*32nd EPS Conference on Plasma Phys. Tarragona, 27 June - 1 July 2005 ECA Vol.**29C**, P-5.022 (2005)*

Detection of radially localized and poloidally symmetric structures in the poloidal flow of tokamak plasmas

A. Bencze[1], M. Berta[2,3], S. Zoletnik[1], J. Stockel[4], J. Adámek[4], M. Hron[4]

[1]*KFKI-RMKI, Association EURATOM, P.O.Box 49, H-1525 Budapest, Hungary*

[2]*Széchenyi István University, Association EURATOM, Győr. Hungary*

[3]*BME-NTI, Association EURATOM, Budapest, Hungary*

[4]*Institute of Plasma Physics, Association EURATOM/IPP.CR, Prague, Czech Republic*

INTRODUCTION

Nowadays it is generally accepted by the fusion community that the understanding of the drift wave - zonal flow turbulence plays a crucial role in the understanding and handling of anomalous transport and different spontaneous transitions of the collective plasma state. The 'equilibrium' spectrum of the fully developed drift wave (DW) turbulence can be unstable in the presence of random shear flows or zonal flows (ZFs) which are potential modes with $(k_r, k_\theta, k_\phi) = (k_r, 0, 0)$. The effect of shearing on the drift waves can be described as a diffusion of the DW radial wave number in **k**-space [1, 2]. We have to mention two recent experimental works on hunting random zonal flows. The first one was performed at the HT-7 tokamak by *G. S. Xu* [3] and his co-workers using specially designed Langmuir probes, detecting floating potential fluctuations. The second direct ZF identification in a stellarator (CHS) was very recentely done in [4] using toroidally separated ($\approx 1.5m$) dual heavy ion beam probes.

Our present measurements aim at the identfication and detailed characterization of ZFs in tokamak plasmas. Autocorrelation-width (ACFW) technique has been used [5] to extract information about the fluctuations in the flow velocity following the time evolution of the autocorrelation structure of the basic micro-turbulence.

AUTOCORRELATION-WIDTH METHOD

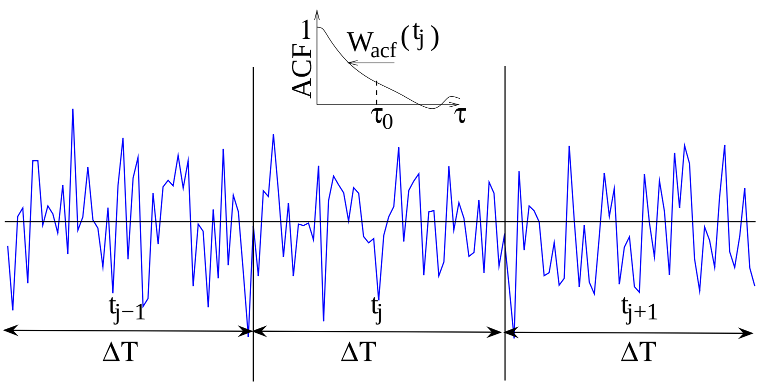

Figure 1: *Autocorrelation method for detection of poloidal flow modulations.*

The ACFW method [5] relies on the assumption: $\tau_{life} \gg \tau_v$, where τ_{life} is the decorrelation time of turbulent structures, $\tau_v = w_\phi / v_\phi$, (transit time) w_ϕ is the poloidal correlation length and v_ϕ is the poloidal flow velocity. If this holds, the autocorrelation function (ACF) of the turbulence is dependent on the flow velocity . The procedure is the following: first we split the whole time record in shorter ΔT intervals, where the $\Delta T \gg w_t$ (w_t is the measured correlation time) relation must be hold. Then we calculate autocorrelation functions from these short time intervals and extract the information about the width of the autocorrelation function. In this way we obtain the ACF-width as a function of time (denoted by $W_{acf}(t)$) with time resolution determined by ΔT (see Fig. 1). After this procedure we are ready to analyse $W_{acf}(t)$ using correlation technique or spectral methods, and this may get informations on the temporal modulation of the flow velocity.

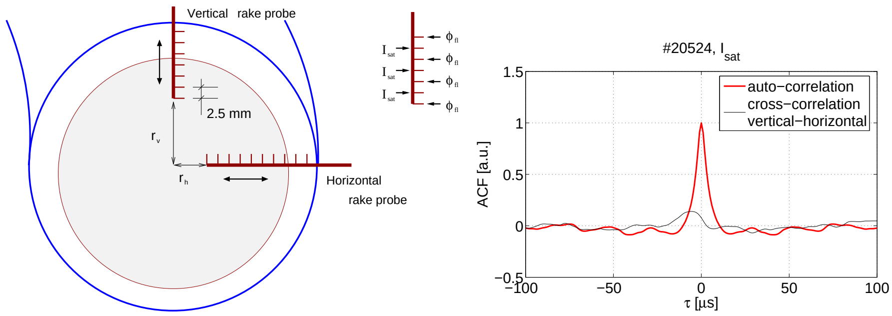

Figure 2: *Experimental setup for fluctuation measurements (left). The auto-correlation and cross-correlation functions for the shorter time-scale (right).*

This measurement technique was implemented on the Castor tokamak using multiple Langmuir probe arrays (rake probes) (see Fig.2, left). These two arrays of Langmuir probes were located at the same toroidal position, polloidally separated by 90^o ($\sim 12cm$ for the innermost tips). $15ms$ long time records of carefully selected, identical shots were involved in the analysis in order to improve statistics.

From direct measurement of the ion saturation current fluctuations, we can estimate the autocorrelation function of the density fluctuations. The $15ms$ long fluctuating signal – after an appropriate detrending procedure – was divided into $\Delta T = 100\mu s$ long sections. These are about 10 times longer than the observed approximately 10 μs autocorrelation time (Fig. 2, right). As it has been pointed out above, the ACFW technique can be used in the cases when the poloidal flow velocity dominates the autocorrelation time of the basic turbulent structures. This condition was verified using two poloidally $4mm$ separated Langmuir probes and by applying edge biasing to enhance poloidal rotation of plasma. This way was possible to observe the effect of velocity change (deduced from the cross-correlation function of poloidally separated channels) on the autocorrelation function (see Fig. 3).

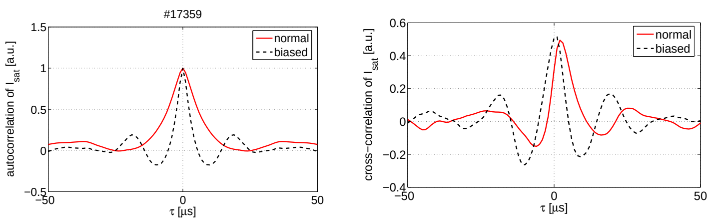

Figure 3: *Effect of flow velocity on the autocorrelation function (left) compared to the same effect on the cross-correlation function (right).*

CHARACTERIZATION OF RANDOM FLOW MODULATION

The $ACF_j(\tau)$ autocorrelation function of density fluctuations is calculated for each jth section. Now we have to give the definiton of the ACF-width which is the main quantity of our procedure:

$$W_{acf}(j) = \int_0^{\tau_0} \tau \cdot ACF_j(\tau) d\tau, \quad \tau_0 = 10\mu s.$$

This definition may be better than the simple half width definition in two aspects:

- as an itegral quantity it can reduces the uncorrelated statistical noise.
- it can be shown that under some conditions (here fulfilled), the quantity defined above can amplify modulations in the autocorrelation time [6].

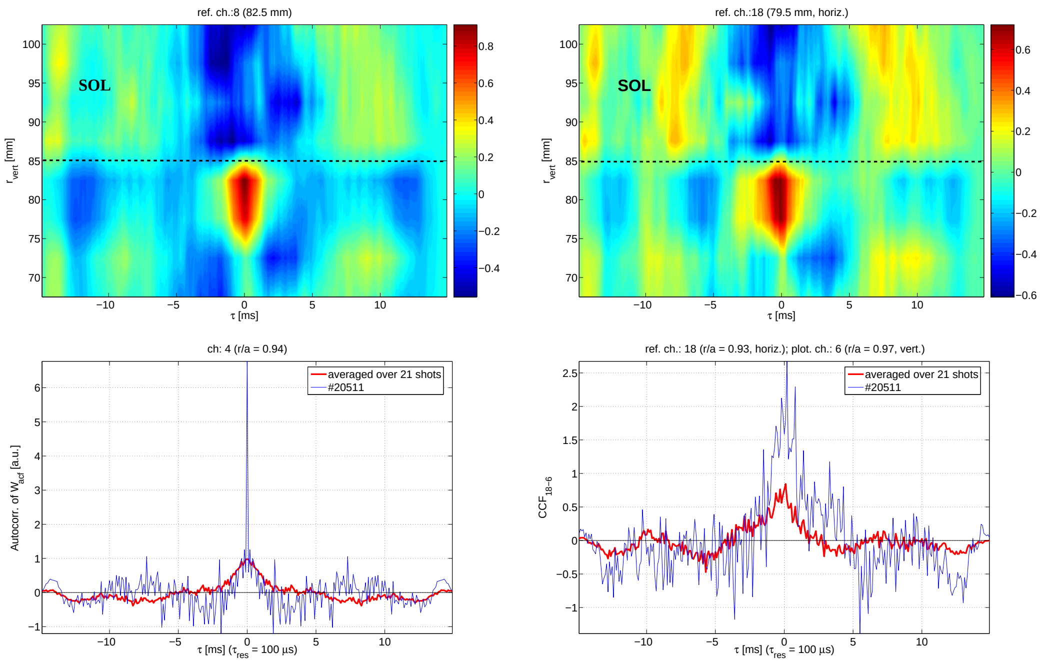

Figure 4: *Space-time correlation structre of ZFs. The left hand side column shows the radial structure of ZFs along a single rake (top) and the autocorrelation function of ZFs in a given channel (bottom). In the right hand side column of the figure, the cross-correlation function between the two rakes is ploted: cross-correlation along the vertical rake probe, taking the reference channel at the horizontal rake probe (top) and the cross-correlation between two channels located at different rakes (bottom).*

After calculating ACF-width signals, $W_{acf}(t)$, for each ion saturation channel we proceed to calculate the detailed correlation structure of the $W_{acf}(t)$. The results are seen in Fig. 4. The left hand side of the figure shows the characteristic time scale of flow modulations (bottom) to be $\sim 1ms$, and the radial structure of the random flows (top) wich clearly indicates radial localization ($1cm$ width) in the edge plasma. Plots in the right hand side show the cross-correlation between the $W_{acf}(t)$ signal of a given reference channel located at the horizontal probe and all other channels at the vertical probe. On the basis of these calculations we can conclude that the flow structures remain significantly correlated in the poloidal direction even when measurement channels are separated by 12 cm which may be a signature of the high poloidal symmetry. It has to be noted that very small correlation is observed between the the two probe arrays in the ambient turbulence itself (Fig.2). In order to check the possibility of misinterpretation of our results by an effect originating from the global plasma changes rather than from relevant local feature, correlations between ACF-width signal and relevant global parameters (loop voltage, horizontal and vertical position of the plasma column etc.) have been determined and no correlated changes have been found.

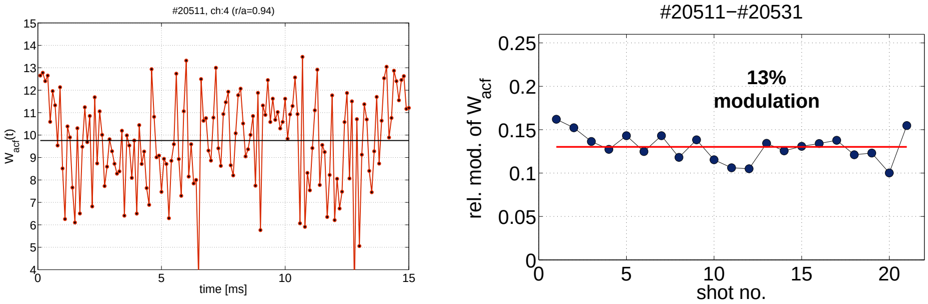

Figure 5: *Time evolution of W_{acf} (left) and its relative modulation (right).*

CONCLUSION

Autocorrelation-width analysis shows the existance of $\sim$ 13% rms modulations in the poloidal flow (Fig.5) wich are radially well localized ($\sim 1cm$) and poloidally symmetric, having a characteristic lifetime of $\sim 1-2ms$. All these features strongly suggest the apparence of zonal flows described by theory as $m = 0, n = 0$ radially localized random potential structures. Our results are also consistent with the recent experimental work reported in [4].

References

[1] A. Yoshizawa, S. Itoh, K. Itoh and N. Yokoi, Plasma Phys. Control. Fusion **43**,$R1-R144$, (2001).

[2] P. H. Diamond,S. Itoh, K. Itoh and T. S. Hahm,Plasma Phys. Control. Fusion **47**,$R35-R161$, (2005).

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

[4] A. Fujisawa, K. Itoh et al., Phys. Rev. Lett. **93**, 165002, (2005).

[5] A. Bencze, S. Zoletnik, Phys. Plasmas **12**, 052323, (2005).

[6] A. Bencze, M. Berta and S. Zoletnik, KFKI-RMKI Report 2005, (unpublished)