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On the effect of the magnetic compressibility in microtearing turbulence

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Anomalous heat transport for electrons due to microtearing (MT) turbulence driven by the background electron temperature gradient degrades the performance of the magnetic confinement. Some gyrokinetic simulations using specific parameters of existing devices provide the quantitative transport level of MT turbulence [see, e.g. 1,2].

The theoretical prediction of the transport level of MT turbulence using the drift-kinetic model is derived as $\left|\widetilde{B_x}/B_0\right| \sim \rho_e/L_{T_{0e}}$ in [3], where B_x and B_0 are the Alfvénic magnetic fluctuation and guide field, respectively. ρ_e and $L_{T_{0e}}$ are the electron Larmor radius and temperature gradient length. For the sake of simplification, however, [3] assumes a high-collisionality condition and ignores the effects of ion physics and compressive magnetic field. The kinetic effect of ions is not yet well understood in MT turbulence, even though the MT has the scale of the ion Larmor radius ρ_i. The compressibility of the magnetic field, which is coupled to the ion physics, is typically ignored in MT studies due to the low-beta ordering.

To understand the fundamental process of the saturation mechanism of MT turbulence focusing on the ion physics and the effect of the compressive magnetic field, we perform gyrokinetic simulations in a slab geometry using AstroGK [4]. Plasma parameters are chosen as $\beta_e = 0.08, T_{0i}/T_{0e} = 0.5, m_e/m_i = 0.001$ and the electron-ion collision frequency normalized by the diamagnetic drift frequency $\nu_{ei}/\omega_{*e} = 0.75$, so as to satisfy the MT mode scale $\delta \sim \rho_i$. The magnetic shear, and electron temperature/density gradients are also specified but are omitted here for clarity. The effect of the compressive magnetic field is included in AstroGK and can be artificially turned off to investigate its contribution to MT turbulence.

Figure 1 (a) shows the energy evolution of MT turbulence. The particle energy of electrons (blue line) is dominant. In the nonlinear phase (Time > 50), the Alfvénic magnetic energy (magenta line), compressive magnetic energy (dark-green line), and the particle energy of ions (red line) are comparable, whereas in the linear regime, the compressive magnetic energy and ion particle energy are sufficiently smaller than the Alfvénic magnetic energy. We find that the particle energy of electrons is supported by the temperature fluctuation being the higher velocity moment. Consequently, the compressive magnetic field is generated to satisfy the pressure balance.

The time evolution of the electromagnetic heat flux for electrons in MT turbulence is shown in Figure 1 (b). The flux is normalized by the gyro-Bohm heat flux. The level of heat transport without the effect of the compressive magnetic field $\delta B_\parallel$ is higher than the case including $\delta B_\parallel$, suggesting the suppression of heat transport due to $\delta B_\parallel$ effect which is typically neglected in MT turbulence owing to the low-beta ordering.

The growth of the magnetic island is induced by the time-dependent thermal force which is the destabilization mechanism of a slab MT instability [5], resulting in the magnetic tension. We speculate that ion flows mediated by the magnetic tension are generated and contribute to the saturation of MT turbulence.

In this presentation, we discuss the detailed effect of the compressive magnetic field and ion physics on the saturation mechanism of MT turbulence.

References
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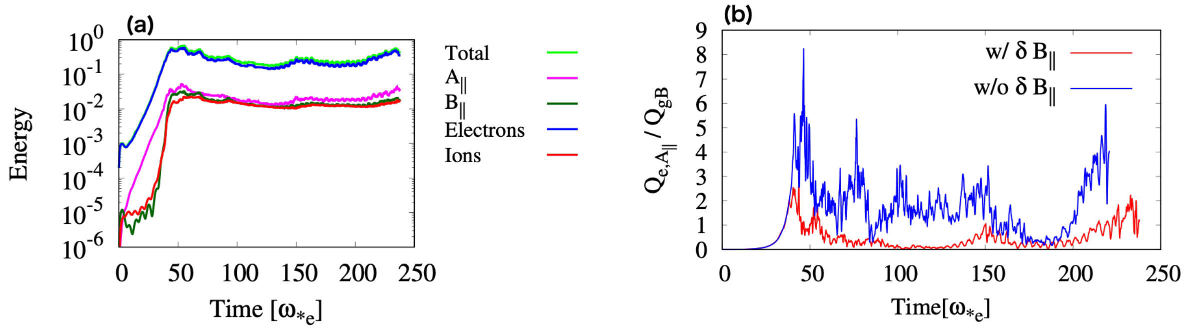

Figure 1. Energy evolution (a) and the heat flux with and without the effect of the magnetic compressibility (b), in MT turbulence. The particle energy of electrons is dominant, and the Alfvénic magnetic energy, compressive magnetic energy, and the particle energy of ions are comparable (a). The compressive magnetic field, typically neglected due to the low-beta ordering, reduces the level of heat transport (b).