Energy partition of thermal and nonthermal particles for a composed spectrum of Maxwellian and kappa distribution function in magnetic reconnection

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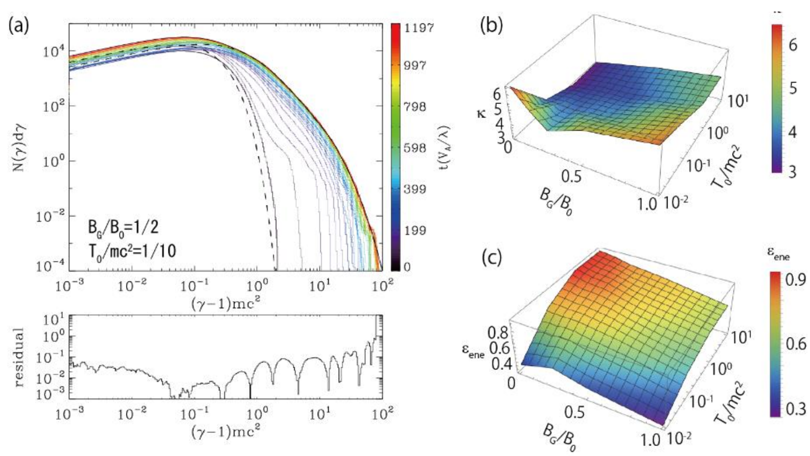
In collisionless plasmas in our space and astrophysical environments, nonthermal particles, whose energies are much higher than the thermal temperature, are often observed, yet our understanding of the energy partition between thermal and nonthermal particles remains to be elucidated. In this presentation, we discuss the energy partion by focusing on magnetic reconnection, which has long been known to be the most important mechanism as quick conversion of magnetic field energy into thermal and nonthermal energies. By using particle-in-cell (PIC) simulations, we have investigated the energy partition for hot plasmas in plasma sheet as a function of plasma sheet temperature and guide magnetic field. For simplicity, we have assumed a pair plasma, and the thickness of plasma sheet normalized by the inertia length has been fixed. We analyzed the hot plasmas heated by reconnection by fitting a model function of a composed function of the Maxwellian and kappa distribution. Shown in the left-hand panel (a) is an example of the energy spectrum obtained in PIC simulation as a function of particle energy $(\gamma\text{-}1)mc^2$. The color lines indicate the time evolution of the spectra, whose time stages are indicated in the right-hand side bar, and the red line is the final stage. The thick solid lines represent the model fitting curve, and the two black dashed lines represent the Maxwellian part in the lower energy regime and the kappa distribution part in the higher energy regime. The bottom panel is the residual of the model fitting. We found that the heated plasmas can be well fitted by the model function. Based on this model fitting, we show the kappa index and the efficiency of the nonthermal particles against heated thermal plasma in the right-hand panels (b) and (c), respectively. The plots are depicted as a function of the initial plasma temperature T_0/mc^2 and guide magnetic field BG/B_0. The temperature and the magnetic field are normalized by the rest mass energy mc^2 and the initial magnetic field B_0, respectively. In relativistic reconnection with anti-parallel magnetic field or weak guide magnetic field, it was found that the nonthermal energy density can occupy more than 90% of the total kinetic plasma energy density with a hard energy spectrum, but strengthening the guide magnetic field suppresses the efficiency of the nonthermal particle acceleration. In nonrelativistic reconnection for anti-parallel magnetic field, most dissipated magnetic field energy is converted into thermal plasma heating with a soft energy spectrum. For a weak guide magnetic field with a moderate value, however, the nonthermal particle acceleration efficiency was enhanced, but strengthening the guide-field beyond the moderate value suppresses the efficiency.



References

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