# Experimental Study of Turbulence and Znal Flows on HL-2A Tokamak

K. J. Zhao[1], J. Q. Dong[1,2] , L. W. Yan[1], W. Y. Hong[1], A. Fujisawa[3] , J. Cheng[1], M. Xu[4], G. R. Tynan[4], P. H. Diamond[4], Z. X. Wang[5], L. Wei[5], Q. Li[1], Y. Huang[1], Yi Liu[1] , X. M. Song[1] , Q. W. Yang[1], X. T. Ding[1] , X. R. Duan[1] and Yong Liu[1]

*[1] Southwestern Institute of physics, P. O. Box 432, Chengdu, China*
*[2] Institute for Fusion Theory and Simulation, Zhejiang University, Hangzhou, China*
*[3] Research Institute for Applied Mechanics Kyushu University 6-1 Kasuga-kouen, Kasuga, 816-8580, Japan*
*[4] Center for Momentum Transport and Flow Organization, University of California at San Diego, California 92093, USA*
*[5] School of Physics and Optoelectronic Technology, Dalian University of Technology, Dalian 116024*

The competition among the low frequency zonal flow (LFZF), geodesic acoustic mode (GAM) and turbulence is demonstrated by their profiles in HL-2A plasmas with ohmic and electron cyclotron resonance heating. The maximum of GAM amplitude is found located near the low order rational flux surface. The LFZF and GAM tend to coexist in the inner region. The direct measurements of turbulence Reynolds stress suggest that the LFZF, GAM are driven by turbulence stresses. The turbulence intensity significantly reduces near the RS and the last close flux surface.

## 1. Introduction

The Zonal flows (ZFs), including low frequency zonal flow (LFZF) and geodesic acoustic mode (GAM) have been extensively investigated in recent years [1-4]. Nevertheless, the radial distributions and competition of multiple shear flows have not been observed when they coexist in the edge of tokamak plasmas. Stresses driving ZFs and the GAM peak located at the low order rational surface (RS) have not been reported yet. In this paper, we present the first study of the radial distributions and competition of multiple shear flows and fluctuations in the edge plasma of HL-2A tokamak using combinations of distributed Langmuir probe arrays.

## 2. The Competition of Multiple Shear Flows and AT

Figure 1(a) shows typical auto-power spectra of the floating-potential fluctuations at the radial positions of △r=-2.4, -2.0, -1.6, and -1.0 cm in ohmic plasmas with edge safety factor of $q_{95}$=4.0, where the minus sign means inwards from the the last closed flux surface（LCFS）. Two distinct features in the spectra are a large power fraction in the frequency range lower than ~5kHz and a sharp peak at f~12-18 kHz, which were identified as LFZF and GAM, respectively. The rest is AT. The intensity of LFZF and AT increases inwards. The GAM power has a maximum at the position near the RS of △r~-2.0 cm. Perhaps, there is a small magnetic island which interacts with GAM near the RS. As a consequence, the GAM is enhanced there.

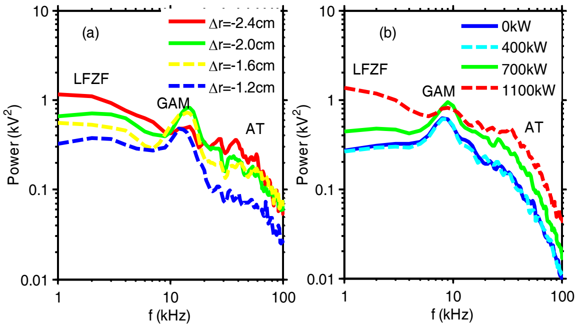

Fig.1 (a) Typical auto-power spectra of floating potentials at four radial positions (b) potential power spectra with ECRH power scan.

The GAM frequency increases from 12 to 18kHz inwards, as expected from theory. However, the LFZF growth and GAM decay inwards do not attribute to the q damping mechanism in that the q value does not change much in the narrow region. The amplitude developments of LFZF, GAM and AT are examined further by electron cyclotron resonance heating (ECRH) power scan of 0, 400, 700 and 1100kW at the radial position of Δr=-1.6cm as shown in Figure 1 (b). The intensity of LFZFs and ATs increases with ECRH power. The GAM firstly also increases with ECRH heating from 0 to 700kW, but decays with strong ECRH heating of 1100kW. In this case, the q value does not change. This investigation indicates that the competition among LFZF, GAM and AT is another important factor of affecting their amplitude development [5].

## 3. The Profiles of Multiple Shear Flows and Fluctuations

The radial structure of the multiple flows and AT are studied further in Ohmic and ECRH plasmas with safety factor of $q_{95}$=3.3. The ECRH power is 500kW. Figure.2.(a) and (b) show the radial electric fields $E_r$ for the LFZF and GAM in Ohmic (light) and ECRH (heavy) plasma, respectively. The radial distributions of LFZF and GAM are roughly similar to those observed in their power intensity shown Figure 1 (a). But, the maximum of GAM amplitudes moves inside and is located at Δr~-3cm near the RS of q=3. The turbulence intensity $<\Phi^2>$ profile plotted in Figure 2 (c) is significantly reduced near the LCFS and in GAM peaking region. The profiles of the LFZF, GAM and turbulence clearly demonstrate the competition among them again.

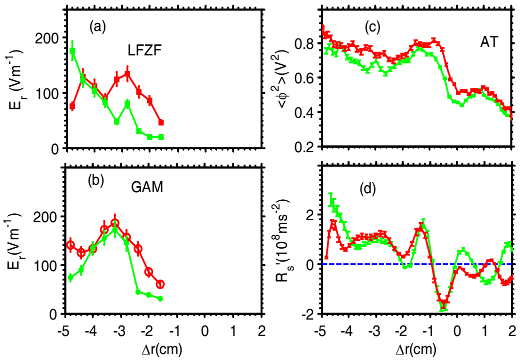

Fig.2. The profiles of LFZF (a) and GAM (b) electric field, turbulence power (c), turbulence stress gradient (d) in Ohmic and ECRH plasmas.

Now we considered the multiple flow generation mechanism from turbulence via Reynolds stress. Figure 2(d) shows the radial distribution of the turbulence Reynolds stress gradient which is estimated as $R_s'=d<v_r v_\theta>/d_r$, here, with $v_\theta$ and $v_r$ being the poloidal and radial fluctuating velocities, respectively. The $R_s'$ profiles are similar to those of LFZF from Δr~ -1cm to -5cm. This observation suggests that the LFZF is driven by stress. The correlation between GAM and stress was not observed in this analysis due to that the GAM has finite frequency. The strong correlation between GAM and the stress gradient in GAM frequency band was measured by correlation analysis. The phase shift of between the GAM flow and the stress gradient is close to $\pi/2$, with GAM lagging the stress gradient. This suggests that the stress indeed drives the GAM.

In summary, the spatial structures and competition of LFZF, GAM and AT are measured. The GAM peak is situated near the RS. The Reynolds stress is found to be well correlated with the LFZF and GAM, suggesting that multiple shear flows are driven by nonlinear interaction with turbulence via the stress. The turbulent intensity significantly reduces in GAM peaking region and near the LCFS.

## References

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