Impact of different confinement regimes on the two dimensional structure of edge turbulence

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Outline

Introduction
   Fast visible camera diagnostic
   TJ-II stellarator

Continuous Wavelet Transformation (CWT) Analysis
   Blob geometry
   Detection / Recognition scheme

Observations and Results
   Effect of sheared flow upon the turbulent structures
   Time scales for sheared flow development
   Radial transport and Poloidal asymmetries

Conclusions
Fast visible camera diagnostics

Fast visible commercial cameras

- Industrial use, crash testing...
- Typical parameters: resolution $80 \times 80$ @ 100 kfps ($10\mu$s)

Used for plasma imaging


- Gas Puffing Injection to increase $H_\alpha$ signal
- $H_\alpha$ signal dependence

$$ S \propto n_0 n_e^\alpha T_e^\beta $$
Fast cameras in TJ-II

TJ-II stellarator
- 4-periods Flexible Heliac
- 400kW ECRH + 400kW NBI

Fast edge plasma imaging
- Neutral recycling at one poloidal limiter used for plasma edge lightening
A sheared poloidal flow is formed in the edge above a density threshold $n_e \approx 0.6 \times 10^{19} \text{ m}^{-3}$ [M A Pedrosa PPCF 2005]
Blob geometric parameters

Blobs are ellipse-like spatially coherent structures.

- **Scale**: structure’s size
- **Orientation angle**: angle between principal axis and x axis
- **Aspect ratio**: ratio of the scale in the principal axis dir. and the dir. perpendicular to this
1 Detection

Original background-subtracted image

Mexican Hat wavelet
\[ k = 1.0 \pm 0.3 \text{ cm}^{-1} \]

Wavelet-convolved image

Threshold and maxima scan
2 Recognition

Original background−subtracted image

Morlet 2D Wavelet

$\text{k} = 1.0 \pm 0.3 \text{ cm}^{-1}$

Angular Response Curve

Angle = 15°

AR = 2.3
Frame series statistics

- Percentage of elongated blobs (measure of stretch)
- Standard deviation of angular distribution (measure of ordering)
Effect of natural shear layer in TJ-II on blob geometry

Ordering + Stretching

![Graph showing ordering and stretching effects with data points and histograms.](image-url)
Comparison with NSTX L and H modes

Results of NSTX blob statistics in L and H regimes are in agreement with TJ-II observations during spontaneous shear flow (close to marginal stability) development.
There are some evidence that the turbulence reduction during external biasing might be scale-selective.
Flow reversal can be seen to happen in few tens of $\mu$s ($\sim 50\mu$s) – few turbulence autocorrelation times.
Radially propagating blobs in the SOL (*with intensified camera*)

$v_r$ up to 1000 m/s  
(In the tail of $v_r = \frac{\langle \Gamma_{E\times B} \rangle}{\langle n \rangle}$ PDFs)

Importance of the dependence $v_r(k)$. Bigger blobs propagate faster/slower?  
O E Garcia *et al*, *Phys. Plasmas* 2005]
Inhomogeneous blob distribution in the SOL

Spatial distribution of detected structures in the SOL is poloidally inhomogeneous.
Conclusions

- Fast camera measurements have been found to be in good agreement with HIBP and Langmuir probes in TJ-II.
- The spontaneous shear flow in TJ-II seems to stretch and order the structures. Similar behavior is found in NSTX when going from L to H regimes.
- During NSTX H-mode and Biasing-induced Improved Confinement Regime in TJ-II, structures where seen to decrease in number.
- Large coherent structures are seen in the SOL of TJ-II. Their spatial distribution seems to be poloidally inhomogeneous.
- Fast visible camera is a valuable plasma diagnostic from which qualitative and quantitative information can be extracted.