

Project Details

ROSES ID: NNH18ZDA001N

Selection Year: 2018

Program Element: Focused Science Topic

Topic: Origins, Acceleration and Evolution of the Solar Wind

Project Title:

Coupling electron and proton kinetic physics in the Solar Wind

PI Name: Tulasi Nandan Parashar

PI Email: atn@g.ucla.edu

Affiliation: University Of Delaware

Project Member(s):

- Matthaues, William H;Co-I;University of Delaware
- Salem, Chadi S;Co-I/Institutional PI;University of California, Berkeley
- Shay, Michael A;Co-I;University of Delaware
- Maruca, Bennett A;Co-I;null

Summary:

Science Goals: The mean free path of particles in solar wind is ~1AU or larger, making it larger than most scales of interest. This implies that the solar wind is extremely weakly collisional. Lack of direct inter-species collisions drives the system into a highly non-equilibrium state where protons and electrons are not in a thermal equilibrium. However a lack of collisions and thermal equilibrium between different plasma species does not imply that the species do not affect each other. Both species affect the evolution and kinetic behavior of the other via electromagnetic interactions. However, which processes and channels enable this interaction, and the resultant effects have not gained much attention at all. It is our aim to develop a research program that addresses this problem using a combination of spacecraft data and kinetic simulations. The objectives of the proposal are: (I) Identify the channels of interaction between protons and electrons, and their relation to reconnection and turbulence in the solar wind (II) Identify the effects of this interaction on kinetic physics of both protons and electrons, (III) Create statistical surveys of correlations between various physical quantities of interest such as relative species heating, turbulence amplitudes, individual species temperatures, temperature ratio of both species, solar wind speed etc. The fundamental goal is to create a comprehensive knowledge base that can guide global simulations of solar wind to improve the thermodynamic representation of these species.

Methodology: The project will employ both, analysis of spacecraft data as well as kinetic simulations to address this problem. The strategy will be two pronged: (I) use kinetic simulations to identify the interaction channels between the two species, and quantify their roles. (II) Use spacecraft data to perform surveys of statistical correlations between various quantities of interest, and to identify specific intervals of interest to simulate using kinetic simulation models. For kinetic simulations, primarily fully parallel electromagnetic kinetic code P3D will be used. Our team has used this code extensively for studying turbulence and reconnection. For spacecraft observations, solar wind data from Wind, ACE, Cluster, Helios, and MMS spacecraft will be used. Single-spacecraft and multi-spacecraft techniques will be used where appropriate. Our team has expertise in analyzing data from all these spacecraft for various turbulence studies.

Proposed Contributions to Focused Science Team Effort: The interplay of protons and electrons in a collisionless system is of interest on its own at a fundamental level. However, the statistical correlations found in this study will be important to empirically represent the thermodynamics of protons and electrons in global models. A preliminary

attempt in this regard has already been made by our collaborator Arcadi Usmanov by incorporating results from one of recent papers into his global heliospheric model. Moreover, the insights gathered from this study will help interpret and analyze data from NASA/ESA missions such as Parker Solar Probe, and Solar Orbiter.

Relevance: The proposed study is directly relevant to LWS program objective 1: "Understand how the sun varies and what drives solar variability" and Focused Science Topic 2: "Origins, Acceleration and Evolution of the Solar Wind". Understanding the interplay of proton and electron kinetic physics is central to a better understanding of the solar wind and its evolution. This study is also relevant to the first science objective defined in the 2014 Heliophysics Roadmap for NASA: "Solve the Fundamental Mysteries of Heliosphere" by understanding not only the fundamental processes that energize particles, but also by enhancing our understanding of the role that magnetic reconnection and turbulence play in the evolution of the solar wind.

Publication References:

Summary: Blah

Reference: Fordin, S., M. Shay, L. B. Wilson, B. Maruca, and B. J. Thompson, A Machine Learning-Based Approach to Time-series Wave Identification in the Solar Wind, *The Astrophysical Journal*, 949, 40, 2023, doi:10.3847/1538-4357/acc8d5.

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

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