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:
Tracking mechanisms efficiently accelerating charged particles at shocks at multiple heliospheric distances out to ~1.5 AU

PI Name: Federico Fraschetti
PI Email: ffrasche@lpl.arizona.edu
Affiliation: University Of Arizona
Project Member(s):
- Lee, Christina O;Co-I;University of California, Berkeley
- Giacalone, Joe;Co-I;University Of Arizona

Summary:
The solar energetic particles (SEPs) are regarded as a major component of space weather forecast and modelling. A primary goal of the upcoming Interstellar Mapping and Acceleration Probe (IMAP) mission is to connect SEPs measured at 1 AU with those over the entire heliosphere. This proposal focuses on such an unchartered domain and will benefit of the currently available Parker Solar Probe (PSP) data. A first step toward predicting the observations of SEP detectors onboard IMAP is the modelling of the evolution of properties of shock-accelerated particles (ions and electrons) between the closest possible approach to the Sun of PSP and Mars. In particular, we propose a targeted investigation to determine the time evolution of time profiles and momentum spectra at shocks at various distances from the Sun (between 10-15 Sun radii and 1.5 AU, i.e., Sun-Mars distance). The proposed study will combine a balance of: 1) data analysis and interpretation of interplanetary shocks by using publicly available high time resolution data collected by SEP detectors and magnetometers onboard PSP, ACE (Advanced Composition Explorer) and STEREO (Solar TErrestrial RElations Observatory) and MAVEN (Mars Atmosphere and Volatile EvolutioN); 2) theory and hybrid/test-particle numerical simulations at shocks to interpret the data.
Science goals   The theory of diffusive shock acceleration (DSA) assumes a population of energetic particles (EPs) with a nearly isotropic pitch-angle distribution in the local plasma rest frame; the DSA theory cannot be applied to particle speed comparable to the flow speed. Using spacecraft measurements obtained at different locations in the inner heliosphere, we will investigate how the time profiles change and how spectra harden or soften at distinct distances from the Sun. This goal meets all three LWS program objectives.
Methodology - For the proposed investigation we will make use of publicly available high-time resolution SEP and magnetic field measurements at PSP (EPI-Lo, EPI-Hi, MAG), at 1 AU from ACE (EPAM, MAG) and STEREO A/B (LET, HET, SEPT, SIT, MAG) and at 1.5 AU from MAVEN (SEP, MAG). We will identify a number of shock events observed in two distinct locations (or only at a single location) and extract at various distances from the shock, both upstream and downstream, particle intensity and pitch-angle distribution. We will perform comparative test-particle and hybrid simulations of the intensity profiles, pitch-angle and momentum distribution at the shock and far downstream and compare with observations.
Feasibility The assembled team has already a series of publication on: 1) the data analysis and interpretation at 1 AU (e.g., Zhou et al., RNAAS, 2,145, 2018, Giacalone, 2015, ApJ. 799,80) and 1.5 AU (Lee et al., JGR, 122, 2017); 2) numerical simulations for particle acceleration at shocks (Giacalone, 2005, ApJ, 628, L37; Fraschetti & Giacalone, MNRAS, 448, 3555, 2015).
Proposed Contributions to the Focused Science Team (FST) Effort - The comparison of SEP observations at multiple distances from the Sun will provide unprecedented constraints on the underlying acceleration mechanism. This project will complement modelling efforts between the Sun and Mars within the same FST team to cover, for instance, the physics of the coronal mass ejections driving the shocks. This project will contribute to the LWS types of investigation Studies of the temporal and spectral properties of large SEP events and Simulations of high-energy particle dynamics and comparison with spacecraft measurements . Milestones: 1) extract from data profiles, spectra and pitch-angle distribution from ~10-15 Sun radii out to 1.5 AU; 2) investigate effects of large-scale geometry and spacecraft angular/radial separation in the interpretation of the data; 3) numerical simulations for the interpretation of data. We will make available some of the numerical codes used. The PI volunteers to serve as FST team-leader.

Publication References:

no references