8th Asia-Pacific Conference on Plasma Physics, 3-8 Nov, 2024 at Malacca

Cold ion effects in density-asymmetric collisionless magnetic reconnection

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Magnetic reconnection is an essential physical process that facilitates many fast-growing phenomena. In space and laboratory environments, magnetic reconnection contains multiple ion species with distinguish properties, such as heavy ions, low-energy (cold) ions and so on.[1] These components can introduce important new features to the plasmas system.

In this work, we focus on the cold ion effects on the reconnection process. Due to the lower temperature, the cold ions have the much smaller gyroradius than the warm ions do. Thus, an intermediate length scale is introduced between the electron scale and the warm ion scale. [2] Therefore, the kinetic feature can be modified by the multi-scale diffusion regions. [3] Previously, the cold ions distributing in the entire region are usually investigated. However, in magnetosphere reconnection, the cold ions in the inner magnetosphere may not exist in the reconnection region initially, which may cause asymmetric cold ion density distributions. In fusion plasmas, the injection depth of the fueling cold ions may also lead to different cold ion distribution.

We perform a series of numerical simulations with different cold ion distributions to investigate the behavior of cold ions and their impacts on magnetic reconnection. The implicit parallel particle-in-cell (iPIC) model is used. It is revealed that the reconnection rate decreases as the distribution depth of the cold ions, which is mainly caused by the mass-loading effect. Particularly, a density-peak structure (Figure1(b)) of cold ions is developed near the X-line because of the bounce motion of cold ions. Besides, a ring structure (Figure1(c)) is formed in the y-v_y phase space of cold ions that correspond to their bounce motion. Figure 1 also gives the test particle trajectories in the reconnection plane (Figure1(a)) and the y-v_y phase space (Figure1(d)). Furthermore, cold ions play a role as the current carrier due to its small inertial scale. Consequently, the asymmetry distribution of cold ions can results in significant asymmetry in the Hall electric field and eventually leading to asymmetric density profiles as the double/single-peak structure of cold ions. The associating structures should be considered when analyze *in situ* spacecraft observations.

This work is supported by the National Natural Science Foundation of China (Nos. 11975087, 42261134533, and 42011530086), the National Magnetic Confinement Fusion Energy R&D Program of China (No. 2022YFE03190400), and the Heilongjiang Touyan Innovation Team Program, as well as China-Russia Belt and Road Joint Laboratory on Advanced Energy and Power Technology and Heilongjiang Provincial International Innovation Research Center for Plasma Physics and Applications.

References

[1] Kistler *et al,* J. Geophys. Res. **121(3)**, (2016)

[2] Divin, A *et al,* J. Geophys. Res. **121(12)**, (2016)

[3] Toledo-Redondo S *et al*, Geophys. Res. Lett. **42(15)**, (2015).

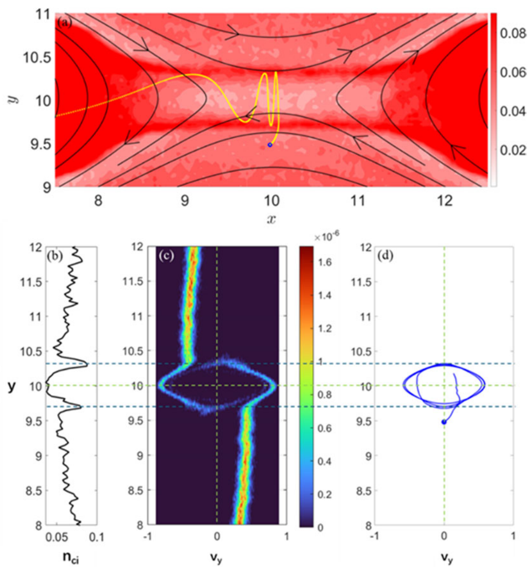

Figure 1. (a) The cold ion density and the trajectory of the test particle initially at the blue dot for Case 4; (b) the cold ion density cut through y=10; (c) the cold ion distribution in the v_y-y phase space for $9.95 < x < 10.05$; (d) the test particle trajectory in the v_y-y phase space.