Guide Field Dependence of Energy Conversion and Magnetic Topologies in Reconnection Turbulent Outflow

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Magnetic reconnection is a practical approach to releasing energy and generating energetic particles in both terrestrial and interplanetary space. Within diffusion regions, particles undergo acceleration and heating, contributing to the formation of high-speed jets in the outflow region. Moreover, it is suggested that these outflow jets can extend further downstream than theoretically predicted, inducing turbulence within the outflow. Within the turbulent outflow of the reconnection, instabilities arising from electron dynamics drive the formation of smaller scale magnetic structures.

The presence of the guide field is believed to play an essential role in changing the regime of reconnection exhaust. In the reconnection outflow, the jet deflection effect can be generated driven by the Lorentz force under the condition of the guide field. From the perspective of energy transfer, the guide field also impacts the energy conversion rate and field spectra of the turbulence within the reconnection outflow.

The turbulent outflow of the reconnection carries the task of energy dissipation by the intermittent structures. These structures can be generated affected by the guide field and efficiently heat ions and electrons through the parallel electric field. And the structures in reconnection can be categorized into X-type and O-type based on the local magnetic topology. The intense current density and the magnetic field topologies can be applied to indicate the intermittent structures with a high possibility of energy conversion and dissipation.

The intermittent structures associated with energy conversion are inseparable from the turbulent outflow. The increasing guide field prompts the generation of small-scale structures in this region. However, the direct relation between the guide field and these structures' properties has not been fully revealed. In this study, we apply full kinetic particle-in-cell (PIC) simulations to verify the effect of the guide field on the turbulent outflow from the perspective of energy conversion and the magnetic field topology. A series of simulation cases are performed with different guide field levels to measure the variation trend of energy conversion and the types of magnetic topology. It suggests that large guide field condition is probably linked to more intermittent structure generation with higher energy conversion. Furthermore, we also seek observational evidence which contains the characteristics of turbulent outflow in magnetotail reconnection events with different guide field. Our results have significant furtherance on the understanding of energy conversion and intermittent structures during magnetic reconnection.

References

[1] Adhikari, S., et al. Physics of Plasmas, 30, 082904. (2023)
[2] Consolini, G., et al. Journal of Physics: Conference Series, 1100, 012007. (2018)
[3] Huang, S. Y., et al. Geophysical Research Letters, 49, e2021GL096403. (2022)
[4] Manzini, D., et al. Physical Review Letters, 130, 205201. (2023)
[5] Pucci, F., et al. The Astrophysical Journal, 841, 60. (2017)
[6] Quattrociocchi, V., et al. The Astrophysical Journal, 878, 124. (2019)
[7] Zenitani, S., et al. Physical Review Letters, 106, 195003. (2011)

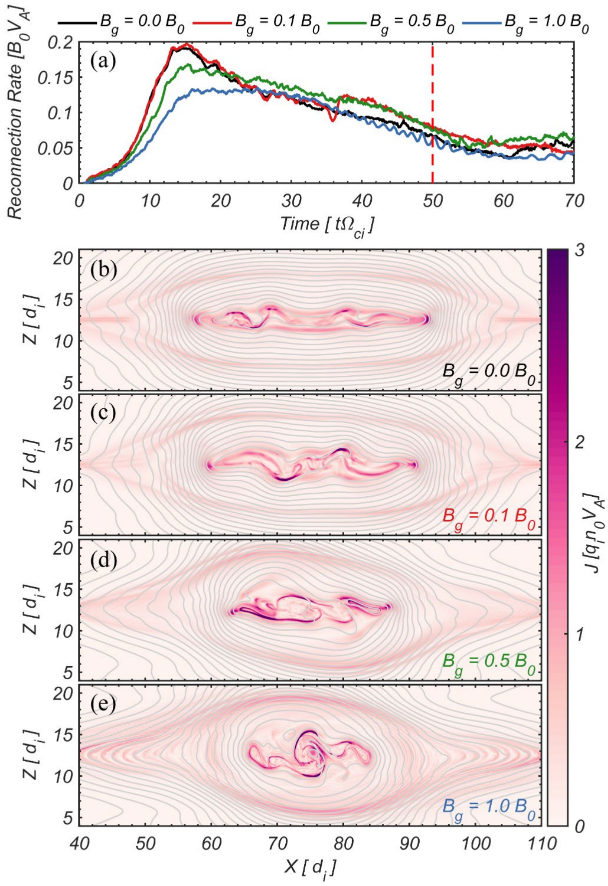

Figure 1. (a) Reconnection rate with time under different guide field levels. The vertical dashed line marks the time $t\Omega_{ci}$ = 50. (b-e) Total current in different run cases normalized by $q_i n_0 V_A$, where q_i is the ion charge, n_0 is the background density, and V_A is the Alfvén speed. The black lines stand for the magnetic field lines.