9th Asia-Pacific Conference on Plasma Physics, 21-26 Sep, 2025 at Fukuoka

Effects of magnetic field geometry on trapped electron mode turbulent transport in finite-beta plasmas

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To realize fusion power plants, achieving high-β plasmas is essential. Finite-beta plasmas exhibit magnetic fluctuations and changes in magnetic geometry, such as the Shafranov-shift. Therefore, it is necessary to understand how finite-beta effects influence microinstabilities and turbulent transport. Among these instabilities, collisionless trapped electron mode (CTEM) is important in burning plasmas, where α-particle heating enhances electron temperature gradients. CTEM generates ion-scale fluctuations together with ion temperature gradient (ITG) instabilities. In previous studies [1][2], the β dependence of ITG instabilities, incorporating the effects of the Shafranov-shift, has been thoroughly analyzed and the associated physical dynamics have been discussed in detail. However, the results and physical dynamics of CTEM have not been thoroughly investigated.

We investigate the β dependence of turbulent transport driven by CTEM, using the local gyrokinetic simulation code GKV [3][4]. The analysis focuses on tokamak plasmas, particularly using parameters from the JT-60U tokamak experiment. We discuss turbulent transport in the outer core region ($\rho = 0.7$) of JT-60U L-mode plasma #E45072[5]. In the β scan without the Shafranov-shift [blue line in Figure1(a)(b)], magnetic fluctuations have little effect on the linear growth rate in the low-wavenumber range. As β increases further, the ballooning mode (BM) becomes dominant. Nonlinear simulation results show that the heat transport increases with increasing β. This behavior contrasts with that of the ITG mode. In the case of ITG, both the linear growth rate and the heat transport decrease due to electromagnetic stabilization [1][2]. These results suggest that the impact of magnetic fluctuations on turbulent transport differs between ITG and TEM. On the other hand, with the Shafranov-shift, the linear growth rate of CTEM increases with increasing β ,and the critical β at which BM occurs is lower. The heat transport increases compared to the case without the Shafranov-shift. This result is consistent with previous studies [1][2] in ITG turbulence. It suggests that the Shafranov-shift enhances turbulent transport in both CTEM and ITG. However, despite the observed increase in turbulent transport driven by CTEM, the wavenumber spectra [Figure1(c)] show that both the turbulent components ($k_y\rho_{ti} \neq 0$) and the zonal flow intensity ($k_y\rho_{ti} = 0$) increase simultaneously. This property contrasts with the case of ITG turbulence. A previous study [1] showed that turbulent transport driven by ITG increases due to an increase in turbulent components and a decrease in zonal flow intensity. These findings suggest that the role of zonal flows in CTEM turbulence differs from that in ITG turbulence.

In conclusion, our results imply that CTEM and ITG exhibit different characteristics. In the conference, we will discuss the reasons for these differences. For example, we will show the temporal evolution of CTEM-driven zonal flow and turbulent transport, the wavenumber spectra, and the Maxwell and Reynolds stresses.

References

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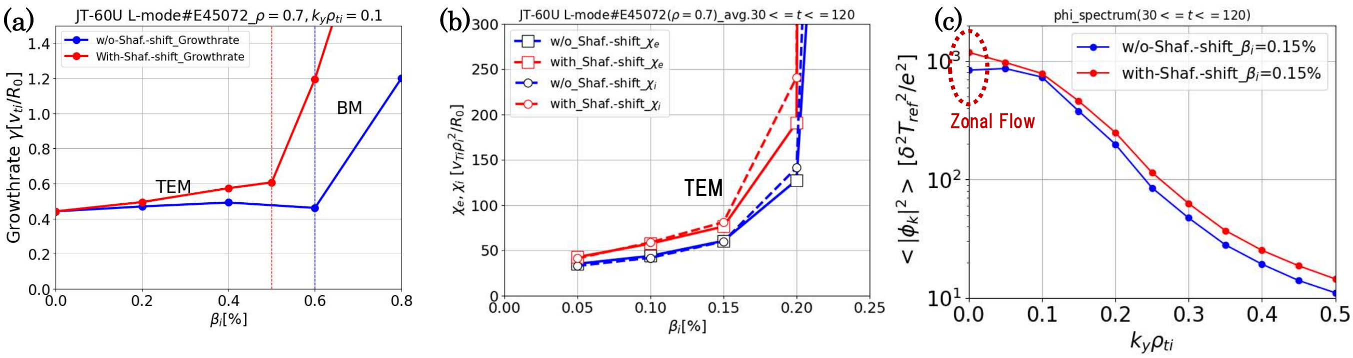

Figure 1. The β dependence of the linear growth-rate γ(a) and the electron and the ion energy diffusivity χ_e and χ_i(b) , the wave spectra in $\beta_i = 0.15\%$(c) by CTEM turbulence at $\rho = 0.7$ in JT-60U L-mode #E45072. The blue line represents the case without the Shafranov-shift, while the red line represents the case with the Shafranov-shift.