6th Asia-Pacific Conference on Plasma Physics, 9-14 Oct, 2022, Remote e-conference

Formation of the electron inflow along the separatrices during collisionless magnetic reconnection

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Magnetic reconnection provides an energy conversion mechanism in plasma, which transfers magnetic energy into plasma kinetic and thermal energy. It is related to a variety of explosive phenomena in space plasma, such as solar flares, coronal mass ejections (CMEs), and magnetosphere substorms[1]. Plasma in space is usually collisionless. In collisionless magnetic reconnection, a small electron diffusion region (EDR) is embedded in a large ion diffusion region (IDR)[2]. The Hall effect, which results from the separate motions between ions and electrons, is considered to play a crucial role in the IDR of collisionless magnetic reconnection[3]. In the IDR, the ion motions are decoupled from the magnetic field, and electrons flow into the EDR along the separatrices. The electrons are accelerated in the EDR, and then flow out along the magnetic field in the outflow region. At last, the Hall current system and the quadrupole Hall magnetic field structure are formed in the separatrix region.

The Hall current system has been studied in both observations and simulations, while the generation mechanism of electron inflow along the separatrices is still in debate. In recent years, a large-scale parallel electric field has been discovered in kinetic simulations[4], which is believed to be responsible for the formation of electron inflow. In the meantime, the magnetic mirror pattern distributed in the separatrix region is considered to be another possible mechanism to drive electron inflow to stream toward the EDR[5]. However, until now, there is no consensus on quantitative contributions of the parallel electric field and magnetic mirror force to the formation of electron inflow along the separatrices.

We quantitatively analyze the formation of electron inflow along the separatrices toward the X-line from the perspective of fluid, by performing two-dimensional (2-D) particle-in-cell (PIC) simulations of collisionless magnetic reconnection in a Harris current sheet. Figure 1 shows the results of the force analysis on the electron inflow in cases with different mass ratios. We found that the formation of electron inflow is contributed by three effects: accelerated by the parallel electric field, accelerated by the magnetic mirror force, and decelerated by the gradient of parallel electron pressure. The acceleration contribution of the parallel electric field is dominant, but that of mirror force cannot be ignored, especially when the background plasma density and temperature are sufficiently high.

References

[1] V. Angelopoulos *et al*, Nat. Phys. **16**, 317-321 (2019)
[2] M. Shay *et al*, Phys. Rev. Lett. **99** (2007)
[3] J. Birn & M. Hesse, J. Geophys. Res. **106**, 3737-3750 (2001)
[4] J. Egedal *et al*, Nat. Phys. **8**, 321–324 (2012)
[5] Q. M. Lu *et al*, J. Geophys. Res. **115**, A11208 (2010)

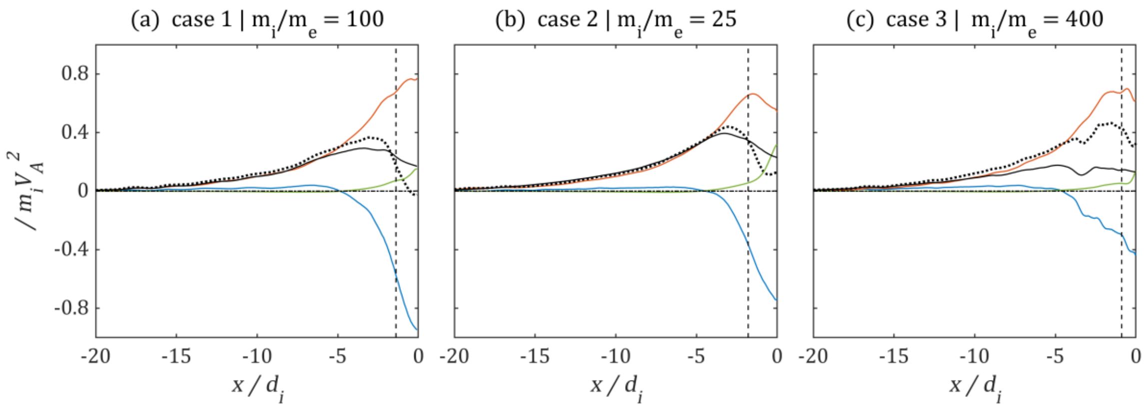

Figure 1. The results of the force analysis on the electron inflow along a selected separatrix in (a) case 1, (b) case 2, and (c) case 3. The red lines are the contribution of the parallel electric field, the blue lines are the contribution of the parallel electron pressure, and the green lines are the contribution of the mirror force. The black solid lines and the black dotted lines describe the equilibrium of the force equation we use. The vertical dashed lines mark the boundaries of the EDR in each case.