Quantifying the Impacts of Interplanetary Propagation on Solar Energetic Particle Intensity-Time Profiles

Alicia K Petersen[12], Stephen M White[2], Stephen W Kahler[2†]

[1] University of Florida, Gainesville, FL

[2] Air Force Research Laboratory, Kirtland AFB

As Solar Energetic Particles traverse the inner heliosphere are their shape parameters impacted by interactions with intervening ICMEs?

Abstract

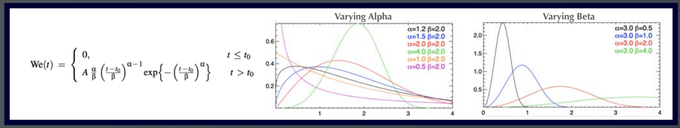
Solar energetic particle events (SEPs) that are produced in the solar corona and propagate through the inner heliosphere and interplanetary space may encounter intervening magnetic obstacles such as interplanetary coronal mass ejections (ICMEs) or the heliospheric current sheet (HCS). Such encounters impact SEP acceleration and propagation. SEP propagation speed and intensity are factors that impact SEP forecasting. We investigate the extent to which unusual in-situ measurements of the rise phase and Weibull fit shape parameters of SEP intensity-time profiles at 1 AU are correlated with interactions with intervening structures in the inner heliosphere. In a multi-year survey using Geostationary Operational Environmental Satellites (GOES) and Advanced Composition Explorer (ACE) observations we quantitatively compare correlations between potential ICME and HCS interactions with features of SEP intensity-time profiles and determine their significance via a resampling test.

Methods

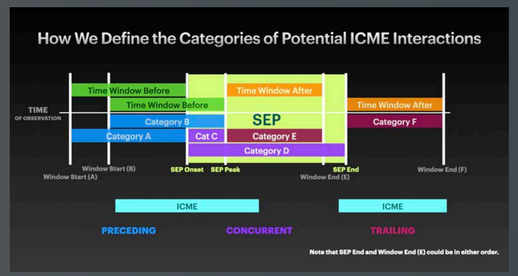
1. Weibull Function fits for 10 MeV GOES protons

(30 MeV, 50 MeV, 100 MeV also examined and not presented here.)

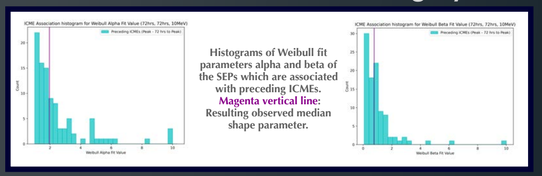
$$We(t) = \begin{cases} 0, & t \le t_0 \\ A \frac{\alpha}{\beta} \left(\frac{t-t_0}{\beta}\right)^{\alpha-1} \exp\left\{-\left(\frac{t-t_0}{\beta}\right)^{\alpha}\right\} & t > t_0 \end{cases}$$



2.



3. Calculate the Weibull fit parameters for each SEP. Determine the median shape parameter value for each coincident ICME category.



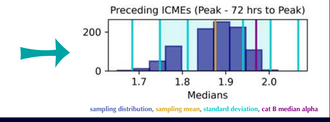
Histograms of Weibull fit parameters alpha and beta of the SEPs which are associated with preceding ICMEs. **Magenta vertical line**: Resulting observed median shape parameter.

4. Determine the Statistical Significance of the Shape Parameters

Example: There are 95 SEPs (10 MeV) with preceding coincident ICMEs. The median alpha value is 1.96. Is this statistically significant?

The Resampling Test:

1. Take a random sample of 95 SEPs from the overall set.
2. Calculate the median alpha and beta fit values.
3. Repeat 1000 times.
4. Calculate the mean and the standard deviation of this new sampling distribution.

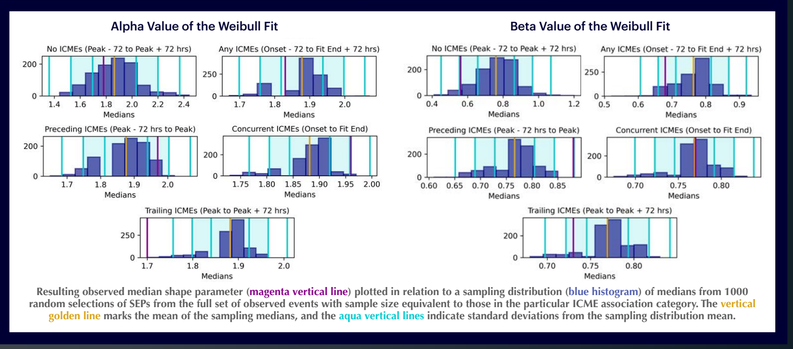


sampling distribution, sampling mean, standard deviation, cat B median alpha

Results: Shape Parameter Values

10 MeV SEPs	Median Alpha	Median Beta	Number of Events
No ICMEs (Onset- 72 to Fit End + 72 hrs)	1.75	0.68	84/154
Any ICMEs (Onset - 72 hrs to Fit End + 72 hrs)	1.87	0.76	103/154
Cat B: Preceding ICMEs (Peak - 72 hrs to Peak)	1.96	0.77	95/154
Cat D: Concurrent ICMEs (Onset to Fit End)	1.90	0.78	126/154
Cat E: Trailing ICMEs (Peak to Peak + 72 hrs)	1.90	0.78	124/154

Results: Statistical Significance



Resulting observed median shape parameter (**magenta vertical line**) plotted in relation to a sampling distribution (**blue histogram**) of medians from 1000 random selections of SEPs from the full set of observed events with sample size equivalent to those in the particular ICME association category. The **vertical golden line** marks the mean of the sampling medians, and the **aqua vertical lines** indicate standard deviations from the sampling distribution mean.

Conclusions

1. **The Weibull Alpha shape parameter, which defines the asymmetry of the intensity-time profile fit, is statistically lower or more asymmetric when the SEP is coincident with an ICME trailing the SEP event observation.**
2. **The Weibull Beta shape parameter, which defines the width/height ratio of the intensity-time profile fit, is statistically higher or broader when the SEP is coincident with an ICME preceding the SEP event observation.**

This research is supported by the National Research Council Research Associateship Program at the Air Force Research Laboratory.
Solar Photograph is by Andrew McCarthy (@cosmic_background).