Motivation

- Coherent filamentary structures dominate turbulent cross-field particle transport in tokamaks [1]
- These intermittent structures' properties govern scrape off layer (SOL) density profile shape [2]
- Unfiltered fast visible cameras (~100 kHz) can passively collect large quantities of filament data
- A better understanding of filaments’ dependence on plasma properties can help minimise wall erosion and maximise machine lifetime

Technique

- Unfiltered fast camera collects mostly \( D_w \) light
  - Intensity, \( I \), function of neutral & electron density, \( n_0 \) & \( n_e \), and electron temperature, \( T_e \)
  - \( I = n_{df} (n_0, T_e) \)

1. Images are processed to enhance filaments:
   - Background subtraction, noise reduction, sharpening
2. Project field lines onto images:
   - Trace field line (FL) grid with Eeff+ equilibrium
   - Project FLs onto camera view
   - Extract pixel intensities along FLs
3. Intensity pseudo-inversion (PI) into \( R - \phi R \) space:
   - FLs parameterised by \( (R, \phi R) \) coordinate of intersection with midplane \( Z = 0 \)
   - Representative intensity along FLs, given by
     - (geometric mean)
4. Identify filaments:
   - Ellipses fitted to 2D intensity peaks to extract position and widths

Benchmarking

- A synthetic diagnostic enables analysis of camera frames with known filament properties
- Enables algorithmic benchmarking and error quantification
  - Detect 80% of input filaments
  - 30% false positive rate
- See more in T. Farley et al., RSI (2018)

Analytic Framework

- Describes SOL density profile shapes and statistics given input filament properties
- Assumes constant generation of independent filaments
- Inputs:
  - Distribution of initial amplitudes, \( P_{\mu 0} \)
  - Distribution of perp. widths, \( P_w \)
  - Average waiting time, \( \tau_w \)
  - Radial shape, \( A(r - r_{sep}) \)
  - Parallel drainage rate, \( F(t) \)
  - Radial velocity variation, \( V(\phi)(t) \)

Pseudo-Langmuir probe analysis

- Taking radial slices through the PI gives time varying radial emission profiles
- Time averaged radial shows exponential fall off with characteristic flattening in the far SOL

Filament statistics

- Filament statistics are calculated to inform inputs to the analytic framework
- Variance of fluctuations
  - Variance increases outside the Separatrix as commonly observed
- Toroidal filament separation
  - Exponential distribution indicates toroidal positions are independent
  - No effective quasi-mode number
- Waiting times
  - Exponential distribution indicative of Poisson process
  - Support assumptions in analytic framework
  - See Fulvio Militello’s invited talk (Friday 11.00, Room: 102ABC)

Future work

- Analysis of SOL density profile flattening and broadening study
- Use analytic framework to interpret phenomena given measured filament statistics
- Generate large filament database to explore dependence of filament properties on machine and physics parameters

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For further information on data and models please contact publicationsmanager@ccfe.ac.uk

References