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

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Magnetic reconnection is a fundamental process to rapidly transfer free-energy stored in magnetic field to particle energy that has been studied as a key mechanism of many impulsive phenomena in space, astrophysical, and laboratory plasmas.[1] One of the important features in magnetospheric reconnection is the Hall effect as well as the corresponding Hall field properties, as it allows reconnection to proceed at a rapid rate and indicates the ion inertial region for in situ satellite observations.[2]

The Hall field structures in two-dimensional (2D) magnetic reconnection has been extensively investigated. Within the diffusion region electrons and ions decouple from the magnetic field on different spatial scales, resulting in a Hall quadrupolar field structure for the symmetric reconnection. Nevertheless, the locality of the satellites constrains the investigation capability of the global view, making it a challenge to attain a comprehensive understanding of the 3D structures and features in the vicinity of 3D magnetic separatrices, particularly the neighborhood of magnetic nulls.

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.

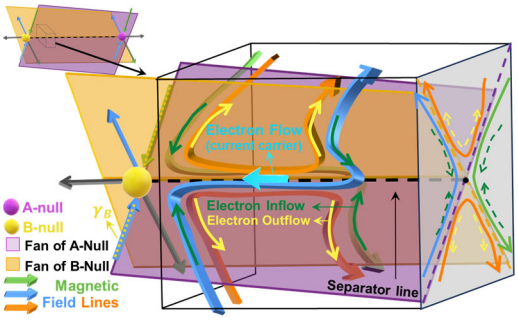

Figure 1. The schematic of separator reconnection with the electron flows (arrowed yellow and green lines). The arrowed dashed lines are for the 2D projection of the electron flows.

We in this work focus primarily on the Hall field structure analysis for two kinds of typical reconnection topology based on a Hall MHD model under the key parameters of SPERF. For X-line configuration, a characteristic Hall quadrupole structure can be observed near the X-line in arbitrary planes vertical to the X-line. Furthermore, a dawn-dusk asymmetry is found due to the Hall effect, which resulting a higher reconnection rate in the dawnside and asymmetric distribution of the X-line. For null-separator reconnection, the reconnection structure around a 3D null also features a Hall quadrupolar field, with its projection on the cross-section vertical to the separator corresponding to a typical 2D quadrupolar pattern, and Hall fields of different polarities distribute on fan surface for different types of nulls. The corresponding model is exhibited in Figure 1. As shown in Figure 2, we in this work reconfirm the separator reconnection model that conjuncts both anti-parallel reconnection and component reconnection by a 3D Hall MHD simulation, and provide the specific quantification of the feature region scale. Extending from a null, the Hall quadrupolar field structure remains a clear pattern in a region with the size of ~5d_i, identifying the region of "anti-parallel reconnection". About >10d_i away from the null, the separator field is strong enough to lead to "component reconnection" geometry and dynamics.

References
[1] M. Yamada *et al*, Rev. Mod. Phys. **82**, 603 (2010)
[2] J. F. Drake *et al*, Phys. Plasmas **15**, 4 (2008)

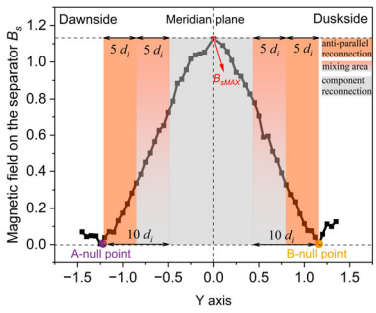

Figure 2. The magnetic field intensity of the separator B_s between the nulls.