11th NASA Space exploration and space weather Workshop

Moon to Mars – Artemis 2024 Initiatives

October 17th, 2019 Building 3 Goett Auditorium
NASA / GSFC

New Ideas on SEPs Precursors

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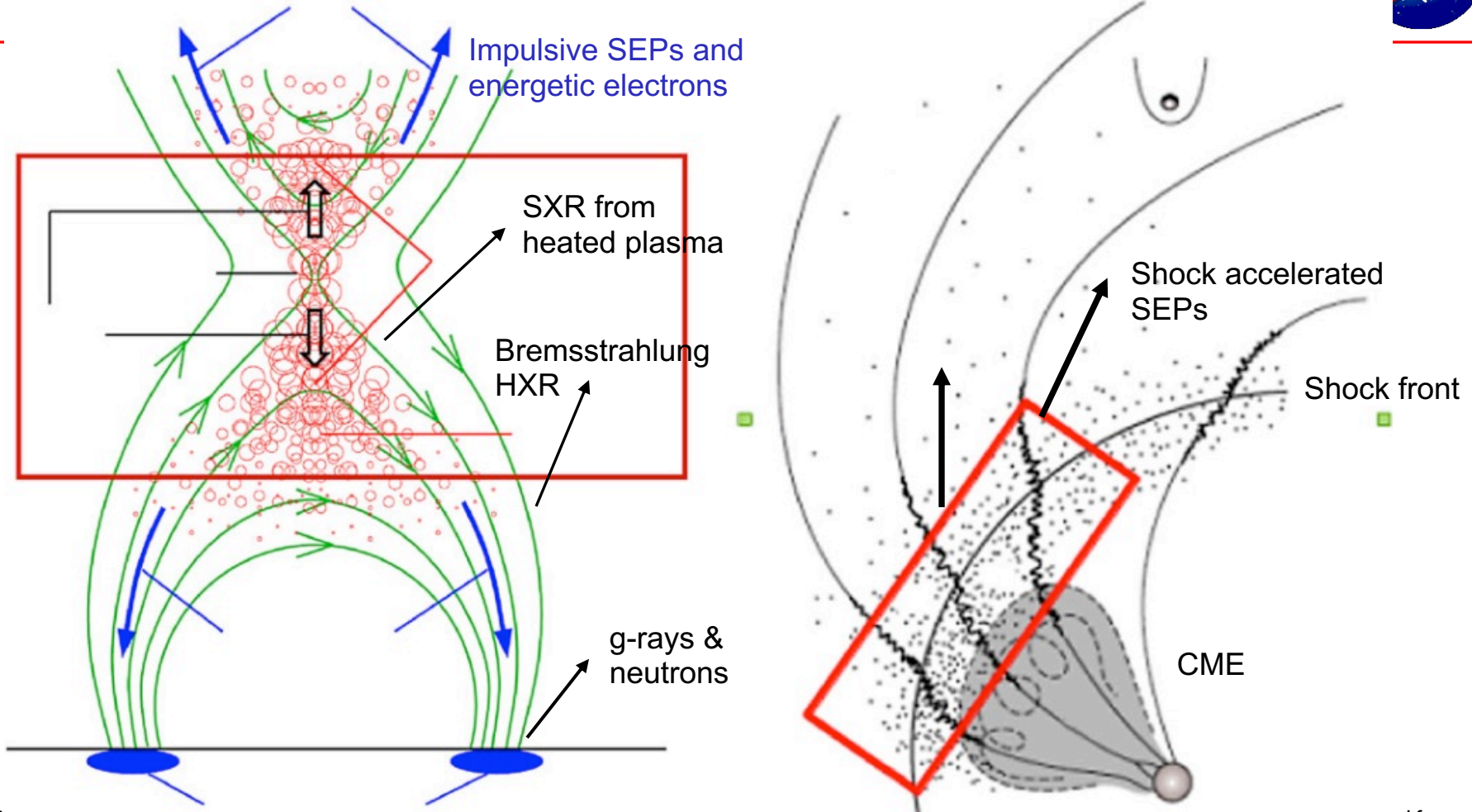
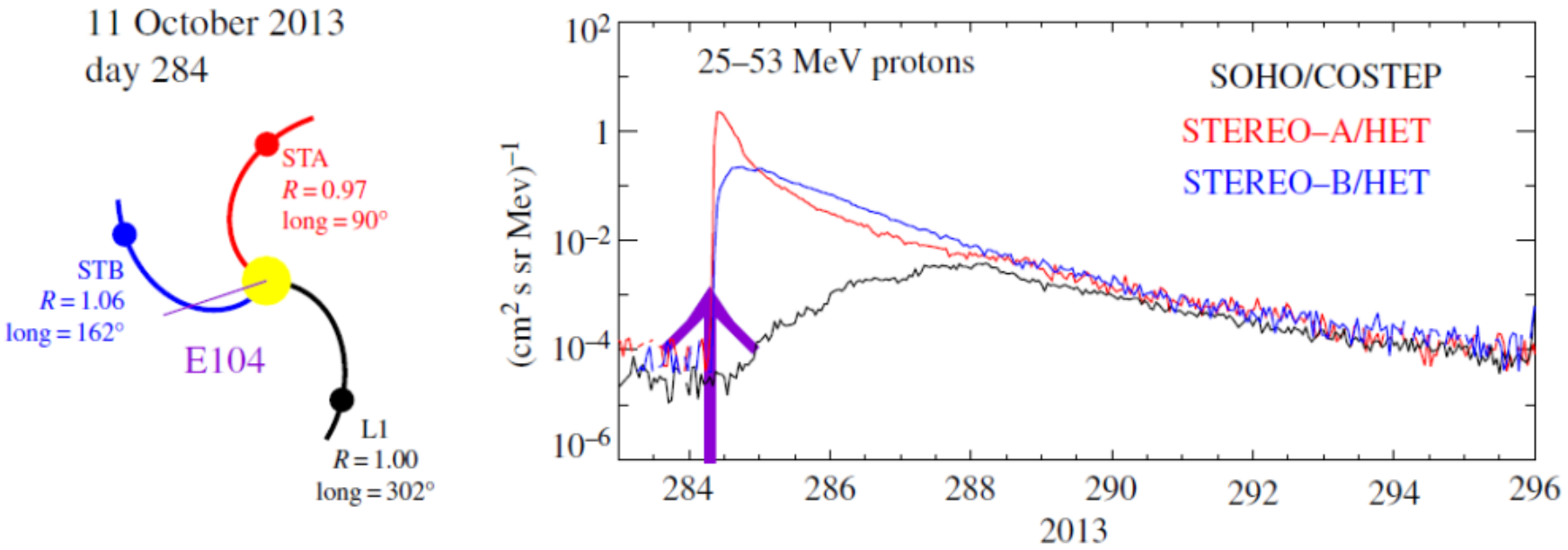
Schematic of the solar flare reconnection site (left), and the corresponding CME - Shock - Heliospheric extension, adapted from Vlahos et al., 2019



Left: Schematic of the reconnecting field (solid green) forming closed coronal loops and open field lines, presumably extending higher up into the corona and the solar wind. The red foam represents turbulence. Acceleration probably takes place in the outflow regions above and below the X-point. Particles (temporarily) trapped here produce the radiation seen above the closed loops, and particles escaping these regions up and down (blue arrows) are observed at 1 AU as SEPs and produce the non-thermal radiation (mainly at the two footpoints; blue ovals), respectively. Right: Similar schematic view, joining the flare site field lines to the CME, the shock, and beyond. The rectangles define the boundary of the acceleration sites and represent the leaky box.

SEP observations at three widely distributed longitudinal locations at ~1AU. Particles arrive first at locations with good magnetic connections and ultimately fill the entire inner heliosphere "reservoir" Anastasiadis et all, 2019.

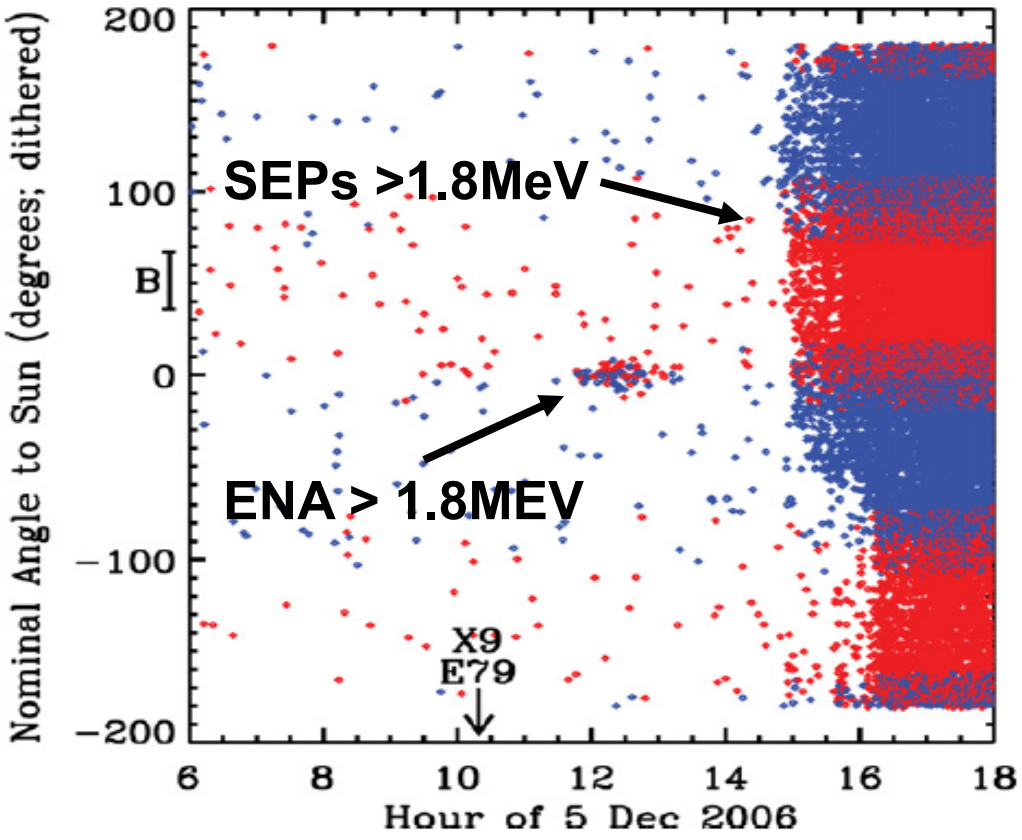


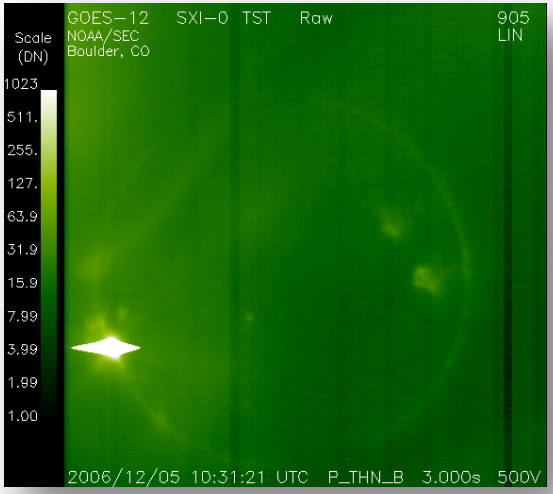
The right-hand side panel shows the intensity time-profiles for 25–53 MeV protons in the 11 October 2013 (DOY 284) event at SOHO (black), STEREO-A (red) and STEREO-B (blue). The 'reservoir' can be seen in the similarity of the time-profiles from 15 October 2013 (DOY 288) onwards. The left-hand side panel depicts the view from the north ecliptic pole showing the locations of STEREO-A (STA; red symbol), near-Earth spacecraft (L1; black symbol) and STEREO-B (STB; blue symbol). The heliocentric inertial longitude (Long) of each location is indicated in the figure. Also shown are nominal IMF lines connecting each spacecraft with the Sun (yellow circle at the centre, not to scale) considering the solar wind measured at the onset of the SEP event. The purple line indicates the longitude of the parent active region (E104 as seen from Earth).

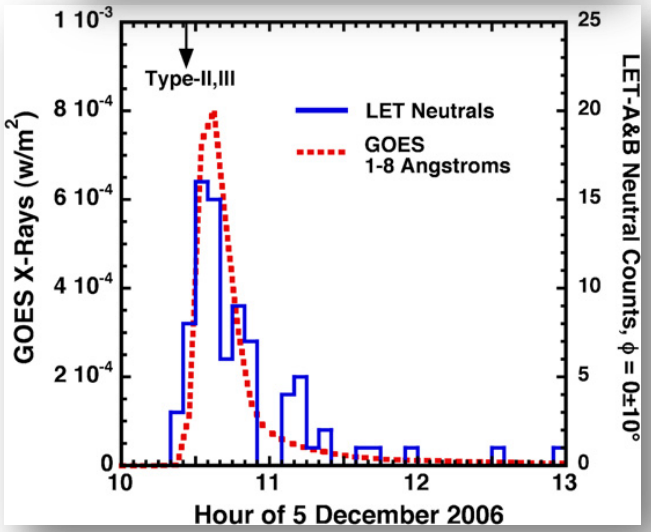
The only ever solar ENA event report (*Mewaldt et al. 2009*)

Mewaldt et al. (2009) reported an intriguing observation that could be explained only as > 1.8 MeV solar ENAs.

- This is the only reported observation of solar ENAs due to specific STEREO configuration at that time and due to complete absence of dedicated solar ENA observations.

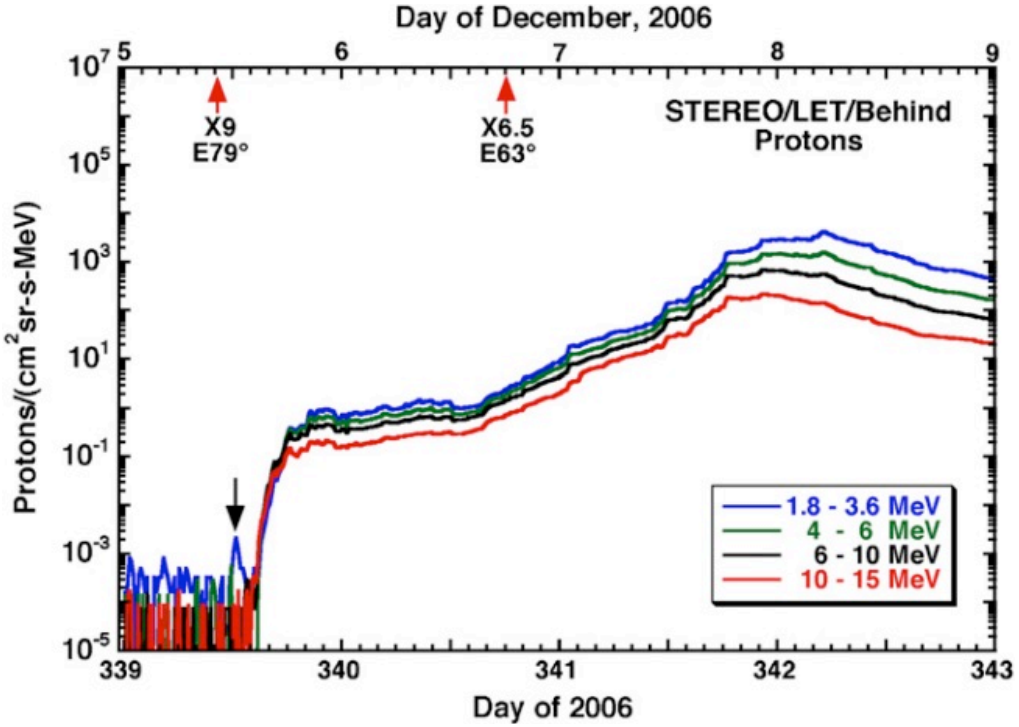


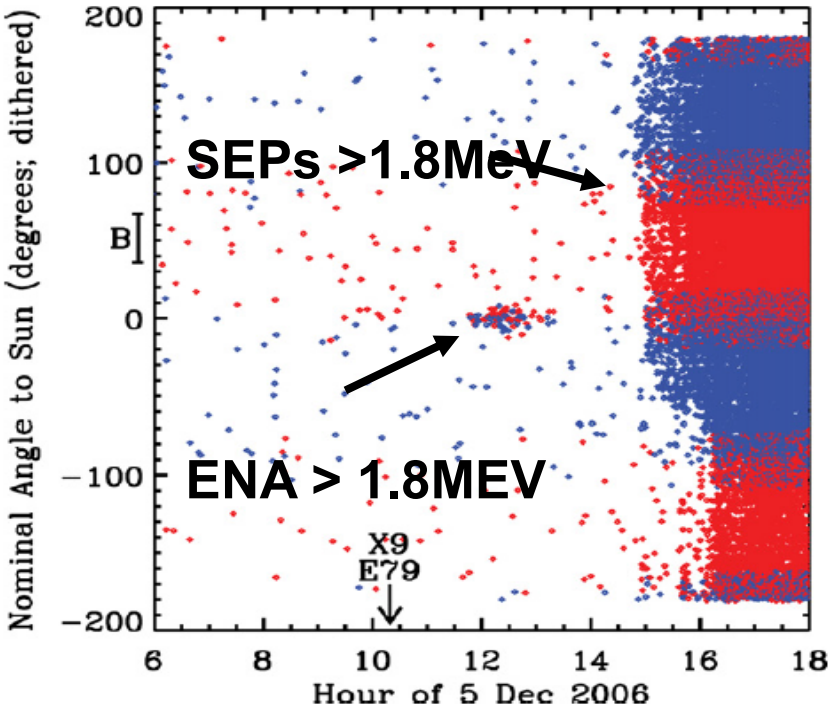




ENA emission associated with an X9 flare.

Soar ENA observations by the two LETs on STEREO A,B right after launch when the two SC were close to each other and to earth.

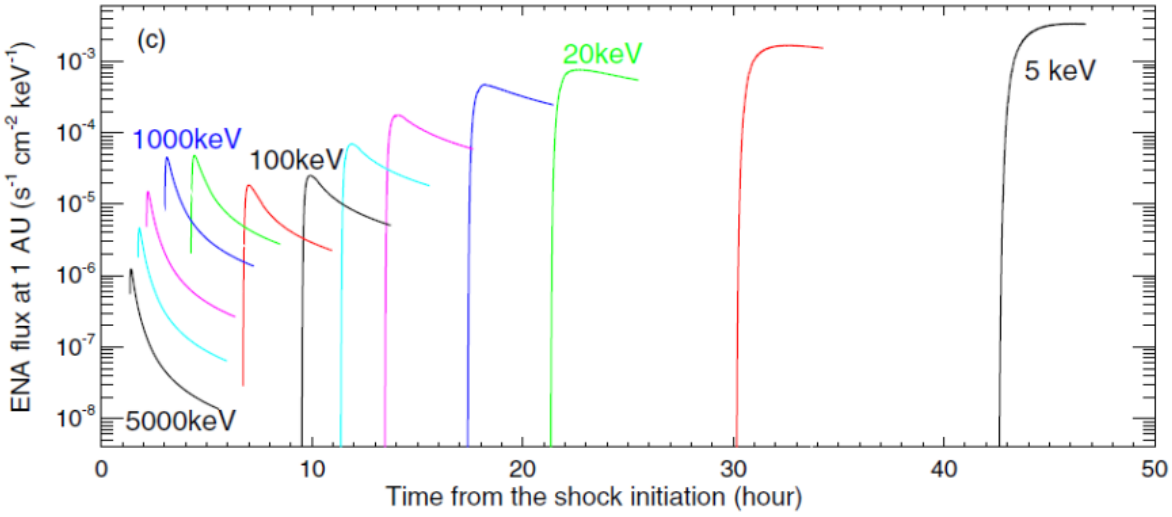


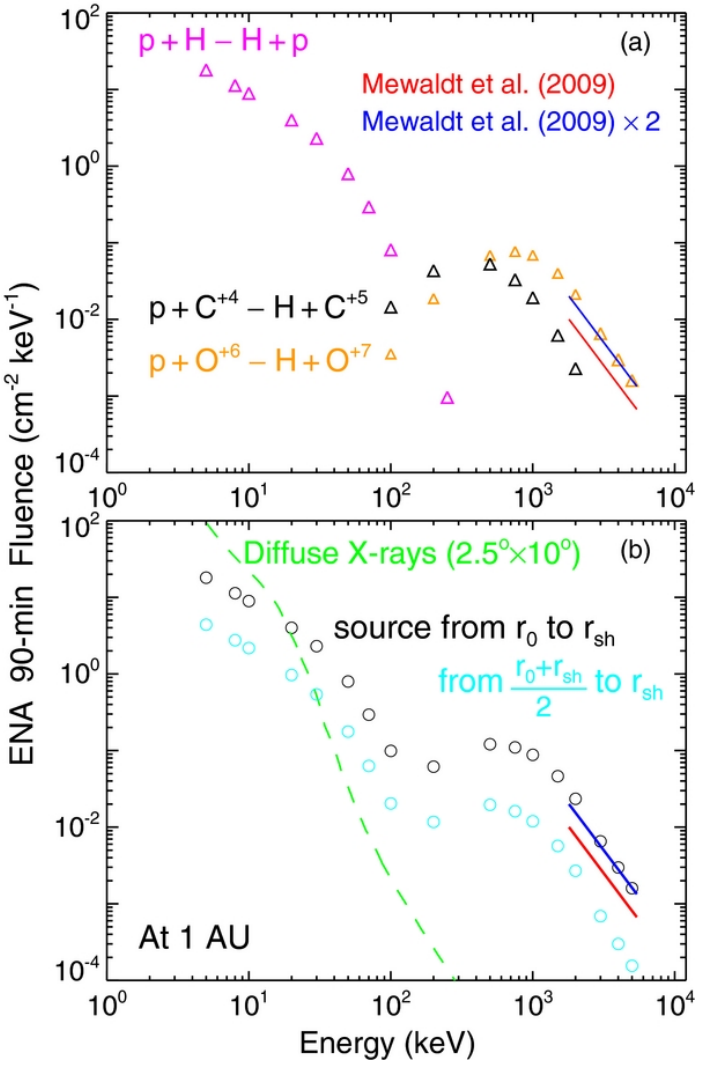


"We report the discovery of energetic neutral hydrogen atoms (ENAs) emitted during the X9 solar event of 2006 December 5. Beginning ~1 hr following the onset of this E79 flare, the Low Energy Telescopes (LETs) on both the STEREO A and B spacecraft observed a sudden burst of 1.6–15 MeV protons beginning hours before the onset of the main solar energetic particle event at Earth. More than 70% of these particles arrived from a longitude within ±10◦ of the Sun, consistent with the measurement resolution. **The derived emission profile at the Sun had onset and peak times remarkably similar to the GOES soft X-ray profile and continued for more than an hour. The observed arrival directions and energy spectrum argue strongly that the particle events <5 MeV were due to ENAs**. To our knowledge, this is the first reported observation of ENA emission from a solar flare/ coronal mass ejection. Possible origins for the production of ENAs in a large solar event are considered. **We conclude that the observed ENAs were most likely produced in the high corona and that charge-transfer reactions between accelerated protons and partially stripped coronal ions are an important source of ENAs in solar events**." *Mewaldt et al.* (2009).

Wang et al. (2014) demonstrated that CME-related shocks can produce observable > 20 keV ENAs at 1 AU.

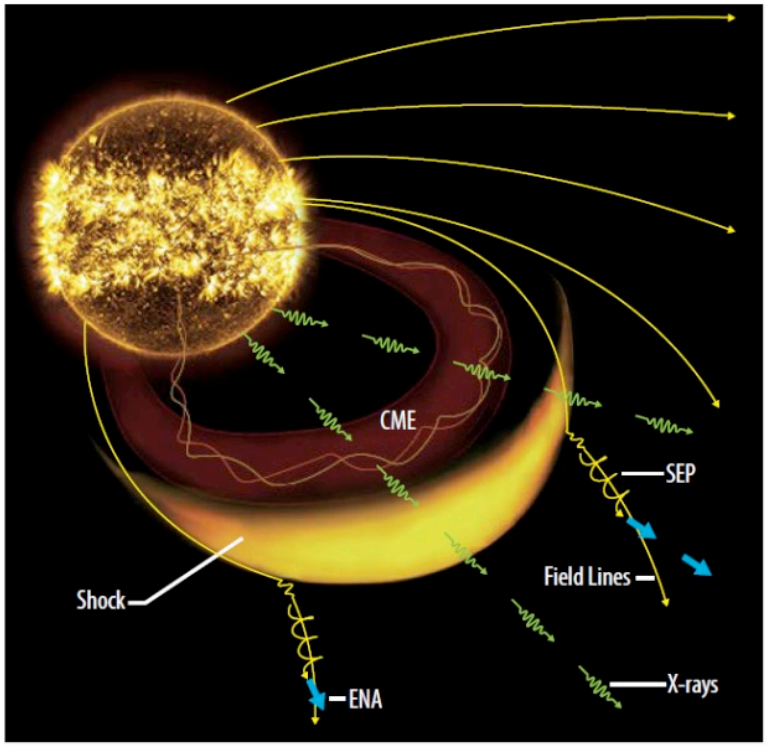
- ENAs can be produced in the solar corona by charge exchange between the energetic protons and neutral H or high charge state ions such as carbon and oxygen.
- ENAs retain the energy and the direction of the ”parent particle” and provide a unique way to probe energetic particle acceleration at shocks and/or flares.
- **Solar ENAs could be a completely new observable for solar energetic particle acceleration science & precursors for predictions of SEPs**





Mewaldt et al. (2009)

NASA/GSFC SETH is a tech demo mission (selected for Step 1). Mission PI Antti Pulkkinen, HELENA instrument PI: Nick Paschalidis



HELENA (HELioENA) is a comprehensive space weather suite designed to resolve the flare / CME/ shock induced: HXR – Energetic Electron – ENA – SEP time and angualr profile.

The instrument is a dedicated sun pointing solar ENA telescope capable to resolve the origin (from east to center to west), time profile and energy spectra of the ENAs.

The instrument is designed to detect HXRs up to several tens of KeV, electrons up to 1MeV, ENAs 100 to >5000KeV and SEPs up to 100MeV.
The goals of the SETH/HELENA investigation are: to:

Detect multiple solar ENA events in combination with HXRs and SEPs.
Refine the modeling of particle acceleration and ENA generation at the solar corona
Inverse the ENA signal and trace back to the origin of particle acceleration.
Remote sense and study particle acceleration at the solar corona
Develop a space weather SEP forecasting capability using ENAs as precursors to SEPs (Complementary to using relativistic electrons Posner et al, 2007)