*33rd EPS Conference on Plasma Phys. Rome, 19 - 23 June 2006 ECA Vol.**30I**, P-4.152 (2006)*

The Origin of Convecitve Structures in the Scrape-off layer of Linear Magnetic Fusion Devices Investigated by Fast Imaging

Ghassan Y. Antar, J. Yu, C. Hollland and G. Tynan

University of California San Diego, 9500 Gilman Dr., La Jolla CA 92093, USA

The understanding and characterization of turbulence in the scrape-off layer (SOL) of magnetically confined plasmas is important and may actually be crucial for ITER. The reason being the SOL is the region where the plasma is in direct contact with the first wall. Plasma in the SOL is mainly caused by turbulence radial transport in L-mode discharges and during ELMs in H-mode discharges [1, 2]. We have dedicated several studies to unviel the different facets of turbulence properties in the SOL. In Ref. [3, 4] it was shown that intermittent events are not caused by self-organization of turbulence in the SOL but rather by non-local structures that have large scales and large radial velocities. In order to be precise we called these events avaloids. Later, the universality of avaloids was shown with excellent agreement among four different devices, including the PISCES linear device [5]. The first study of the origin of intermittency in linear devices was done on PISCES where two probes were used [6] one vertical and the other horizontal. It was shown that bursts in the far SOL are correlated to a low frequency mode inside the main plasma column.

This article presents the results of our continued effort to have a better understanding of the origin of intermittent structures in linear devices. Indeed, the extrapolation to toroidal confinement deivces is not straightforward but since strong similarities exist between the various machines a similar process may be occurring. Here, we mainly use high speed imaging in order to investigate the onset and the correlation between the far SOL and inside the main plasma column. The linear device used is CSDX where a transition to turbulence has been studied in details [7].

CSDX is a linear plasma device with a helicon wave source at 13.56 MHz with a power of 1,500 W. Equally spaced coils produce an axial magnetic field with intensity that can be changed between 200 and 1,000 Gauss. The full length of the chamber 2.8 m is used in this experiment where the end-plate is a glass window at the end of the machine. The diameter of CSDX is about 20 cm whereas the belljar, where the source is, is about 10 cm. The gas used here is Argon at a pressure of 3 mTorr. The main diagnsotic is the Phantom V7 camera used with 1 micro-second exposure time and 10 micro-seconds between frames. The number of pixels is 64x64. When a 25 mm lens is used, it covers an area about 10x10 cm^2; for a 50 mm one the area is reduced to about 5x5 cm^2.

Before showing the main results, we cross-correlated the probe ion saturation fluctuations to that of the light intensity. Fig. 1 shows the raw signals where rather good correlation exists. The latter is quantified using the cross-correlation coefficient plotted in Fig. 1(b) where the amplitude is close to 0.5. Analysis of the power spectra shows that it is the high-frequency, hence small scales, that are not correlated. The small scales are not resolved by the camera because of line integration. We deduce that good correlation exists between the probe signals and imaging for relatively large-scale fluctuations.

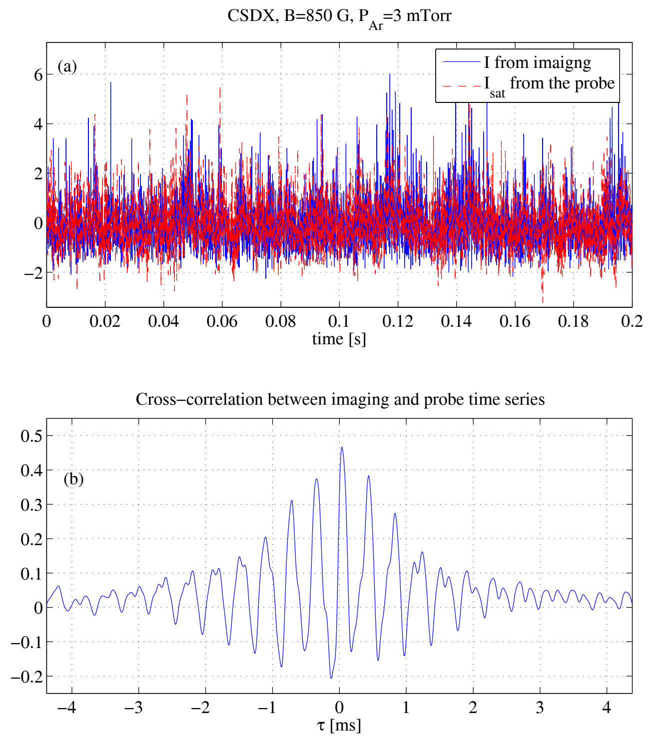

Figure 1: (a) shows the raw flcutuation signals detected by the camera and the Langmuir probe biased toward the ion saturation current. (b) illustrates the cross-correlation coefficient between the two signals the high level of correlation indicates that the density fluctuations affect both signals.

Using the 50 mm lens Fig. 2 shows nine consecutive images. The camera is focused on the probe that can actually be seen on the right-hand side as the structure passes by it. The area that is imaged is on the right hand side of the main plasma column. Only its edge is seen on the left where strong density fluctuations exist. In order to obtain Fig. 2, an average image is first calculated from about 5,000 frames, then, each image is subtracted from the average one. We note several features. The convective structure remains attached to the plasma and does not form a "blob" but is rather *finger-like*. The structure is clearly moving in the radial direction at a rate of $\sim 10^5$ cm/s in excellent agreement with the probe measurements done on PISCES and also on toroidal devices. Also the structure is moving in the poloidal direction at a rate of 8×10^4 cm/s. This velocity is smaller than the main plasma poloidal rotation.

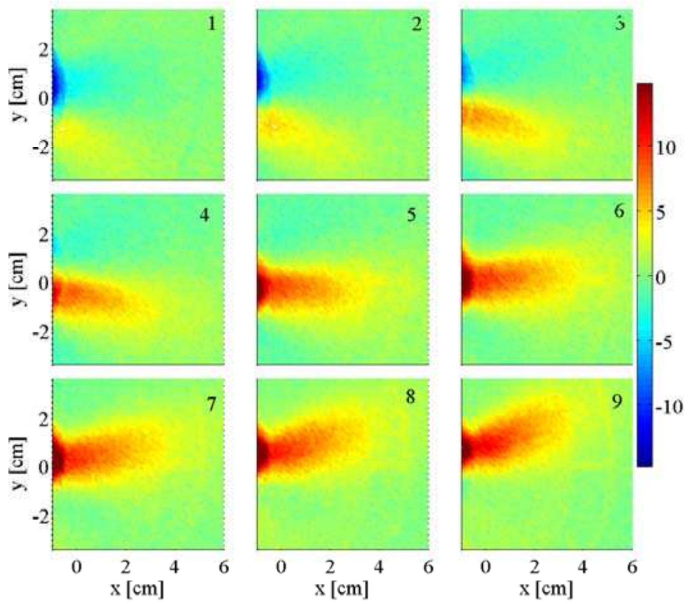

Figure 2: Nine consecutive images obtained after subtraction from an average image.

We use conditional averaging in order to study the onset of convective structures in CSDX. The idea is to present how, on the average, convective structures grow and live. In order to do so, the light intensity fluctuations are recorded for the full 50,000 images at one position in the far SOL. Then, maxima are selected with intensity that are greater than 2.5 times the standard deviation of the total time serie. For $B = 850$ G this leads to 277 events. For each high intensity burst, a movie is made from 20 images before and after each burst. Then an average over the 277 movies is taken leading to an "average movie" the describes the evolution of convective structures in the SOL. In order to relate the far SOL fluctuations to inside the main plasma, we use the 25 mm lens that images the main plasma column as well as the SOL. The results obtained were confirmed using a 50 mm camera and looking only at half of the plasma.

Fig. 3 shows 16 consecutive images from the "average movie". In the middle is the main plasma column surrounded by the SOL. From frame 1 to 8, one sees the onset of an $m = 1$ mode rotating poloidally in the counter clock-wise direction. From image 9 to 16 the onset of a convective structure is observed. A study of the fluctuations inside the plasma column revealed that fluctuations and for a lapse of time select a certain mode. Hence, the average power spectrum describes the different modes that exist over time. Fig. 3 indicates that the

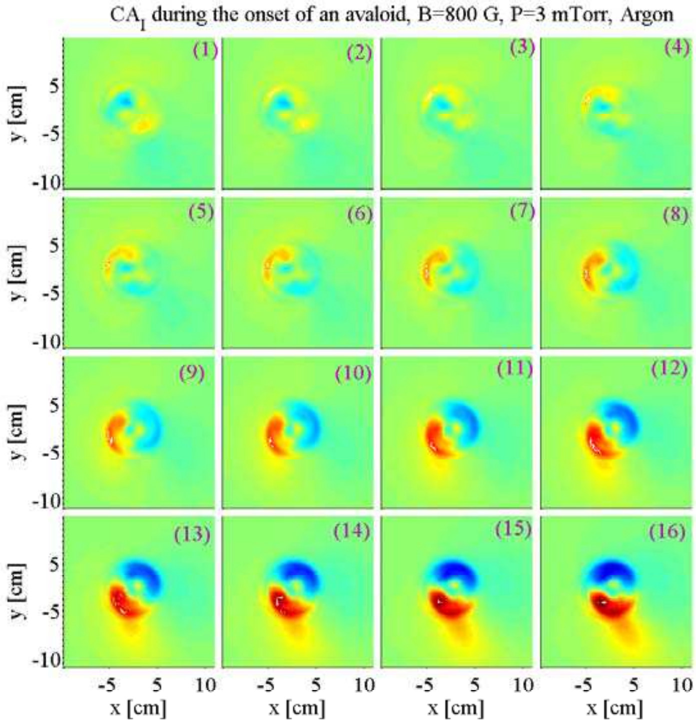

Figure 3: 16 consecutive images from the average movie obtained after averaging over 277 events.

onset of convective transport in CSDX is linked to the non-linear evolutio of the $m = 1$ mode.

In agreement with previous studies made on PISCES, imaging plasma on CSDX have shown that there is a clear correlation between the $m = 1$ mode inside the main plasma column and the high intensity bursts in the far SOL. Also it revealed that bursts do not detach from the main plasma but rather stay attached to it and rotating along.

References

[1] G. Y. Antar, Physics of Plasmas **13**, 052508 (2006).

[2] A. Kirk *et al.*, Plasma Physics and Controlled Fusion **47**, 315 (2005).

[3] G. Antar, P. Devynck, X. Garbet, and S. C. Luckhardt, Phys. Plasmas **8**, 1612 (2001).

[4] G. Y. Antar *et al.*, Phys. Rev. Lett. **87**, 065001 (2001).

[5] G. Antar *et al.*, Phys. Plasmas **10**, 419 (2003).

[6] G. Antar, Phys. Plasmas **10**, 3629 (2003).

[7] M. J. Burin *et al.*, Physics of Plasmas **12**, 052320 (2005).