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Divertor-localized fluctuations in NSTX-U L-mode discharges

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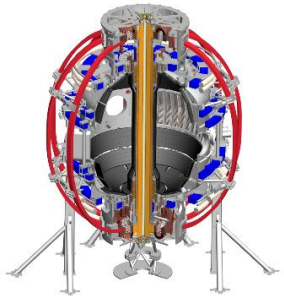
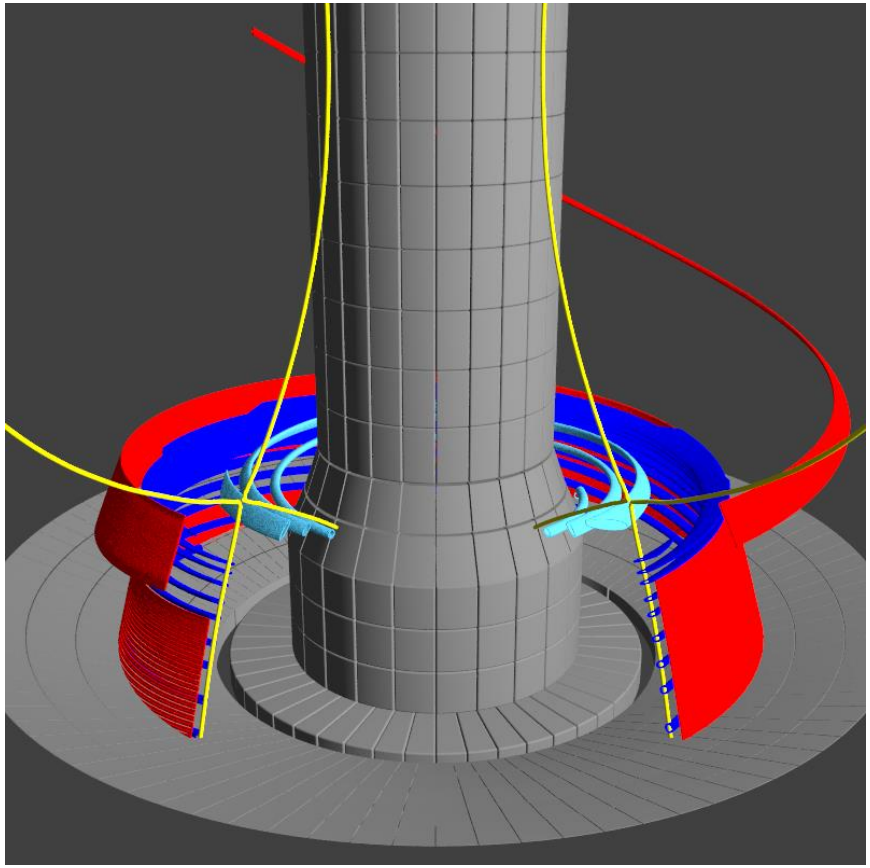


Characterization of divertor-localized turbulence in NSTX-U via imaging of divertor fluctuations



Divertor fluctuations due to:

- Upstream turbulence ('blobs')
- Divertor-localized instabilities:
  - First observed in MAST [Harrison PoP 2015], Alcator C-Mod [Terry, NME 2017]

Divertor-localized fluctuations observed in region where upstream turbulence is disconnected from divertor plate

- Imaging fluctuations via emission from different species to isolate fluctuations in different regions

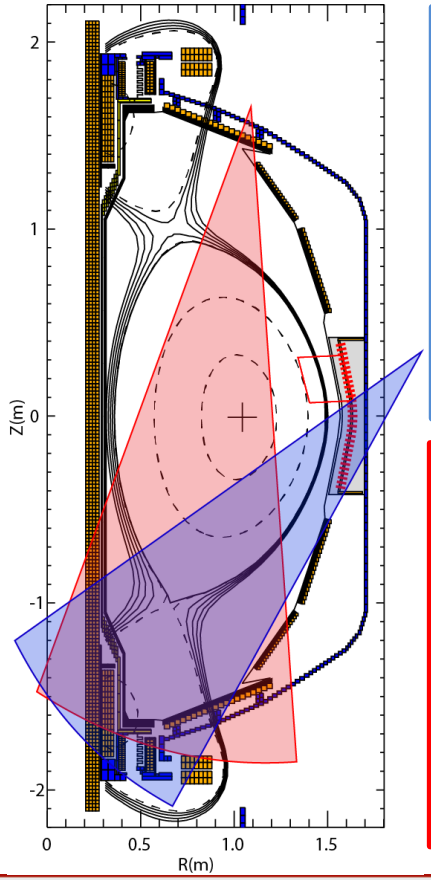
Possible implications for divertor heat/particle fluxes, interpretation of divertor measurements

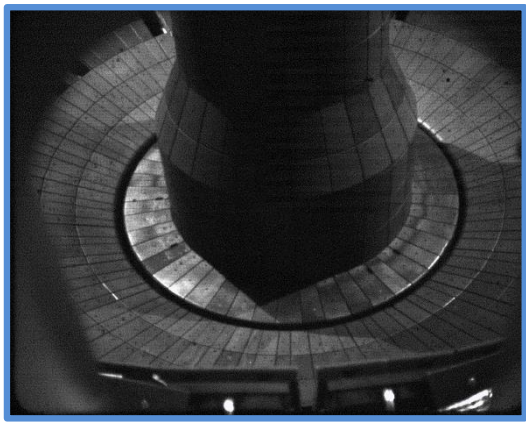
Characterization of divertor localized fluctuations in NSTX-U

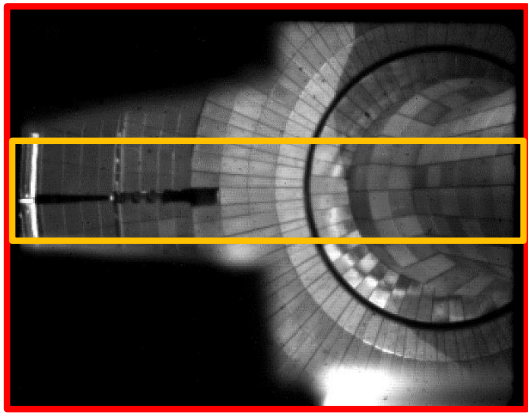
- Statistical properties, correlation lengths, radial localization, dynamics

New fast camera and high X-point L-mode discharges enabled near-separatrix filaments imaging in NSTX-U

- NBI-heated NSTX-U L-mode discharges
  - Lower divertor biased double null
  - I_p = 650 kA, f_G ~ 0. 3, BT=0.65T
  - X-point height ~ 0.5 m (κ~1.8, δ~0.45)
- Simultaneous imaging with 3 fast cameras
- Passive D-α imaging at midplane for upstream turbulence (GPI view)
  - 100 kHz, 9μs exposure
- Passive C III imaging in divertor
  - Emission along divertor leg
  - 100 kHz, 9μs exposure
- Passive D-α imaging in divertor
  - Surface localized emission
  - 280 kHz, 3μs exposure

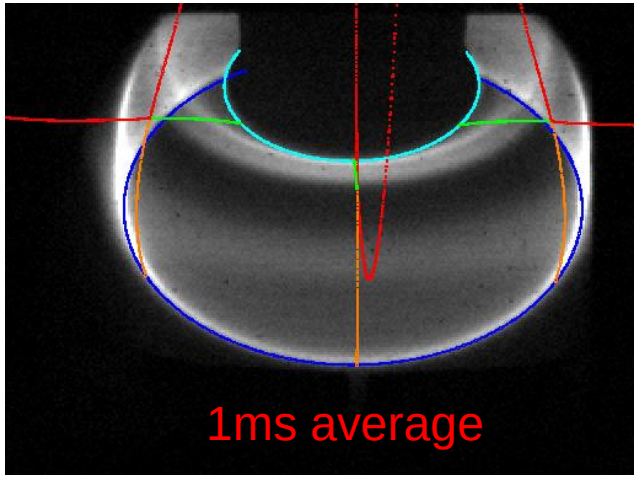


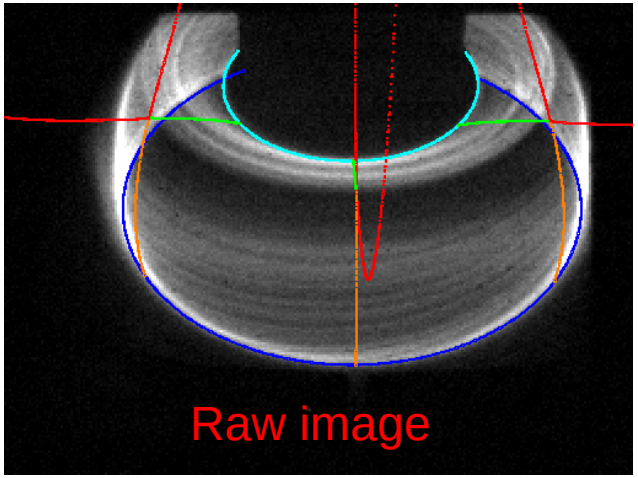


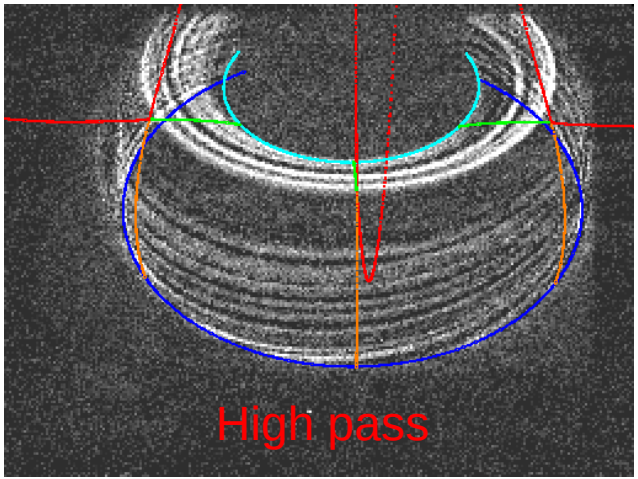


Field-aligned filaments observed in inner and outer divertor legs

- Spatial calibration enables projection of 3D structures and spatial localization of emission
- High pass filtering and cross correlation employed for analysis
- Intermittent filamentary structures on both inner and outer divertor leg
  - Observed in lower divertor biased or double null shape with attached plasma conditions

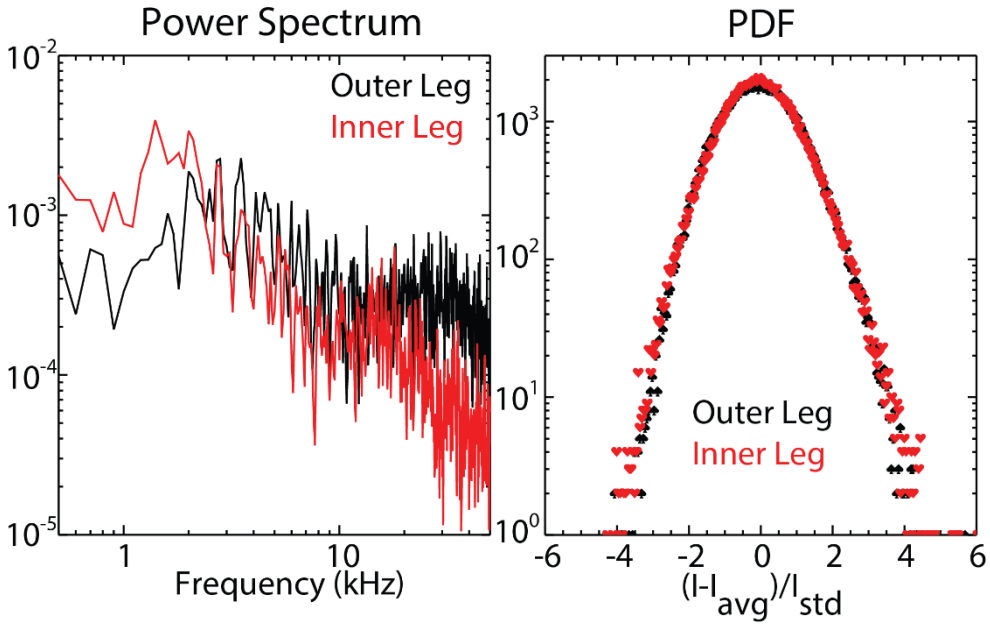






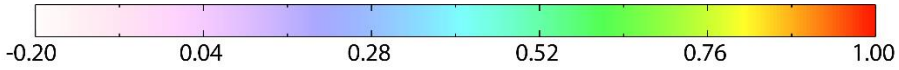
Divertor leg fluctuations are proportional to ~ $\tilde{n}_e$, no correlation with upstream fluctuations

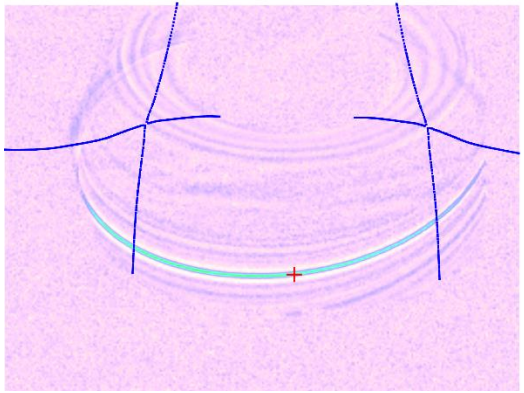
- Broadband fluctuations at 10-50 kHz, δI/I ~10-20%, lifetime ~50-100 μs
- Intensity fluctuations ~ $\tilde{n}_e$
  - C III and D-α fluctuations are correlated (up to 0.7, peaked at zero delay)
- Comparable near-Gaussian PDF for inner and outer legs filaments
- No correlation with upstream turbulence
  - Cf. correlation observed for SOL blobs
- Flute-like filament shape suggests generation in divertor region

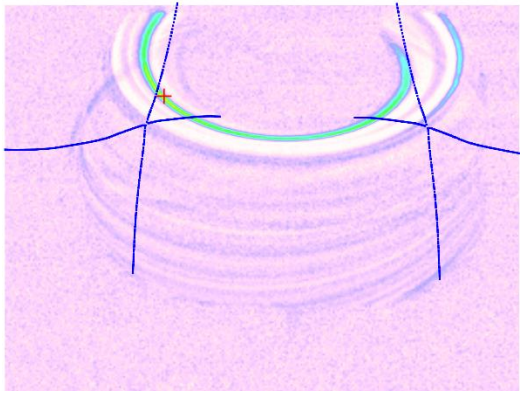


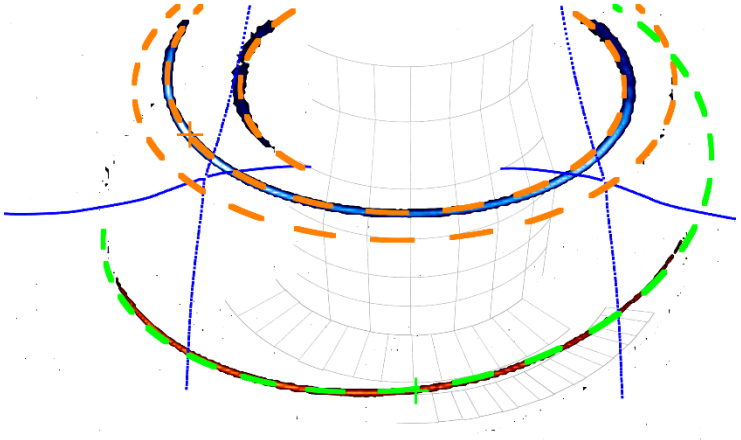
Field-aligned fluctuations, no correlation between inner and outer leg filaments

- Zero-delay cross corr. of pixel with rest of images over 5 ms
- No correlation inner to outer
- Poloidal correlation lengths 1-3 cm ~ 10-50 ρ_i
- Parallel correlation lengths ~ 3m
- Toroidal mode number for outer leg filaments ~10-20
- Field-aligned, radially localized around leg
  - Inner leg filaments localized to private flux region

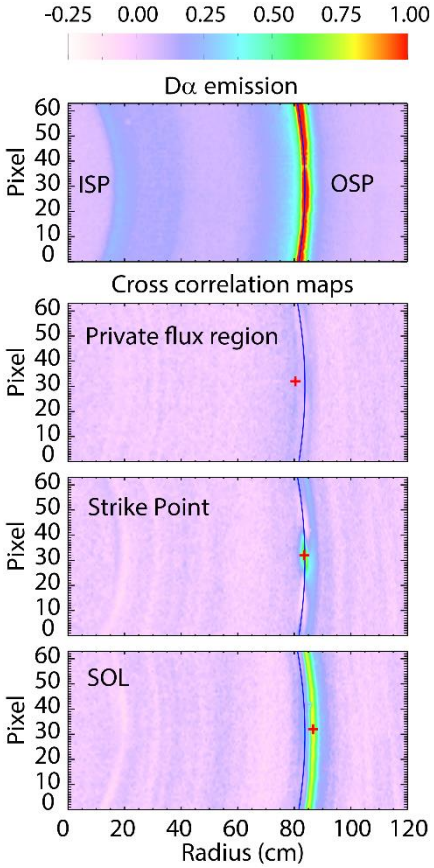


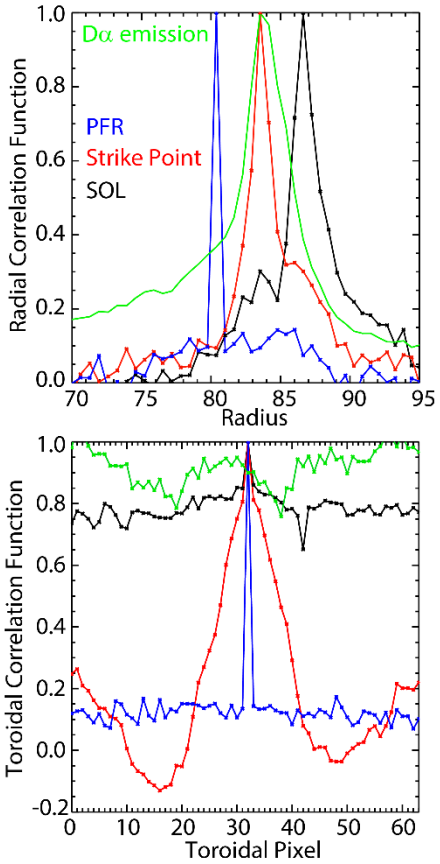






Outer leg filaments are connected to target plate, radially localized to strike point

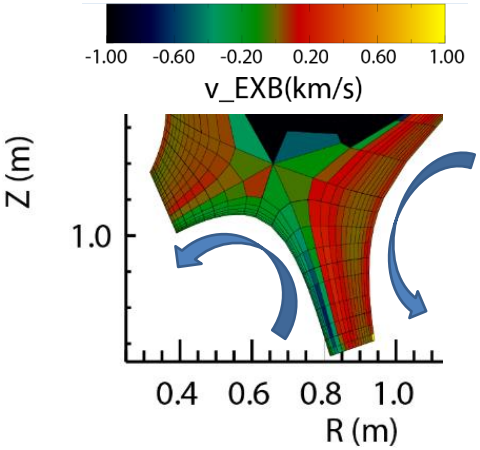


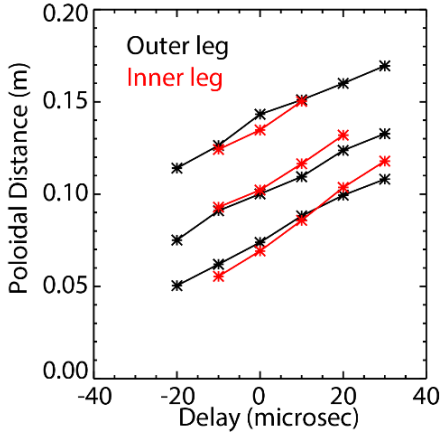


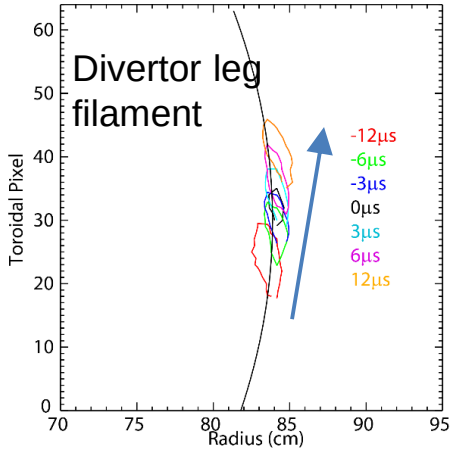
- Top-down view via D-α emission provides imaging of filaments footprint
- Zero delay cross corr. at different radii:
  - In SOL cross correlation regions are spirals with uniform toroidal cross correlations
    - Footprint of upstream blobs
  - Approaching LCFS cross correlation regions have finite toroidal correlation length, radial corr. lentgth ~1-2 cm
    - Footprint of divertor filaments
  - No correlation regions observed in private flux region

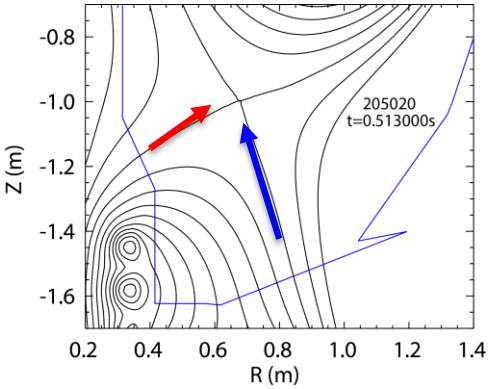
Inner and outer leg filaments rotate in opposite toroidal direction, poloidal velocity ~1 km/s

- Time-delayed cross corr. for average filament propagation
- Poloidal motion (1-2km/s) for inner/outer leg filaments towards X-point
  - Propagation reversal for inner leg filaments at low upstream density
- Outer leg filaments propagate in counter current direction
  - Small but finite radial propagation observed
  - Opposite rotation to footprint of SOL blobs (downward poloidal motion)
- Multi-fluid UEDGE simulations with full cross field drifts model
  - Filament velocity in outer leg qualitatively consistent with UEDGE estimates for ExB velocity









Summary

- Observation and characterization of near-separatrix divertor-localized fluctuations in NSTX-U
  - Intermittent filaments in C III, D-α emission on divertor legs with no correlation with upstream blobs
  - Localized in private flux region on inner leg, separatrix on outer leg
  - Comparable poloidal and radial correlation lengths (1-3 cm)
  - Apparent filament motion is towards X-point on both legs
  - Shape, dynamics and absence of upstream correlation suggest fluctuations are generated and localized on divertor legs
  - Consistent observations with MAST, Alcator C-Mod