

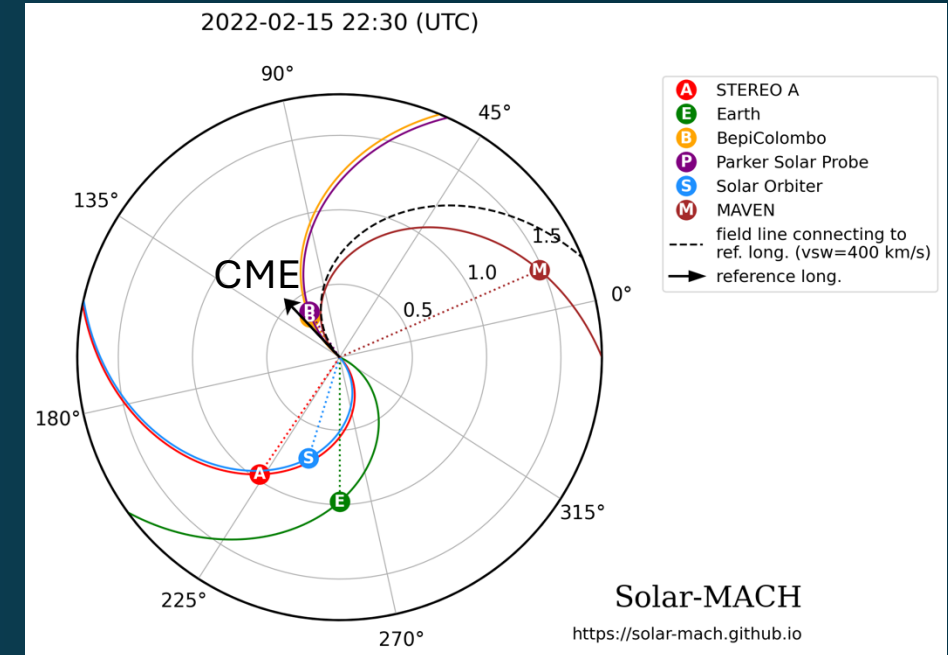
Very Large and Long-lasting Anisotropies Caused by Sunward Streaming Energetic Ions

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Background

Sunward streaming energetic ions are energetic particles that predominantly travel towards the Sun.

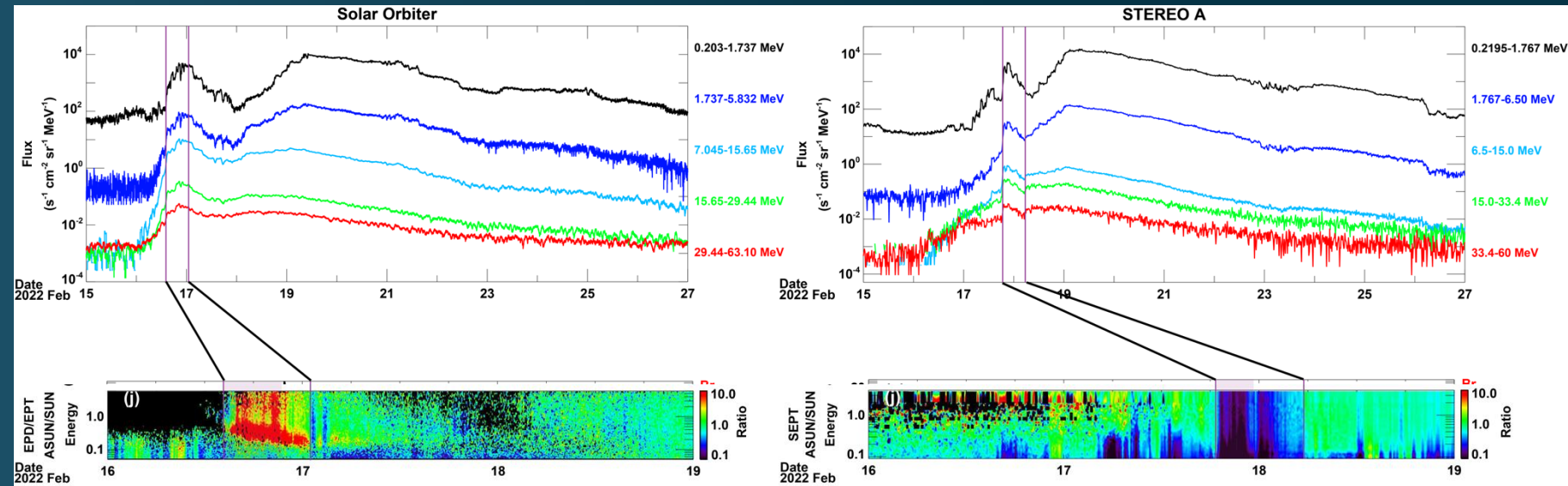
- The Sun is a major source region of energetic particles, which typically move in an anti-sunward direction. Therefore, it is less common to observe particles propagating sunward.
- The anisotropy of energetic particles is commonly utilized to gain insights into their spatial distributions, injection, and transport processes.
- One property that stands out and is of particular interest for the solar and heliospheric sources is **anisotropies** associated with sunward streaming in the inner heliosphere.
- STEREO, alongside other spacecraft, has enabled observations of solar energetic particle (SEP) events from multiple vantage points, providing a unique opportunity to investigate the radial and longitudinal evolution of these energetic particles.



Positions of STEREO-A and Solar Orbiter along with other s/c in the inner solar system during the 15 February 2022 coronal mass ejection (CME) event. The CME propagation direction is marked by the black arrow, and the positions of several s/c are indicated by the colored symbols as listed in the legend. Solid curves indicate the nominal Parker spiral lines connecting the Sun to different s/c, based on their observed solar wind speeds. Charged energetic particles are expected to usually move along the Parker spiral. (Credit: Adapted from Wei et al. 2024).

Analysis

- STEREO-A and Solar Orbiter (SO), which were nearly aligned along the same nominal Parker spiral, observed a special ion enhancement during the widespread SEP event on February 15, 2022.
- Data used were from STEREO-A IMPACT and PLASTIC and SO SWA, EPD, and MAG
- Both ion enhancements occurred under similar background solar wind conditions.
- STEREO-A spacecraft was rolled and the SEPT telescope was not along Parker spiral during this time period. This must be taken into account to correctly understand the direction of the particles it observed.
- Both spacecraft show periods of sunward streaming energetic ions, as marked by the two solid vertical lines in the right-hand figure.

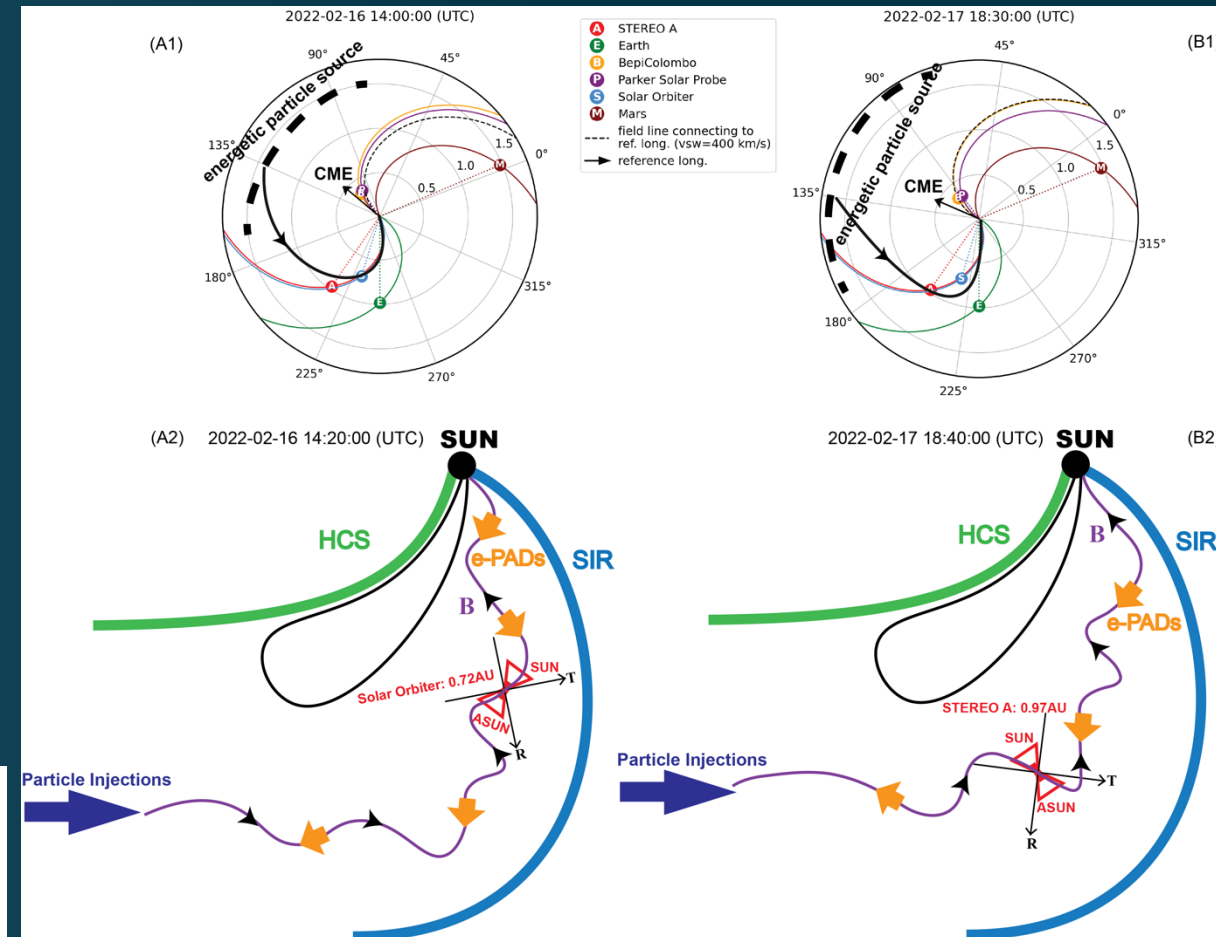


Solar Orbiter (left) and STEREO A (right) observations during Feb. 15-26 (top) and February 16-19, 2022 (bottom). The top panel shows the energetic ion intensities of the widespread SEP event at several selected energies. The bottom panel displays the **directional** energetic ion distributions as a function of energy around the identified ion enhancement of interest as marked by the two solid vertical lines, which occurs in the rising phase of the SEP event. Because STEREO-A was flipped during this time period the ratio values in the bottom row are reversed, but both the Solar Orbiter and STEREO-A data show more sunward moving energetic ions. (Credit: adapted from Wei et al. 2024).

Findings

- The investigation found predominantly sunward streaming energetic ions with very large and long-lasting first-order anisotropy. This may be the first reported event of this kind.
- The sunward streaming energetic ions were injected from a particle source that is located beyond STEREO-A's orbit.
- Their very large and long-lasting anisotropy indicates the spacecraft, especially Solar Orbiter, observed a very early phase of ongoing ion injections.
- The source of the energetic ions is thought to be open field in the form of a small flux rope perhaps connected to a shock generated by the February 15 CME.

A sketch to describe Solar Orbiter (A1–A2) and STEREO-A (B1–B2) observations. Figures (A2) and (B2) indicate the solar wind structures and particle features when Solar Orbiter and STEREO A encounter the focused anisotropy event at different locations, respectively. In the figures, an open small flux rope (purple line) and a following closed loop (black line) are embedded between the **stream interaction region (SIR)** and the **heliospheric current sheet (HCS)**. The yellow arrows show directions of the anti-sunward flowing suprathermal electrons (e-PADs). **The sunward moving energetic ions are moving in the direction of magnetic field show by the black arrows.** (Credit: Wei et al. 2024).



Impacts

- Solar Energetic Particles (SEPs) can be a hazard to spacecraft and astronauts, especially those traveling outside of the Earth's magnetosphere. It is important to understand their sources and how they move through the solar system. **In these observations we have SEPs coming from an unusual source beyond 1 AU and moving in the sunward direction, which is important to understand.**
- Analysis of the anisotropic distributions of energetic ions provides important information about the source locations, interplanetary magnetic field (IMF) topologies, and acceleration and transport of energetic particles. This information is key to understanding and predicting energetic particle variability.
- The alignment of STEREO-A and Solar Orbiter along the Parker Spiral made it possible to understand the sources and characteristics of the energetic ions in this event. This highlights the importance of multi-vantage point observations of the Heliophysics System Observatory in studying these events. The knowledge gained from this research will benefit future particle anisotropy studies of this kind.

Publication Information

- Reference:
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