2nd Asia-Pacific Conference on Plasma Physics, 12-17,11.2018, Kanazawa, Japan

Multi-scale interaction and parity mixture between turbulence and magnetic islands

A. Ishizawa[1]
[1] Graduate School of Energy Science, Kyoto University
ishizawa@energy.kyoto-u.ac.jp

We have developed a new computational methodology in multi-scale/cross-scale interactions spreads over machine size to the Larmor radius such as interactions between turbulence and magnetic island by gyrofluid [1-5] and gyrokinetic simulations.

Turbulent transport is significantly influenced by the presence of magnetic island. The heat transport is enhanced inside the separatrix of the island, because meso-scale fluctuation is enhanced by the coexistence of the island and turbulence, while a steep temperature gradient is formed just inside the radius of the rational surface of the island, because strong flow shear suppresses the turbulence at the separatrix as shown by flux-driven global gyrofluid simulations [3]. This happens even if the growth rate of tearing mode is smaller than drift-wave instability, because the island suppresses drift-wave turbulence, so that the large eddy of tearing mode is stronger than the small eddy due to drift-wave instability, and dominates turbulence [3]. This dominance of the large eddy is a general feature of multi-scale interactions in magnetically confined plasmas. On the other hand, turbulence influences the threshold of the appearance of magnetic islands. Turbulence drives and sustains magnetic islands of width equal to multiples of the Larmor radius through the nonlinear multi-scale interactions [4]. These multi-scale interactions are recently observed by experiments in DIII-D, H2LA, and KSTAR.

The parity symmetry plays crucial role in these multi-scale interactions between turbulence and magnetic islands. This is because only the odd parity mode satisfies the nonlinear gyrofluid/gyrokinetic equations [6, 7]. Here, magnetic islands belong to the odd parity mode and drift-wave turbulence normally belongs to the interchange/ballooning parity (even parity) mode. Since both modes satisfy the linearized equations, the parity of interchange/ballooning mode is conserved in its linear growth. However, when the amplitude of the mode becomes finite and nonlinear effects are dominant, the pure interchange/ballooning mode does not satisfy the nonlinear equations. Hence, the nonlinear energy transfer takes place from the even parity mode (interchange/ballooning mode) to the odd parity mode (magnetic islands). Through this process, the magnetic islands are produced by turbulence, this is called nonlinear parity mixture. A typical nonlinear parity mixture is presented in terms of modulational instability analysis of zonal flow production. In the modulational instability, zonal flow and a side-band mode grow with the same growth rate, and this side-band mode is actually magnetic islands produced by the pump mode representing turbulence in electromagnetic systems [7]. These are found by global gyrofluid simulations, and some global gyrokientic simulation results will be reported as well.

In summary, when tearing mode is unstable, magnetic islands dominate turbulent transport even if its growth rate is smaller than micro-turbulence [1-3] (Fig. 1). In the multi-scale interactions magnetic island suppresses KBM and the spectrum of turbulence is broadened [3], and the island, diminishes zonal flows [1, 2]. In addition, turbulence cause the anomalous resistivity on tearing modes.

When tearing mode is stable/marginal stable, turbulence excites magnetic islands [4], and the rotation of magnetic perturbation is changed to influence polarization current driving island [5] (Fig. 2). Nonlinear parity mixture is the fundamental mechanism of magnetic island production and the mechanism is divided into two groups: direct excitation by nonlinear mixture and modulational parity instability [7].

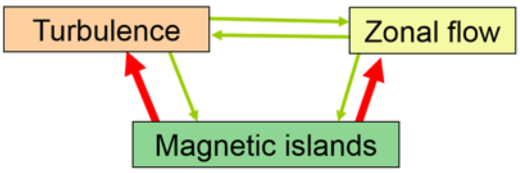

Fig. 1. Multi-scale interaction among turbulence, magnetic islands, and zonal flows, when tearing mode is unstable.

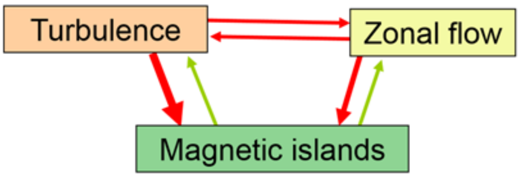

Fig. 2. Multi-scale interaction among turbulence, magnetic islands, and zonal flows, when tearing mode is stable.

References

[1] A. Ishizawa and N. Nakajima, Physics of Plasmas **14**, 040702 (2007)
[2] A. Ishizawa and N. Nakajima, Nuclear Fusion **47**, 1540 (2007)
[3] A. Ishizawa and N. Nakajima, Nuclear Fusion **49**, 055015 (2009)
[4] A. Ishizawa and N. Nakajima, Physics of Plasmas **17**, 072308 (2010)
[5] A. Ishizawa and F. L. Waelbroeck, Physics of Plasmas **20**, 122301 (2013)
[6] A. Ishizawa, S. Maeyama, et.al., Journal of Plasma Physics **81**, 435810203 (2015)
[7] M. Sato and A. Ishizawa, Physics of Plasmas **24**, 082501 (2017)