P1.412

Energy Partition in Kinetic Turbulent Reconnection

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Outline

•Magnetic reconnection is ubiquitous in fusion and astrophysical plasmas, which allows topological change of field lines, and convert field energy into plasma flow and heat.

•In weakly collisional plasmas, phase mixing processes, such as Landau damping or finite Larmor radius (FLR) effects create oscillatory structures in velocity space. Those structures suffer strong collisional dissipation.To address thermodynamic properties of such plasmas, collisional effects are essential even though collisions are rare.

•Heating mechanism due to phase mixing ha been demonstrated using a fully gyrokinetic model [Numata and Loureiro, JPP (2015)].

•It has also been found that, for high beta gyrokinetic plasmas, the current sheet becomes unstable, and the resultant plasmoid (secondary island) can significantly alter the efficiency of electron and ion heating. This finding suggests that more efficient energy conversion may take place in turbulent reconnection, which is likely to be present in natural environments.

•In this work, we present a preliminary study of plasma heating in turbulent reconnection in strongly magnetized plasmas. More thorough and systematic survey on the effects of external forcing will be performed.

•Main results:

- Two different types of external driving mechanism have been implemented and tested. I) Oscillating Langevin Antenna, which is already implemented in AstroGK code to study Alfvénic turbulence [TenBarge *et al.*, CPC (2014)]. II) Newly implemented direct driving force term, which drives perpendicular flows.
- Direct forcing seems more efficient to drive turbulence than the antenna in 2D simulations. Direct forcing enables to compare the gyrokinetic simulations with the similar study in the framework of MHD [Loureiro et al. MNRAS (2009)].
- Antenna drive may not be suitable for reconnection study because it directly changes reconnecting magnetic field.

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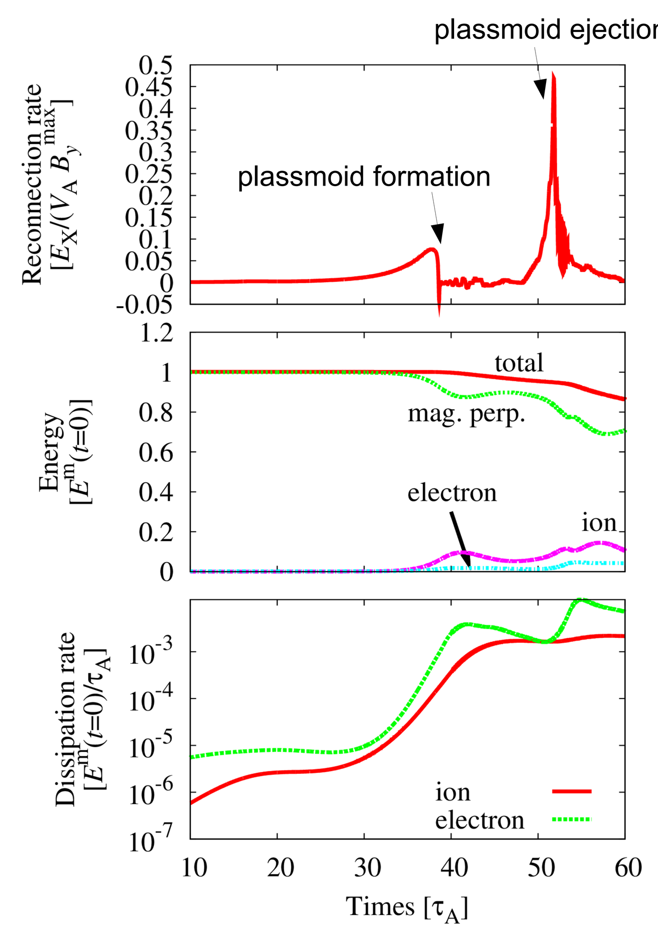
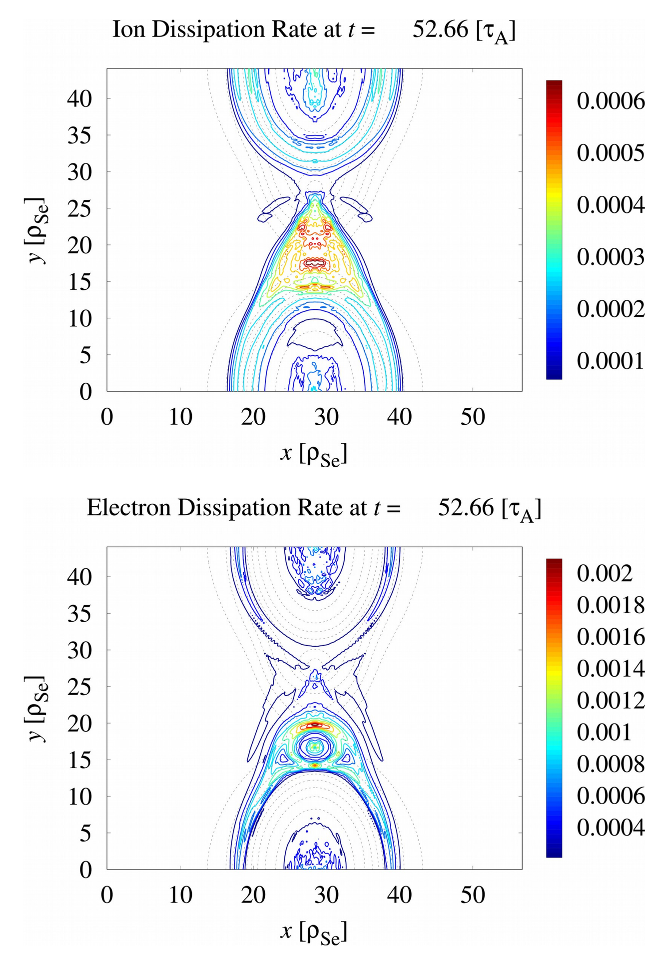
Heating via Phase Mixing

Magnetic reconnection can efficiently convert energy to heat via phase mixing in strongly magnetized plasmas, as has been proved by gyrokinetic simulations. [Numata and Loureiro, JPP (2015)]



Reconnection rate, energy components, and dissipation rates

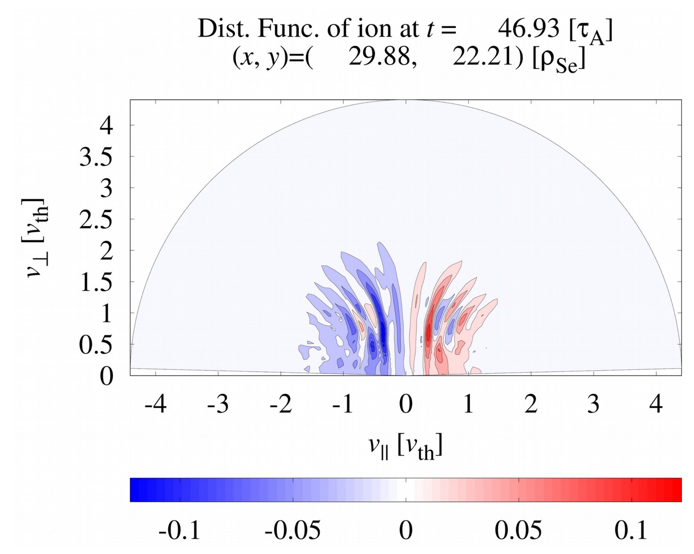


Spatial distribution of dissipation rate

•Energy dissipation rate gradually increases in the reconnection phase, and an appreciable amount of energy is converted into ion and electron heating.

•Energy dissipation of electrons are significantly enhanced when plasmoid is formed and ejected.

•Phase mixing structure in velocity space is seen at the places where strong dissipation is occurring.



Typical phase mixing structure in velocity space

Driving Turbulence in Gyrokinetic Magnetic Reconnection

The finding that plasmoid formation and ejection can activate heating via phase mixing suggests more efficient energy conversion may take place in turbulent reconnection. To study efficient energy conversion by turbulence during magnetic reconnection, we drive turbulence in the system.

Oscillating Langevin Antenna [TenBarge *et al.*, CPC (2014)]

It drives current in the z direction (perpendicular to the reconnection plane). It consists of the driven/damped oscillator and white noise:

$$\frac{d A_{\parallel,k_a}}{dt} = -i\omega_a A_{\parallel,k_a} + F_a$$

ω_a: complex frequency
k_a: wave number that we wish to drive
F_a: random number

•Antenna drive directly changes reconnecting magnetic field and reconnection rate significantly:
→ We observe from one simulation that thin current sheet is supported for long time and higher reconnection rate.

•Turbulence seems not to be excited in the 2D simulation.

Direct Forcing

We can add direct driving force in the gyrokinetic equation:

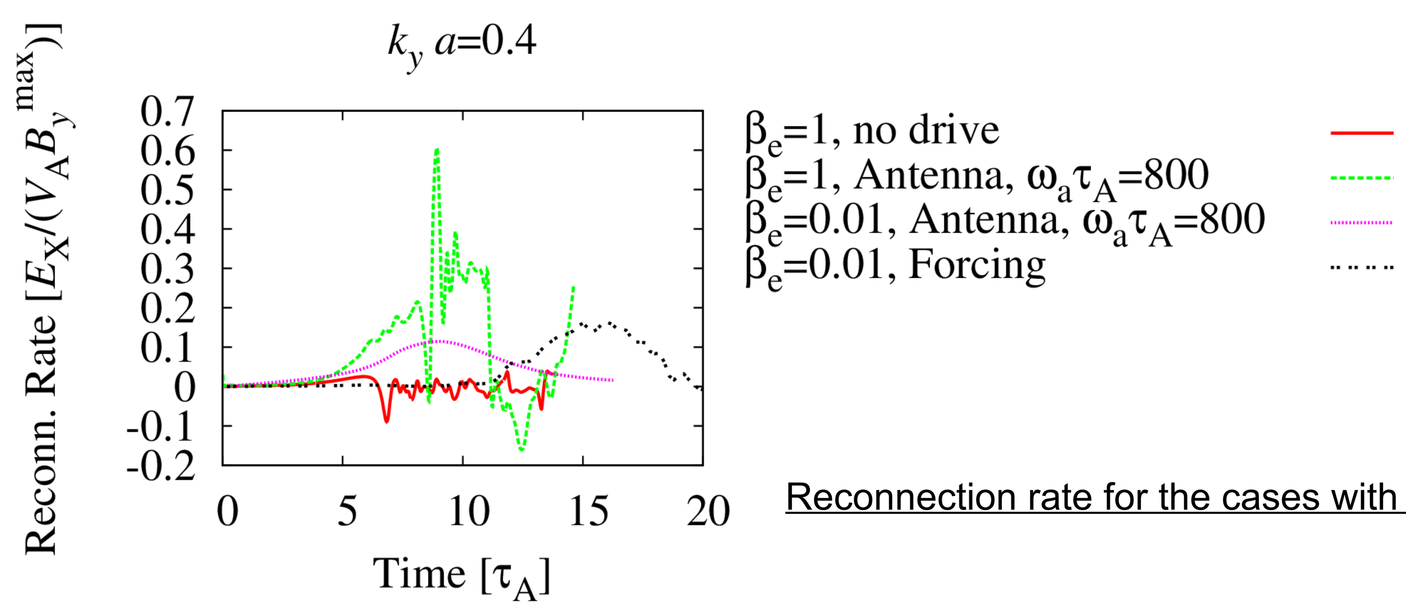
$$\frac{\partial h_s}{\partial t} = \cdots + F f_{0s}$$

h_s: non-Boltmann part of dist. func. obeying GK eqns.
f_{0s}: Maxwellian distribution function
F: random noise

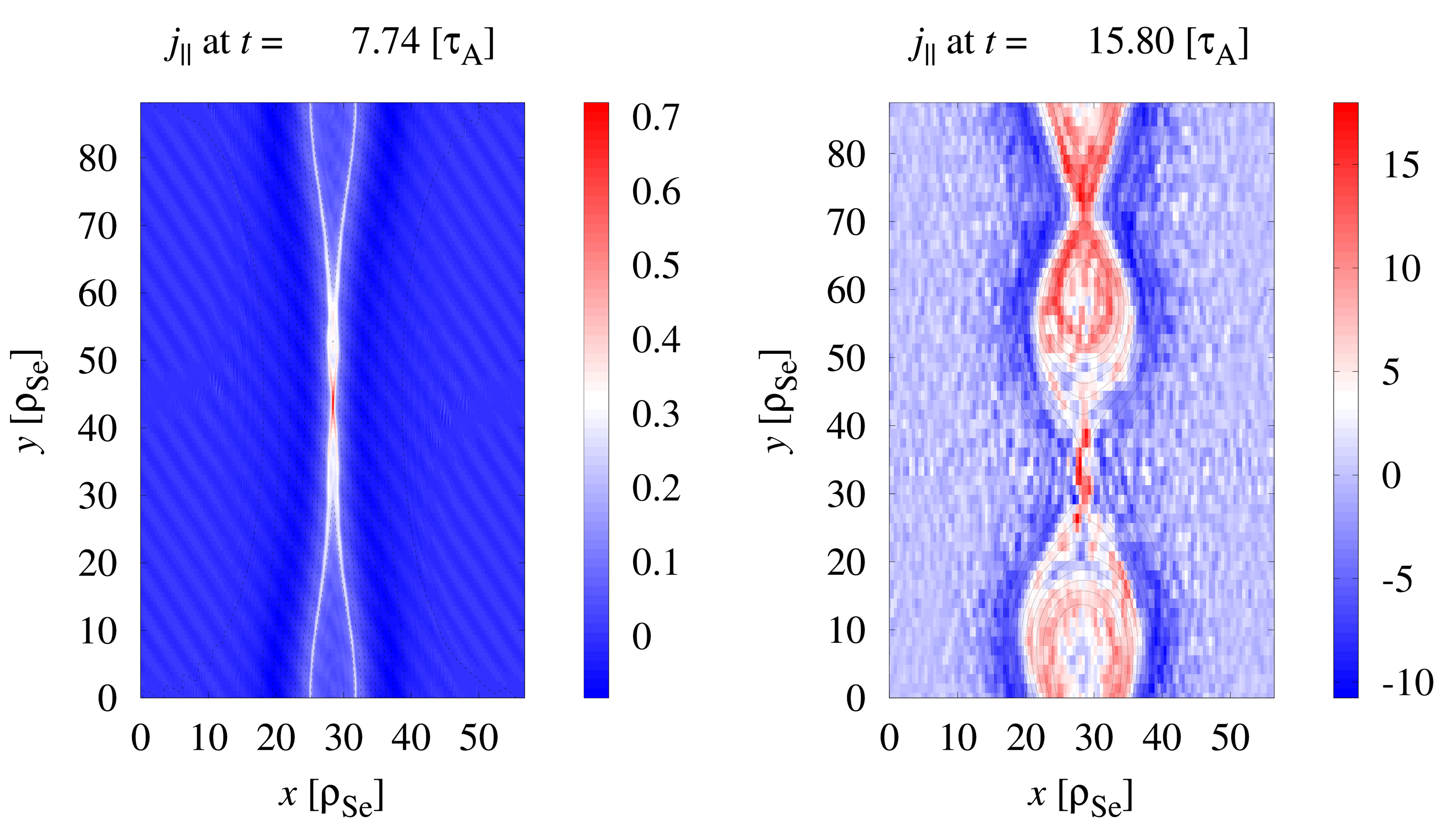
This forcing induces perturbation of density and ES potential, thus results in driving perpendicular flows due to the $E \times B$ drift.

•Direct forcing can efficiently drive turbulence

•Directly comparable with the similar study in the framework of MHD [Loureiro et al. MNRAS (2009)]



Reconnection rate for the cases with various forces



Current distribution for β_e=1, $\omega_a\tau_A$=800 case (Left) and β_e=0.01, direct forcing case (Right)

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