Project Details

ROSES ID: NNH20ZDA001N
Selection Year: 2020
Program Element: Focused Science Topic

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

Project Title:
Investigating the roles of turbulence and reconnection in generating suprathermal seed populations for SEP events

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Summary:
Scientific Objectives

Solar energetic particles (SEPs), which have energies ranging from a few tens of keV to several GeV, pose severe hazards to astronauts and spacecraft components beyond the protection of Earth s magnetic field. A fundamental goal of space weather forecasts is the capability to predict SEP events reliably.

Suprathermal particles play a crucial role as the seed population that can be further accelerated by other mechanisms to produce SEPs. However, the mechanisms that generate the suprathermal particles and ultimately determine their energy distribution remain elusive. An in-depth understanding of these mechanisms is essential for predicting SEP events and determining their energy spectrum under various circumstances.

To address this question, we propose a research project based on recent first-principles simulations performed by the proposing team. These simulations indicated that the omnipresent small-scale reconnection sites in a magnetized turbulent plasma play a crucial role in generating the seed particle population, even though the reconnection sites do not account for the majority of particle energization. Observational evidence indicates that the solar corona is turbulent. We conceive that small-scale reconnection in turbulence may be the source of the suprathermal particles that seed SEP events. The ongoing Parker Solar Probe (PSP) mission may be able to probe these small-scale reconnection sites.

The primary objective of the proposed research is to investigate the roles of turbulence and magnetic reconnection as the cause of suprathermal particles with state-of-the-art numerical simulations, theoretical analysis, and comparison with PSP observations.

Methodology

The numerical simulations will involve multiple models, including MHD, five and ten-moment multi-fluid models, test-particle simulation, and fully kinetic particle-in-cell (PIC) simulation. Among the fluid models, the five and ten-moment multi-fluid models have been demonstrated to capture essential kinetic physics beyond MHD. Fully kinetic PIC simulation resolves the smallest scales and will be employed to produce the seed population. This step provides first-principles input of the seed populations that will be injected as test particles in fluid simulations to investigate the further acceleration of SEPs under various large-scale circumstances, including solar flares, coronal mass ejections (CMEs), and CME-driven shocks. In situ measurement of SEPs from PSP will be employed to test and validate theories and numerical simulations.

Proposed Contributions to the Focused Science Team Effort

This project is fully in line with the Focused Science Topic #3   The Origin and Consequences of Suprathermal Particles that Seed Solar Energetic Particles. We propose the following investigations:
Determine the distribution of suprathermal particles. By performing PIC simulations, test particle simulations, and theoretical analysis, we will determine how the distribution of suprathermal particles depends on plasma parameters and the charge-to-mass ratio of different elements and isotopes. The distribution of each species will directly impact its relative abundance in SEPs. The prediction will be tested against in situ observations of the Parker Solar Probe during quiet periods.

Investigate the effects of suprathermal particles on SEPs under various circumstances. To test whether the physics-based suprathermal seed particles generated by turbulence can lead to the high energy and intensity of observed SEP events, we will inject the seed population into fluid simulations of solar flares and CME-driven shocks to be further accelerated, corresponding to impulsive and gradual SEP events.

Publication References:

Summary: Blah

Reference: L. Comisso and L. Sironi, Ion and Electron Acceleration in Fully Kinetic Plasma Turbulence, The Astrophysical Journal Letters 936, L27 (2022)

- **Investigation Type:** Other Investigations
- Blah

Summary:

Reference: