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Electromagnetic effect on turbulent transport in Tokamak based on global Landau fluid simulation

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Electromagnetic effect or finite β effect on micro-instabilities and turbulence makes significant changes on linear growth rates, frequencies, nonlinear saturation levels, and so on. The ion temperature gradient mode (ITG) is stabilized with β value increasing, while the kinetic ballooning mode (KBM) is unstable at high β. Nonlinear behaviors of ITG turbulence have been investigated widely by the numerical simulation where zonal flow (ZF) created by Reynolds stress plays an important role in the saturation of the ITG turbulence. However, as for the saturation of KBM turbulence, different conclusions are obtained by the different gyrokinetic numerical code [1-4] in local or global configuration. On the one hand, Ref. [2] shows that the zonal flow is weak with a high β value and nonlinear coupling between the dominant unstable mode and its twisted modes makes a major contributor in turbulence saturation. On the other hand, global simulation by Ref. [3-4] stress that zonal flow and other zonal mode may still be effective in suppressing the turbulence.

Here we investigate the electromagnetic effect on turbulent transport dominated by ion temperature gradient mode or kinetic ballooning mode based on global electromagnetic Landau fluid simulation in Tokamak plasmas. By increasing plasma beta value up to and beyond the kinetic ballooning threshold, the level of nonlinear turbulent ion heat transport and particle transport first decreases and then increases, coincident with the behavior of the linear growth rate. KBM turbulence reaches the saturation state with stronger magnetic perturbation and weaker zonal flow compared to ITG turbulence. Similar ion heat transport levels are obtained in ITG and KBM turbulence with $\beta_i = 0.1\%$ and $\beta_i = 1.0\%$ respectively, even though the maximum linear growth rate of KBM is much larger than ITG's. This is because of the smaller phase factor in KBM. The spatiotemporal characteristic of zonal flow shows that in ITG turbulence system, two different types of zonal flows, i.e. stationary zonal flows in a low q (safety factor) region and oscillatory ones with finite frequency in a high q region, are excited simultaneously while in KBM turbulence system, the frequency spectrum of zonal flow is widened in high q region.

We repeated the simulations, by removing the zonal component of the electrostatic potential or magnetic vector potential. The ion heat flux profiles in each case are shown in Fig. 1. In the ITG turbulence, zonal flow play an important role in suppressing the turbulent transport while in KBM turbulence, ion heat transport level does not change too much in the absence of zonal flow, indicating that in higher beta parameter regime, zonal flows does not make a major contributor in suppressing turbulent transport. Zonal field does not show much effect on the saturation level in both case, except that a peak in flux profile is observed in KBM turbulence around $q = 2$ rational surface.

The distinction of zonal flow behavior can be explained with energy transfer analysis (Fig. 2). From the analysis of the energy transfer channel between zonal flow and turbulence, it is founded that when beta is high, zonal flow exhibits a different energy transfer process compared to the low beta case and the coupling between zonal flow and turbulence becomes weaker particularly in high q region.

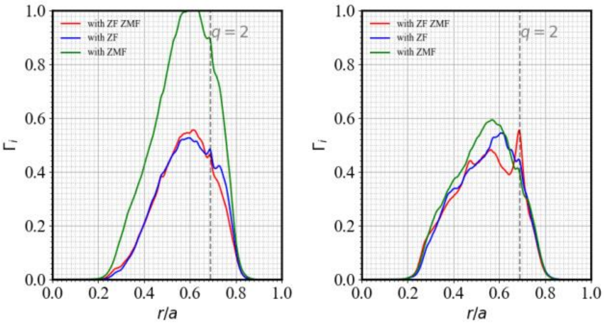

Fig. 1 Time averaged profiles of heat flux with $\beta_i = 0.1\%$(left) and $\beta_i = 1.0\%$(right).

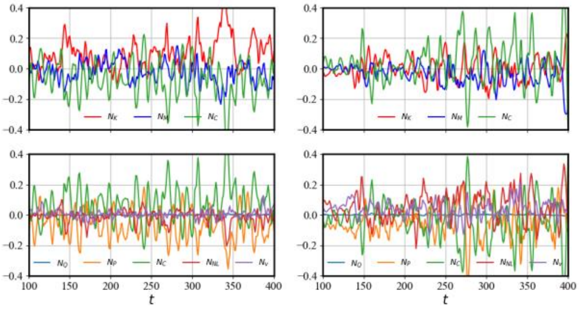

Fig. 2 Temporal evolution of ZF(upper) and ⟨psinθ⟩ (lower) energy drives with $\beta_i = 0.1\%$(left) and $\beta_i = 1.0\%$(right).

References

[1] M. Pueschel *et al.,* Phys. Plasmas. **15**, 102310(2008)
[2] S. Maeyama *et al.,* Phys. Plasmas. **21**, 052301(2014)
[3] G. Dong *et al.,* Phys. Plasmas. **26**, 010701(2019)
[4] A. Ishizawa *et al.,* Phys. Plasmas. **26**, 082301(2019)