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

Selection of flow chirality in drift-mode and D'Angelo-mode fluctuations

M. Sasaki[1,2], N. Kasuya[1,2], K. Itoh[2,3], S. Toda[4], T. Yamada[2,5], Y. Kosuga[1,2], Y. Nagashima[1,2], T. Kobayashi[4], H. Arakawa[6], K. Yamasaki[1], A. Fujisawa[1,2], and S.-I. Itoh[1,2,7]

[1] Research Institute for Applied Mechanics, Kyushu University, [2] Research Center for Plasma Turbulence, Kyushu University, [3] Institute of Science and Technology Research, Chubu University, [4] National Institute for Fusion Science, [5] Faculty of Arts and Science, Kyushu University, [6] Institute of Science and Engineering, Academic Assembly, Shimane University, [7] Graduate School of Engineering, Chubu University

e-mail: sasaki@riam.kyushu-u.ac.jp

Helical flows are ubiquitous in nature. The helical flow, which consists of an axial and azimuthal flows, can be seen in a wide range of phenomena, such as a straight pipe flow [1] tornadoes [2] and cosmic jets [3] and so on. In magnetized confined plasmas, helical flows are spontaneously formed; flows in the parallel and perpendicular to the magnetic field directions, where the parallel flow is often related to toroidal intrinsic rotations [4], and the perpendicular flow includes zonal flows and poloidal mean flows [5]. These flows contribute to the stabilization of the MHD instabilities and the suppression of the transport. Flow bifurcations have often been observed; the inversions of the toroidal flow [4], the poloidal flow [6]. The topology of the helical flow, such as the chirality, is bifurcated in these cases. In such a plasma, multiple free energy sources for instabilities coexist. The temperature and density gradients drive the drift wave type instabilities. The inhomogeneities of flows excite Kelvin-Helmholtz instability, the interchange mode, and the D'Angelo mode [6]. In such a system, the fundamental processes of the formation of the helical flow and the flow inversion are should be understood.

A three-dimensional simulation of turbulence is performed [7]. We consider a cylindrical plasma, where the magnetic field has only the axial component with constant intensity. The direction of the magnetic field is set to z-direction. The density and the parallel flow is assumed to have their gradients in radial direction. In order to consider a situation when the density and the parallel flow are inhomogeneous in space, the particle and parallel momentum sources are introduced. The intensities of the sources control the stabilities of the drift wave and the D'Angelo mode. In order to change the dominant instability, the simulations are performed by changing the density source intensity shot-by-shot with the fixed parallel momentum source.

The bifurcation of the turbulent states is obtained by the change of the particle source intensity. The transitions among three states are observed: the D'Angelo / resistive drift wave is dominant when the particle source intensity is small / large, respectively. In the intermediate region, the hybrid mode becomes dominant, which has a characteristics both of the D'Angelo mode and the drift wave, but is a different type of mode [8]. The flow topology is also bifurcated, associated with the transition of the turbulent states. The turbulent fluctuations drive the mean azimuthal flows and induce the parallel momentum flux, so that the flow with the structure of co-axial helix is formed. The spatial patterns of fluctuations and the flows are shown in Fig.1. Depending on the turbulent states, the spatial patterns of the fluctuation change, which leads to the change of spatial structures of the momentum transport, and the flow formation. The results illustrate the generic feature of turbulence flow generation in non-equilibrium magnetized plasmas.

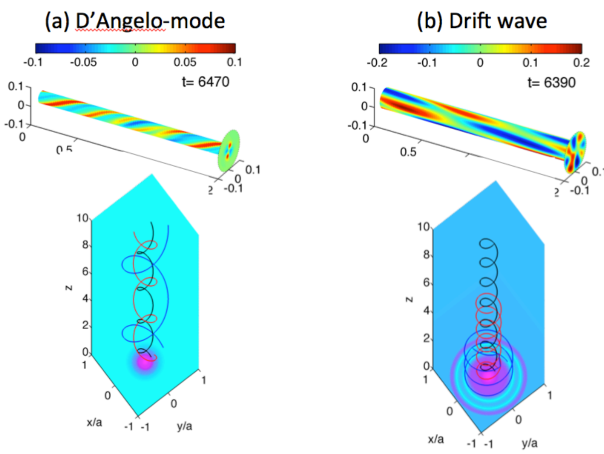

Fig.1 Spatial patterns of the fluctuation and stream lines in cases of (a) D'Angelo mode and (b) drift wave.

References

[1] O. Kitoh, J. Fluids Mech, 225, 445 (1991).
[2] J. Wurman, et. al., Science, 272 (5269), 1774 (1996).
[3] A. P. Lobanov, et. al., Science 294, 128 (2001).
[4] P. H. Diamond, et. al., Nucl. Fusion, 53, 104019 (2013).
[5] P. H. Diamond, et. al., Plasma Phys. Control. Fusion, 47, R35 (2005).
[6] S. Inagaki, et. al., Sci. Rep., 6, 22189 (2016).
[7] M. Sasaki, et. al., Phys. Plasmas, 24, 112103 (2017).
[8] M. Sasaki, et. al., Plasma Fusion Res. 12, 1401042 (2017).