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Influence of *ExB* sheared velocities in the statistical properties of fluctuations in the plasma boundary of the TJ-II stellarator

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Introduction. Understanding the physics of turbulent transport remains as an open key issue in magnetic fusion research. In an effort to improve our knowledge of it, the statistical properties of fluctuations in floating potential and ion saturation current have been investigated in the last few years [1-3]. Competition processes, universality of PDFs among different fusion and non fusion plasma devices, and coupling between sheared flows and turbulence are among the most significative results in those experiments. Improved confinement regimes are reached whenever turbulent transport is reduced and a highly sheared plasma flow is observed [4]. This behaviour is interpreted as turbulence suppression occurring when the shearing rate of *ExB* velocity drift exceeds a critical value related to broadband turbulence frequency and spatial scales [5]. This work reports the investigation of the influence of *ExB* sheared velocities and magnetic topology in the statistical properties of turbulence in the plasma boundary region of the TJ-II stellarator.

Experimental set-up. Experiments were done in electron cyclotron resonance heated (ECRH) plasmas with $B_T = 1$T, $R = 1.5$m, $\langle a \rangle \leq 0.22$m and $\iota(a)/2\pi \approx 1.6$. Radial profiles of ion saturation current and floating potential were simultaneously measured in the plasma edge region using Langmuir probes. The design of the probe allow to measure radial profiles up to 3 cm inside the last closed flux surface (LCFS) in the plasma edge of the TJ-II stellarator [6]. Probe signals were digitized at a sampling rate of 500 kHz. In these experiments the overall plasma density was systematically modified (shot to shot) to match regimes with and without edge velocity shear layer [7]. Further investigation was done in experiments involving ECRH power modulation (P_{ECRH}).

Statistical properties. Characterization of the statistical properties of fluctuations was focused on skewness and time asymmetry of the signal. Given N samples $[x(i), i = 1, ..., N]$ of a time series $x(t)$, the third order moment, skewness, of the probability density function, may be estimated as

$$S = \frac{1}{N\sigma^3(x)} \sum_{i=1}^{N} [x(i) - \mu(x)]^3, \quad (1)$$

where

$$\sigma(x) = \left(\frac{1}{N}\sum_{i=1}^{N}[x(i)-\mu(x)]^2\right)^{1/2} \quad , \quad \mu(x) = \frac{1}{N}\sum_{i=1}^{N}x(i)$$

are the standard deviation and the mean value estimates respectively. In order to quantify the degree of time asymmetry of turbulent events, the skewness of the time derivative of the signal is calculated as

$$A = \frac{1}{N\sigma^3(\dot{x})}\sum_{i=1}^{N-1}[\dot{x}(i)-\mu(\dot{x})]^3 \qquad (2)$$

where $\dot{x} = dx/dt$ is the time derivative of the signal, being $\dot{x}(i) = [x(i+1)-x(i)]/\Delta t$, and Δt the sampling period. Positive values of A indicate that the signal has, on average, fluctuations with a rise time shorter than its decay time. The opposite happens for values of $A < 0$.

Influence of $E \times B$ sheared flows and magnetic topology. In the plasma edge of the TJ-II stellarator, radial profiles of temperature (T_e) are smooth and ion saturation current ($I_S \propto nT_e^{1/2}$) could be taken as a measure of the local plasma density (n). For the same reason and considering that the plasma potential is related to floating potential by $\phi_p \approx \phi_f + 3T_e$, gradients give an estimation of radial electric fields ($E = -\nabla\phi_p$) and $E \times B$ drift velocities.

Figure 1 shows the radial profile of the mean plasma ion saturation current and the mean plasma floating potential. As the plasma density increases in the plasma edge ($r/a < 1$), the floating potential decreases and its gradients get higher, generating radial electric fields up to -20 V/cm. In the scrape-off layer (SOL) of the plasma, where magnetic field lines are opened, the floating potential is positive as well as radial electric fields.

The skewness (S) of density and floating potential fluctuations is represented in figure 2. In agreement with previous findings [1], ion saturation current fluctuations are non Gaussian, with an extra feature: there is a common region where the skewness show a well. The sign of ϕ_f skewness is strongly affected by the presence of $E \times B$ sheared flows. In particular, the skewness is positive for plasma densities below a threshold, and becomes negative for values above it.

In low density regimes (where no sheared flows are developed), time asymmetry (see figure 3) of ion saturation current and floating potential fluctuations decreases from the SOL ($r/a \approx 1.2$) to the plasma edge region ($r/a \approx 0.9$). Once sheared flows are generated, I_S pulses are symmetric in the plasma edge, but remains clearly asymmetric in the SOL.

Influence of heating power. The degree of symmetry of pulses was also investigated in experiments with P_{ECRH} modulation, where the initial plasma density was set near the critical value to trigger the onset of sheared flows. Figure 4 shows the time asymmetry of ion saturation current fluctuations. P_{ECRH} heating pulses modify the radial structure of asymmetry making it bigger near the LCFS.

Conclusions. Present findings show the importance that sheared flows, magnetic topology and heating power have in the modification of the statistical properties of both, ion saturation current and floating potential fluctuations, calling into question previous analysis which emphasized the leading role of $E \times B$ sheared flows to explain the symmetry of pulsesc̃itestacha. Experiments are in progress in order to study turbulent transport under the influence of magnetic topology, sheared flows (naturally occurring and biasing induced) and heating power.

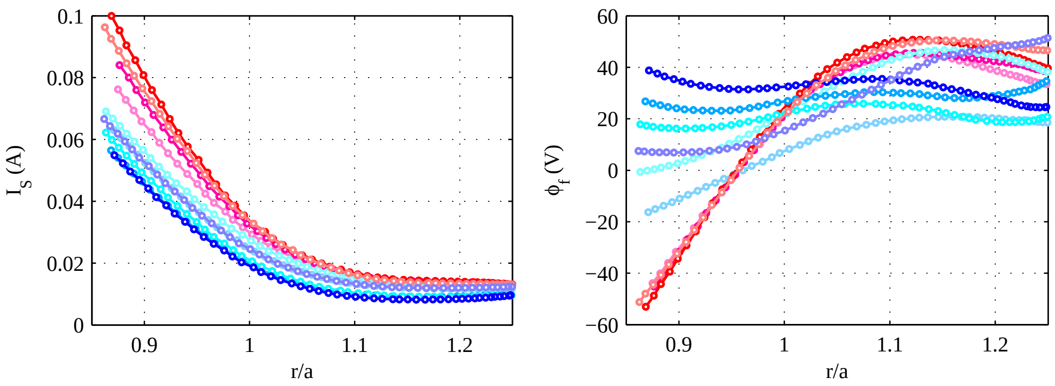

Figure 1: *Radial profiles of mean ion saturation current (I_S) and floating potential (ϕ_f).*

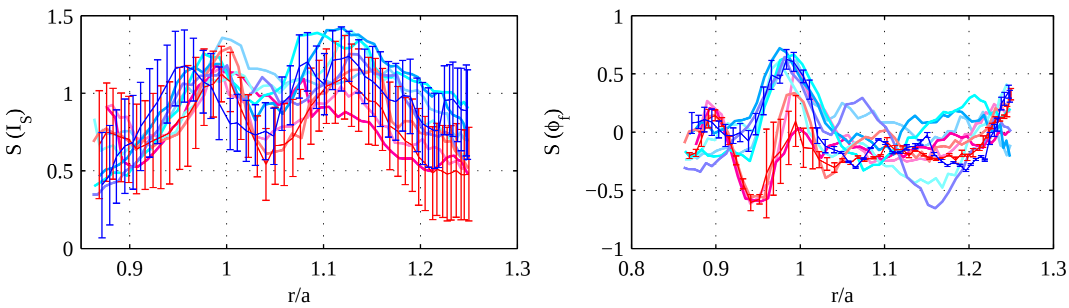

Figure 2: *Radial profiles of skewness (S) for ion saturation current (I_S) and floating potential (ϕ_f) fluctuations.*

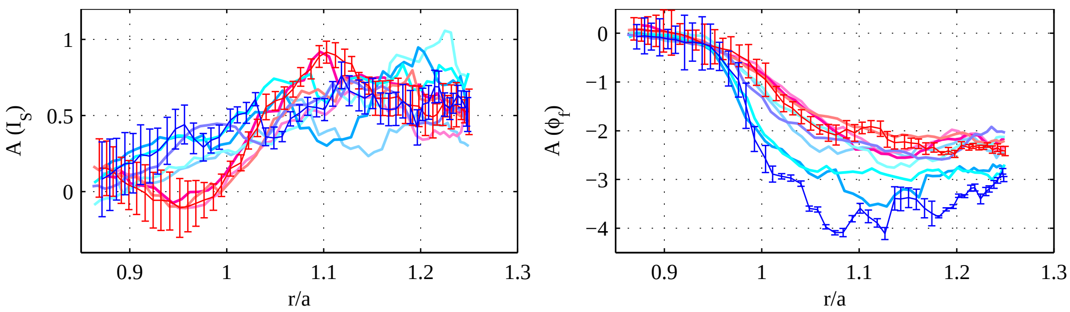

Figure 3: *Radial profiles of time asymmetry (A) for ion saturation current (I_S) and floating potential (ϕ_f) fluctuations.*

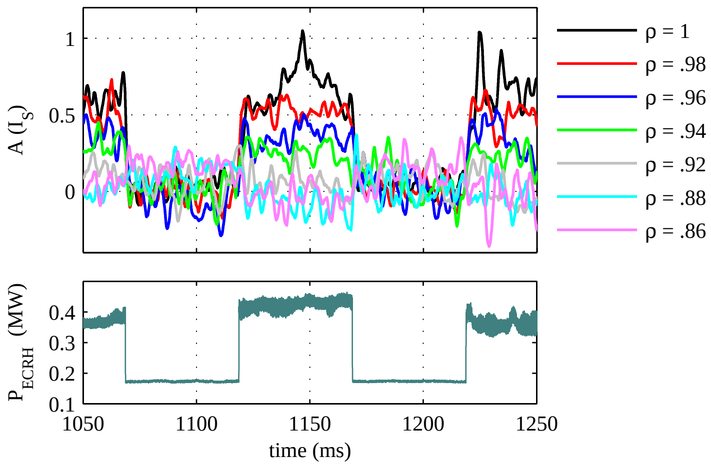

Figure 4: *Power heating (P_{ECRH}) modulation and its influence on time asymmetry (A) for ion saturation current (I_S) fluctuations at different positions ($\rho = r/a$) in the plasma boundary region.*

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