भारतीय खगोलभौतिकी संस्थान
INDIAN INSTITUTE OF ASTROPHYSICS
कोरमंगला **Koramangala,** बेंगलूरु **Bengaluru – 560034.**

Ph.D THESIS DEFENCE

Name: Mr. Samriddhi Sankar Maity, IIA – JAP, Student

Title: "Confronting realistic MHD simulations of solar eruptions with observed space based data".

Research Supervisor : Dr. Piyali Chatterjee and Prof. Dipankar Banerjee
Nominal supervisor : Prof. Rajeev Kumar Jain

सार Abstract

Solar flares and Coronal Mass Ejections (CMEs) are among the most energetic and powerful events in the solar system. Solar flares cause sudden bursts of electromagnetic energy, while CMEs involve the expulsion of magnetized plasma clouds and high-energy particles from the Sun. Both phenomena can significantly disrupt space weather on Earth, making their study crucial for better understanding and mitigating their effects. Our research aims to distinguish between eruptive and confined solar flares by analyzing changes in magnetic patterns at the photosphere. We examined 26 eruptive and 11 confined major solar flares using SHARP vector-magnetograms from NASA's Helioseismic and Magnetic Imager (HMI) and Atmospheric Imaging Assembly (AIA), and compared these observations with data from two synthetic flares modelled in a δ-sunspot simulation. During flares, we observed a rapid increase in the horizontal magnetic field along the polarity inversion line (PIL) and a significant change in the downward-`directed Lorentz force. Importantly, all confined flares exhibited a total Lorentz force change below a certain threshold, helping to distinguish them from eruptive flares. Additionally, the change in total Lorentz force depends on the reconnection height in the solar corona at flare onset, shedding light on the propagation of force that leads to change in photosphericmagnetogram.

Simultaneously, we investigated the evolution of reconnection flux during CME eruptions using a realistic 3D magneto-hydrodynamic (MHD) model. Our simulations start from an isothermal atmosphere with a potential arcade topology for the ambient magnetic field. The arcade topology mimics the region below coronal streamers. We continuously inject a highly twisted flux rope into the coronal domain between the footpoints of the parallel arcade. This process causes the surrounding magnetic field to stretch and compress, triggering magnetic reconnection and leading to the eventual expulsion of the flux rope due to ideal MHD instabilities like torus instability and/or helical kink instability. Using a novel approach to directly calculate the reconnection flux during eruptions, we compared our simulations with data from HMI, AIA, and Solar TErrestrial RElations Observatory (STEREO). We found that variations in reconnection flux are crucial for CME development in the lower corona, with the speed of the flux rope closely correlated to these flux variations, showing different patterns before and after eruptions.

Our study provides a near-realistic simulation of solar eruptions, offering valuable insights into the complex dynamics of CME initiation and progression. By better understanding the interactions between magnetic reconnection, Lorentz forces, and flux rope evolution, we can improve our ability to predict and mitigate the impacts of these powerful space weather events, ultimately enhancing our preparedness for such solar phenomena.

बुधवार Wednesday 12, फरवरी 2025

Venue: Conference Room, Physics Department (Hybrid Mode) Time: 11:00 AM

MS Teams Link :
https://teams.microsoft.com/l/meetup-join/19%3ameeting_NzM5ODRkMDMtMjNiOC00Y2ViLTllMmQtZTRmOTVkY2UyNzBi%40thread.v2/0?context=%7b%22Tid%22%3a%226f15cd97-f6a7-41e3-b2c5-ad4193976476%22%2c%22Oid%22%3a%22fe073038-f62a-4ef1-b27e-5e8f90b96b88%22%7d

सभी का स्वागत है All are welcome