Analysis of Electrostatic Turbulence Drive in Texas Helimak

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Abstract: Plasma turbulence and particle transport in Texas Helimak change with the radial electric field profile modified by an external voltage bias [1]. When the bias is positive, the turbulence shows enhanced level and broadband spectra with extreme events, similar to the turbulence in tokamak scrape-off layer. However, negative bias reduces the turbulence level and decreases the spectrum widths [2]. Moreover, for negative biased shots, the particle transport is strongly affected by a wave particle resonant interaction. On the other hand, for positive bias values, the plasma presents a transport barrier in the reversed shear flow region.

Texas Helimak is a basic plasma experiment located at the University of Texas at Austin, which has a toroidal symmetry. A combination between the toroidal and a small vertical field creates helical magnetic field lines with curvature and shear (Fig. 1). This configuration is an approach to a sheared cylindrical slab since the field line connection lengths are long and the end effects can be neglected. Texas Helimak has a vacuum vessel with a rectangular cross section, major radius R_{major} = 1.6 m, minor radius R_{minor} = 0.6 m, and height = 2 m. On these experiments, performed with Argon gas at 10^{-5} Torr, the gas is heated by ECRH (Electron Cyclotron Resonance Heating) with 6kW of power inserted through a window located on the inner side of the vacuum vessel. The diagnostic system counts with more than 700 Langmuir probes. For bias alteration, four sets of bias plates are used.

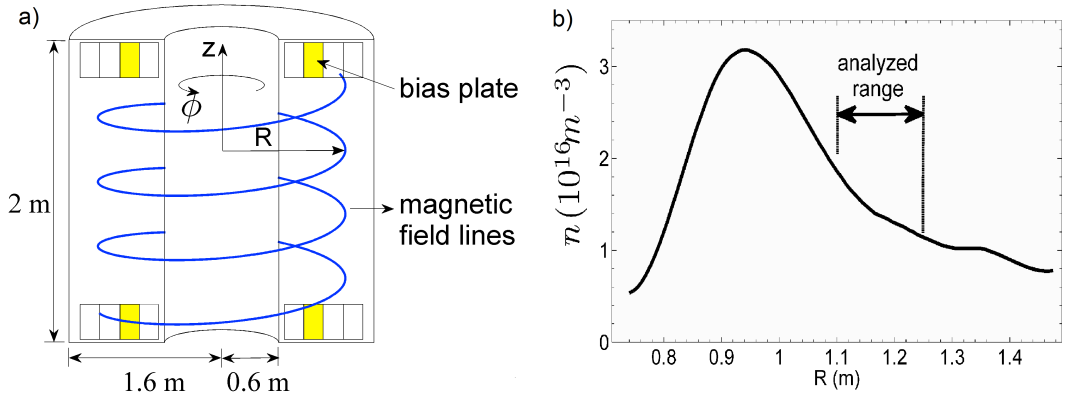

Fig. 1. Magnetic field lines in Texas Helimak (a). Radial profile of plasma electronic density in unbiased shots (b).

The analysis of the saturation current turbulence changes, induced by the bias, is presented here. Thus, the radial profiles of spectrum width (Δf) are calculated for several bias values (Fig. 2). The external bias induces different behavior at the plasma turbulence, enlarging the broad band for positive bias and creating frequency localized modes for negative bias [3]. Because of these different effects, turbulence will be separately analyzed for positive and negative perturbing bias.

For positive bias, extreme events (bursts) in the electrostatic fluctuations are often observed (Fig. 3). The relationship between the skewness and kurtosis follows the typical parabolic dependence $K=K_0+S^2$ observed in plasma edge turbulence in tokamaks.

For negative bias, the radial profiles of frequency spectrum width and summed bicoherence follow similar trends. This result suggests that the broadband enhancement observed in the negative bias experiments can be related to the enhancement of the nonlinear wave coupling (Fig. 4). This hypothesis is consistent with the changes on the growth rate of sidebands generated from wave-flow coupling computed by using a four-wave coupling model.

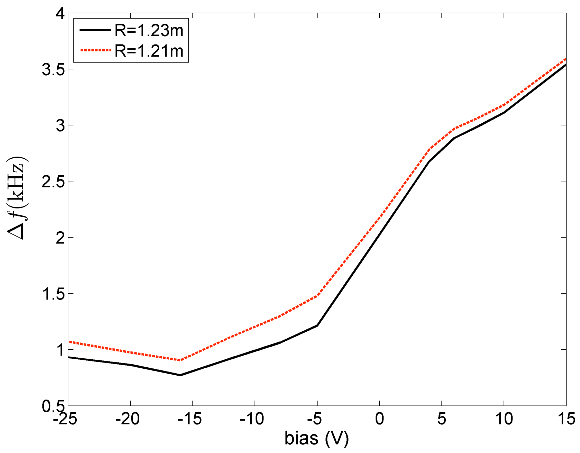

Fig. 2. Saturation current spectrum width (Δf) as a function of external bias values for two radial positions

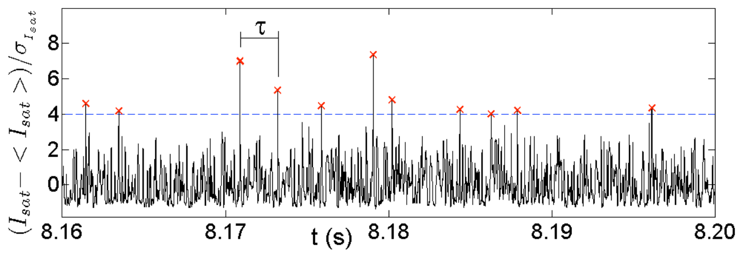

Fig. 3. Time series of plasma fluctuations showing extreme events.

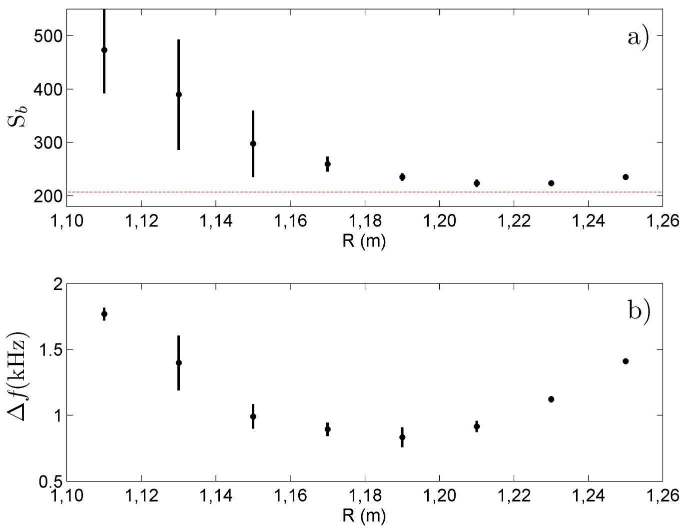

Fig. 4. Radial profiles of the summed bicoherence (a); and spectral width (b) for -12V of bias values.

The radial profile of the turbulence induced particle transport was measured for several external bias values [3].

The chaotic particle transport depends on the profile of radial electric field. A relevant parameter is the trapping profile, U (x), proportional to the difference between the phase velocity and the electrical drift velocity [4, 5]:

$$U \sim \frac{d\phi_0(x)}{dx} - V_{ph}B_0 \sim V_E - V_{ph}$$

When the parameter U is close to 0 the wave is resonant and the chaotic transport of particles is high.

For discharges with a positive bias, the particle transport is small where the velocity shear is null (Fig. 5). This is an indication of a shearless barrier. The chaotic transport is reduced in the shearless region, where the trapping profile (U) is non monotonic.

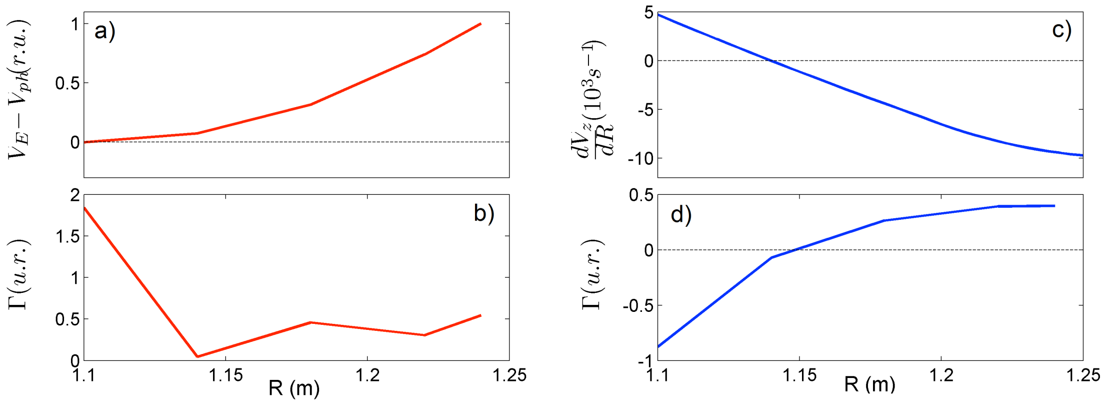

Fig. 5. Radial profiles of the difference between ExB drift velocity and phase velocity (a) and turbulence induced particle transport (b) for -8V external biasing. This velocity difference is proportional to the trapping profile (U). Radial profiles of vertical velocity shear (c) and of turbulence induced particle transport (d) for +10V of external bias.

Thus, we conclude that the properties of the plasma turbulence in Texas Helimak are very different when considering positive and negative biasing experiments. For negative bias, the turbulence properties are well described by wave-flow coupling and the turbulence driven particle transport is maximum where trapping profiles (U) is null, as described by the chaotic transport theory. For positive bias, the turbulence exhibits a broadband spectra with extreme events with statistical properties similar to the tokamak plasma edge turbulence, and the transport is low where the velocity shear is zero, an evidence of a shearless transport barrier.

References:

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