Modelling Space Plasma in the Inner heliosphere and its impact on Earth's Magnetosphere

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The heliospheric plasma is also a powerhouse for micro-scale processes including magnetic reconnection and particle acceleration. Magnetic reconnection has been detected in a variety of locales, including the Solar corona and planet magnetospheres, and is frequently accompanied by the presence of a velocity shear. Furthermore, macro-physical phenomena occurring inside the heliospheric plasma domain, such as the propagation of Coronal Mass Ejections (CMEs) and the interplay of slow and rapid solar wind, influence in-situ particle acceleration via shocks. Linking various scales that account for the interaction of numerous physical processes necessitates the use of unique numerical modeling methodologies.

In this presentation, I'll discuss new efforts to model space plasma using 3D global-MHD and MHD-PIC models from the open source astrophysical gasdynamics code PLUTO. The discussion will concentrate on how large-scale dynamical processes inside the inner heliosphere affect the Earth's magnetosphere, especially in terms of assessing its geo-effectiveness. Initially, I'll show how ambient solar wind influences CME evolution and how it interacts with stream/corotating interaction zones (SIR/CIR) using the indigenous SWASTi framework [1]. The unique role of CME shocks in creating solar energetic particles, as well as the mechanism of fast reconnection in double layer current sheets as plausible techniques for accelerating particles within the inner heliosphere, would be discussed. Using this toy model, we discovered that the scaling of the reconnection rate with shear is altered due to a structure-driven instability. We also discover that shocklets linked with small plasmoid injections are in charge of energizing particles within the domain's large scale plasmoids [2]. In addition, we will discuss our latest results from the 3D global-MHD, which use the adaptive mesh refinement (AMR) technique to examine the process of magnetic reconnection in a more realistic scenario of dayside magnetopause. The talk will further specifically demonstrate the production and evolution of Flux Transfer Events (FTEs) in our simulation as helical flux ropes at the dayside magnetopause, as well as discuss our unique toolkit for isolating the volumes of these structures using an agglomerative hierarchical structure detection algorithm and studying FTE evolution from a volumetric perspective [3]. Our findings confirm that the mechanism of continual reconnection is the primary cause of FTE development during the early to mid stages of evolution. We also discover that the FTE volumes rapidly drift towards a linear force free configuration over time; however, the continual reconnection prevents this from happening. We also compare the flux content of these FTEs to the estimates supplied by the observational models and discover that the observations regularly underestimate the FTE flux content by a significant margin. Lastly, for assessing the geoeffectiveness of these transient events, we would outline a two-way coupled ionospheric model into the global-MHD model.

References

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