Project Details

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Selection Year: 2021
Program Element: Focused Science Topic

Topic: Understanding the Large-Scale Evolution of the Solar Wind

Project Title:
Investigating the radial evolution of the interactions between solar wind plasma, macroscopic structures, and intermediate frequency waves

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Summary:
One of the key problems in developing accurate models for predicting space weather is understanding the co-evolution of waves and particles with solar radial distance. The coupled processes modify the temperature, energy and momentum of solar wind plasma, which are critical parameters for determining the interaction of the solar wind with the Earth's magnetosphere, and, ultimately how changes in the Sun impact life and technology. Our overall science goal is to determine nature of the interactions between intermediate frequency waves and large-scale solar wind structures and electrons and ions as they stream away from the Sun. We define intermediate frequency waves as approximately the range from the lower hybrid frequency to the ion plasma and electron cyclotron frequencies. We will concentrate on the evolution between ~15 solar radii (reached by Parker Solar Probe during encounter 8) and ~1 AU.

To address our science goal, we will focus on these specific questions:
1. What is the interdependence between intermediate frequency waves and large-scale structures including interplanetary shocks and stream interaction regions?

2. How do the occurrence, properties and dominant instability mechanisms of intermediate frequency waves depend on distance from the Sun?

3. How do the changes in dominant wave modes impact the evolution of electrons and ions?

4. Near 1 AU, how do these waves depend on solar cycle?

Technical approach: We will utilize in-situ plasma and waves data from spacecraft at varying distances from the Sun to examine wave properties and occurrence rates, and their relationship to electron and ion properties. We will focus on data from Parker Solar Probe, STEREO and Wind. As necessary to increase statistical significance or to examine regions farther from the Sun, we will use data from Solar Orbiter, Cluster, ARTEMIS, Cassini, and Juno. Waveform capture data provide the most detailed information on wave modes and properties, while on-board spectra and bandpass filter data yield the continuous (or longer duration) observations needed to accurately assess occurrence rates and radial dependence. STEREO and Wind provide data over multiple solar cycles to assess changes in the waves and particles with solar cycle at ~1 AU. We will utilize cold and warm plasma dispersion relation solvers, and fully kinetic simulations (FKS) simulations to determine instability mechanisms. Both particle tracing codes and (FKS) simulations will be used to assess the interactions of the waves with particles. Errors in data sets and data analysis and in theoretical techniques will be addressed.

Relevance to goals of LWS and of FST 3: Our science objective and questions are directly relevant to FST 3, specifically to the goals to understand (1) the physical processes driving the formation and propagation of solar-wind structures throughout the heliosphere and their variability with the solar cycle and (2) how the solar magnetic field and coronal structure determine the plasma and magnetic-field conditions in the inner heliosphere throughout the solar cycle." As described above we will establish how solar wind particles interact with intermediate frequency waves at different distances from the Sun , and, in addition, the solar cycle dependence around 1 AU. Our contribution to the Science Team effort will be providing a detailed understanding of the physics of intermediate frequency waves, their role in the radial evolution of solar wind plasma, and interactions with macroscopic solar wind structures. The insights we develop will be important for other teams , for example those who are

examining MHD turbulence, the connectivity of solar wind structures to the solar corona, and evolution of the solar wind to the outer parts of the heliosphere. The new understanding that will be obtained through our research is needed to develop accurate predictive models for space weather, thus safeguarding life and technologies.

Publication References:

no references