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PLASMA TURBULENCE ANALYSIS IN TEXAS HELIMAK

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Abstract: We analyze alterations on the electrostatic turbulence in experiments with imposed bias to control the plasma radial electric field in Texas Helimak (K. W. Gentle and H. He, Plasma Sci. and Technology **10**, 284 (2008)), a toroidal plasma device with a one-dimensional equilibrium, magnetic curvature, and shear.

keywords: Fluidodynamics, Plasma and Turbulence; Nonlinear Dynamics in Thermal and Fluid Sciences; Time Series Analysis.

Electrostatic turbulence has been investigated in plasmas with flow and magnetic shear in helimaks [1-3]. These basic plasma toroidal devices have a sheared cylindrical slab that simplifies the turbulence description. The plasma in helimaks has similar characteristics to those observed in the plasma edge and the scrape-off layer in major fusion machines [4, 5].

In Texas Helimak, turbulence biasing control has been investigated and, in the biased region, states of greatly reduced turbulence have been achieved [1, 2]. As the plasma is cold and its density is low, it is possible to use a large set of diagnostic probes. These characteristics make the Texas Helimak an interesting device to investigate the plasma flow shear influence on wave turbulence, density structures propagation and fluctuation driven particle transport.

Moreover, it was found evidences that induced transport turbulence in Texas helimak is much affected by wave particle resonances and, eventually, by a shearless transport barrier [6]. Overall, for positive biasing, turbulence shows enhanced broadband spectra and non Gaussian PDF with extreme events [7]. In other words, plasma turbulence in the density fluctuations consists of two components: a broadband background fluctuation and a sequence of large intermittent bursts.

In this article we analyze fluctuation changes due to alterations on the radial electric field profile, in a plasma region of Texas Helimak with roughly uniform equilibrium gradients, compelled by external positive voltage bias applied to a set of border plates [8].

In Texas Helimak the field lines are helices as shown in Figure 1, spiraling from bottom to top. The indicated plates at the top and on the bottom are used to apply external electric potentials (bias) to changes the radial electric field profile. In the analyzed experiments, the dominant toroidal field is about 0.1 T and the weaker vertical field creates magnetic field lines with 40m of connection length at the middle of the machine. The vessel has a rectangular cross section of external and internal radius of 1.6 m and 0.6 m, respectively, and a height of 2m.

The probability distribution function (PDF) of the saturation current signal is shown in Figure 2, for a discharge with 14V of bias values and fluctuations measured by a probe positioned at R = 1.17m and z = 0.253. At this figure a dashed red line with a Gaussian PDF is included to facilitate the observation of the PDF. Observing the PDF we note a long tailed related with the presence of the extreme events on Texas Helimak plasma.

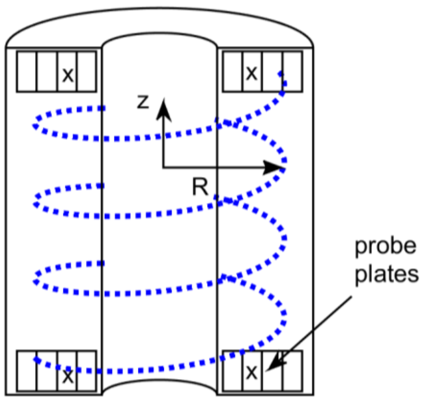

Figure 1 – Texas Helimak representation. The doted blue line represents one of the helical magnetic lines. The "x" marks the bias plates, used to impose the external electric potential to the plasma.

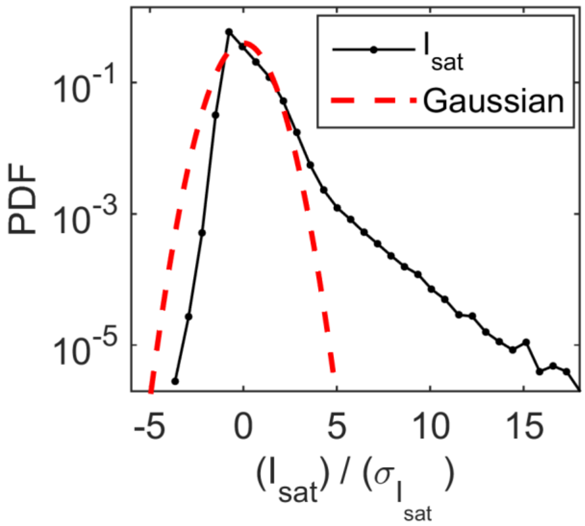

Figure 2 – Probability distribution function (PDF) of the saturation current signal for a discharge with bias = 14V measured by a probe at R = 1.17m and z = 0.253. The dashed red line is a Gaussian PDF.

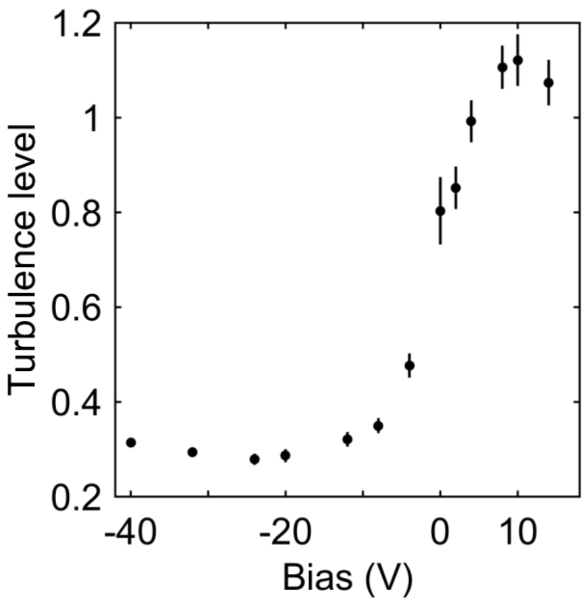

Figure 3 – Turbulence level of the saturation current for several imposed bias values measured by a probe at R = 1.17m and z = 0.253m.

The turbulence level of the ion saturation current, measured by a probe at R = 1.17m and z = 0.253m, changes with the imposed bias values, as shown in Figure 3. Here the turbulence level is calculated dividing the standard deviation, in a chosen period, by its mean value. It is clear the effect of the bias in the turbulence, reducing it for negative values and increasing it for positive values. This increase of the turbulence level is related with the increase of the extreme events occurrence [6].

The turbulence spectrum width measured at R = 1.17m and z = 0.253 m depends on the imposed bias values, as shown in Figure 4. The spectrum width is estimated considering the number of channels that needs to be summed in order to reach half of the total spectral power [7].

We observe the effect of the positive bias, increasing the spectrum width as the positive bias value increase.

Figure 5 shows the radial profiles of velocity shear (blue dashed) and turbulence induced radial particle transport (solid red) for a discharge with bias = +15V. Comparing these two radial profiles, we note a radial region where the velocity shear and the transport are close to zero, an evidence of the presence of a shearless barrier [6].

Figure 6 shows the radial profiles of the flow and phase velocities difference (blue dashed) and turbulence induced radial particle transport (solid red) for a discharge with bias = -8V. Analyzing these two profiles we note that the transport is high for small radial positions, where the difference between flow and phase velocities is small. This is an indication that the transport is strongly affected by a wave particle resonant interaction [6].

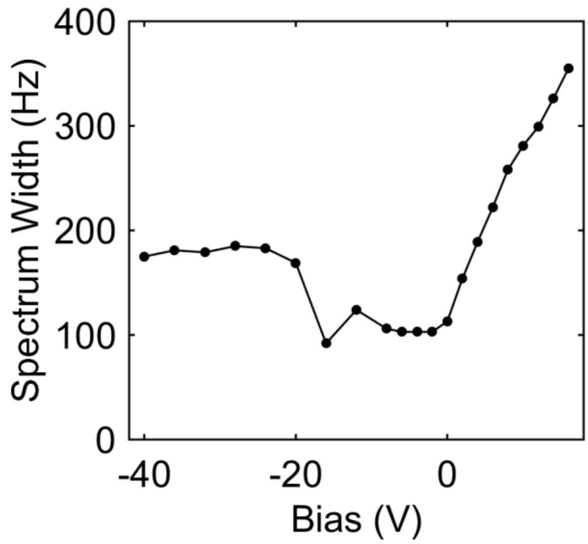

Figure 4 – Turbulence spectrum width measured at R = 1.17m and z = 0.253 m for several imposed bias values.

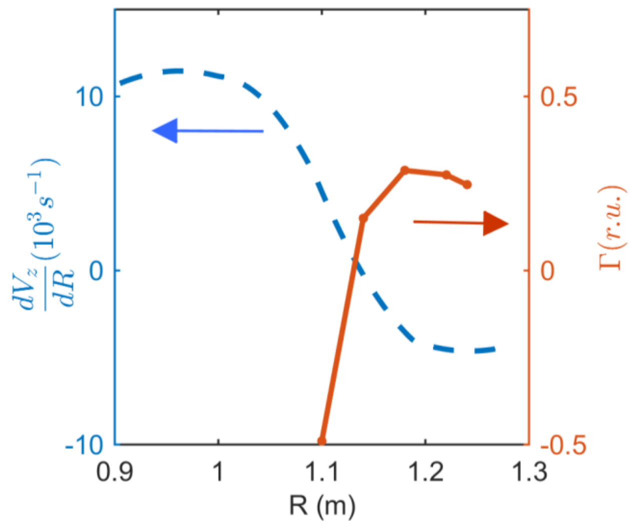

Figure 5 – Radial profiles of velocity shear (blue dashed) and turbulence induced radial particle transport (solid red) for a discharge with bias = +15V.

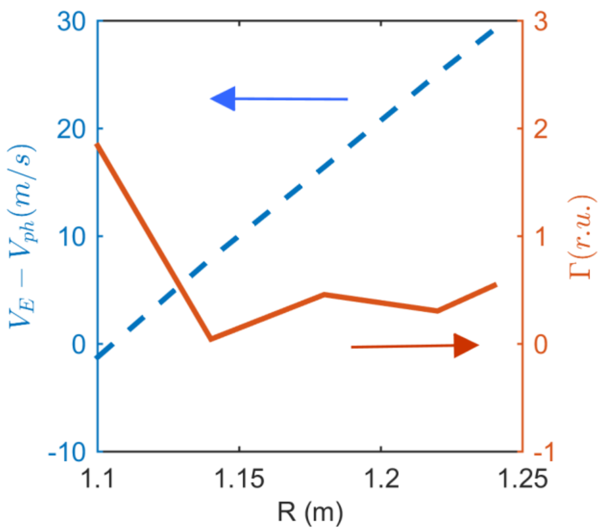

Figure 6 – Radial profiles of the difference between flow and phase velocities (blue dashed) and turbulence induced radial particle transport (solid red) for a discharge with bias = -8V.

In conclusion, when the bias is positive, the turbulence shows enhanced and broadband spectra with non Gaussian PDFs having noticeable long tails (extreme events). On the other hand, negative bias reduces the turbulence level and decreases the spectrum widths. Moreover, for a negative bias, the transport is high where the waves propagate with phase velocities near the plasma flow velocity, an indication that the transport is strongly affected by a wave particle resonant interaction. On the other hand, for positive bias values, we find evidences of shearless transport barrier.

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