24A10

Study of Turbulence-Zonal Flow Interactions in Magnetically Confined Plasmas

M. Xu[1,2], P. Manz[1,2], G. R. Tynan[1,2], P. H. Diamond[1,3,4], K. J. Zhao[5], J. Q. Dong[5, 6], C. Holland[2], N. Fedorczak[1,2], S. Chakraborty Thakur[1,2], S. Muller[1,2], J. H. Yu[2], J. Cheng[5], W. Y. Hong[5], L. W. Yan[5]

[1]*Center for Momentum Transport and Flow Organization*

[2]*Center for Energy Research & Department of Mechanical and Aerospace Engineering*

[3]*Center for Astrophysics and Space Science & Department of Physics,*

University of California at San Diego, California 92093, USA

[4]*WCI Center for Fusion Theory, National Fusion Research Institute, Gwahangno 113, Yusung-gu, Daejeon 305-333, Korea*

[5]*Southwestern Institute of Physics, P. O. Box 432, Chengdu, China*

[6]*Institute for Fusion Theory and Simulation, Zhejiang University, Hangzhou, China*

This talk gives a brief summary of several recent experimental studies on the zonal flow-turbulence interactions, particularly with the focus on the energy transfer measurements in both laboratory and fusion plasmas. It will also present some on-going work in a linear plasma device and in the HL-2A tokamak.

The interaction of sheared flows with gradient-turbulence in magnetically confined plasmas is a problem of fundamental importance in magnetic fusion, and also bears striking similarities to related problems in geophysical and astrophysical systems and thus is also of broad scientific interest. This talk gives a brief summary of several recent experimental studies on this problem, updated with some on-going work in the linear plasma device CSDX (Controlled Shear Decorrelation Experiment) and in the HL-2A tokamak.

First, in CSDX the development of nonlinear energy transfer during a controlled transition to a state of weak drift-interchange turbulence is studied. When magnetic field strength is increased the system undergoes several changes from a quasi-periodic to a phase locked to a weakly turbulent regime [1]. The polarization drift nonlinearity transfers kinetic energy to larger scales. The $\vec{E}\times\vec{B}$ drift nonlinearity provides access to the free energy by coupling density fluctuations at smaller scales to the larger scale potential structures, resulting in a formation of a very robust phase-locked regime and acting as a mechanism of self-sustainment in the weakly turbulent regime. Although the interplay between these nonlinearities is different in the different regimes, it results in a successive increase in the degrees of freedom in all regimes, which is the most important feature of a transition to turbulence. At high magnetic field kinetic energy transfer results in the formation of a sheared flow as indicated by other time-domain studies.

In fusion devices, correlation studies have been conducted to characterize the spatial structures of the low frequency ZFs (zonal flows) and GAMs (geodesic acoustic modes) [2, 3, 4]. The results clearly demonstrated their theoretical expected symmetry properties. Most recently, an experiment aimed to measure the nonlinear kinetic energy transfer at different heating power using a frequency-domain bispectral technique was conducted on the HL-2A tokamak. I was found that turbulent kinetic energy is transferred into both ZFs and GAMs, as well as fluctuations with higher (>80 kHz) frequencies, consistent with the observed spectral broadening of 2D turbulence. It was also observed that when the heating power was increased, the energy transfer from turbulence into GAMs first increased then decreased while the energy transfer into ZFs and the ZFs themselves both became stronger monotonically, suggesting that ZFs very likely play a leading role in the low to high (L-H) plasma confinement transition [5].

Experiments in the TJ-K torsatron provide the first study of turbulent spectral energy transfer in the wavenumber domain [6]. Results show a dual transfer of energy in which kinetic energy accumulates in large scale zonal flows, while density fluctuations are scattered to small spatial scales corresponding to dissipation scales. When a radial current is injected into the plasma with a biased electrode aligned with the magnetic flux surface a mean shear flow sustained by non-turbulent processes is created [7]. Studies of the nonlinear turbulent kinetic energy transfer into the large spatial scales indicate that the strength of the energy transfer is increased by the imposition of an externally driven flow. Such a response should act to amplify the large scale shear flow and thus setup the conditions necessary for the formation of a state of strong shear flow and weak turbulent transport.

All of the above experiments are consistent with the theory that ExB sheared flows can be self-generated and amplified by turbulent stresses, and support the critical role that ExB sheared flows play in turbulent transport regulation and in the transition to the improved confinement.

References

[1] M. J. Burin, G. R. Tynan, and G. Y. Antar et al., *Phys. Plasmas* **12** 052320 (2005)

[2] Fujisawa A. *et al*, *Phys. Rev. Lett.* **93** 165002 (2004)

[3] K. J. Zhao et al., *Phys. Rev. Lett.* **96**, 255004 (2006)

[4] G. S. Xu, B. N. Wan, M. Song and J. G. Li, *Phys. Rev. Lett.* **91**, 125001 (2003)

[5] M. Xu, G. R. Tynan, and P. H. Diamond et al., to be submitted to *Phys. Rev. Lett.* (2011)

[6] P. Manz, M. Ramisch, U. Stroth, *Phys. Rev. Lett.* **103**, 165004 (2009)

[7] Y. Xu et al, *Nucl. Fusion* **51**, 063020 (2011)