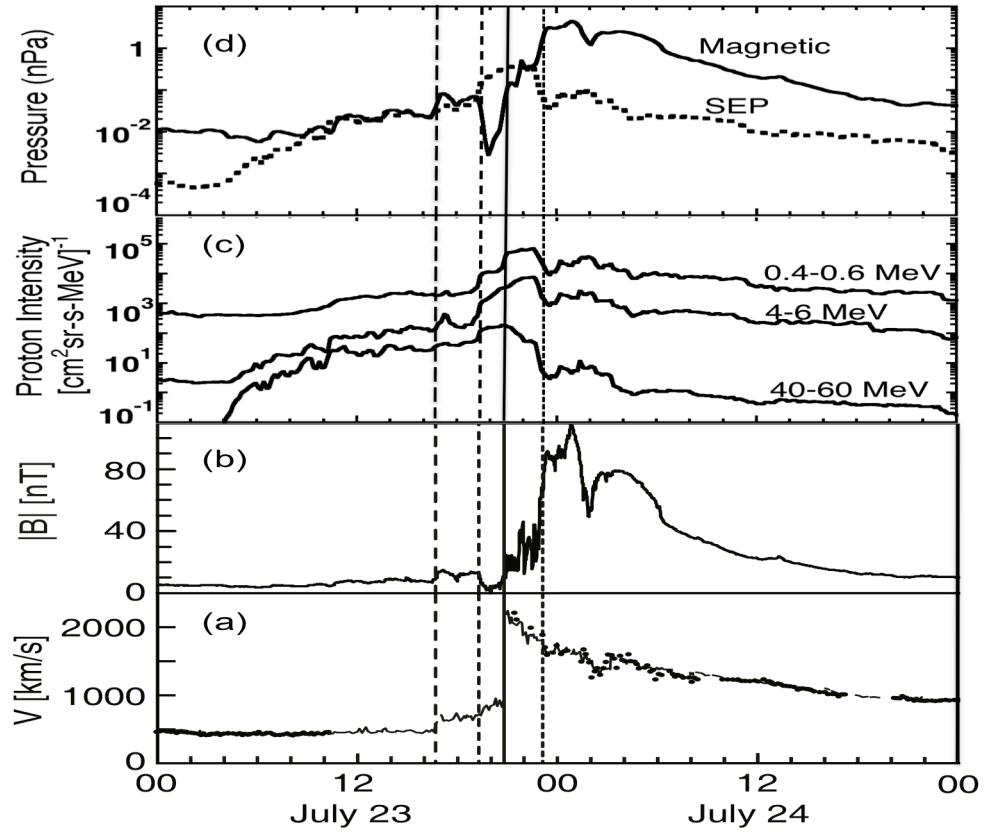

Figure 5: Time history of the July 23, 2012 event observed by STEREO-A (see [5]. This 4-panel Figure shows details of the July 23, shock that resulted in a very intense ESP event. Panel A (bottom) shows the solar wind speed, which reached 2280 km/s. Shortly threreafter the magnetic field reached 108 nT,.

Several of the properties of the July 23, 2012 event were extraordinary! Note the following:

- The STEREO/PLASTIC instrument recorded ~2280 km/s solar wind. [3].
- The interplanetary magnetic field strength reached 109 nT! [3].
- The peak >10 MeV proton intensity reached 35,800 per cm^{2}sr-s. [5]. Only two GOES events have exceeded this.

It is somewhat surprising that the September 18 CME was so effective at accelerating particles to 250 times their ambient density. However it is clear that it had a very elevated seed particle density resulting from the front-side activity. Both Luhmann et al. [5] and Bruno et al. [1] suggest that beginning on September 11 the density of energetic ions at STEREO-A began to rapidly increase as a result the broad spread of ions from the September 10 event gaining access to this region. In this case the September 18 CME was re-accelerating ions from the September 10 event (see Figure 3 of Bruno et al. [1].

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3. References

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