Project Details

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Selection Year: 2017
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:
3D Modeling of Particle Acceleration and Transport at a CME-driven shock

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Summary:
Science goals and objectives:

We propose a 4-year project that addresses the 2017 LWS Focused Science Topic (FST): Toward a Systems Approach to Energetic Particle Acceleration and Transport on the Sun and in the Heliosphere. We will combine a well- established 3D MHD code Multi-Scale Fluid-Kinetic Simulation Suite (MS-FLUKSS) and a newly improved Particle Acceleration and Transport in the Heliosphere (iPATH) model that describes the acceleration of energetic particles at shock waves and their subsequent transport in the interplanetary medium to provide a more realistic multi-dimensional temporal description of particle acceleration at CME-driven shocks. We will focus on the following science questions:

1) How does shock geometry affect the acceleration process? Along a shock surface, are regions with a quasi-parallel configuration more efficient particle accelerators than regions with quasi-perpendicular configurations?

2) What is the cause of the systematic heavy ion (Q/A) dependence of spectral breaks?

3) What is the effect of perpendicular diffusion on the observed particle time intensity profile and particle spectra at different locations in the interplanetary medium?

Methodology: Two major numerical codes, both developed at UAH, will be combined in the proposed project. The MS-FLUKSS is a suite of codes solving the coupled MHD and kinetic Boltzmann equations in the adaptive mesh refinement (AMR) framework. It will be used to describe the large-scale heliosphere into which a CME will be driven. We drive simulations using photospheric vector magnetograms. This makes it possible to implement a mathematically-consistent, characteristic boundary conditions and create a suitable background solution for the CME propagation. We have developed a novel method to insert CMEs into the solar wind. It is based on the generalized Gibson-Low approach that uses multi-viewpoint remote observations of CMEs by SOHO and STEREO. The MS-FLUKSS ability to track surfaces passively propagating with the solar wind makes it easy to develop AMR algorithms for precise tracking of a CME and related shocks as they propagate toward Earth. The iPATH model numerically follows particle acceleration and transport in the heliosphere. The current iPATH code is a 2D particle acceleration model that extends the earlier PATH model, developed originally by Zank et al (2000). We propose to further extend iPATH to 3D. This will be done with an "operator split" in the two non-radial directions based on the geometry of the CME-driven shock relative to the local interplanetary magnetic field. To obtain instantaneous particle spectra at the shock, knowledge of the local magnetic field geometry and plasma density jump is required, which are derived from MS-FLUKSS.

Contributions to the Focus Team Effort: Understanding particle acceleration and transport is central to describing the origin of gradual SEP events. By combining a mature, well tested and state-of-the-art 3D MHD code with a mature, well-tested, and state-of-the-art particle acceleration and transport code, the 3D iPATH model, we will provide a major advance to both the physics and modeling of gradual SEP events. Our model will yield time intensity profiles and particle spectra as time-dependent functions of longitude, latitude, and radial distance, making our results highly relevant to the upcoming Parker Solar Probe and Solar Orbiter missions.

Relevance: This proposed work addresses the LWS FST "Toward a Systems Approach to Energetic Particle Acceleration and Transport on the Sun and in the Heliosphere." Specifically, the proposal addresses the goal of identify[ing] the mechanisms by which impulsive energetic particle events or gradual events of large angular extent occur and the goal of understand[ing] the relative roles of flares and CMEs in producing energetic particles as well as the underlying acceleration mechanisms.

Publication References:

no references