Project Details

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Program Element: Focused Science Topic

Topic: Toward a Systems Approach to Energetic Particle Acceleration and Transport on the Sun and in the Heliosphere

Project Title:
An investigation on the roles of the shock acceleration and the interplanetary transport on the spectra of solar energetic particle events

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Summary:
Summary: Power-law spectrum is the most common type of spectra of energetic particles. However, the energy spectra of solar energetic particles (SEPs), observed by spacecraft located at 1 AU, often exhibit double power-laws with break energies ranging from one to tens of MeV/nucleon. The break energies for different ion species were reported to be correlated with particle charge-to-mass (Q/A) ratio. While the existence of single power-law has a strong theoretical foundation, there is no clear explanation for the double power-laws. Some literature attributes it to a mechanism of particle acceleration in a shock environment, while some suggest it is due to particle propagation from a remote source. In order to understand whether the double power-law features result from the source or the transport process from the Sun to 1 AU, we propose to undertake an investigation on the roles the shock acceleration and the interplanetary plays in breaking the energetic particle spectra.

Objectives: Our proposed research focuses on finding the origins of the double power-law spectral profile observed at 1 AU. Specifically, we will examine the following two hypotheses: (1) the double power-law energy profile is generated, close to the sun, due to the finite shock lifetime or size, or shock geometry in the standard shock acceleration theory; (2) the double power-law spectra are due to the transport process from the sun to 1 AU. If the first hypothesis is proved, we will examine the dependence of the break energies and their Q/A correlation on shock parameters and other conditions near the shock region. For a coronal mass ejection (CME) event, with the observed/simulated structures of the CME-driven shock, we will calculate the spectral shape of SEPs in the source region. The result can also serve as an input to the subsequent interplanetary transport process. If the second hypothesis is proved, we will examine the dependence of the spectral properties and its Q/A correlation on the interplanetary transport processes. Combining with the energy spectra obtained from other CME-driven shocks or solar flares simulations by other members of the team, we could forecast the energetic particle flux and total radiation at Earth.

Methodology: Both data analysis and numerical simulations will be performed. In our investigation of shock acceleration, we solve the focused transport equation for particle acceleration with self-consistent wave generations close to the sun. In the code, we will use observationally reconstructed CME shock or numerical simulation from the team as an input of plasma and magnetic field. The waves are used to determine parallel and perpendicular diffusion coefficients. The same focus transport equation will be used to calculation SEP interplanetary transport. By comparing the results of calculations with observations, we will analyze the spectral properties in a large number of SEP events observed by spacecraft. Specifically, we will analyze the spectral shape for whole SEP events as well as in various phases. The correlation between the spectral properties and the interplanetary magnetic field properties will be analyzed. With the combination of theoretical calculations and data analysis, we can gain a full understanding of various physical processes in modulating the energy spectra of SEPs.

Proposed Contributions to the Focused Science Team Effort: Our proposed work is directly related to the Focused Science Topic (2): toward a systems approach to energetic particle acceleration and transport on the sun and in the heliosphere. We will provide team members with the understanding of the physical mechanisms of the energy spectra breaks. We contribute to the determination of the relative importance of shock acceleration and particle interplanetary transport in modulating the particle energy spectra in SEP events. Our work will also contribute to the forecast of the radiation environment during solar energetic events.

Publication References:

no references