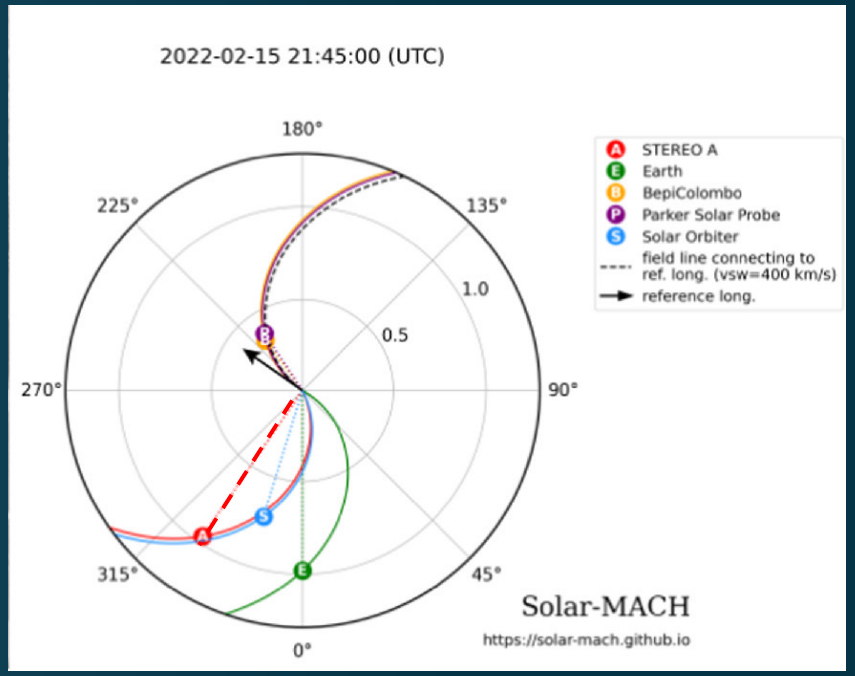
# STEREO Science Highlight

## Energetic Neutral Atom Detection from Solar Event

Cohen, C. M. S., Leske, R. A, St. Cyr, O. C., Mason, G. M. (2024) , *ApJ*, 966, 19; doi: 10.3847/2041-8213/ad4038

# Background

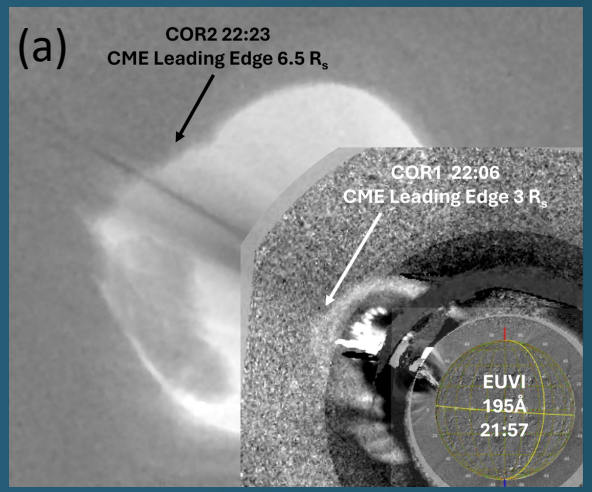
- Energetic neutral atoms (ENAs) are expected to be created from solar energetic particles (SEPs) via charge exchange near the Sun
  - Unlike SEP ions, ENAs are not affected by the interplanetary magnetic field (IMF) and so are a direct probe of the acceleration processes and conditions close to the Sun.
  - In the absence of a dedicated solar ENA instrument, SEP instruments have provided limited ENA detections under very particular conditions in which the ENAs can be distinguished from the more abundant SEP protons.
  - Previously only detected once before by STEREO (Mewaldt et al. 2009) and by SAMPEX (Mason et al. 2021) .

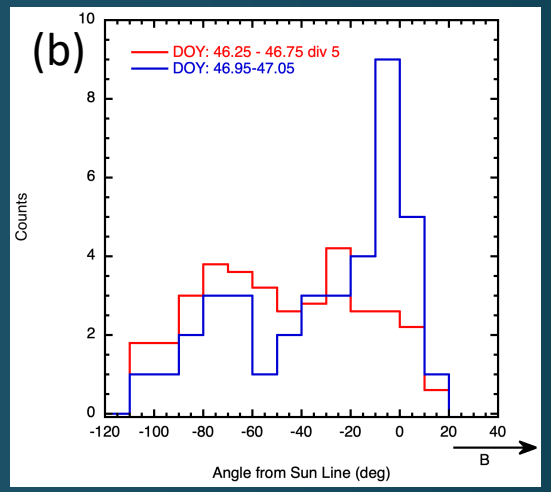


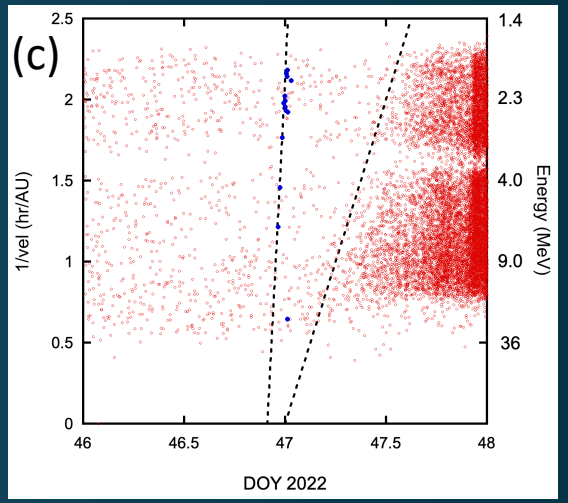

The relative locations of different spacecraft, including STEREO-A at the time of the eruption. The direction of the Coronal Mass Ejection (CME) associated with the ENA's is shown by the black arrow. SEPs travel along roughly spiral paths due to twisting of the IMF (see solid lines for the different spacecraft), but ENAs travel directly from the acceleration site to the observer (red dashed line) Adapted from Cohen *et al.* 2024

# Analysis

- Associated with the 15 February 2022 coronal mass ejection (CME, panel a), STEREO-A/LET observed a clear signature of ENAs. Other data from STEREO-A IMPACT and SECCHI instruments were used to establish the signals were due to ENAs and not SEPs.
  - Their arrival directions were strongly peaked in the direction of the Sun, not the IMF direction (panel b).
  - Their velocity dispersion was consistent with a pathlength of the radial distance of STEREO-A and not the longer pathlength observed for the later arriving SEPs (panel c).



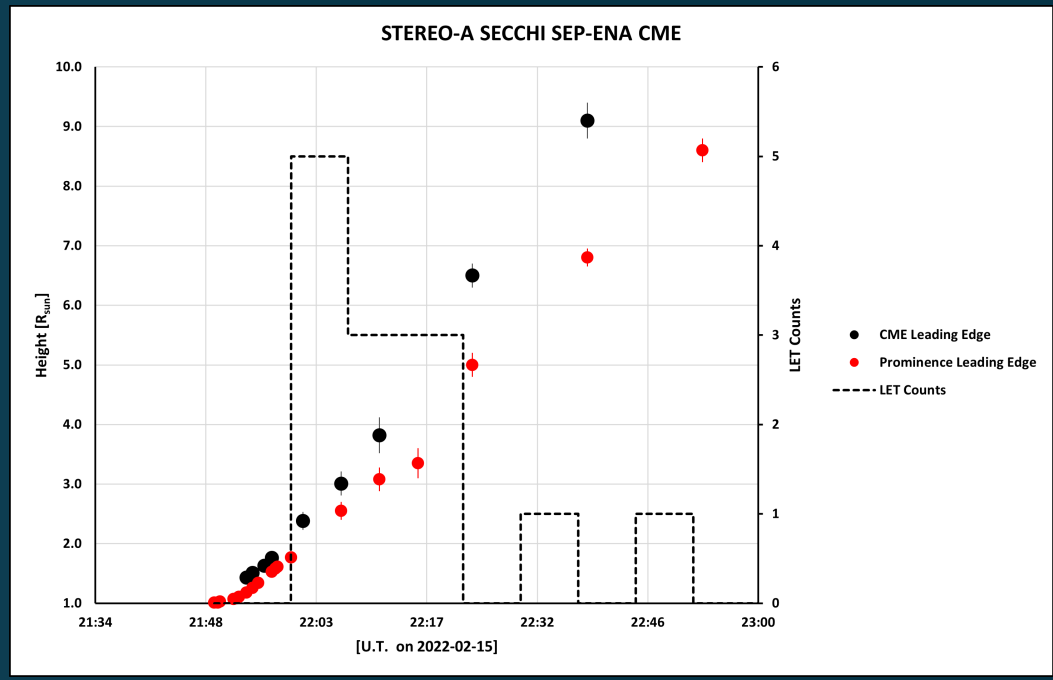




(a) Images from STEREO-A/EUVI, COR1 and COR2 at different times showing the leading edge of the erupting CME. (b) Distribution of particles in angle from the Sun line during the ENA time period (blue) and an earlier period (red). (c) Inverse velocity vs time of the ENA events (blue) and other particles (red). The onset of the SEP event is the increase in dot density in the first half of day 47. Lines indicate pathlengths of ~1 AU (left) and 6 AU (right), illustrating the difference between the ENAs and SEPs. Credit: Cohen *et al* 2024

# Findings

- This is only the second STEREO ENA observation
  - The first was described in the seminal paper by Mewaldt *et al.* 2009).
  - More could be found through a systematic search of the 18-year long STEREO dataset.
- Comparison of the spectra with model results and the timing of the ENA release at the Sun indicates that they likely originated in the vicinity of the CME-driven shock when the CME was at ~2-3 solar radii (figure).
- The solar event was unique in the amount of prominence material ejected (which was tracked in EUV wavelengths to distances of 6 solar radii). Whether this played a role in the creation of the ENAs is not clear without event-specific modeling.




Height as a function of time for the leading edges of the CME (black points) and the prominence (red points). For comparison the release time profile of the ENAs is overplotted. The time for light to travel from the Sun to STEREO-A is added to enable direct comparison to remote sensing data. Credit: Cohen *et al.* 2024

# Impacts

- ENAs provide a unique probe of particle acceleration because they come directly from the site of their formation, unaffected by the interplanetary magnetic field in the way charged solar energetic particles are.
- Energetic particles can be a hazard to spacecraft and astronauts, especially those traveling outside the Earth's magnetic field. ENA's can help us understand where and how they are produced and thus, ultimately, to predict them better.
- Part of the reason ENA's from the Sun have rarely been observed is because instruments have not been designed to observe solar ENAs.  This new detection is important for establishing the potential utility of an instrument actually designed for that purpose.

# References


Cohen, C. M. S., Leske, R. A, St. Cyr, O. C., Mason, G. M, "Energetic Neutral Atoms Detected in the 2022 February 15 Solar Energetic Particle Event" ApJ, 966, 19, 2024; doi: 10.3847/2041-8213/ad4038

Mason, G. M., Greenspan, M. E., Kanekal, S. G. et al., "Evidence for Energetic Neutral Hydrogen Emission from Solar Particle Events," ApJ, 923, 195, 2021 doi: 10.3847/1538-4357/ac2fa2

Mewaldt, R.A., Leske, R.A., Stone, E.C., et al., "STEREO Observations of Energetic Neutral Hydrogen Atoms During the 2006 December 5 Solar Flare," ApJ, 693, 11, 2009, doi: 10.1088/0004-637X/693/1/L11

# Publication Information

"Energetic Neutral Atoms Detected in the 2022 February 15 Solar Energetic Particle Event "

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