Alabama Research Experiences for Undergraduates

Project Title:
Space Plasma Physics: Solar wind, pickup ions, turbulence, and particle acceleration

Subproject 1:
Cowling Resistivity Distribution in Partially Ionized Solar Chromospheric Plasma: A Parametric Study

Project Reference Code:
UAH-Yalim

Host Facility:
The University of Alabama in Huntsville

Host Facility Location:
301 Sparkman Dr.
Huntsville, AL 35899
https://www.uah.edu/

Project Description:
The Sun plays an important role in space plasma physics. The surface of the Sun expands outward at a certain speed (called the solar wind), until the ram pressure of the solar wind is balanced by the interstellar medium pressure. The expansion of the solar wind stops, forming a bubble-like space area in the interstellar medium, called the heliosphere. Due to the rotation of the Sun, the solar wind forms a Parker spiral in the expansion process. Note that the magnetic field freezes in the solar wind plasma and convects with it. Solar wind provides a unique opportunity to study various processes in plasma. In the solar wind, waves and turbulence are everywhere. The dissipation of turbulence is thought to be responsible for the heating of coronal plasma to millions of degrees Kelvin, the acceleration of the solar wind, and the heating of the solar wind. Similarly, several theoretical (Zank et al. 2014, 2015; le Roux et al. 2015, 2016, 2018) and observational (Khabarova et al. 2015, 2016, 2017, 2018; Zhao et al. 2018, 2019; Adhikari et al. 2019) studies have found that when solar energetic particles (SEPs) propagate through the "sea" of magnetic islands, they accelerate in situ. In addition, some studies have also shown the presence of pickup ions (PUIs) in the solar wind (Zhao et al. 2019). PUIs are produced due to the charge exchange between solar wind protons and interstellar neutrals. Waves, turbulence, and PUIs have their own characteristics, and they can change the shape of the heliosphere, and the termination shock (TS).

We divide the project into six sub-projects. Our research project involves i) a parametric study of cowling resistivity, ii) mapping of the solar wind's magnetic field, iii) evolution of turbulence in the inner heliosphere, iv) magnetic reconnection and plasma acceleration, v) the generation and propagation of interstellar pickup ions, and vi) hybrid simulation including neutrals. The student are feel free to choose any one of our project. Students will be involved with state-of-the-art research under the direction of Dr. Zank (and his research scientists Dr's Lingling Zhao and Mehmet Yalim (Sarp) and postdocs, Dr's Samira Tasnim, Masaru Nakanotani, Haoming Liang, and Laxman Adhikari).

Description of Subproject:

Chromosphere is a very complex region to model physically and solve numerically. The plasma temperature increases from photosphere to corona from O(103) K to O(106) K through the chromosphere and the transition region in only 10,000 km. Certain regions of the solar atmosphere are at sufficiently low temperatures to be only partially ionized, in particular the lower chromosphere. This leads to Cowling resistivities orders of magnitude larger than the Coulomb values. In order to evaluate the expression for the Cowling resistivity ηc (Cowling, 1957) external magnetic field, and an estimate for the neutral fraction ξn as a function of bulk plasma density and temperature are required. Accordingly, we will follow the formulations in Leake & Arber, 2006 to calculate ηc.

In this project, we will perform a parametric study to compute the Cowling resistivity distribution in a local domain in the vicinity of an active region in terms of varying external magnetic field, bulk plasma density and temperature in order to find the effect of these parameters on the Cowling resistivity. The external magnetic field in the local domain will be provided by extrapolating the magnetic field from the SDO/HMI SHARP vector magnetogram data on the photosphere by using non-force-free field extrapolation (NFFF) technique (Hu et al., 2010). Temperature and density, which are functions of height from the photosphere, are highly stratified in chromosphere. We will calculate their distributions from the formulations in Jiang et al., 2016. We will vary the uniform values for temperature and density on the photosphere individually. We will repeat this analysis for 5 active regions of diverse complexity.

Disciplines:
Physics, Math, Computer Science, Space Science

Is U.S. citizenship required to participate in this project?
Yes

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The name and contact information of personnel at the host facility is provided for further assistance with questions regarding the host facility or the project.

Interns will not enter into an employee/employer relationship with the host facility. No commitment with regard to later employment is implied or should be inferred.