

Dynamical study of the radial structure of the fluctuations measured by a reciprocating Langmuir probe in Tore Supra

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1 Introduction

The fluctuations in the Scrape Off Layer (SOL) of Tore Supra are studied with a movable Langmuir probe biased to ion saturation current. The probe system consists of three probes separated poloidally (0.68 cm between two nearby probes). The probe has no magnetic connection to the mid plane limiter on which the plasma is leaning, but the radial profile of the ion saturation current fluctuations displays a dip at the limiter position. At the same location the ion saturation current displays an inflexion point. A correlation analysis technique is developed to study the radial behaviour of the fluctuations. It reveals that this dip is associated with a reduction of the poloidal velocity of the fluctuations with no sign reversal. In the dip the mean poloidal correlation length of the fluctuations is also reduced. These observations are consistent with a reduction of the fluctuations by a shear of the radial electric field created at the limiter surface. The auto-correlation time is also calculated. It increases slightly in the dip and is found to be sensitive to both the convection time and lifetime of the turbulent structures, because these quantities are of the same order

2 Experimental set-up

The probe which is used is the standard reciprocating probe used in Tore Supra as a Mach probe which measures routinely the density and temperature profiles at the plasma edge and in the scrape off layer. The probe consists of 6 composite carbon tips of 6 mm diameter poloidally and toroidally separated. All these tips are shielded from the plasma by a 4 cm diameter cylinder with holes drilled through it. The surface collection of the probe is then defined by the size of the holes which are 4 mm in diameter. Three probe tips poloidally separated by 0.68 cm are facing the plasma in the upstream current direction and three other are facing the plasma in the downstream direction. The probe tips are biased relatively to machine ground at -100 V to measure the ion saturation current. The reciprocating probe is located on a vertical port and moves at 1.5 m/s. The acquisition system is composed of a fast acquisition (1 MHz) which is triggered at a selected probe penetration. For each probe plunge, typically 10 kbytes are recorded per probe tip, allowing to make correlation studies between the poloidally separated tips. A slow acquisition measures the root mean square level (averaged over 1 ms) of the fluctuations all along the probe reciprocation. Therefore, both the profiles and fine details of the fluctuations of the ion

saturation current are available during one reciprocation.

3 Experimental results

Figure 1 shows the plasma scenario on which the analysis is performed. The plasma major radius is $R = 2.4$ m, the minor radius is $a = 0.72$ m, the toroidal magnetic field is 3.8 Tesla. The plasma current is 1.3 MA. The density is increased during the shot and changes from a line integrated density of 2 to about $4 \times 10^{19} \text{ m}^{-2}$ and 2 MW of LH power are applied to the plasma. The probe plunges 4 times, before and during the LH heating. The magnetic connection of the probe is illustrated on Fig 2. In Figure 2, the x axis corresponds to 3 toroidal and the y axis to 1 poloidal turns unfolded. The plasma is leaning on the inertial limiter lying in the outboard/inboard midplane but the probe is not magnetically connected to it for at least 3 toroidal turns. The probe is connected in the SOL at short distance (2 m) to an ergodic divertor module and to the two hybrid antennas with a connection length of about 6 m.

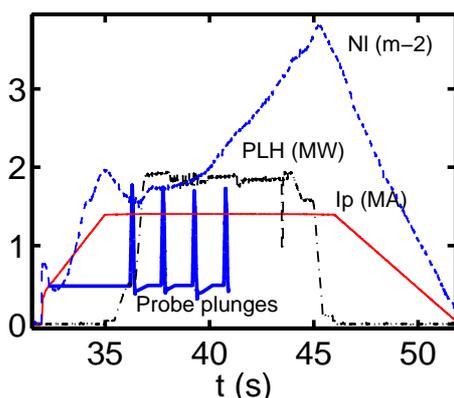


Figure 1: Plasma scenario

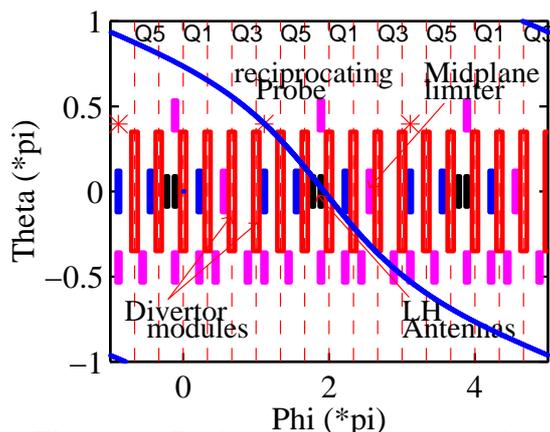


Figure 2: Probe magnetic connections

Figure 3a shows the profile of the fluctuating ion saturation current (δj) measured by the RMS acquisition system. The three vertical bars on the figure correspond to the radial locations of the limiter, the lower hybrid antennas and the ergodic divertor module. The profile displays a dip just at the limiter radial position. A close examination of Figure 3a reveals that a feature is also associated with the hybrid antennas on the δj profile (a small plateau) at $r = 0.749$ m. The dip has a width of 5 mm and corresponds to a 50% decrease of δj .

In Figure 3b, the ion saturation (j_{sat}) profile displays an inflexion point but no strong reduction at the position where the dip is observed. As a consequence, the relative fluctuation level $\delta j / j_{sat}$ plotted in Fig. 3c is reduced by 50%. This behaviour is obtained for the 4 consecutive probe plunges exactly at the same radial location thus proving that the phenomenon is robust and stationary. The 1 MHz acquisition is used to recover more detailed information by calculating the cross and autocorrelation functions of consecutive 800 points segments overlapping by 700 points.

Figure 4 shows the fluctuations poloidal velocity profile deduced from the crosscorrelation calculated between two probes. The poloidal velocity shows a dip at the same radial position where the fluctuation level is decreased and goes from 900 m/s down to 400 m/s. In fact, the dip is a double shear configuration. It must be noted that the poloidal velocity does not reverse, so that this shear phenomenon does not correspond to the usual observation of the E_r inversion radius. The E_r inversion radius in Tore Supra is usually found to be a few centimeters inside the plasma [1]. The poloidal correlation decreasing length (l_θ) at $1/e$ is also calculated by fitting the cross correlation amplitude of three probes with a decreasing exponential. It's radial profile is shown in Figure 5.

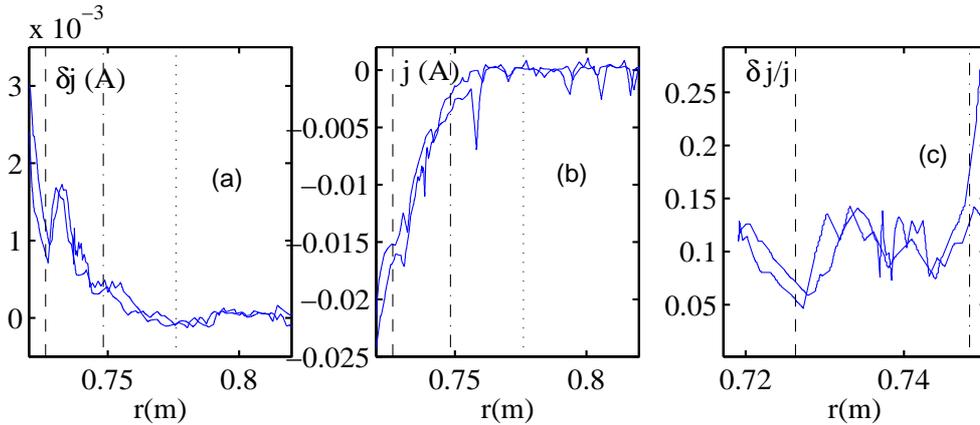


Figure 3: In (a) and (b), profile of the rms and the average values of the ion saturation current; in (c) the result of the normalisation. The dashed, dotted and dash-dotted vertical lines denote the limiter, the ergodic divertor and the LH antenna radial positions.

l_θ is found to decrease from 1.2 to 0.4 cm in the dip and recovers after the dip. This suggests that the shear is responsible for the decorrelation of the fluctuations in poloidal direction and most probably in the radial one, leading to the turbulence reduction. Finally, the turbulent structures lifetime (τ_{turb}) is obtained using the following expression of the autocorrelation function.

$$\tau_l = (1/\tau_{turb} + 1/\tau_{conv})^{-1} \quad (1)$$

where τ_l is the width of the measured autocorrelation function at $1/e$, $\tau_{conv} = l_\theta/v_\theta$ is the convection time with l_θ and v_θ as determined above. Using expression (1), the three different times are found and are plotted in Figure 6 as a function of the geometrical radius. τ_l increases only slightly in the dip although v_q is reduced by a factor of 2. This can be explained by the fact that τ_{conv} does not change too much. As the poloidal speed and length of the fluctuations are both reduced l_θ/v_θ remains unchanged. Figure 6 also shows that for this particular case, the autocorrelation time depends equally on both convection and lifetime of the turbulence because these quantities are found to be of the same order.

4 Discussion

At the limiter radial position, we observe that the fluctuations are decorrelated and reduced. This coincides with a shear of the poloidal velocity which is dominated by the $E_r \times B$ term. As the probe is not magnetically connected to the limiter, the perturbation of the radial electric field created by this limiter must extend poloidally. In fact, the limiter radial position defines two regions of closed and open field lines and a perturbation of E_r is expected at the frontier. Some instabilities can be created by the limiter and have been observed in Tore Supra [2] but they propagate along the magnetic field lines and cannot be seen by the probe because of the lack of reasonably short magnetic connection to the limiter. The results of the data analysis are consistent with what is usually interpreted as a radial electric shear effect in other machines [3]. Finally, this observation suggests that the shear effect on turbulence is a universal phenomenon which exists for dynamical events such as ion transport barriers, L to H transitions etc. but which can also be associated to limiters and other static objects as is shown in this paper.

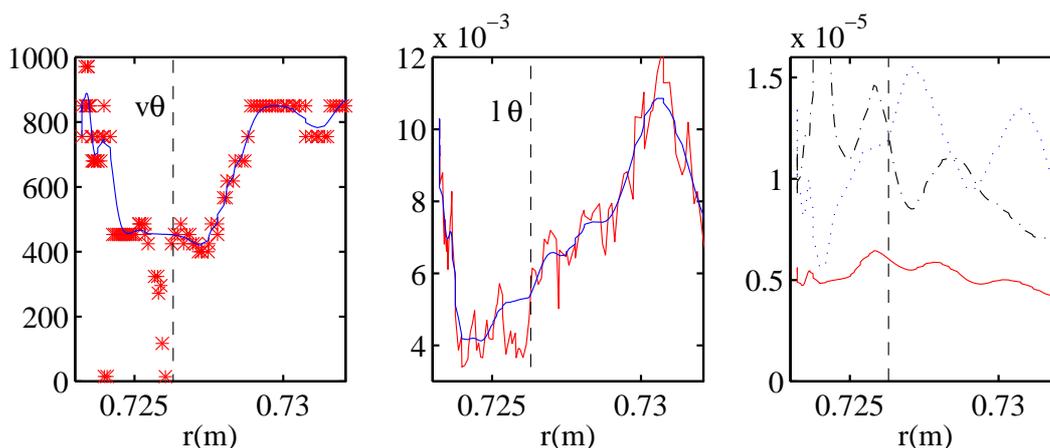


Figure 4: Poloidal Velocity profile Figure 5: Poloidal correlation length Figure 6: Autocorrelation (solid line) convection (dotted) and life time (dash-dotted).

References

- [1] X. Garbet et al, *Plasm. Phys. and Control. Fusion*, vol. 32 (12), p. 2147(1992).
- [2] C. Fenzi et al., this Conference.
- [3] Ch. P. Ritz et al, *Phys. Rev. Letters*, vol 65 (20), p. 2543 (1990).