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A gyrokinetic simulation study of parallel flow fluctuation effects on zonal flow generation

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When drift waves are coupled to ion acoustic waves in a three-dimensional system, zonal flow (ZF) is expected to be driven by the compression of fluctuating parallel flow [1,2]. In this work, we show that parallel compression indeed contribute to ZF generation in ion temperature gradient turbulence in a toroidal magnetic geometry. By using gyrokinetic simulations, we examine characteristics of the zonal flow generated by different levels of parallel flow fluctuations, which are obtained by varying the equilibrium parallel flow shear. In the case with the equilibrium parallel rotation shear, strong zonal flow is driven at the location of the rotation shear, leading the radial profile of zonal flow to be different from that in the absence of the equilibrium rotation shear.

We analyze the processes of zonal flow generation in the framework of a kinetic version of the potential vorticity (PV) mixing theory [3]. The PV flux estimated from the flux of gyro-center density well explains the generation of zonal flow. We decompose the mechanisms of the gyro-center density evolution into the drift motions of gyro-center. We find that the grad-B drift of the temperature fluctuation, the parallel compression of the parallel flow fluctuation, and the $E \times B$ advection are dominant processes. Unlike a simplified picture of toroidal ITG mode, the parallel compression becomes comparable to the grad-B drift for some spectral components even in the case without the equilibrium rotation shear.

Furthermore, we evaluate the gyro-center fluxes caused by the parallel and perpendicular dynamics, i.e. the parallel compression versus the other contributions. The parallel and perpendicular dynamics induce the gyro-center fluxes in the opposite directions, whose magnitude are very similar. The net gyro-center flux is determined by their difference. Usually, the perpendicular dynamics dominates the parallel compression. As the parallel compression increases with the equilibrium rotation shear, it takes over the perpendicular dynamics for more spectral components. Thus, the net gyro-center flux at the location of the strong rotation shear is reversed from outward in the no rotation cases to inward. These PV transport analysis results identify that the compression of parallel flow fluctuation is an essential element of the zonal flow generation in toroidal ITG turbulence.

References

[1] H. Jhang, S. S. Kim, S. Tokunaga, P. H. Diamond, Proc. 24th IAEA Fusion Energy Conf. (San Diego, CA, 2012) http://www-naweb.iaea.org/napc/physics/FEC/FEC2012/papers/142_TH62.pdf
[2] Lu Wang, P. H. Diamond, T. S. Hahm, Plasma Phys. Control. Fusion 54 (2012) 095015.
[3] C. J. McDevitt, P. H. Diamond, O. D. Gurcan, T. S. Hahm, Phys. Plasmas 17 (2010) 112509.