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:
Determining the radiation level of galactic cosmic rays and solar energetic particles in the heliospheric magnetic field based on magnetogram measurements of the solar photosphere

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Summary:
Background: Galactic cosmic rays (GCRs) and solar energetic particles (SEPs) are two major sources of energetic radiations that affect the space weather. GCRs are modulated by the solar wind mainly in the 11-year solar cycle and to some small magnitude (Forbush decreases) by interplanetary disturbances. The most reduction of GCR intensity occurs in the heliosheath. The intensity of SEPs is highly variable, and the occurrence appears random. The majority of SEPs are produced by solar flares, or coronal mass ejection (CME) shocks deep in the solar corona or near the surface where seed particle density is high. Solar flares and CME shocks cover limited ranges of longitude and latitude, so a direct connection by magnetic field lines between SEP source and observer is not always guaranteed. Yet, it is quite surprising that SEPs are often detected over wide ranges of longitude even for those events with characteristics of impulsive events. To understand or predict GCR and SEP radiation hazards, we need to look at how energetic particles propagate through coronal and interplanetary magnetic fields. With this understanding, we can connect the particle source to the observed properties, such as the boundary condition, the timing, location, spectrum, anisotropy, and composition.

Objectives: We will investigate the effects of energetic particle transport in data-driven MHD corona and heliosphere models. Since SEPs and GCRs share the same particle transport mechanisms and magnetic field media, we intend to treat the GCR modulation and SEP propagation problems consistently and systematically. Our research consists of three parts: (1) Improve our GCR modulation and SEP propagation investigations with a more realistic combined data-driven MHD-based MAS, CORHEL, and MS-FLUCKSS heliosphere models to understand how particle radiation varies with solar wind condition and solar eruptions; (2) Apply our model calculation results and our expertise to the team effort in analyzing specific SEP events and GCR modulation phenomena; (3) Obtain understanding of the physics of particle acceleration and transport through comparison between observations and model simulations.

Methodology: We will rigorously solve the transport equations for particle propagation (also acceleration) in 3-D coronal and heliospheric magnetic fields. We will use a data-driven model from time-dependent MHD simulations constrained with measurements of the solar wind and photospheric magnetic field. The transport equation contains all the relevant mechanisms of particle transport: pitch angle scattering, perpendicular diffusion, magnetic focusing, anisotropic adiabatic energy loss or gain, streaming along the magnetic field, and convection with the solar wind, and gradient/curvature drift. It is solved using corresponding stochastic differential equations using both time-forward and time-backward approaches. Using the results of SEP source acceleration, we will produce predictions of particle flux at any specified location in the heliosphere. Our product will be the time profile of GCR and SEP flux at all energies, which can then be directly compared with observations.

Contribution to the Focus Science Team Effort: We bring the focus science team an indispensable, unique, state-of-art, and proven capability of calculating GCR modulation and SEP propagation through data-driven 3-D magnetic fields with essentially all particle transport mechanisms including perpendicular diffusion. We will provide team members with model calculations and expertise in data analysis, and, more specifically, the interpretation and prediction of SEP and GCR fluxes under various coronal and heliospheric configurations. When combined with simulations of CME-driven shocks or solar flares by other members of the team, we can also make further contributions to the understanding of particle acceleration and transport processes.

Publication References:

no references