Alabama Plasma Internship Program

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

Subproject 6:
Computer Simulation: Hybrid Simulation Including Neutrals

Project Reference Code:
UAH-Nakanotani

Host Facility:
The University of Alabama in Huntsville

Host Facility Location:
301 Sparkman Dr.
Huntsville, AL 35899
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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).

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Description of Subproject:
Collisionless plasma in which a collision between particles is absent has been considered a standard plasma in space for several decades. However, multiple studies in these years claim that the presence of neutrals in plasma can bring several non-negligible effects into plasma. For instance, the structure of the heliosphere is greatly modified because of an interaction between the solar wind plasma and neutrals in the interstellar medium [Zank 2016]. Far away from the Sun, it is implied that the presence of neutrals can play an important role for particle acceleration at supernova remnant shocks [Ohira 2013]. A key process in the both of examples is pickup ions (PUI) which are produced by the charge exchange between a proton and a neutral. Although we need to consider neutrals in plasma, we do not understand basic plasma physics including neutrals especially in a kinetic regime.

Hybrid simulation in which ions and electrons are treated as particles and fluid is suitable for describing an ion kinetic regime phenomenon. While magnetohydrodynamic (MHD) simulation is capable of handling a larger scale phenomena at a lower computational cost than hybrid simulation, kinetic effects of ion are sacrificed. On the other hand, full particle-in-cell simulation in which ions and electrons are treated as particles can resolve electron scale dynamics and kinetic effects of ion and electron. The simulation size is, however, restricted in a smaller scale than hybrid simulation because of a huge computational cost. Therefore, hybrid simulation is well balanced to perform a decent scale size simulation and include an ion kinetic effect.

The purpose of this project is that the student writes a 1D hybrid simulation code including a charge exchange process between protons and neutrals and apply it to investigate a PUI production and relaxation in the solar wind self-consistently. S/he also may want to use it for several different parameters. If time permits, s/he will compare the simulation results with observational data. Through the topic, the student will learn how neutrals modify plasma.

Disciplines:
Physics, Math, Computer Science, Space Science

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

Name(s) of Mentor(s) and contact information:
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Internship Coordinator/ HR manager:
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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.