9th Asia-Pacific Conference on Plasma Physics, 21-26 Sep, 2025 at Fukuoka

Numerical MHD Modelings of Failed Solar Eruptions: Constraints and Observational Manifestations

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Observations revealed that a great amount of solar eruptions remain restricted to the lower corona, rather than developing into coronal mass ejections (CMEs), classified as failed eruptions or confined flares. While previous investigations have already noticed that the confined and eruptive solar flares can be discriminated from their magnetic environment, critical physical processes governing the confinement or successful eruption, such as constraints and observational manifestations, still remain elusive. Here, through observational data-driven and data-inspired magnetohydrodynamic (MHD) simulations, we investigate (1) the generation mechanism of downward Lorentz forces that suppress flux rope ascent, (2) the role of external magnetic reconnection in ruining eruptive flux ropes, and (3) associated multi-wavelength signatures, such as filament rotation, EUV late-phase, return electric current, and the morphology of flare ribbons and loops. These results elucidate fundamental confinement mechanisms while establishing quantitative relationship in coronal magnetic topology that determine eruption outcomes, providing valuable insights for predicting the success or failure of solar eruptions from the configuration of coronal magnetic fields.

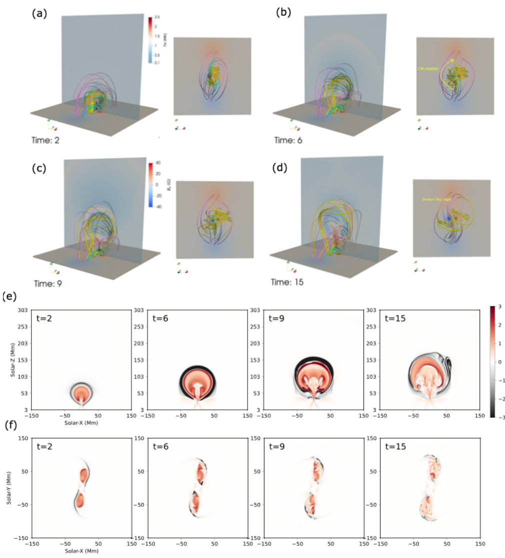

Figure 1: Evolution of the flux rope in a confined flare

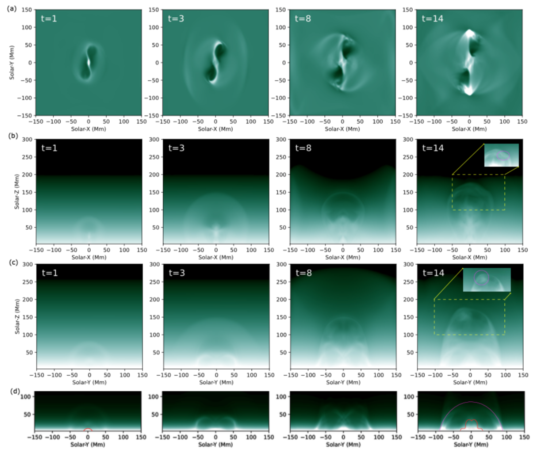

Figure 2: Synthesized EUV images of the confined flare

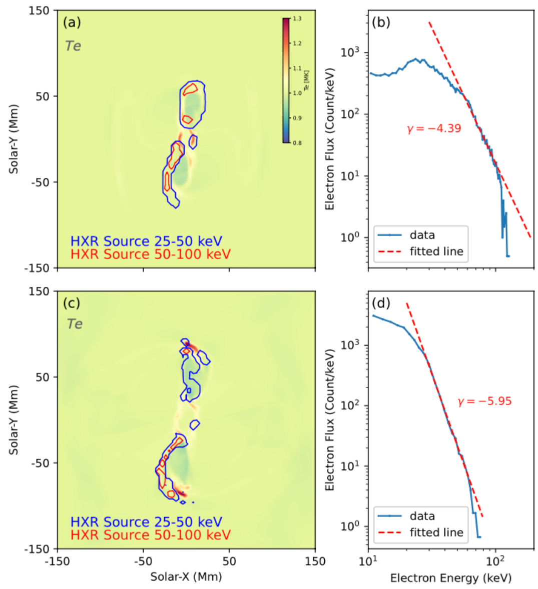

Figure 3: Non-thermal responses of electron acceleration

References
[1] J. H. Guo et al. 2025, in preparation