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Energy Partition during Magnetic Reconnection in Weakly Collisional Plasmas

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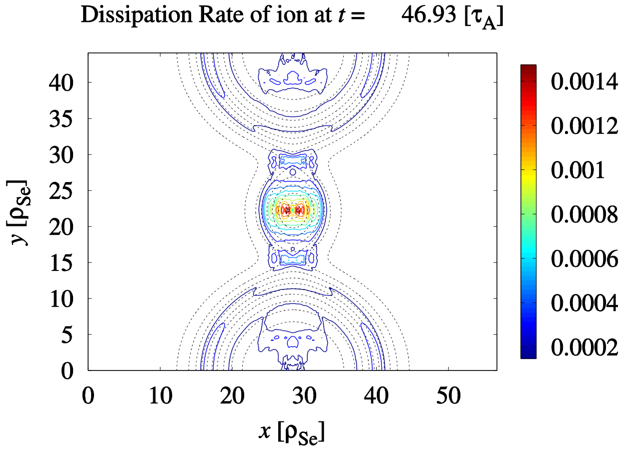
Magnetic reconnection is a commonly observed fundamental process in both astrophysical and fusion plasmas. It allows topological change of magnetic field lines, and converts the free energy stored in the magnetic field into various forms of energy, such as bulk plasma flows, plasma heating, or non-thermal particle acceleration.

In weakly collisional plasmas the phase mixing process caused by kinetic effects, such as Landau damping and finite Larmor radius (FLR) effects, creates oscillatory structures in velocity space, which must eventually regularized by collisions. Therefore, even if collisions are infrequent, energy dissipation and resultant plasma heating may be significant, as demonstrated by recent investigations using both a reduced [1] and a fully gyrokinetic model [2] . The study of plasma heating due to phase mixing has also been extended for high beta plasmas [3], where ion heating is also expected to be significant since compressible fluctuations will be excited which are strongly damped collisionlessly. It has also been shown that, for high-beta plasmas, the current sheet becomes unstable, and the resultant plasmoid can significantly alter the efficiency of electron and ion heating.

Figure 1 shows spatial distribution of the energy dissipation rate for ions obtained from the gyrokinetic simulation of magnetic reconnection for a high beta plasma. In this case, the ion energy is strongly dissipated to cause heating after the reconnection rate is peaked. It is shown that ion heating is localized to the reconnection site, unlike the electron heating which spreads along the separatrix. The heating of ion for high beta plasmas becomes comparable to that of electrons.

To demonstrate that the heating is due to phase mixing, we plot the ion distribution function taken where the dissipation rate is large. The ion distribution function develops structures in $v_\perp$ direction, as well as the parallel direction, manifesting the perpendicular FLR phase mixing. Since the FLR phase mixing is nonlinear, it is significant only when nonlinear effects are well developed.

In this presentation, we summarize the study of gyrokinetic magnetic reconnection and heating mechanisms of ions and electrons. We also discuss recent advancement of this study by taking into account the secondary island formation (plasmoid) and externally driven turbulence, which may accelerate magnetic reconnection and may enhance the energy dissipation.



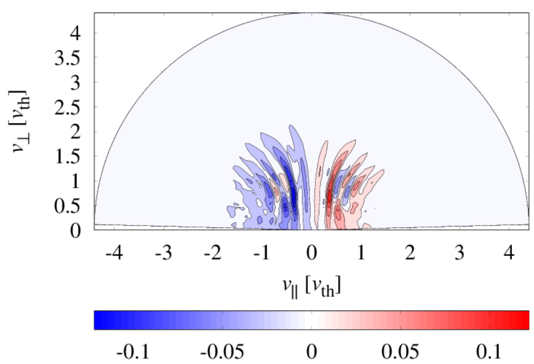


Figure 1 Spatial distribution of the dissipation rate for ions (top) and the distribution function of ions (bottom) taken where the dissipation rate is large.

References

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