Plasma blobs in a basic toroidal experiment: Origin, dynamics and induced transport

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Motivation

- Blobs: “Intermittently encountered, isolated propagating structures of increased plasma density”
  - Large bursty events dominate SOL particle transport
  - Localized wall loads may become critical for ITER

- Idea: setup relevant test scenarios in basic experiments
  - Configuration in TORPEX with core-SOL-like transition
  - Exploit better diagnostics

NSTX gas-puff imaging (Courtesy R. Maqueda)

TCV Langmuir probe (Courtesy J. Horacek)

Fluid simulations (ESEL; V. Naulin): Quantitative agreement with LP measurements
TORPEX – Core-SOL-like configuration

- $R = 1\,\text{m}$
- rf waves
- $B \sim 0.1\,\text{T}$
- $n \sim 10^{17}\,\text{m}^{-3}$
- $T_e \sim 5-8\,\text{eV}$
- $\rho_s \sim 1-15\,\text{mm}$

Magnetic-field topology different from tokamak

Core-like region (slab-like)

Transition region

SOL-like region (source free)
A Drift-Interchange (D-I) wave propagates vertically upward along outboard profile slope

40% of spectral power @ ~15 kHz

\[ k_\parallel \sim 0 \]

\[ \nabla B \]

Diagnostic: 2D Langmuir probe array
- 86 tips (here: \( I_{\text{sat}} \))
- 4 \( \mu \text{s} \) resolution
Blob ejection from wave crests of D-I wave

Wave crests of D-I wave radially unstable and elongate

Resolution: 12 μs

Outer part lags behind and gets “sheared off”

A blob completely detaches and continues to propagate radially outward
Quantitative analysis of blob dynamics

  - Pos./neg. structures from threshold segmentation ($\delta n > \delta n_{th}$ / $\delta n < -\delta n_{th}$)
  - Trajectories from tracking criterion
Statistical analysis of trajectory database

- Spatial abundance of trajectories / average motion patterns
  - Blobs in many aspects similar to tokamak observations

**positive structures**

**negative structures**

Radial propagation
\[ v_{r,\text{blobs}} = 1-2 \text{ km/s} \]

Vertical propagation
(positive and negative wave crests)

Skewness gradient
from core to SOL

Wave region:
double-humped PDFs

SOL region:
“Universal-type” PDFs
Blob-induced transport

- Instantaneous fluxes during events from ensemble average (arrows)
- Time-average transport by counting “transport events” through test surfaces

Size of inst. fluxes: \( \sim 3 \times 10^{19} \text{ m}^{-2}\text{s}^{-1} \)
Parallel losses: \( \sim 5 \times 10^{18} \text{ m}^{-2}\text{s}^{-1} \)

Statistics of transport events

- Inter-event times distributed exponentially
  - Increasing time constants for increasing radial position
Conclusions

- Relevant scenario to test blob models in a basic toroidal experiment identified
  - Blobs are observed with very similar properties to tokamak observations
  - Magnetic-topology change seems not essential for blob formation
- Origin of blobs in TORPEX
  - Blobs are sheared-off from elongated wave-crests of a Drift-Interchange wave (Mechanisms? → Ivo Furno, next talk)
- Transport properties
  - Fluxes during events 10 x larger than steady-state parallel losses
  - Time-average effect 10 x smaller than steady-state parallel losses

- Outlook: use data from tokamak SOLs, basic toroidal devices and linear devices together to validate SOL simulation codes
Pilot chart and death-birth conditional prob.

- Clear change in average structure orientation in ejection region
- Deceleration from ~1750 m/s to 1000 m/s along radial propagation
- Conditional birth probability of blobs reaching the far SOL peaks at (-5,-10) cm
  - Blobs travel distances of order of minor radius as coherent structures
Legend

Pilot chart

- Prop. to probability of propagation direction
- Each half tail: 250 m/s
- Average orientation and extension

Area of circle prop. to # trajectories

Birth/death chart

- Color: probability that a structure dies at B, given that it was born at A
- Background color: probability that a structure is born at A

Legend

B
A

Background color: probability that a structure is born at A

Color: probability that a structure dies at B, given that it was born at A