Energy budgets from collisionless magnetic reconnection site to reconnection front: the effects of guide field and background plasma parameters

Y. Shu[1], S. Lu[2,3], Q. Lu[2,3], R. Wang[2,3], J. Zheng[1] and W. Ding[1]
[1] School of Nuclear Science and Technology, University of Science and Technology of China
[2] CAS Key Laboratory of Geospace Environment, School of Earth and Space Sciences, University of Science and Technology of China
[3]CAS Center for Excellence in Comparative Planetology, Hefei, Anhui, China
e-mail (speaker): ykshu@mail.ustc.edu.cn

As an effective energy-converting process either in space or in experimental plasmas, magnetic reconnection is one of the key problems to investigate in modern plasma physics. It releases magnetic energy stored in the plasma system such as the magnetosphere, the solar corona, and the controlled fusion facilities. During the process, the plasma is accelerated and heated.

Triggered at the magnetic reconnection site, magnetic reconnection usually ejects reconnection fronts downstream. It is found that energy conversion is not restricted near the reconnection site; the reconnection fronts take up a large proportion of energy conversion during the whole process.[1, 2, 3] The reconnection rate, defined as the normalized reconnection electric field at the X-line does not peak simultaneously with integral energy conversion ($\mathbf{J}\cdot\mathbf{E}$) over the whole reconnecting region, according to simulation results[3, 4]. Thus, the reconnection rate cannot well represent the global energy converting process of nonsteady state magnetic reconnection.

Through particle-in-cell simulations, we unraveled the connection between the reconnection site and the reconnection fronts in terms of energy conversion during the collisionless magnetic reconnection process. The well-developed reconnection fronts are no longer related to the reconnection site. The energy income at the reconnection fronts is mainly the Poynting flux from their top and bottom boundaries, most of which is transformed to enthalpy flux flowing downstream out of the moving front through the work by the electric field. The overall bulk kinetic energy does not gain much due to the approximate balance between the electric force and the pressure gradient force.

Apart from the parallel reconnection case, we also investigate how the guide field and the background plasma density and temperature influence the energy converting process. It is shown that the guide field reduces both the reconnection rate and the energy conversion rate. The major input of the Poynting flux participating in energy conversion comes from the upper and lower boundaries of the reconnection front. Apart from the reconnection rate and the energy conversion rate, the energy outflow is altered by varying background plasma density and temperature. Our research implies the reconnection front can be an effective energy converter independent of the reconnection site once formed from the transient magnetic reconnection.

This work was supported by the Strategic Priority Research Program of Chinese Academy of 366 Sciences, Grant No. XDB 41000000, the NSFC grant 42174181.

References

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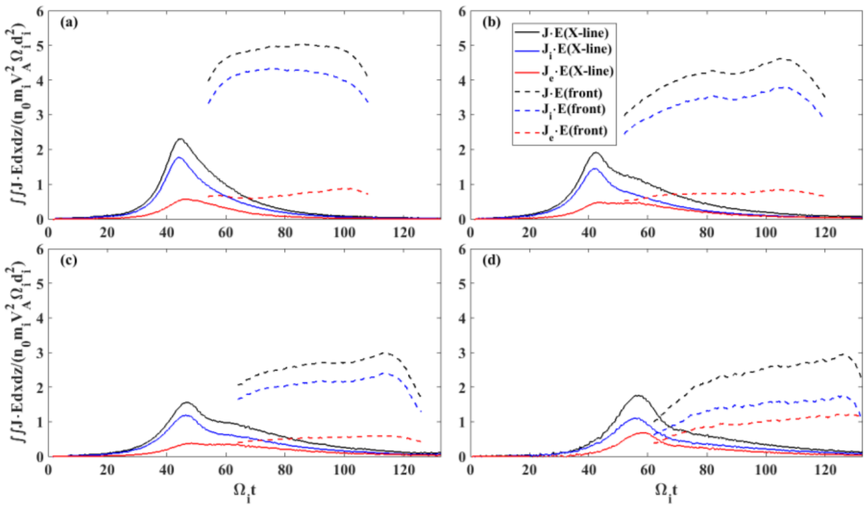

Figure 1. Integration of work $\mathbf{J}\cdot\mathbf{E}$ over regions of the reconnection site and the reconnection front when (a)$B_g = 0$, (b)$B_g = 0.5B_0$, (c)$B_g = B_0$, (d)$B_g = 2B_0$.