Project Details

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Program Element: Focused Science Topic

Topic: The Origin and Consequences of Suprathermal Particles that Seed Solar Energetic Particles

Project Title:
Suprathermal Seeds for Solar Energetic Particles: Two-stage Acceleration from Flares to CME-Shocks

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Summary:
(I) Science Goal and Objectives:

We propose a cross-disciplinary, paradigm-shifting investigation of the mechanisms of particle acceleration and transport in solar eruptive events, including particle acceleration and transport at the flare site on the Sun and at the CME-driven shock in the heliosphere. We will focus on the coupling between these processes, which were traditionally treated separately, but can play a crucial role in providing the seed population for solar energetic particles (SEPs), with flare-produced suprathermal particles to be re-accelerated by the CME-driven shock.

Specifically, we aim to address: (1) the mechanism(s) of particle acceleration at the coronal flare site, most likely via stochastic acceleration (SA) by plasma turbulence; (2) the processes that govern the escape and transport of flare-accelerated suprathermal particles to the CME-driven shock; (3) diffusive shock acceleration (DSA) of particles at the CME-driven shock, using the escaping flare particles as seeds; (4) the escape of particles from the CME-driven shock, upstream to 1 AU as SEPs and downstream to the Sun as gamma-ray producers, especially in those long-duration and behind-the-limb flares detected by Fermi.

(II) Methodology:

We will adopt a novel, systems approach consisting of balanced, mutually supporting elements of theoretical development, numerical modeling, and data analysis.

(1) This will be pursued in the framework of a hybrid model involving kinetic treatment of particles on microscopic scales and fluid (magnetohydrodynamic, MHD) treatment of the macroscopic development of the CME and shock evolution. The kinetic treatment involves SA and DSA of charged particles, as well as their two-way transport between the flare site, the CME-driven shock, and the in-situ instruments. We will perform data-driven simulations of well-observed events, where the MHD modeling will provide shock parameters for modeling DSA and magnetic connectivity for modeling particle transport.

(2) The modeling results will be rigorously compared and validated with remote-sensing and in-situ observations. Special attention will be paid to (i) nonthermal flare radiation, at X-rays from RHESSI, gamma-rays from Fermi, and radio from ground based telescopes and (ii) accelerated electron to proton ratios and isotopic enrichments of ions, such as 3He, that are sensitive to the underlying acceleration mechanisms.

(III) Relevance, Impact and Contribution:

Relevance: The proposed investigation directly addresses two of the three objectives of this LWS FST regarding (i) "the relative roles of solar flares and CMEs in producing large SEP events", and (ii) "particle acceleration mechanisms for producing suprathermal particles at the Sun and in the heliosphere and for accelerating these particles to high energies". It is also relevant to the third objective regarding "particle transport ... and other effects that result in the observed variability in the properties of SEP events at 1 AU."

Impact and Contribution: (1) The proposed study, when fully executed, will have the potential to revolutionize our understanding of SEP production in solar flares and CMEs as a coupled system. (2) To the best of our knowledge, no previous studies have

tackled this important aspect of SEP production by self-consistently including flare-accelerated particles as the seed population. We will be able to fill this gap and contribute to the FST with a fully-developed modeling suite that can track particle acceleration at the flare site and at the CME-driven shock, as well as particle transport in between. (3) With an over-arching systems approach, it can also potentially contribute to the FST by tying together works by individual teams that focus on different aspects of the problem and by performing end-to-end validation of modeling results with observations.

Publication References:

no references