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Nonthermal particle acceleration in 3D turbulent magnetic reconnection

Masahiro Hoshino[1]
[1] Department of Earth and Planetary Science, School of Science, the University of Tokyo
e-mail (speaker):mhoshino@g.ecc.u-tokyo.ac.jp

Magnetic reconnection has long been known to be the most important mechanism not only for mixing the plasmas by changing the magnetic field topology but also for releasing the magnetic field energy into the plasma kinetic energy. During magnetic energy release, it is possible for some of the heated plasma to be accelerated to energies much higher than the thermal energy.

Recently, it has been reported that the efficiency of the nonthermal particle acceleration is high, and the nonthermal energy density is comparable or larger than the thermal energy density in observations and numerical simulations. Specifically, by using particle-in-cell (PIC) simulations, it has been shown that the acceleration efficiency of nonthermal particles increases with increase in the plasma temperature, and the nonthermal energy density occupies more than 90% in the total heated plasma when the Alfvén velocity is close to the speed of light, c [1,2]. In the high-energy astroplasma applications with a relativistic plasma temperature, reconnection should play an important role on the production of nonthermal particles (cosmic rays).

However, the magnetic energy release rate is known to decrease with the increase of the guide magnetic field, and the acceleration efficiency has been mainly studied in two-dimensional systems without the guide magnetic field so far. It is important to study the three-dimensional effects with the guide magnetic field, where the patchy and turbulent reconnection can dynamically occur. In this talk, three-dimensional (3D) PIC simulations are used to study the effects of three-dimensional relativistic reconnection on a pair plasma with the guide magnetic field. Figure 1 shows an example of the density structure obtained for the 3D reconnection with the guide magnetic field. We can clearly see that the plasma density structure becomes turbulent.

Based on the 3D PIC reconnection simulations as the function of the guide magnetic field, the energy spectra and the energy partitioning between the thermal and nonthermal components during reconnection have been studied. As the result, we show that 3D reconnection is able to maintain a hard nonthermal energy spectrum even in the presence of a strong guide magnetic field, although nonthermal particle production decreases with increasing guide magnetic field [3].

References

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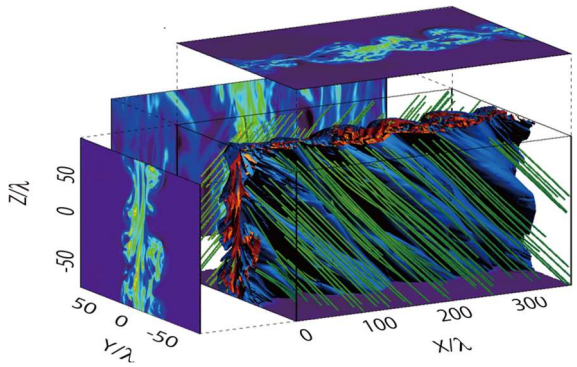

Figure 1. Structure of magnetic reconnection with the guide magnetic field. The red and blue isosurfaces show high and low plasma densities, respectively. The green lines are magnetic field lines, and two-dimensional contours in the xy-, yz-, and xz-planes are the slices of the plasma density.