STATISTICAL PROPERTIES OF FLUCTUATIONS IN A LINEAR PLASMA MACHINE:COMPARATIVE STUDIES WITH FUSION PLASMAS

O.F.Castellanos, J.M. Sent es, E. Anabitarte

Departamento de F sica Aplicada. Universidad de Cantabria

39005 Santander, Spain

1. Introduction

Although anomalous transport in plasmas has been the subject of many theoretical studies and experimental works, there is not yet a complete understanding of the dynamical mechanisms underlying the anomalous transport processes. Furthermore, direct experimental corroborations of theoretical results scarcely exist. In this context, comparative studies of the plasma turbulence structure in different fusion devices have been carried out [1]. These comparisons support the view that plasma turbulence displays universality [2]. Recent results emphasize the importance of comparative studies between fusion and non fusion devices[1].

In order to improve our knowledge of the anomalous transport, it is important not only the fluctuation-induced transport, but also the statistical properties of plasma fluctuations and induced particle flux [3][4].

In this paper the statistical properties of plasma fluctuations have been investigated along the whole plasma radial column of a Linear Plasma Machine (LPM). Probability distribution functions (PDFs) of electron density, floating potential and fluctuation—induced flux have been determined. PDFs of fluctuating magnitudes and its time derivatives are compared with those of Fusion Plasma devices[3].

2. Experimental Setup

Plasma fluctuations measurements have been characterized in a LPM. The plasma is performed in a cylindrical glass vessel with an internal diameter of 0.07 m and a length of 1m. The vessel is located inside a circular waveguide of 0.08 m in diameter. A longitudinally magnetized plasma is produced by launching longitudinally (LMG) electromagnetic waves (f=2.45 GHz, 600 kW < P_{LMG} < 6 kW) and the system operates in a continuous regime. The stationary longitudinal magnetic field (0.05 T < $\boldsymbol{B}_0$ < 0.15 T) is generated by six water-cooled coils, which are concentric with the waveguide. Measurements are performed for Helium and Neon plasmas. The mean electron density is determined using an 8 mm interferometer and typically ranges from 10^{15} m^{-3} to 10^{18} m^{-3}. Two radially movable array of Langmuir probes provide local value of electron density, floating potential, electron temperature and its fluctuations along the whole plasma radial column. One of them has three Langmuir probes using a double probe configuration (plasma profile measurements) or triple probe configuration (electron density and floating potential fluctuations measurements) with two cylindrical tips (2 mm long, 0.5 mm in diameter) aligned perpendicular to the magnetic field and separated poloidally Δ_θ= 2 mm. The second array has four probes positioned along the three directions, parallel, radial and poloidal with respect to the magnetic field. All measurements were undertaken for probe arrays that were moved radially on a shot to shot basis. Typical profiles for Helium plasmas are shown in Fig.1.

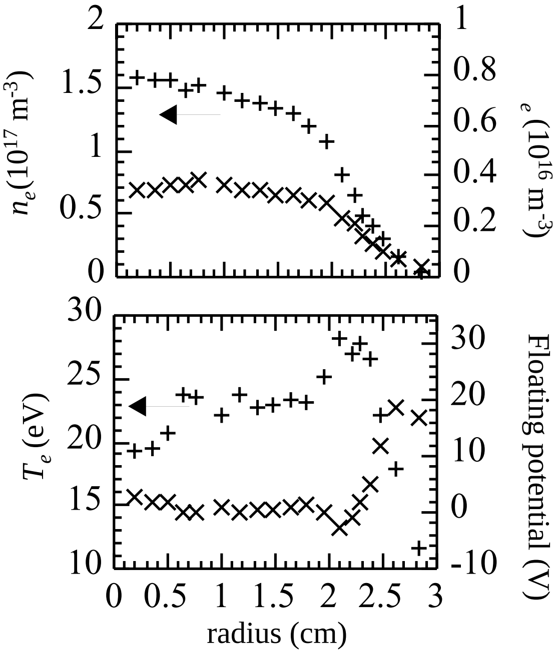

Fig.1 Typical Helium plasma profiles

3. Results

a. <u>Velocity Shear Layer</u>

The poloidal phase velocity of the fluctuations is computed from the $S(\omega,k)$ using two floating potential signals [5] as $v_\theta = \sum_{\omega,k}(\omega/k)S(\omega,k)/\sum_{\omega,k}S(\omega,k)$. Phase velocity are typically around 10^2 m/s (positive values corresponding to electron diamagnetic drift direction). The velociy shear layer position is located several ion gyroradius from the external surface of the plasma column(see fig. 2).

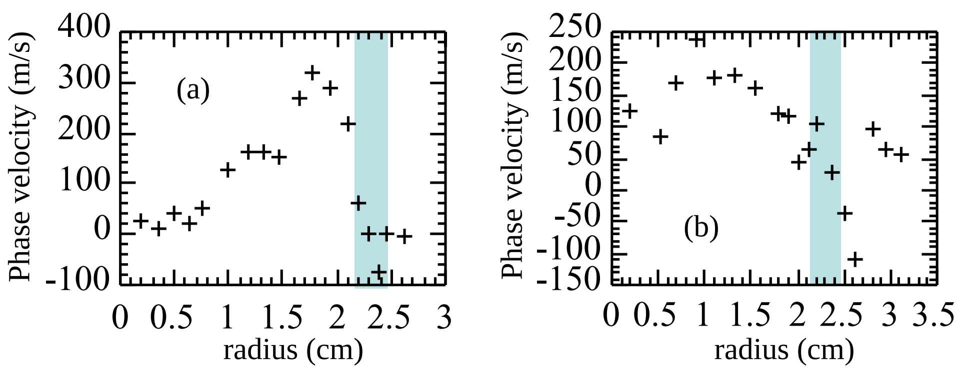

Fig.2 Radial profile of poloidal phase velocity of fluctuations (a) Helium; (b) Neon

b. Statistical properties of fluctuations

The PDFs of ion saturation current, floating potential and fluctuation induced flux are non-Gaussian. A characterization of the statistical properties of the PDF is done through the determination of skewness, the kurtosis and the asymmetry (skewness of the time derivative)[3]. Given N samples (x(i), i=1, . N) of a time series $x(t)$, the skewness (S), kurtosis(K) and asymmetry (A), may be estimated as: $S = \frac{1}{\sigma^3(x)N} \sum_{i=1}^{N} [x(i) - \mu(x)]^3$

$$K = \frac{1}{\sigma^4(x)N} \sum_{i=1}^{N} [x(i) - \mu(x)]^4 \qquad A = \frac{1}{\sigma^3(x')N} \sum_{i=1}^{N-1} [x'(i) - \mu(x)]^3$$

where μ is the mean value, σ the standard deviation and x« the time derivative.

Fluctuation-induced fluxes have a bursty character . The time evolution of the normalized turbulent radial flux is show in fig 3. As in other devices is predominantly positive (the particle transport, is on average, outward). Statistical properties of the turbulent flux are shown (see fig 4). Skewness goes S=0 (Gaussian condition) around the shear layer position. However, Kurtosis is well above the expected value for a Gaussian distribution (K=3).

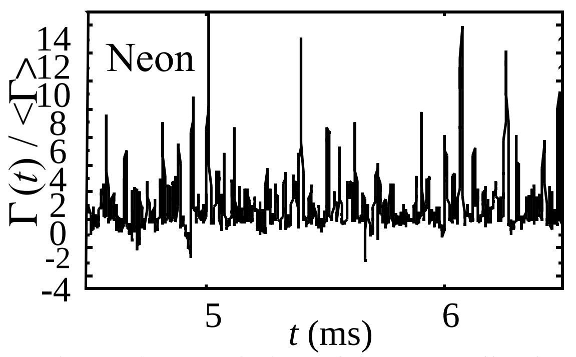

Fig. 3 Time evolution of the normalized turbulent particle flux measured for r=2 cm.

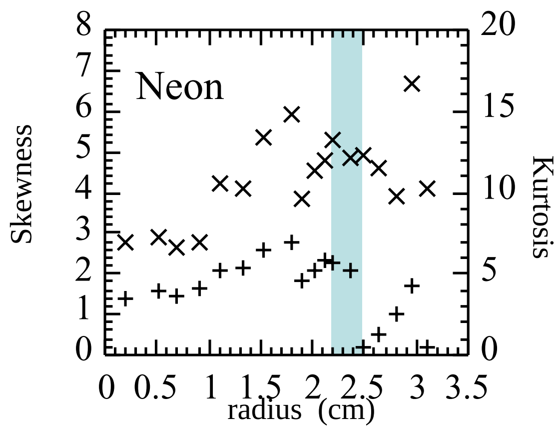

Fig. 4 Skewness(+) and Kurtosis (x) of fluctuation-induced particle flux

The skewness and the asymmetry of the ion saturation current and floating potential have been computed using the former definitions. The skewness of the floating potential deviates from a normal distribution except for the shear layer position(see fig 5). Ion saturation current has a value of S>0 along the radial column. The asymmetry for floating potential and ion saturation current is positive. This parameter shows the degree of time asymmetry in turbulent bursts[3]. For A>0 fluctuation pulses have a rise time shorter than their decay time.

A clear change can be observed around the shear layer position for all calculated parameters. Finally, no significant differences between Helium and Neon plasmas have been found.

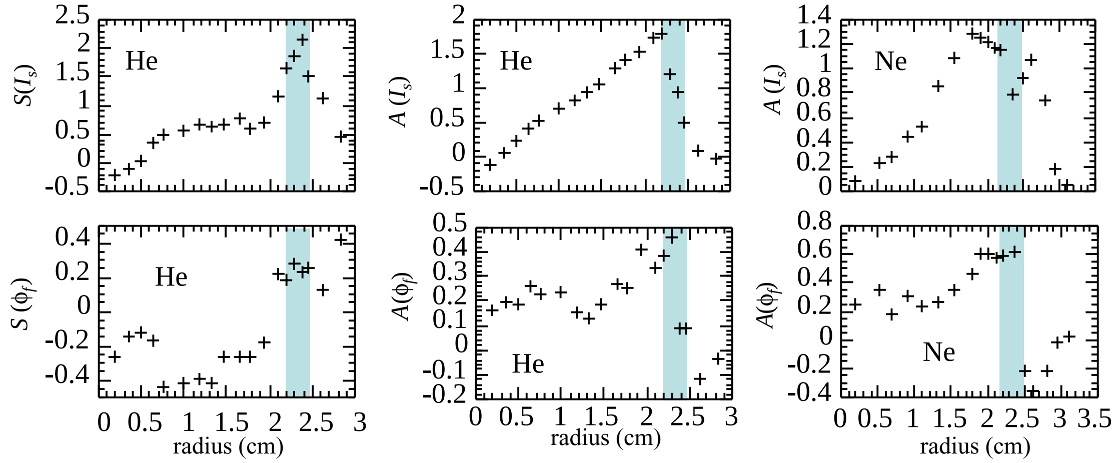

Fig.5 Skewness and Asymmetry of Ion Saturation Current and Floating Potential for Helium and Neon Plasmas

4. Summary

Fluctuations have a non-gaussian behaviour, mainly out of the velocity shear layer position. The radial depence of $S(\phi_f)$ and $A(\phi_f)$ is very similar to that measured on fusion plasmas.

Unlike it happens on fusion plasmas $S(I_s)$ and $A(I_s)$ are always positive, in particular they are not cero close to the shear layer. For positive defined signals a non-gaussian PDF is expected (if $\mu \approx \sigma$). However, changes observed around the shear layer suggest that this not the key to explain the lack of gaussianity measured in fluctuations. Fluctuations signals show a bursty character, with spikes nonsymmetric in time as is shown by the skewness of the time derivative. The striking similarity between the PDFs measured in this machine with those of fusion plasmas, could be an indication that the transition from closed to open magnetic field lines is not an important element in order to interpret the structure of turbulence. Finally, experimental results emphasize the important role that nonfusion plasma devices could play in order to clarify some aspects of plasma turbulence.

Acknowledgment: This work was supported by Direcci n General de Investigaci n of Spain under Project No. FTN200-0924-C03-03

References

[1] J.W. Connor et al. Plasma Phys. Control. Fusion 41, 693 (1999)
[2] M.A. Pedrosa et al. Phys. Rev. Lettt 82, 3621 (1999)
[3] E. S nchez et al. Phys. Plasmas 7, 1408 (2000)
[4] B.A. Carreras et al Phys. Plasmas 3, 2664 (1996)
[5] S. J. Levinton et al Nucl. Fusion 24, 527 (1984)