Project Details

ROSES ID: NNH19ZDA001N
Selection Year: 2019
Program Element: Focused Science Topic

Topic: Variable Radiation Environment in the Dynamical Solar and Heliospheric System

Project Title:
Diffusive Particle Acceleration and Extreme Solar Energetic Particle Gradual Events

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Summary:
Objective: Gradual solar energetic particle (SEP) events are associated generally with interplanetary shocks driven by coronal mass ejections (CME), where energetic ions are thought to be accelerated via diffusive shock acceleration (DSA). Close to the Sun, strong shocks can occasionally accelerate particles to GeV energies. Most typical CME-driven shocks tend to accelerate charged particles to quite modest energies, and the total energy contained within the accelerated SEPs is typically a small fraction (
Methodology: For Goal #1, we propose to develop a theoretical model of SEP mediated shock propagation in the inner heliosphere. The shock model will treat SEPs as a separate component from the bulk solar wind, using a diffusive transport equation formulation. To describe the scattering of particles, we will couple modern scattering theories for the spatial diffusion tensor to modern theories of turbulence transport. The PI and Co-Is have previously developed models for the structure of energetic particle mediated shock waves, charged particle scattering theories, and turbulence transport models. These models will serve as the starting point of our investigation. To accommodate the realistic solar wind, we will develop numerical solutions for 2D time-dependent shocks and solve the SEP transport equation. For Goal #2, we will solve the gyrophase-averaged particle transport equation for SEPs in the solar wind away from the shock to obtain their energy and pitch-angle distribution. The PI and Co-Is have developed numerical codes previously that solve the focused transport equation for energetic particles using a stochastic simulation method, and these will be the basis for modeling extreme SEP events. To validate our theoretical and numerical models, we will compare them against in-situ observations of plasma, magnetic fields, and SEPs from Parker Solar Probe, Helios, ACE, Wind, Ulysses, and the upcoming Solar Orbit and IMAP missions during extreme SEP events. Our existing iPATH (improved Particle Acceleration and Transport in the Heliosphere) code has successfully simulated some selected normal SEP events. However, it does not apply to extreme SEP events. We will compare the new model results i.e., the SEP-mediated extreme events, with the non-feedback (normal) models (using iPATH) to contrast the differences.

Contributions to the Focused Science Team: Our proposed investigation will contribute directly to FST #1 by focusing on the acceleration and transport of extreme SEP events, which contribute to the interplanetary radiation environment. As these extreme SEP events are often associated with CME-driven interplanetary shocks, this work may provide insight into the prediction of extreme SEP events.

Publication References:

Summary: Blah

Reference: L.-L. Zhao (PI), G. P. Zank (Co-I), M. Nakanotani, and L. Adhikari (Co-I), Observations of waves and structures by frequency-wavenumber spectrum in solar wind turbulence, 2023, ApJ, 944, 98.

- **Investigation Type:** Other Investigations
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