Dependence of Energetic Storm Particle Heavy Ion Peak Intensities and Spectra on CME Source Longitude and Speed

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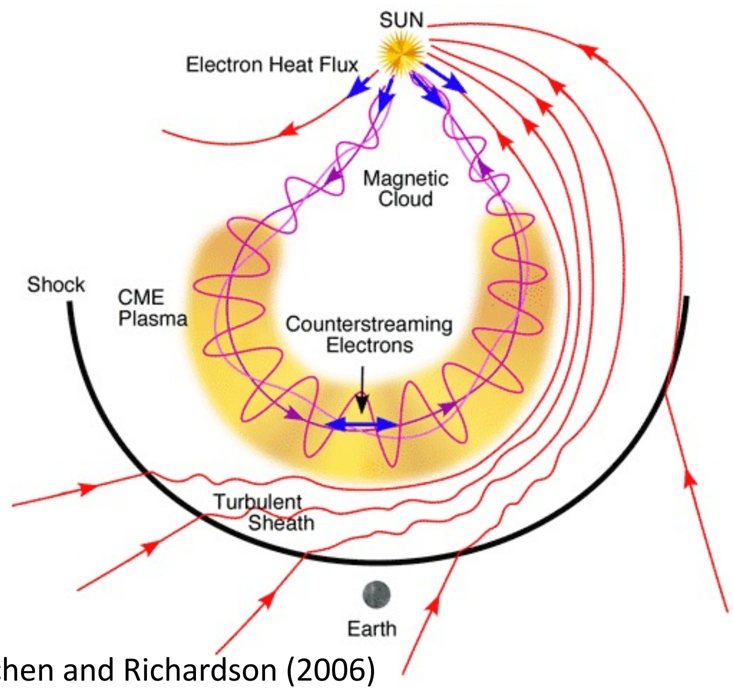
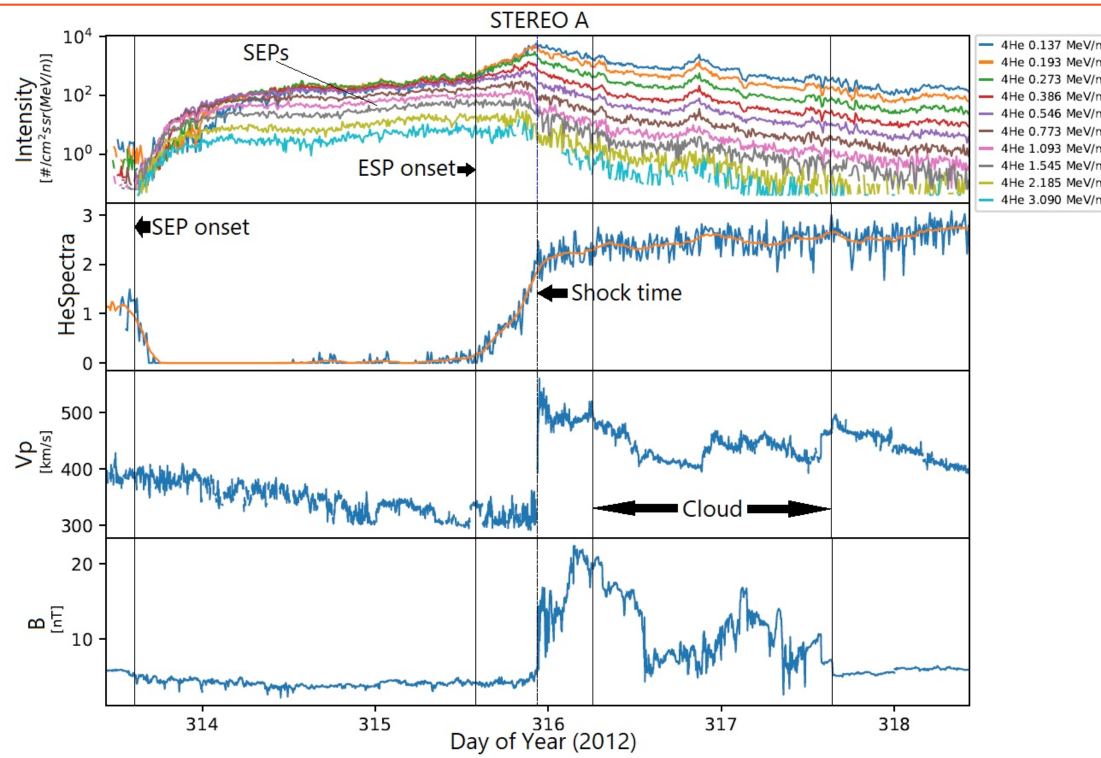
Energetic Storm Particles (ESPs)



Zurbuchen and Richardson (2006)

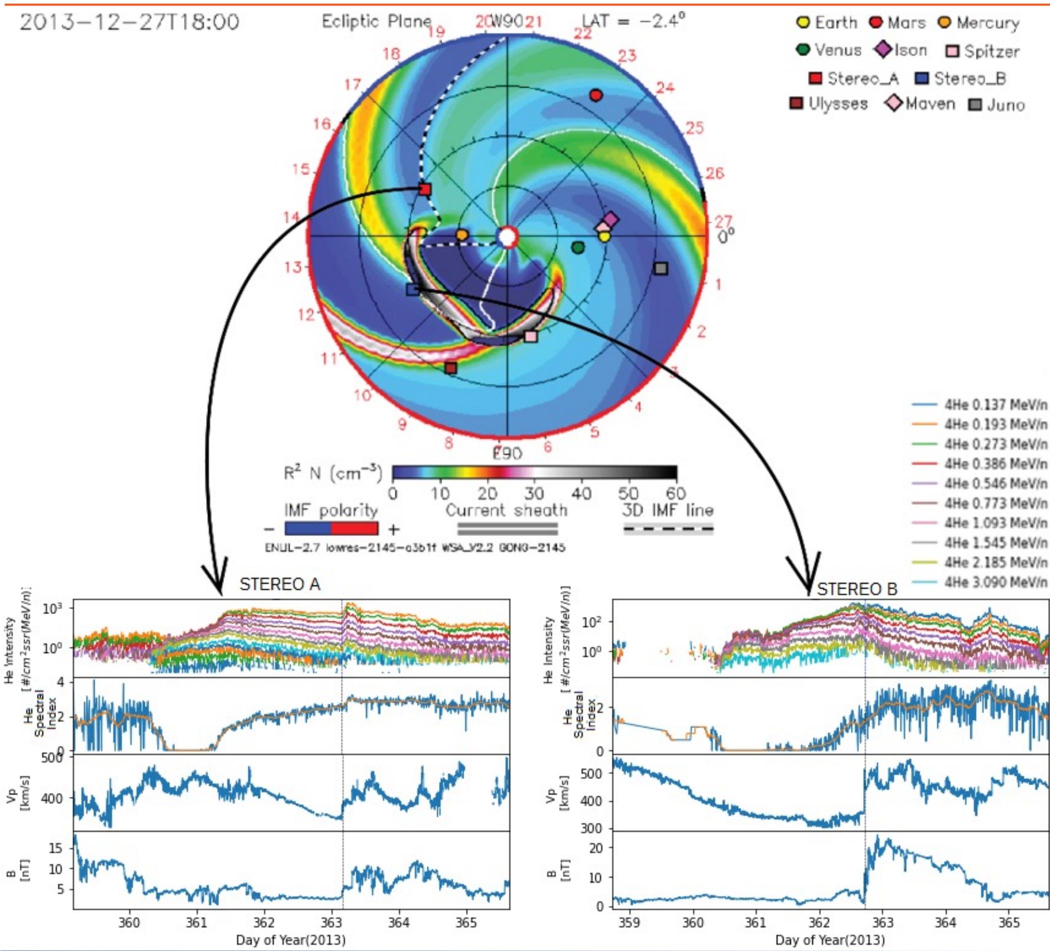


ICMEs produce an IP Shock wave where particles are accelerated via processes such as diffusive shock acceleration (DSA).

The increase of the intensity of the energetic particles is known as an ESP event when observed near 1 AU.

This study focuses on the heavy ion properties of ESP events and the causes of their variability.

Example of a multi-spacecraft ESP

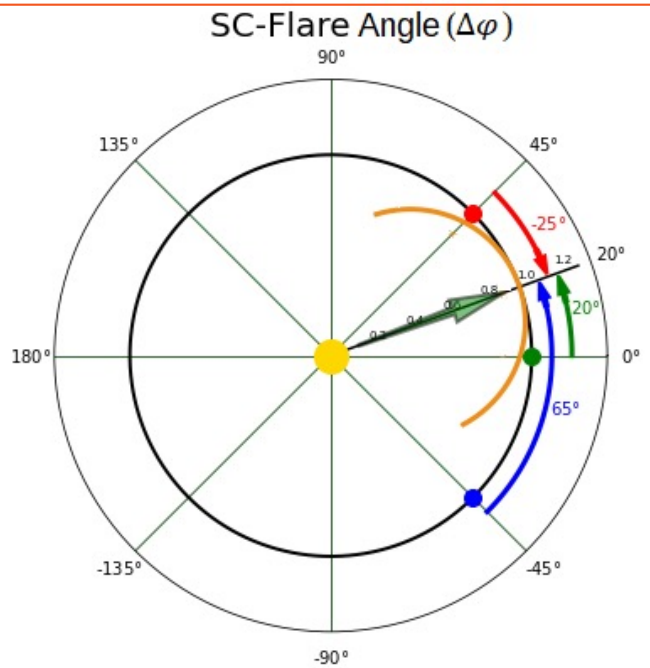


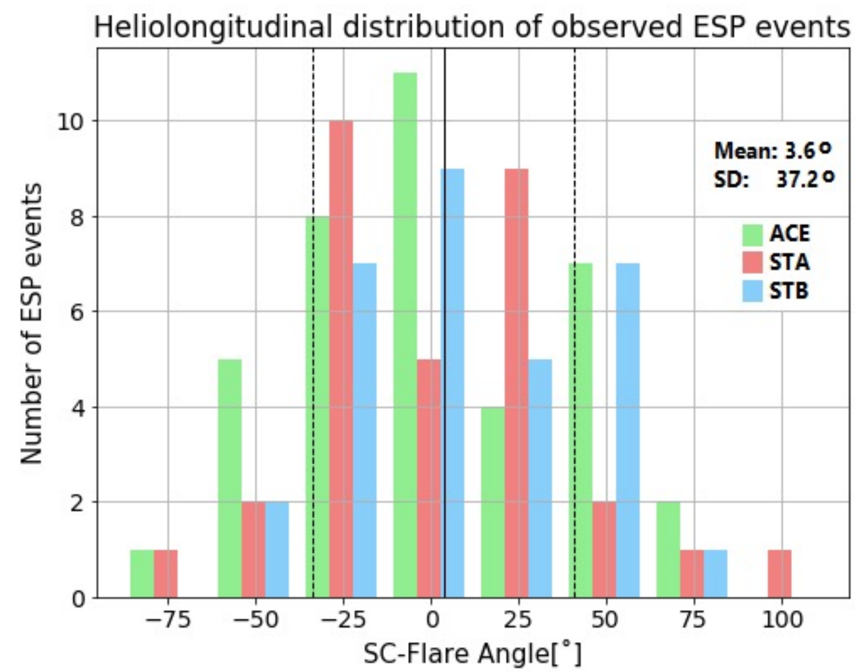
This study uses both single and multi-spacecraft observations of ESP events at 1 au from STEREO-A, STEREO-B, and ACE.

The focus of this study is to determine how ESP peak intensities and spectra depend on CME source longitude and speed.

DONKI (2020), Space Weather Database Of Notifications, Knowledge, Information (DONKI). https://kauai.ccmc.gsfc.nasa.gov/DONKI/

Heliolongitude distribution of ESP events

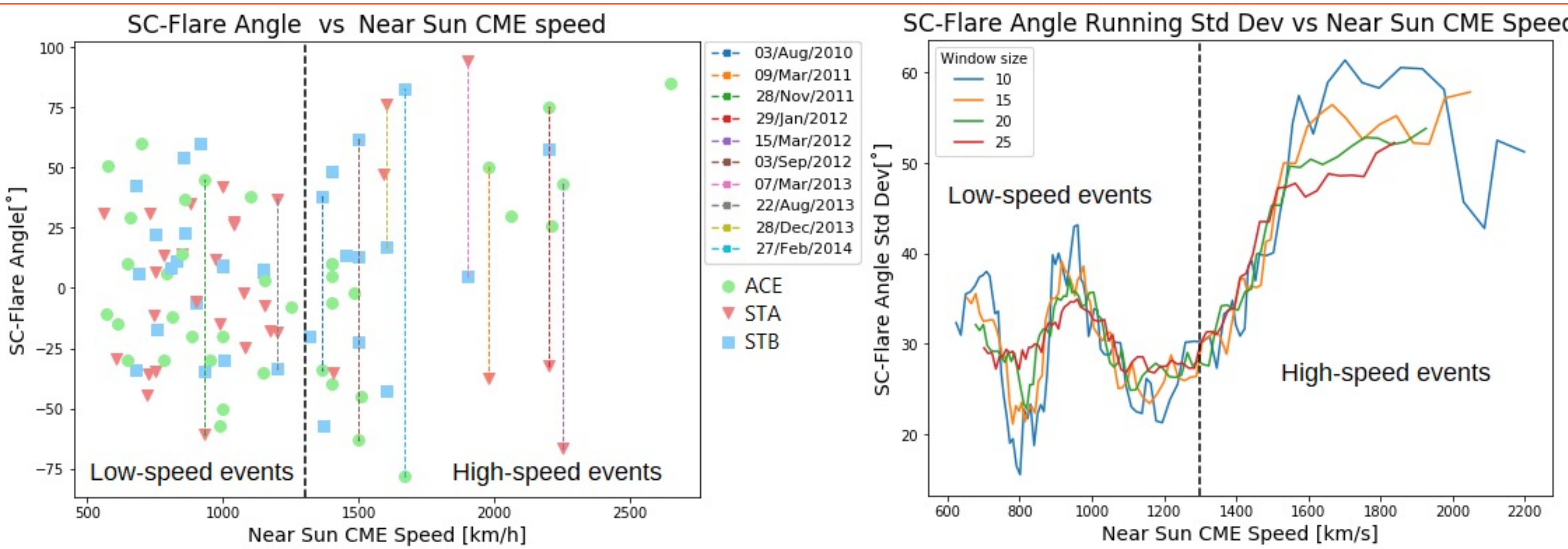




The SC-Flare Angle ($\Delta\varphi$) is the difference between the longitude of the solar flare, used to approximate the CME solar source, and the longitude of the spacecraft that observes the ESP event at 1 au.

Longitudinal distribution of ESP events observed at ACE (green), STEREO-A (red) and STEREO-B (blue) relative to their SC-Flare Angle.

SC-Flare Angle vs Near Sun CME Speed



Multi-spacecraft events are connected by colored dash lines. (Right) Running average of the standard deviation for the SC-Flare Angle as a function of near Sun CME speed. Running average windows of 10, 15, 20 and 25 events are used in the analysis.

CME Speed Ratio longitude distribution

$$\overline{V_{CME\ Transit}} = \frac{R}{\left(t_{1AU} - t_{1\,R_\odot}\right)} \qquad (1)$$

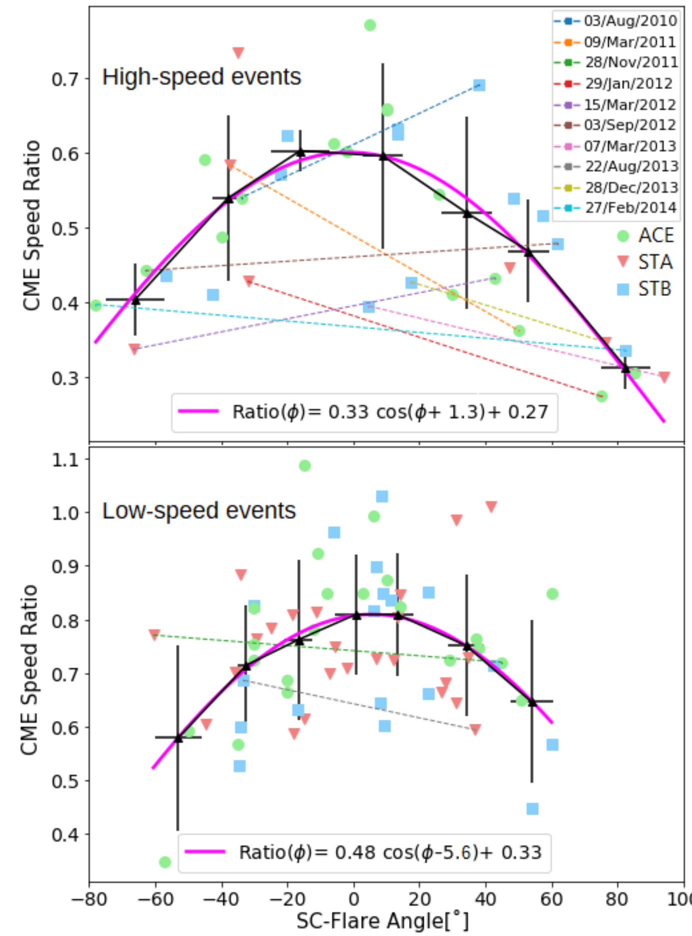
$$CME\ Speed\ Ratio = \frac{\overline{V_{CME\ Transit}}}{V_{CMENearSun}} \qquad (2)$$

$$CME\ Speed\ Ratio(\varphi) = V_0 cos(\Delta\varphi - \varphi_0) + V_1 \qquad (3)$$

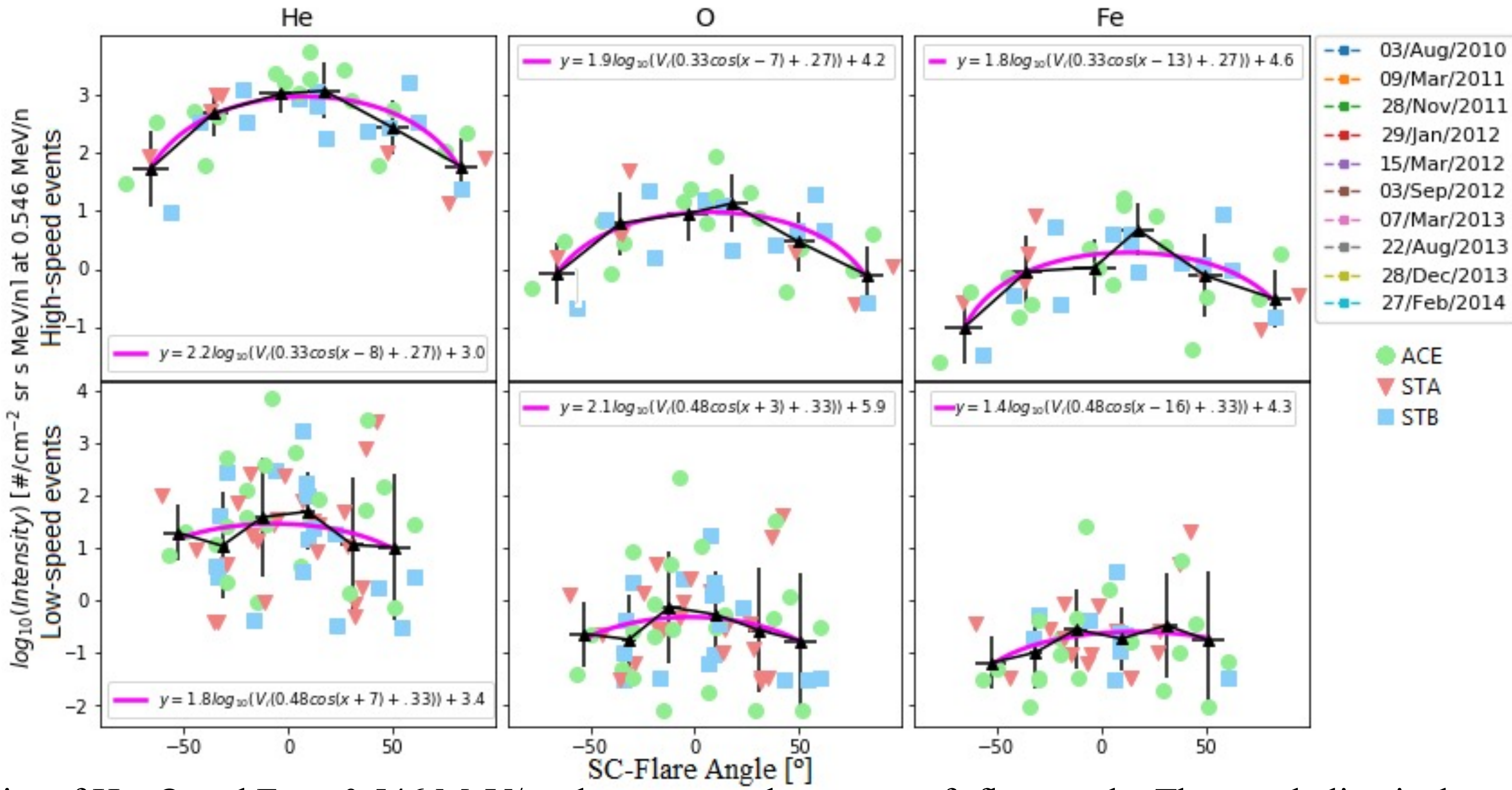
Adapted from *Smart and Shea* [1985]

$$\overline{V_{CMETransit}} = V_{CMENearSun} * (V_0 cos(\Delta\varphi - \varphi_0) + V_1) \qquad (4)$$

Longitudinal distribution of the ratio between the transit time and near Sun CME speeds for the hi-speed (top plot) and low-speed (bottom plot) ESP events.



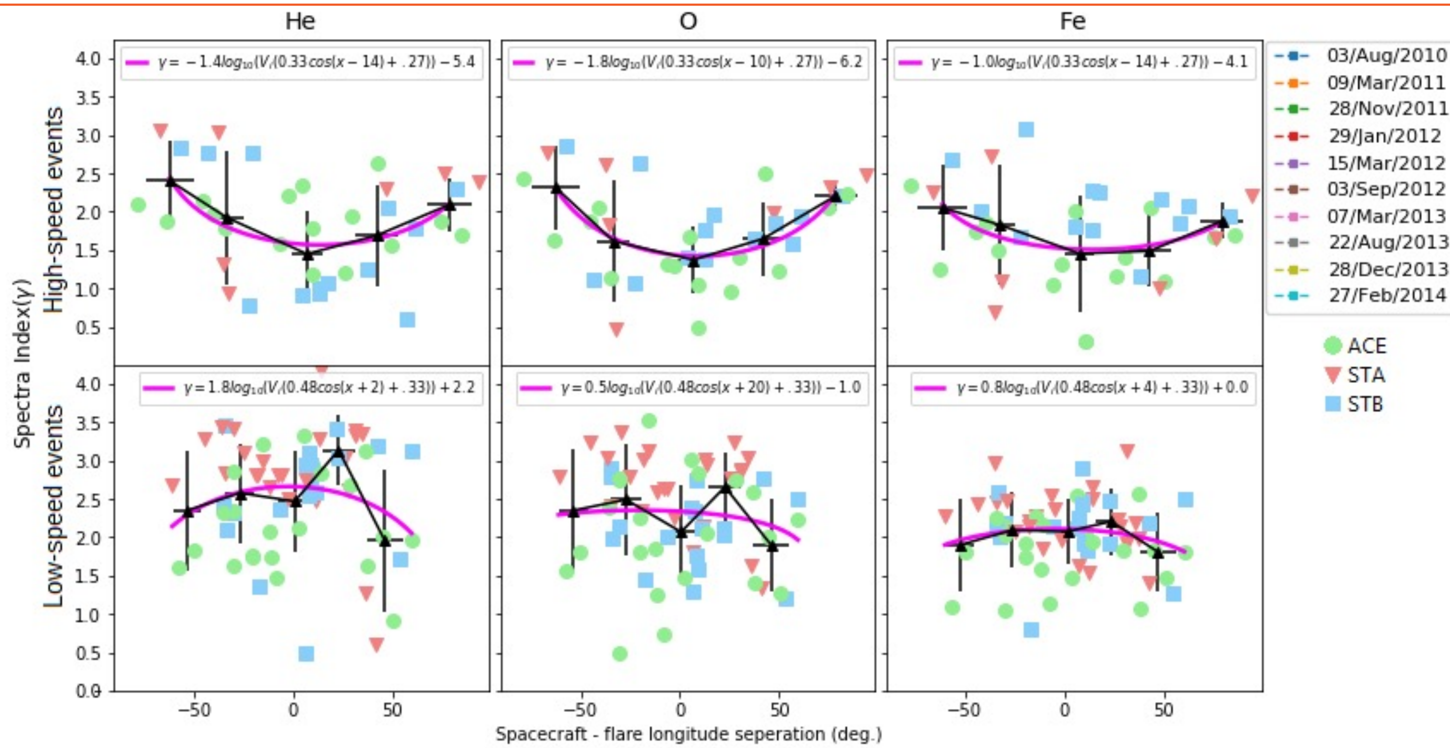
ESP Peak intensity vs Helio-longitude



ESP Peak intensity of He, O and Fe at 0.546 MeV/nucleon versus the spacecraft-flare angle. The purple line is the estimated trend based on equation 6, where the median near Sun CME Speed was used.

$$\boxed{log_{10}(j) = C_1 * log_{10}\big(V_{CMENearSun} * (V_0 cos(\Delta\varphi - \varphi_0) + V_1)\big) - C_0 \qquad (6)}$$

ESP Spectral Index vs Helio-longitude



Longitudinal distribution of spectral index for 0.1 – 3 MeV/nucleon He, O and Fe ions.

$$\gamma = C_1 * log_{10}(V_{CME\ Near\ Sun} * (V_0 cos(\Delta\varphi - \varphi_0) + V_1)) - C_0 \qquad (8)$$

Summary

1. The longitude distribution of ESP events is organized by near Sun CME speed, the angular width of the events showing a threshold at ~1300 km/s.
   - Events above this threshold show significantly larger angular extent compared to slower events.

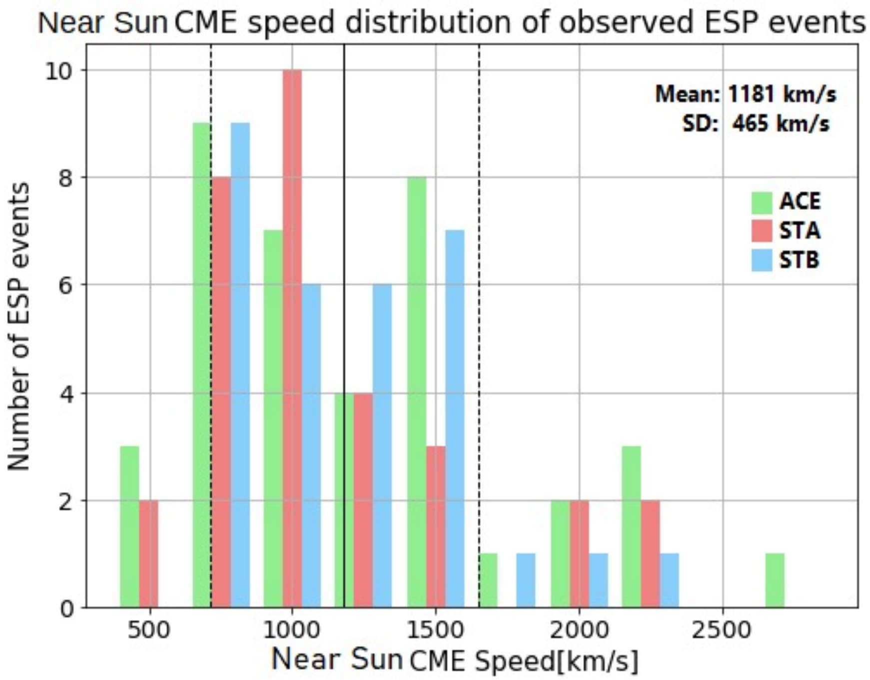
2. The heavy ion peak intensities and spectral indices for events with fast (> 1300 km/s) near Sun CME speeds show a clear organization along the CME shock at 1 au.
   - The peak intensities are largest and spectral indices are smallest near 0° longitude, at the nose of the shock.

3. The organization along the shock for slower events (< 1300 km/s) is not as clear.
   - The ESP events are observed over a narrower range of longitudes.

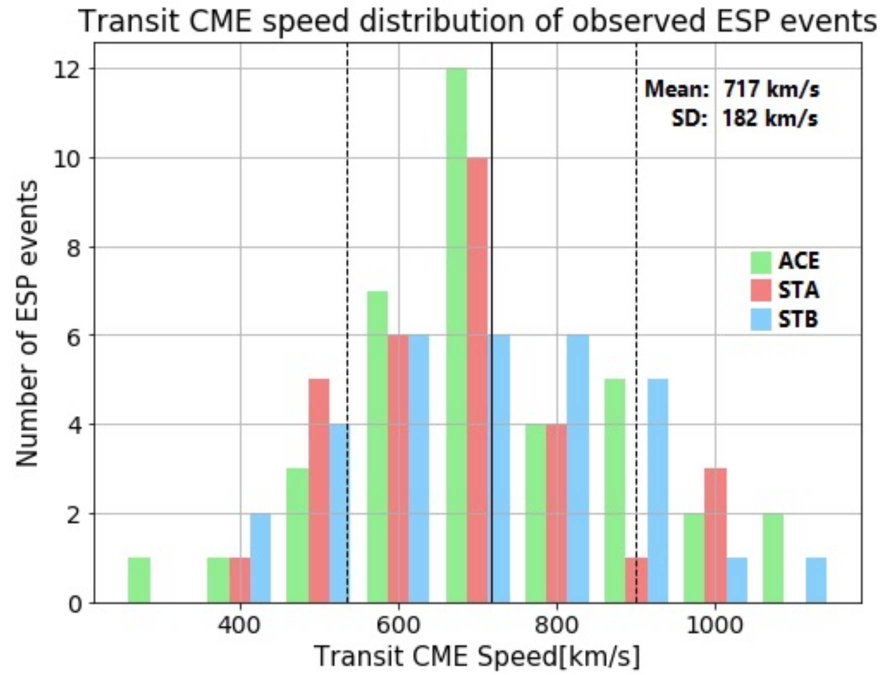
These results support the interpretation that particle acceleration is more efficient near the nose of an IP shock compared to the flanks, especially in events with high near Sun CME speeds.

Thank you

Near Sun and Transit CME Speed Distributions



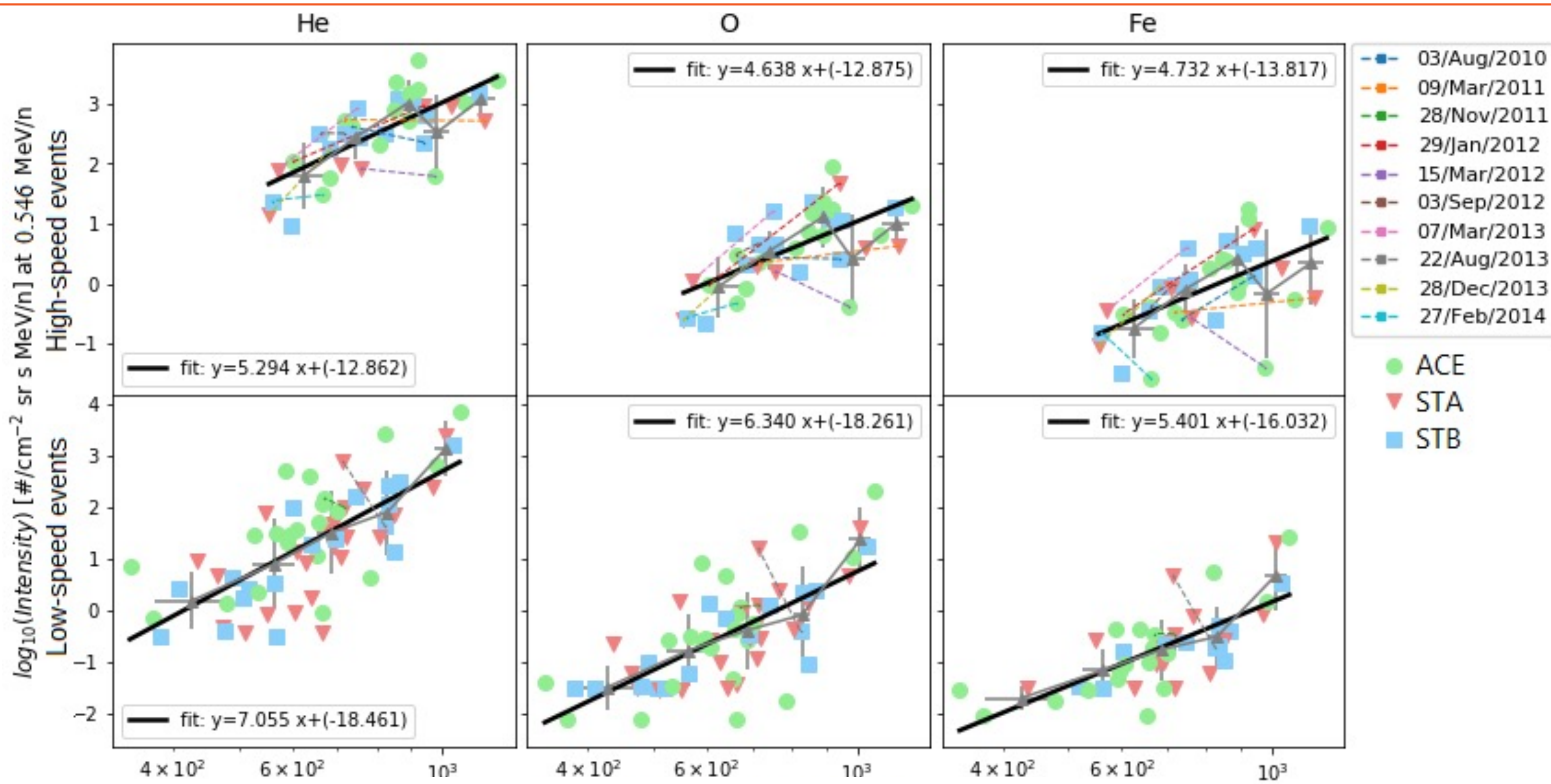
Distribution of near Sun CME speeds at 21.5 R_{Sun} for ESP events observed at ACE (green), STA (red) and STB (blue) spacecraft.



Histogram of average CME transit speeds at 1 au for observed ESP events.

$$\overline{V_{CME\ Transit}} = \frac{R}{(t_{1AU} - t_{1\,R_\odot})} \qquad (1)$$

Peak intensities vs average transit CME speed



$$\overline{V_{CMETransit}} = V_{CMENearSun} * (V_0 cos(\Delta\varphi - \varphi_0) + V_1) \quad (4)$$

$$log_{10}(j) = C_1 * log_{10}(\overline{V_{CME\ Transit}}) - C_0 \quad (5)$$

Where j is the intensity