Alabama Plasma Internship Program

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

Subproject 4:
Magnetic Reconnection and Plasma Acceleration

Project Reference Code:
UAH-Liang

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).

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Description of Subproject:
Magnetic reconnection is a fundamental plasma physical process. During magnetic reconnection, two flows of plasmas with anti-parallel magnetic fields are pushed together and form a thin current sheet. As plasma continue flowing towards the current sheet, magnetic field lines break and reconnect in a lower energy state and plasmas are accelerated and released as two symmetric outflow jets. Therefore, reconnection is a process where the magnetic field topology is dramatically re-arranged and the magnetic energy is violently released to high speed flows and thermal energy of plasma.

Magnetic reconnection is believed to be ubiquitous in the universe. It heats plasma at the solar surface in the form of solar flare and coronal mass ejections (CMEs). For magnetized planets like Earth, it occurs where the interplanetary magnetic field interacts with the magnetosphere, i.e., the magnetopause, and allows the solar wind plasma to break into the magnetosphere. It also occurs inside the long tail of the magnetosphere and triggers a series of disturbed geomagnetic activities such as strong geomagnetic storms and enlightened aurora. Recent studies further discovered that reconnection occurs within the solar wind and that it is one important mechanism that dissipates turbulent magnetic energy.

This project is designed to study magnetic reconnection and associated plasma acceleration by performing fully kinetic numerical simulations. The simulation to be studied is Particle-in-Cell (PIC) simulation. The student will learn the elementary theories about magnetic reconnection and run an open-source PIC code on cluster computers. The student will analyze electromagnetic fields, the energy partitions, and particle acceleration mechanisms associated with reconnection, and will compare the simulation output with satellite observations. Through this project, the student will acquire skills on performing cluster computing, data analysis and visualization based on software such as Interactive Data Language (IDL), and usage of satellite data, e.g., Cluster or Magnetospheric Multiscale (MMS) mission.

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:
Haoming Liang (haoming.liang@mail.wvu.edu)
Gary Zank (gpz0001@uah.edu)

Internship Coordinator/ HR manager:
Dana Waller (dsw0012@uah.edu)

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.