Plasma instability analysis and control in Texas Helimak

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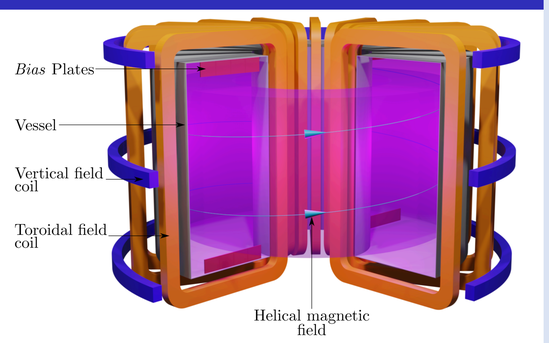
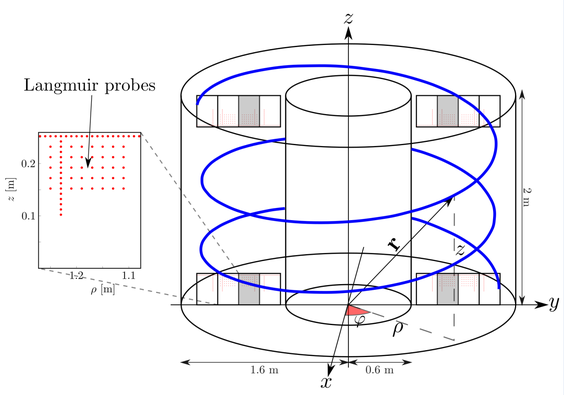
Introduction

Texas Helimak is a toroidal magnetic confinement device in a configuration known as Simple Magnetic Tori (SMT). Its simple geometry and wide radial region provide plasma density and temperature conditions analogous to the edge and *Scrap-Off Layer* (SOL) of tokamak devices [1].

We implement tools for analyzing and interpreting data obtained through a set of Langmuir probes along the radial coordinate in experiments conducted in an argon plasma under different bias conditions to evaluate the effect of bias imposition on turbulence characteristics in the Helimak.





Methods

- **Spectral analysis**: used to represent the experimental time series of ion saturation current in the frequency domain and to function as a band-pass filter.
- **Transfer Entropy**: nonlinear analysis technique, related to the mutual information, which has proven useful for determining causal relations between plasma variables and the study of heat transport [2], can be written as

$$T_{X\to Y} = \sum p(y_{i+1}, y_{i-k}, x_{i-k}) \log_2 \frac{p(y_{i+1}|y_{i-k}, x_{i-k})}{p(y_{i+1}|y_{i-k})}$$
$$T_{net} = T_{X\to Y} - T_{Y\to X}$$

- **Conditional Analysis**: used to investigate the burst spatial properties along the radial direction in the Texas Helimak [3].

Outcome

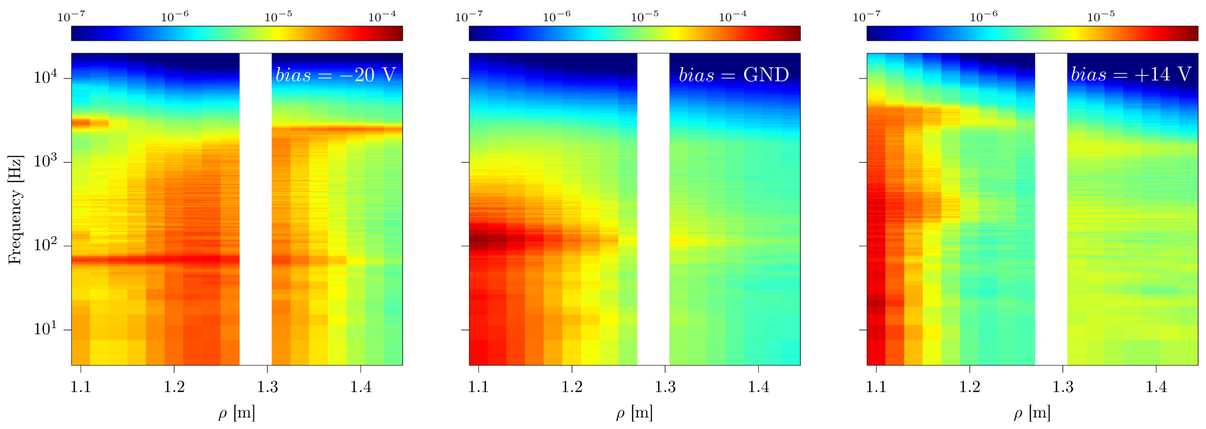


Figure 1: Power spectrum of the time series for ion saturation current as a function of radial position in the Helimak, for discharges with bias settings of –20 V, ground (GND), and +14 V.

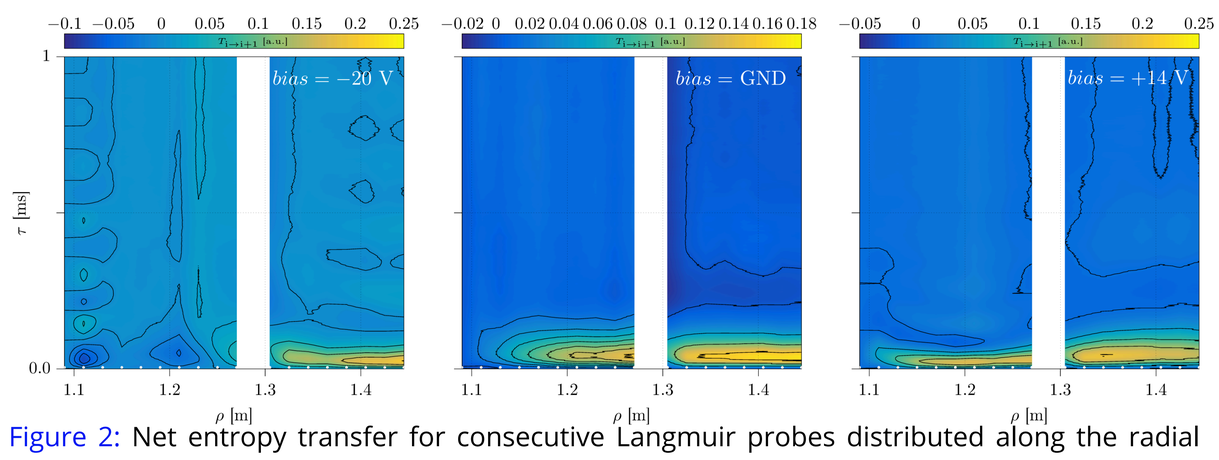


Figure 2: Net entropy transfer for consecutive Langmuir probes distributed along the radial direction in the Helimak, determined after applying a band-pass filter to retain signal components above 0.5 kHz, for discharges with bias settings of –20 V, ground, and +14 V.

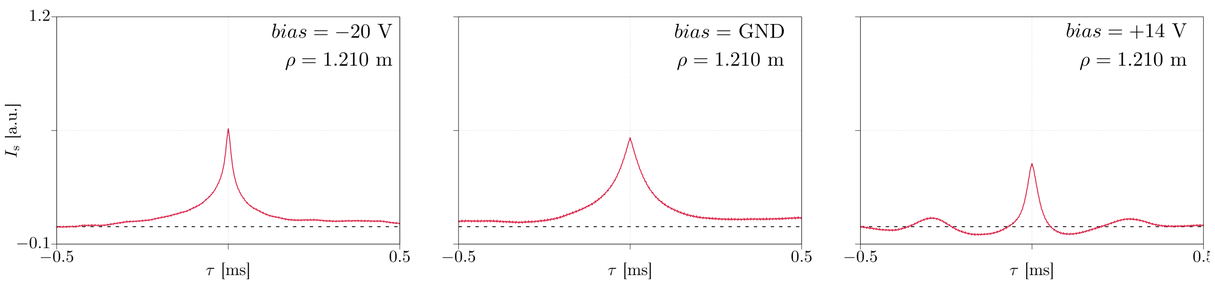


Figure 3: Conditional mean of bursts for the Langmuir probe L3-14 located at the radial position of 1.210 m, for discharges with bias settings of –20 V, ground, and +14 V.

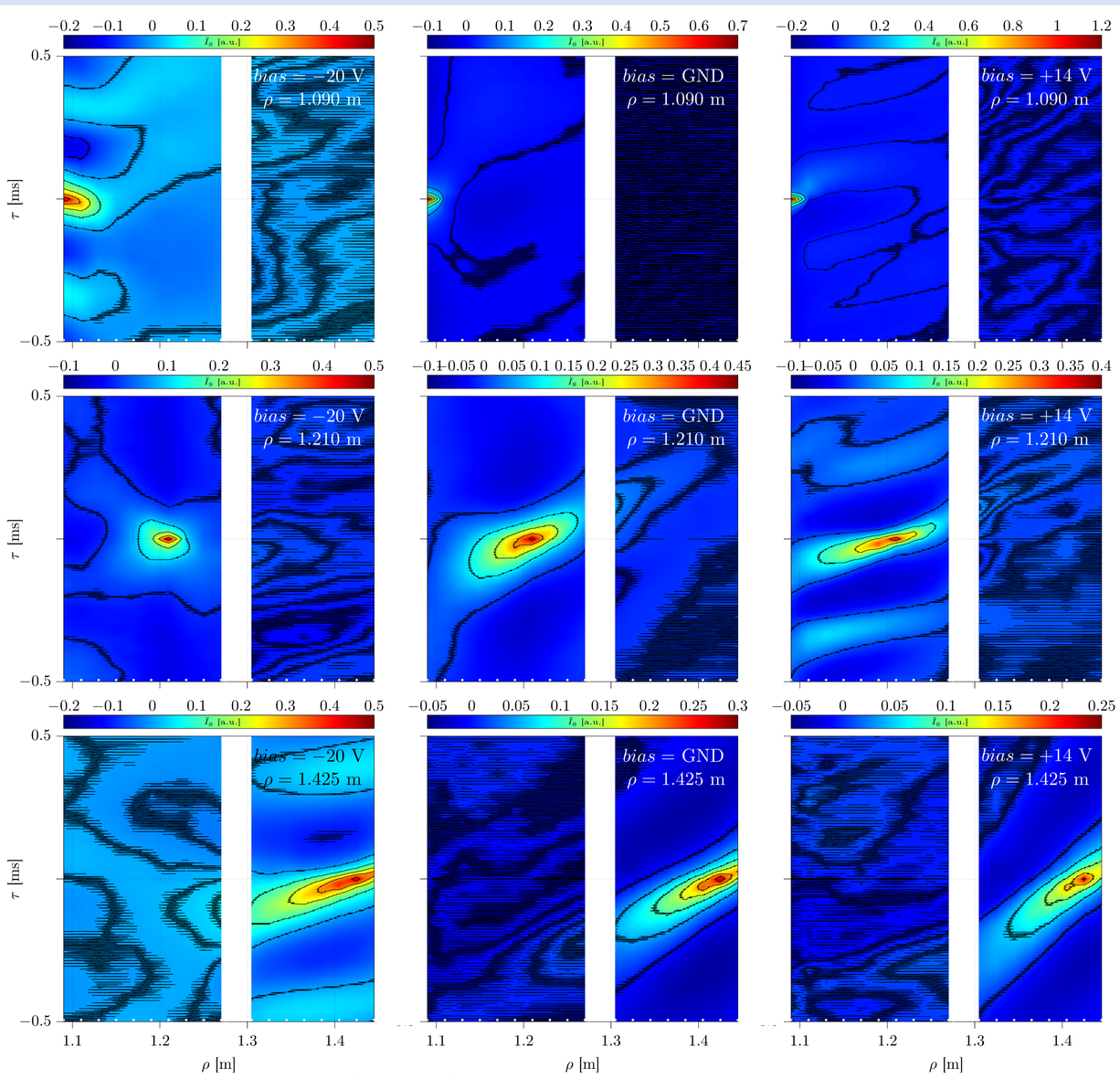


Figure 4: Conditional mean of bursts for the Langmuir probes L3-02, L3-14, and L4-15 at radial positions 1.090 m (upper region), 1.210 m (middle), and 1.425 m (lower region), with bias values of –20 V (left region), GND (center), and +14 V (right region). The radial drop from the peaks indicates the typical size of the structures in the radial direction (horizontal axis), while the temporal drop (vertical axis) is consistent with the turbulence decorrelation time. The inclination of the elliptical contours could be due to the radial propagation of the structures.

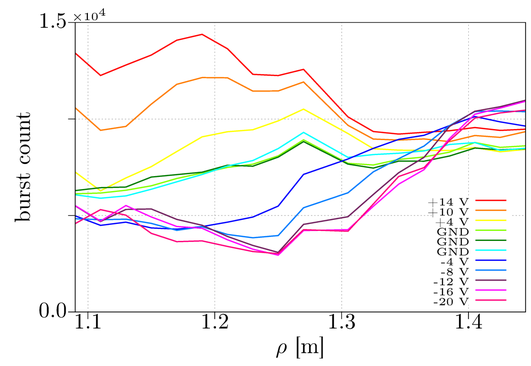


Figure 5: Number of bursts identified along the radial direction as a function of the applied bias voltage. This graph shows the number of extreme events identified for the previously mentioned discharges, as well as the results for two discharges with zero bias (GND) and six discharges with bias values between –16 V and 10 V.

Conclusion

- The presence of resonances around 3 kHz (Fig. 1) across certain radial regions for the observed discharges determines the appearance of an apparent oscillation in the conditional mean of the bursts (Figs. 3 and 4).
- The analysis of radial Transfer Entropy between consecutive probes provides valuable information about the transport due to extreme events and their mobility.
- The application of external bias is presented as a consistent mechanism for controlling turbulence and the occurrence of extreme events in the Texas Helimak.

Acknowledgments

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