Project Details

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Topic: Shock acceleration of solar energetic particles by interplanetary CMEs

Project Title:
Modeling and Observations of Solar Energetic Particle Spectral Breaks

PI Name: Richard Mewaldt
PI Email: RMewaldt@SRL.caltech.edu
Affiliation: California Institute of Tech
Project Member(s):
- Cohen, Christina M. S.; Co-I; California Institute of Technology
- Mason, Glenn M; Co-I; JHU / APL
- Li, Gang ; Co-I; null
- Haggerty, Dennis K; Co-I; The Johns Hopkins University Applied Physics Laboraotry

Summary:
Recent measurements show that in essentially all large solar energetic particle (SEP) events the energy spectra have a power-law component at low energies followed by a significant break in the spectra at higher energies (e.g., between ~5 to 50 MeV for protons). The spectra above the break sometimes are exponential in shape, but often a second power-law extends to hundreds of MeV/nucleon. The location of spectral breaks and the spectral shape above the break play key roles in determining whether an SEP event represents a radiation hazard. We propose to combine a self-consistent, detailed model of shock acceleration and interplanetary transport with state-of-the-art SEP measurements to investigate why spectral breaks occur, which physical parameters affect their location, and what determines the spectral shape at high energies.

The SEP data are from the EPAM, ULEIS, and SIS sensors on ACE and instruments on GOES and SAMPEX. These data will produce energy spectra from ~0.1 to ~100 MeV/nucleon for H, He, and heavy-ions from C to Fe. The observations already demonstrate that all ion species typically share a common spectral form, with spectral features that are organized by charge-to-mass ratio (Q/M). These spectra thereby provide critical information for investigating the physics of SEP acceleration and transport.

To investigate SEP spectra theoretically we propose several improvements to the SEP acceleration and transport model of Li, Zank and Rice. This model produces SEP spectra very similar to those observed, with spectral breaks that are apparently related in part to the spectrum of Alfven waves generated by protons escaping upstream of the shock, a critical element of the shock acceleration process. Other aspects of the acceleration process that will be investigated include: the seed-particle energy spectrum; the level of pre-existing upstream turbulence; shock speed and strength; and the rate and rigidity dependence of particle escape from the shock. By systematically varying the initial conditions and model parameters and then comparing with observations of large SEP events, we will isolate the parameters and conditions that have the strongest effect on SEP spectral characteristics.

This work will address several key scientific questions about SEP acceleration by CME-driven shocks, including: What seed-particle spectra and composition are needed to match the observations and how are they altered during the acceleration process? What conditions govern the acceleration rate, spectral slopes, break energies, intensity, and temporal evolution of SEP events? What combinations of these parameters result in very large SEP events like those on October 28, 2003 and July 14, 2000? Answering these questions is a prerequisite to building real-time models that can forecast when large SEP events will occur and how they will evolve - goals of both LWS and the 2005 S3C Strategic Roadmap.

Publication References:

Summary: no summary

Reference: Mewaldt, R. A.; (2006), Solar Energetic Particle Composition, Energy Spectra, and Space Weather, Space Science Reviews, Volume 124, Issue 1-4, pp. 303-316, doi: 10.1007/s11214-006-9091-0

Summary: no summary

Reference: Li, G.; Zank, G. P.; Verkhoglyadova, Olga; Mewaldt, R. A.; Cohen, C. M. S.; Mason, G. M.; Desai, M. I.; (2009), Shock Geometry and Spectral Breaks in Large SEP Events, The Astrophysical Journal, Volume 702, Issue 2, pp. 998-1004, doi: 10.1088/0004-637X/702/2/998