8th Asia-Pacific Conference on Plasma Physics, 3-8 Nov, 2024 at Malacca

Global Scale Magnetohydrodynamics Modelling of the Slow Solar Wind

Sahel Dey[1], David Pontin[1]
[1] School of Information and Physical Sciences, University of Newcastle Australia
e-mail (speaker) : sahel.dey@newcastle.edu.au

The solar wind is a continuous stream of charged particles emanating from the Sun that fills the entire solar system. With characteristics that drastically fluctuate, it is the primary driver of space weather and, therefore, maintains the Sun-Earth connection. Space weather impacts space-based and Earth surface infrastructure and as our society becomes increasingly dependent on technologies. Extreme space weather events, e.g., “solar storms” – release massive amount of radiation and high-energy particles, that endanger the lives of astronauts, health of high-altitude-aircraft passengers, damage satellite electronics and degrade satellite navigation, cause power grid failures. Estimates of the economic losses due to a severe space weather event are in the hundreds of billions of dollars.

Spacecraft observations show that there exist two different types of solar wind, distinguished by their speed, dynamic nature, and composition. The properties of the fast solar wind are well explained by established theory (**Hundhausen 1977**) but, by contrast, the Slow Solar Wind (SSW) is extremely poorly understood. Its origin at the Sun is not well constrained by observations, and its speed, composition, and high degree of variability remain a mystery (**Fisk & Schwadron 2001**). The Earth and planets are generally embedded in the highly-fluctuating SSW for more than half of the 11-year solar cycle period, so understanding the nature of the slow solar wind is paramount of interest for understanding or predicting the space weather that propagates from the Sun to Earth.

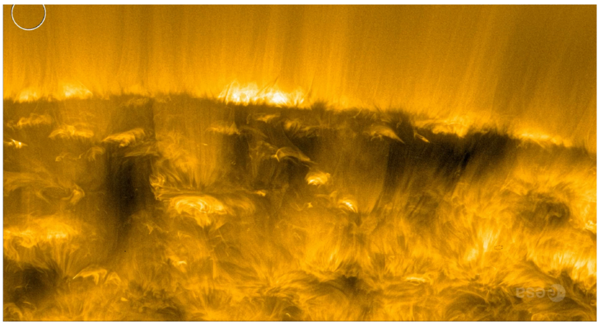

Figure: A high-resolution observation of the solar polar region by the Solar Orbiter telescope, showing intricate structures of plasma outflows as the solar wind.
Credit: Solar Orbiter Webpage

The aim of this scientific exploration is to test the leading hypothesis, process of Interchange Magnetic reconnection (**Antiochos et al., 2011**), for understanding the source and properties of the SSW. Previous approaches to understanding the consequences of IMR have been largely conceptual, invoking a simple ‘cartoon’ reconnection process and/or considering only static equilibrium. Here we present state-of-the-art three-dimensional computational modeling that include the full dynamics, a representative coronal field structure, and a realistic coronal reconnection process with highly dynamic, non-laminar current layers. We simulate interchange reconnection between open and closed magnetic fields using the MPI-AMRVAC code that employs adaptive mesh refinement to resolve the turbulent nature of the IMR process. The results will then be coupled to those from an efficient global model of the Sun’s magnetic field that includes electric currents/free magnetic energy and, therefore, faithfully reveals the magnetic field structure in the corona on global scales. Using our IMR simulations, we will generate testable predictions for comparison with state-of-the-art data from Parker Solar Probe. This will allow us to test whether the mechanism provides a source of outflows with the correct properties, such as its filamentary structure and fluctuations in velocity and plasma content. For the first simulation, we start from a simple initial setup, and then sequentially and systematically increase the complexity by incorporating several realistic physical processes, e.g., thermal conduction, radiative cooling, and Ohmic heating, as well as different magnetic structures. In tandem with these local simulations we will probe the large-scale evolution in an efficient global model that includes the coronal free energy. The strength of this dual approach is that we can then ‘couple’ the results of the local and global models in order to address global questions of energy and mass transport.