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

Numerical analysis of three-dimensional magnetopause-like reconnection properties by iPIC3D simulation for SPERF-AREX

X. He[1], A. Mao[1.2.3], M. Sun[1], J. Zou[1], X. Wang[1,2,3]
[1] School of Physics, Harbin Institute of Technology, [2] Laboratory for Space Environment and Physical Sciences, Harbin Institute of Technology, [3] China-Russia Belt and Road Joint Laboratory on Advanced Energy and Power Technology, Harbin Institute of Technology
e-mail (speaker): hexianglei@hit.edu.cn

Magnetic reconnection is a fast topological rearrangement of magnetic field lines by either/both free energy due to the inhomogeneous distribution of plasma currents or/and the external driving by injected energy, resulting in rapid conversion of magnetic energy into the kinetic/thermal energy of plasma.[1-3] Most studies have focused on explosive behaviors in the process based on a two-dimensional (2D) spontaneous reconnection, and fundamental features of fast reconnection have been identified.

Nevertheless, further understanding of 3D features for dayside magnetic reconnection requires a global view of topological characteristics for the magnetosphere coupled with IMFs of various orientations. Due to the limitations of satellite observations, the systematic study of three-dimensional asymmetric magnetic reconnection requires further investigation, making it a challenge to attain a comprehensive understanding of asymmetric structures and features.

The Space Plasma Environment Research Facility (SPERF) has been built at the Harbin Institute of Technology in China as a “mini magnetosphere” for experimentally simulating fundamental plasma physics processes in the magnetosphere. As a ground-based experiment facility, SPERF can be a more powerful component for investigating the global reconnection structures compared with the satellite observations.

For proposed experiments in process and further understanding of magnetic reconnection, we focus primarily on the 3D structure analysis for the typical reconnection topology based on an iPIC3D model under the key parameters of SPERF.

In the iPIC3D simulation, we successfully modeled the pulsed driving effect of the magnetosheath coils (which generate solar wind-like plasma) under the dipole coil configuration, based on the actual physical and engineering parameters of the SPERF device. The study reveals that magnetosheath coils can generate solar wind-like plasma, producing a front structure similar to that observed in experiments, as well as a magnetic field pile-up effect resembling experimental results. Further analysis shows that magnetic reconnection occurs both among the four magnetosheath coils and between the magnetosheath coils and the dipole coil. Our research analyzes the spatiotemporal evolution of SPERF pulse-driven magnetic reconnection and conducted a detailed investigation into the three-dimensional structure and topology of the magnetic reconnection occurring between the magnetosheath coils and the dipole coil. Besides, it’s found that these reconnection structures exhibit strong asymmetry in both the dawn-dusk and Sun-Earth directions.

References
[1] M. Yamada et al, Rev. Mod. Phys. 82, 603 (2010)
[2] D. Biskamp, Astrophys. Space Sci. 242, 165 (1996)
[3] J. F. Drake et al, Phys. Plasmas 15, 4 (2008)

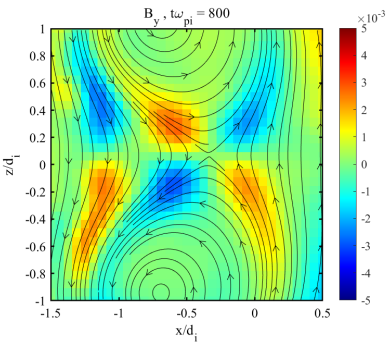

Figure 1. The Hall field structure of the reconnection occurs inside the magnetosheath coils.

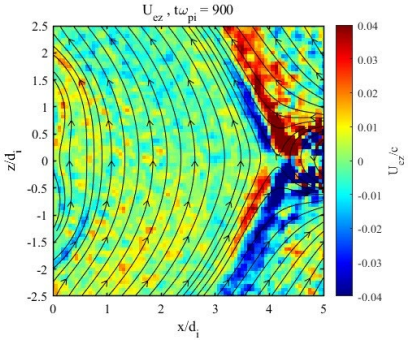

Figure 2. The electron current structure of the reconnection occurs between the magnetosheath coils and dipole coil.

Note: Abstract should be in (full) double-columned one page.