Hall field structure analysis of three-dimensional magnetic reconnection in SPERF-AREX for simulated magnetopause events

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Magnetic reconnection is a fast topological rearrangement of the magnetic field 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 the magnetic energy into the kinetic/thermal energy of the plasma. Of key importance to the reconnection process in space is the Hall physics and its accompanying Hall magnetic fields, as it allows reconnection to proceed at a rapid rate and indicates that the diffusion region is in proximity for *in situ* satellite observations.

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 characteristic 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 further understand the three-dimensional (3D) structures of the Hall magnetic field in the dayside magnetic reconnection process for the magnetosphere coupled with IMFs of various orientations.

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 powerful supplement for investigating the global reconnection structures.

We in this work focus primarily on the Hall field structure analysis for asymmetric reconnection process based on a Hall MHD model to numerically simulate the global 3D reconnection configuration under the topology and key parameters of SPERF. Our results reveal that the reconnection structure of 3D null point also features a Hall quadrupolar field, with its projection along the separator line corresponding to a typical 2D quadrupolar pattern. Figure 1 illustrates the 3D global reconnection topology for a "southward IMF" drive with a dawn-dusk component (Fig. 1(a)), and the corresponding Hall field structure at the reconnection region (Fig. 1(b) and Fig. 1(c)). It indicates that the fan surface with different types of nulls (A-type or B-type nulls) correspond to Hall fields of different polarities. Our research contributes to a deeper understanding of the relationship between 2D and 3D Hall field structures.

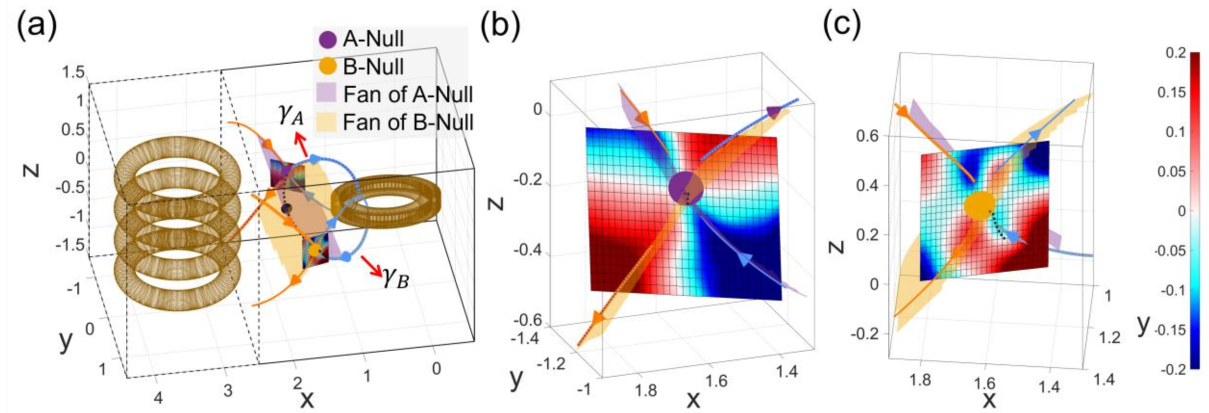

Figure 1. (a)The 3D view of the topological structure for a "southward IMF" drive with a dawn-dusk component; (b) the local hall magnetic field structure for the A null in Fig. 1 (a); (c) the local hall magnetic field structure for the B null in Fig. 1 (a).