

Magnetohydrodynamic waves and plasma dynamics in quiet Sun and coronal holes

Research project objectives:

The proposed project aims to understand the role of MHD waves in the localized heating of the quiet-Sun chromosphere as well as in driving the plasma ejecta (e.g., chromospheric spicules, tornadoes, network jets, swirls) that may supply mass to upper layers of the solar atmosphere and contribute to the formation and acceleration of the solar wind. These two fundamental problems are typically considered by the solar physics community as the most longstanding puzzles that require urgent solutions, which are the main objectives of this proposal. Apart from these two problems, properties of MHD waves (their propagation, dissipation, conversion) and other dynamical phenomena in the quiet-Sun corona and coronal holes are also aimed to be understood by the proposed research; a specific attention will be given to a way the physical phenomena occurring in the solar corona are linked to the wave and plasma dynamics of the underlying chromospheric layers. The latest observations and our stringent numerical modeling will explore the coupling of various layers of the solar atmosphere in terms of MHD waves and confined transients, and will allow us understanding their role in the localized atmospheric heating and dynamics of the solar atmosphere. In particular, we shall focus on complexity of solar magnetic fields in the solar chromosphere, which underlies the quiet-Sun corona/coronal hole, where the fast solar wind originates.

Research project methodology:

In the proposed research, we will use the advanced analytical and numerical tools to model the quiet- Sun and coronal holes as well as the lower layers, including the upper layers of the solar convection zone. Some additional analytical and numerical tools to perform the proposed research will also be developed. The propagation and attenuation/dissipation properties of MHD waves will be explored within the framework of the realistic models of quiet-Sun, coronal holes, polar plumes, and inter-plume regions, and it will be studied how plasma and magnetic field affect MHD waves in various parts of the solar atmosphere. These realistic models will be verified by the contemporary high-resolution observational data (such as from IRIS, SDO, Hinode/EIS) and analytically derived signatures of MHD waves in the quiet-Sun and coronal hole regions and its diversity of magnetic structures.

Expected impact of the research project on the development of science, civilization and society:

The proposed research will be used to explain a wide range of activities occurring in the solar atmosphere, develop a theoretical basis for interpretation of the current and future solar observations, and identify the principal energy sources of the solar atmosphere and the basic physical processes responsible for creating the heliosphere. Advancing the existing knowledge about some aspects of our nearest star will further shed some light on similar distant objects. This will greatly enhance our current

understanding of the Sun and its atmosphere, and their important role on the origin and sustaining our civilization. The proposed project will also have a broader impact since the obtained results will be widely disseminated through various venues, including our project website, journal publications, and special sessions at major conferences. All computer codes, demonstrations, and preprints will be made available at the project website for other interested researchers to download. We shall enhance graduate and undergraduate education by involving PhD graduate and undergraduate students in this project, and incorporating the research accomplishments of this project into existing graduate and undergraduate courses in astrophysics and solar physics.

JUSTIFICATION - BASIC RESEARCH

The Sun has been the subject of our interest from the dawn of time. It provides energy that makes our environment habitable but its variability such as flares and coronal mass ejections, solar wind can affect our civilization (e.g., forcing weather and climate changes). These violent explosions originate in very hot and magnetized solar atmosphere and travel through the still poorly explored solar atmosphere, and wind. Therefore, the exploration of local magnetic fields, plasma structures, wave/plasma dynamics give more information about the solar atmospheric conditions where even such eruptions are generated. In this project, we aim to understand the reasons that make solar atmosphere very hot, and originate the solar wind. Knowing about exact structure of localized magnetic fluxtubes, local perturbations in plasma threaded by magnetic field and associated MHD waves, as well as their properties may shed new light on the local conditions of the solar atmosphere, and significantly to contribute to the solution of the solar atmosphere heating problem, and the origin and acceleration of the solar wind. The proposed studies will be also used to better understand distant stars whose physical parameters are similar to our Sun. One of the main justifications for the proposed project is provided by the recent (IRIS) mission launched by NASA in June 2013, which already have given unprecedented observational data of the chromosphere and transition region, and demonstrated that waves and oscillations do exist in the solar atmosphere on small spatial and temporal scales. Among the observed MHD waves, the obtained data clearly show that Alfvén waves do carry enough energy to heat the solar corona, and trigger and accelerate the solar wind. Therefore, studies of these waves are urgently needed and this is one of the main goals of this proposal. It is important to point out that our studies will be based on the powerful analytical and numerical tools (the FLASH code), which will be used to investigate linear and nonlinear Alfvén, as well as magnetoacoustic waves in the solar atmosphere with 1D, 2D and 3D geometries of magnetic fields. The obtained results will be tested against the available observational data and will also be used to develop a theoretical basis for interpretation of observational results to be collected by the Advanced Technology Solar Telescope (ATST) and the currently operating ground-based GREGOR telescope.