NSTX

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Edge turbulence and SOL blobs in the National Spherical Torus Experiment (NSTX)

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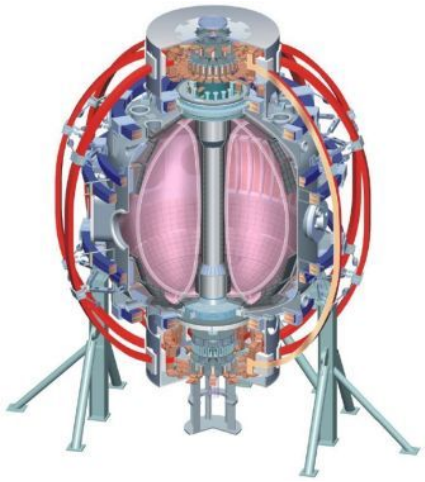

Overview

- Edge turbulence and intermittent filamentary structures (blobs) routinely seen in low field side scrape-off layer.
- The main L-H transtion is seen as a sharp reduction in edge/SOL turbulence.
- Quiet periods, with a frequency of ~3 kHz, are seen in L-mode before the transition. Poloidal flow tends to reverse direction.
- Fine structured, intermittent filaments are also seen on the lower divertor target plates.
- Divertor filaments correspond to interaction with target plates of midplane blobs.
- Correlation between divertor and midplane lost close to the outer strike point, consistent with 'magnetic shear disconnection' (Cohen and Ryutov, Nucl. Fus. 37, 621 (1997)).
- Experimental data used in collaboration with SOLD 2-D fluid turbulence code to study cross-field energy transport in SOL.

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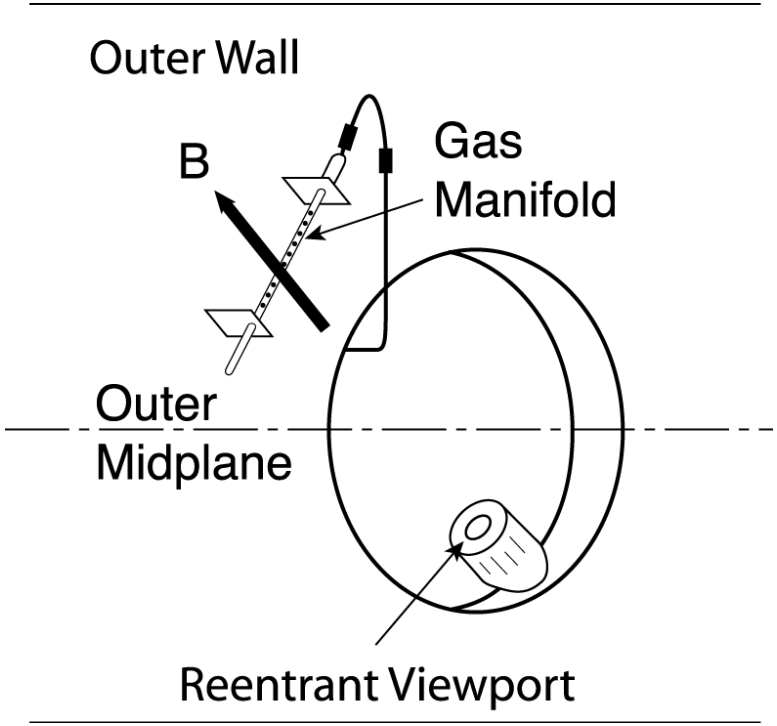
Experimental setup
(GPI diagnostic)

- Camera used to view visible **D_α emission** from 24 x 24 cm box of the edge plasma just above low field side (outer) midplane.
- Deuterium gas puff is injected to increase image contrast and brightness. Gas puff does not perturb local (nor global) plasma.
- View aligned along B field line to see 2-D structure ⊥ B. Typical edge phenomena has a long parallel wavelength, filament structure.
- For more diagnostics details: R.J. Maqueda et al., Rev. Sci. Instrum. 74(3), p. 2020, 2003.



- For previous GPI results see: S. J. Zweben, et al., Nucl. Fusion 44, p. 134, 2004.

Blob simulation and synthetic GPI in the SOLT code

J. Myra, D. Russell, D. D'Ippolito, Lodestar Research Corp.

- The 2D fluid turbulence code SOLT simulates blob formation and propagation at the midplane.
  - Recent code upgrades allow synthetic GPI for a D-puff (as well as He-puff)
  - The equation set has been expanded to included the collisional (disconnected) regime.
  - The NSTX SOL is typically in the sheath connected regime.
    - Sheath connection is confirmed by results from the linear full geometry 2DX code [Baver et al.] except near the separatrix.
- In low power, ELM-free H-mode simulations, blob emission is present only when triggered by a transient perturbation. Results compare qualitatively to sparse emission in the experimental data.
  - near SOL width appears not to be set by detached blobs
- In higher power NSTX discharges, simulated and observed turbulence levels, as characterized by $\delta I_{rms}/\langle I \rangle$ are insensitive to I_p (at constant B) in two comparison shots.

SOLT code: D. A. Russell et al., Phys. Plasmas #122304 (2009)

Quiet Periods and the L-H Transition

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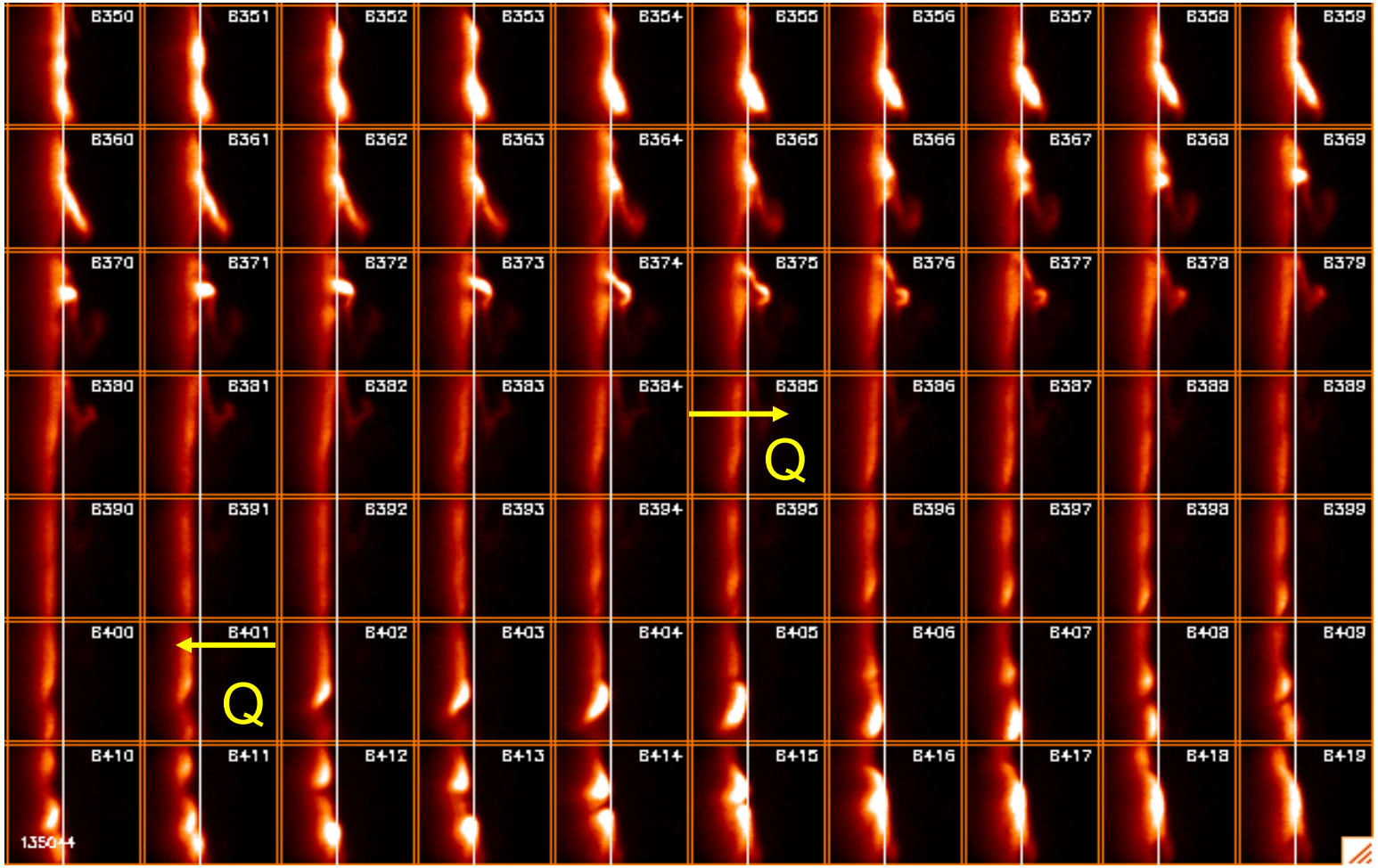
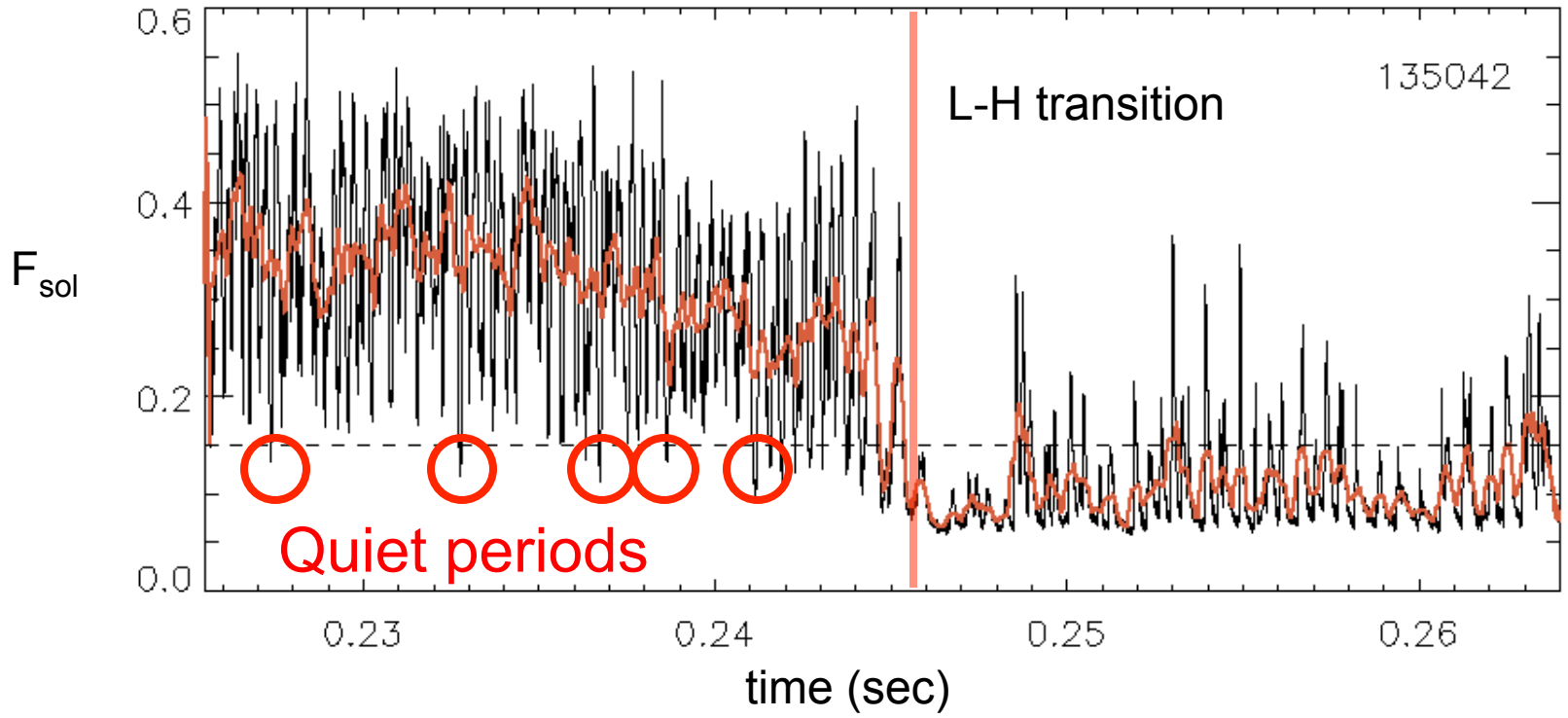
Quiet Periods Preceding Transition

- Sometimes GPI images in L-mode look like H-mode !



Define "Scrape-off Layer Fraction"

- F_{sol} = fraction of GPI D_α light located outside separatrix
- Measures "H-mode-ness", $F_{sol} \leq 0.15$ seen in H-mode
- F_{sol} determined by shape of n, T_e profiles near separatrix

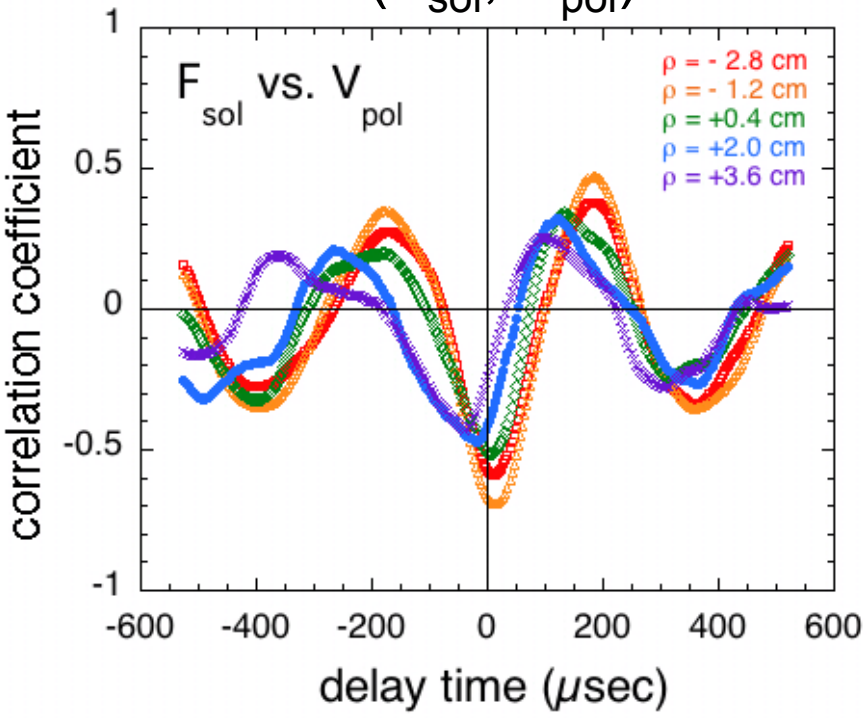


- F_{sol} frequency spectrum has a broad peak at f ~ 3±1 kHz
- Quiet periods occur up to 30 msec before L-H transition

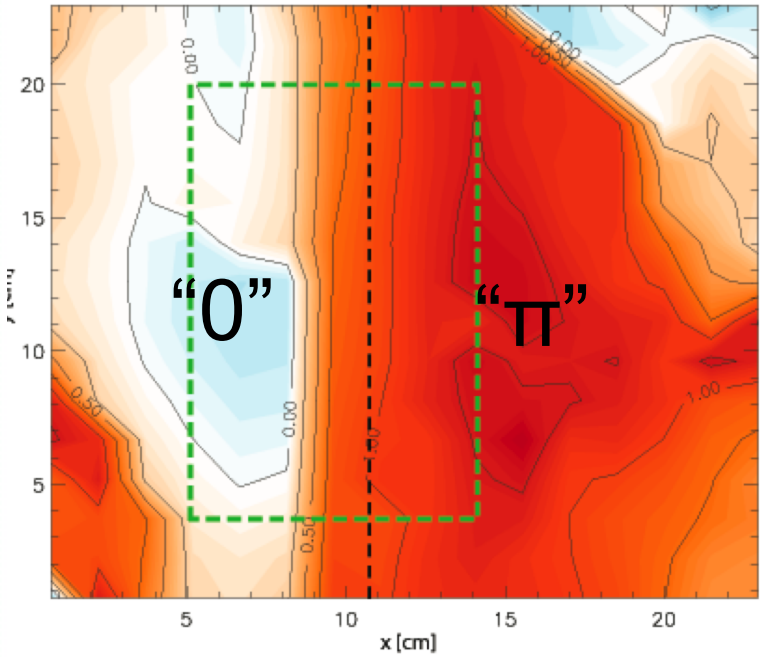
Quiet Periods vs. Poloidal Flow

- Poloidal flow V_{pol} measured from GPI turbulence motion
- F_{sol} and V_{pol} ~50% correlated within ±3 cm of separatrix

(F_{sol}, V_{pol})



Cross-phase vs. radius



Sechrest and Munsat

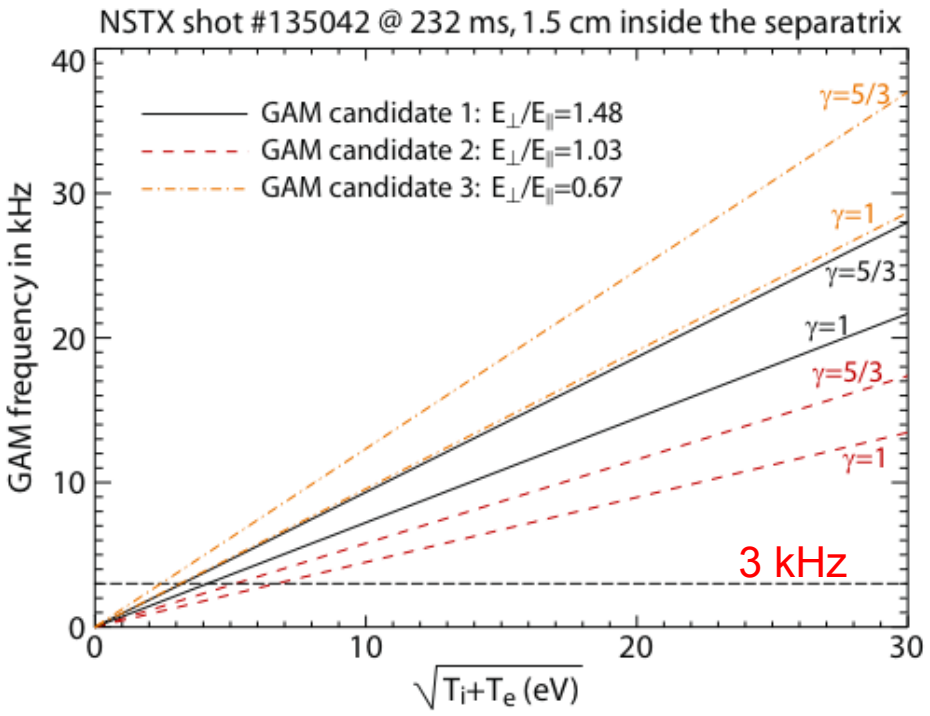
Geodesic Acoustic Mode (GAM) Analysis

R. Hager, K. Hallatschek, IPP Garching

- GAM expected roughly at f(Hz)= $(1/\pi R)\,[\gamma(T_i+T_e)/m_i]^{1/2}$ G

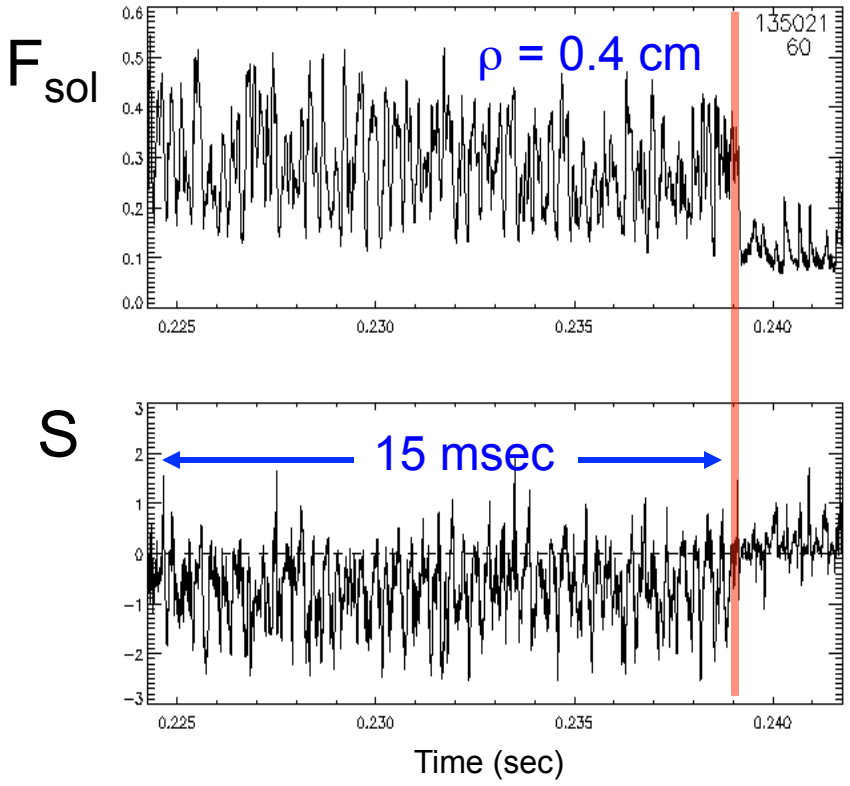
- linear simulations show three GAM candidates for NSTX #135042

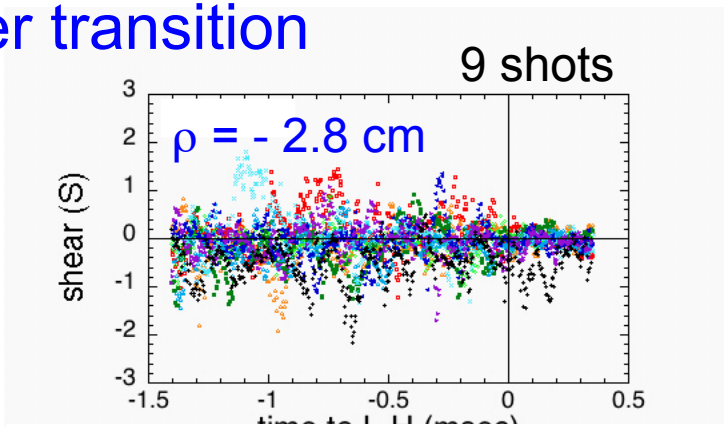
- nonlinear simulations show low frequency mode (red) excited at 3 kHz for $T_i+T_e \sim 40$ eV

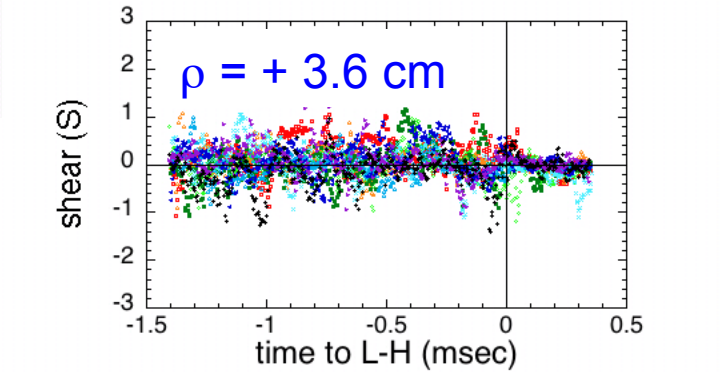


Shear Preceding Transition

- Dimensionless shear: $S = (dV_{pol} / dr)\,(L_{rad} / L_{pol})\,\tau$
- V_{pol} and S reverse sign during quiet periods (F_{sol} <0.2)
- Turbulence shear S is not changing before L-H transition, so does not appear to trigger transition





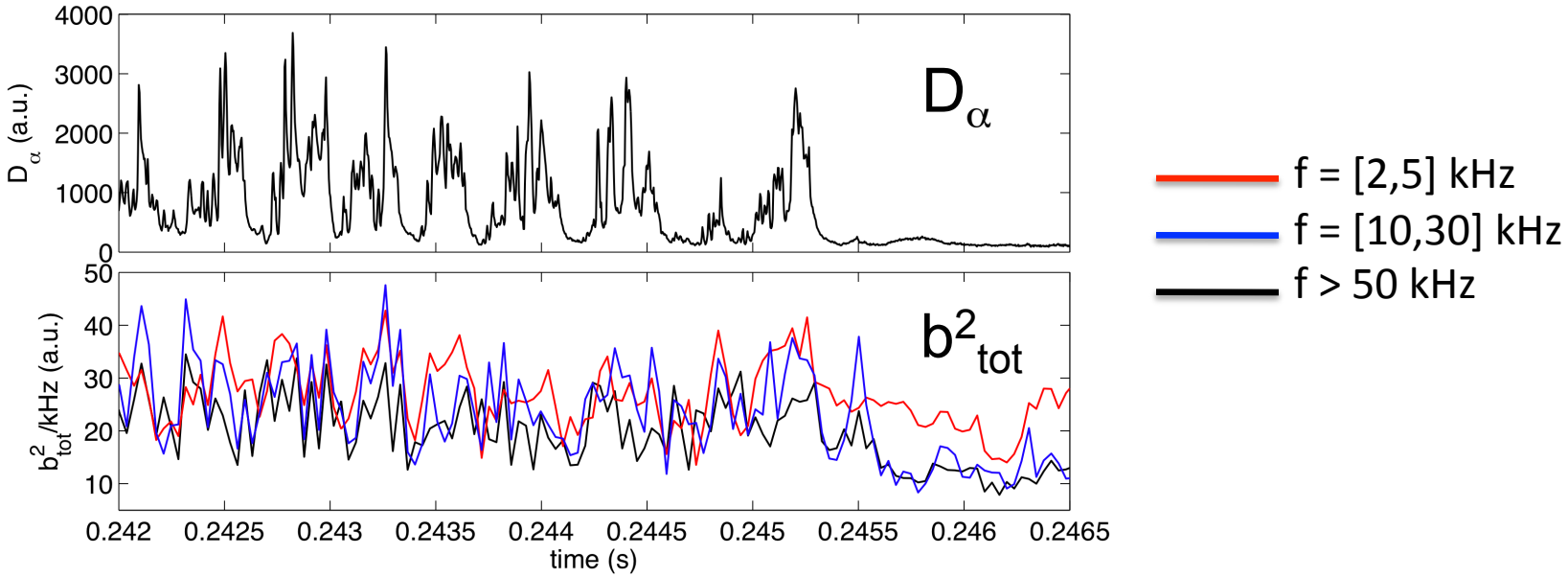


Nonlinear Bicoherence Analysis

F.M. Poli, U. Warwick

- Total bicoherence b^2_{tot} has minima during quiet periods in all frequency ranges until 2 ms before L-H transition

- Total bicoherence slightly increases ~0.5 ms before transition in the low- to intermediate- frequency range



Intermittency on the divertor target

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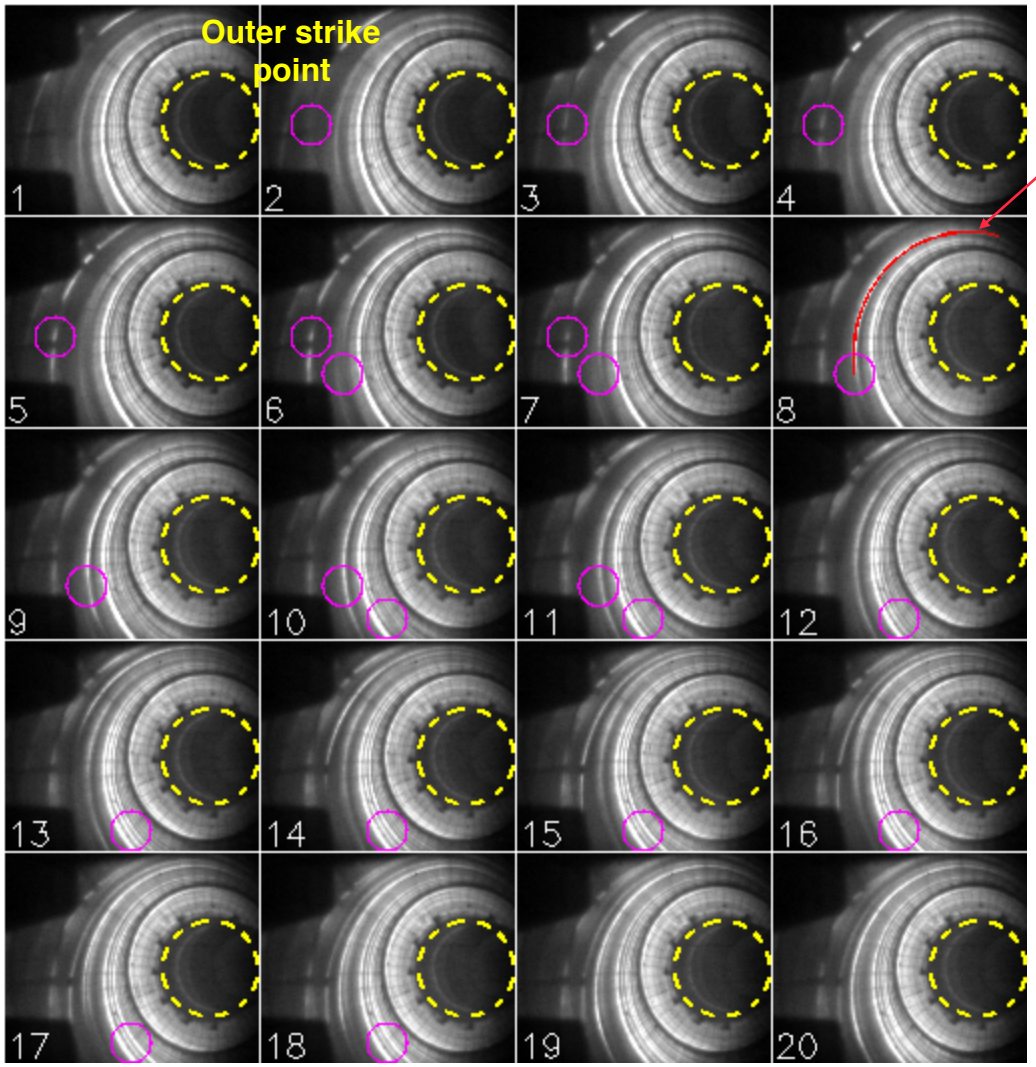
Moving striations seen on divertor target

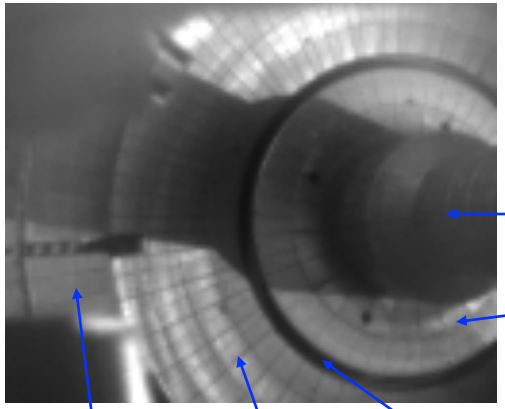


LiI images

Shot 124750: 596.525 ms to 596.739 ms

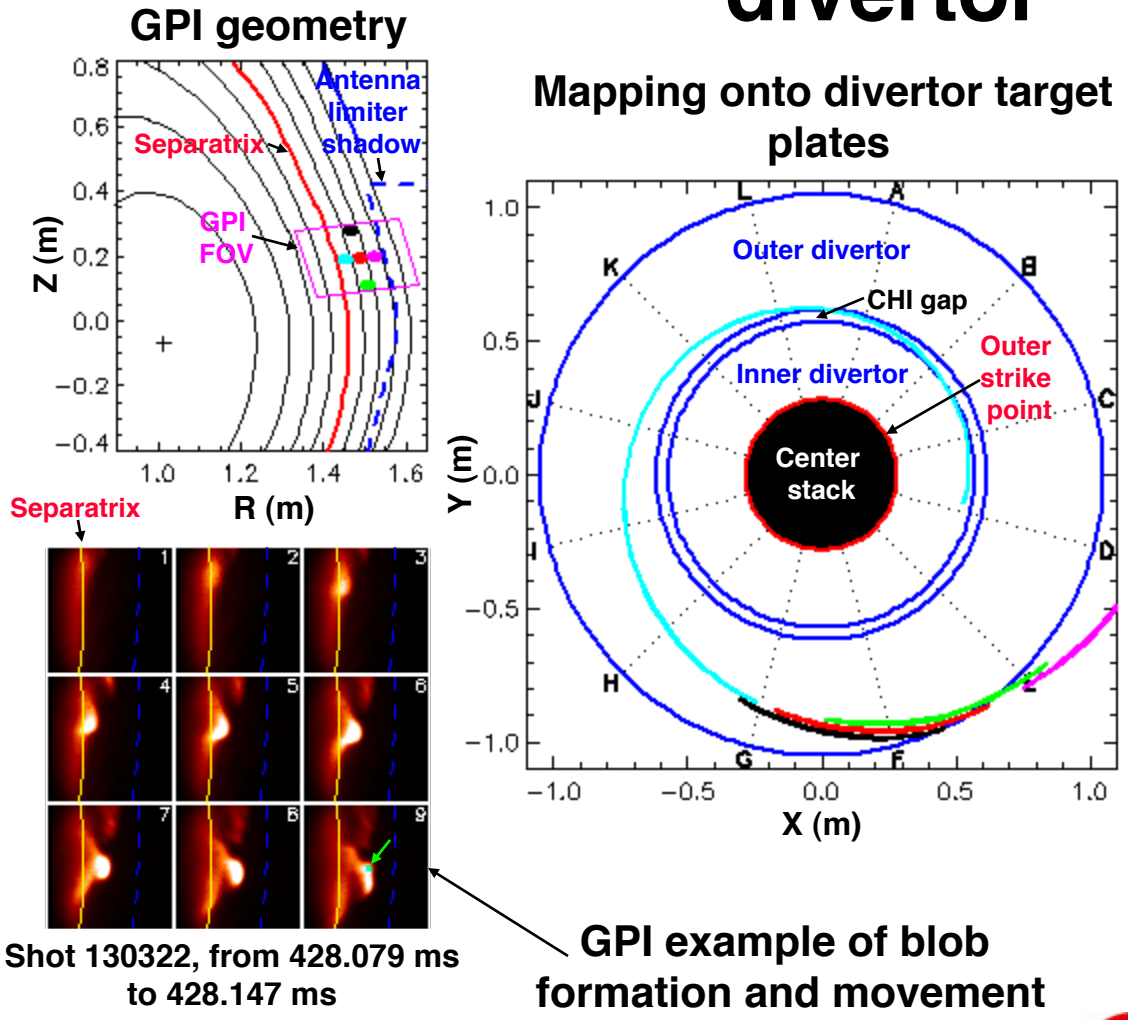
Footprint of 3 cm diameter flux tube

Vessel illumination



- Striations move toroidally (counter-clockwise from above) and radially outwards.

As blob filaments move in the SOL, their footprints move toroidally/radially in the divertor

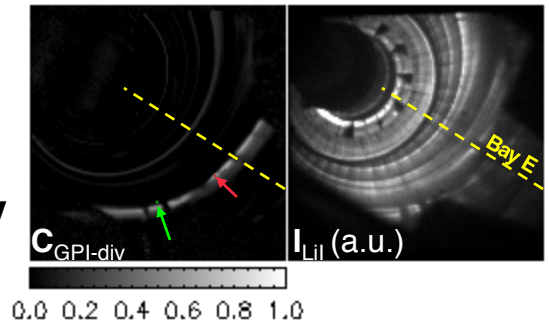


- Radial movement (cyan-red-purple) results in movement "along" the striation spiral.
- Poloidal movement (black-red-green) results in toroidal movement (or, due to barber-pole effect, inward radial movement).
- Connection length from GPI plane to divertor is ~4 m in the far SOL.

Good correlation observed between GPI and divertor target Li light

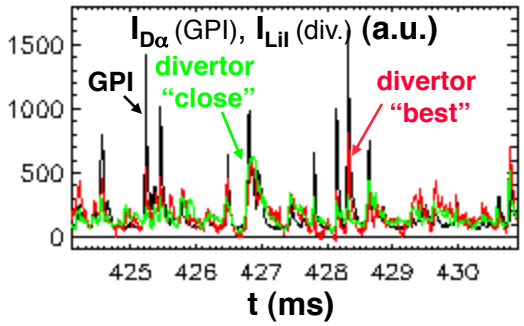
- **Red arrow** indicates position of best cross-correlation.
- Green arrow indicates position of mapping between GPI image (slide 13) and divertor.

Cross-correlation image 0-time delay

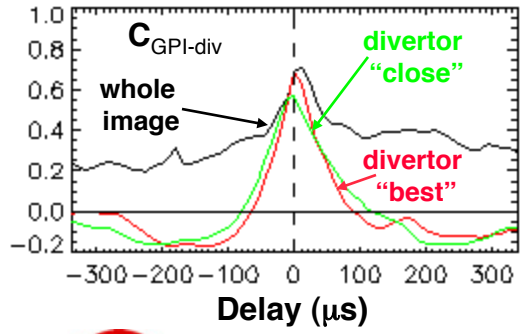


Reference LiI image showing striations

- Toroidal mismatch between red and green positions due to high uncertainty (uniformity) in the toroidally elongated footprints.
- Radial mismatch possibly due to uncertainty in the separatrix position at the midplane. Good correlation is observed 1.2 cm (mapped to midplane) outboard of green mapped position.

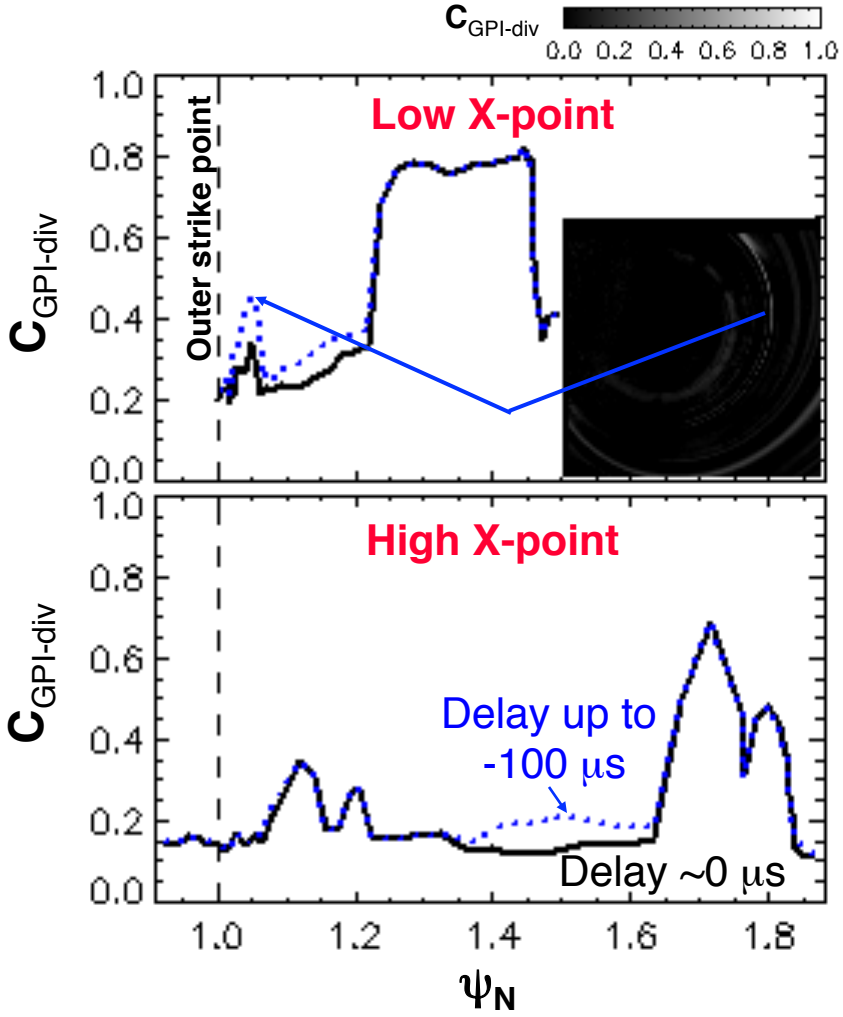


Raw time-series check (divertor linearly scaled to GPI)



Time-delayed cross-correlation

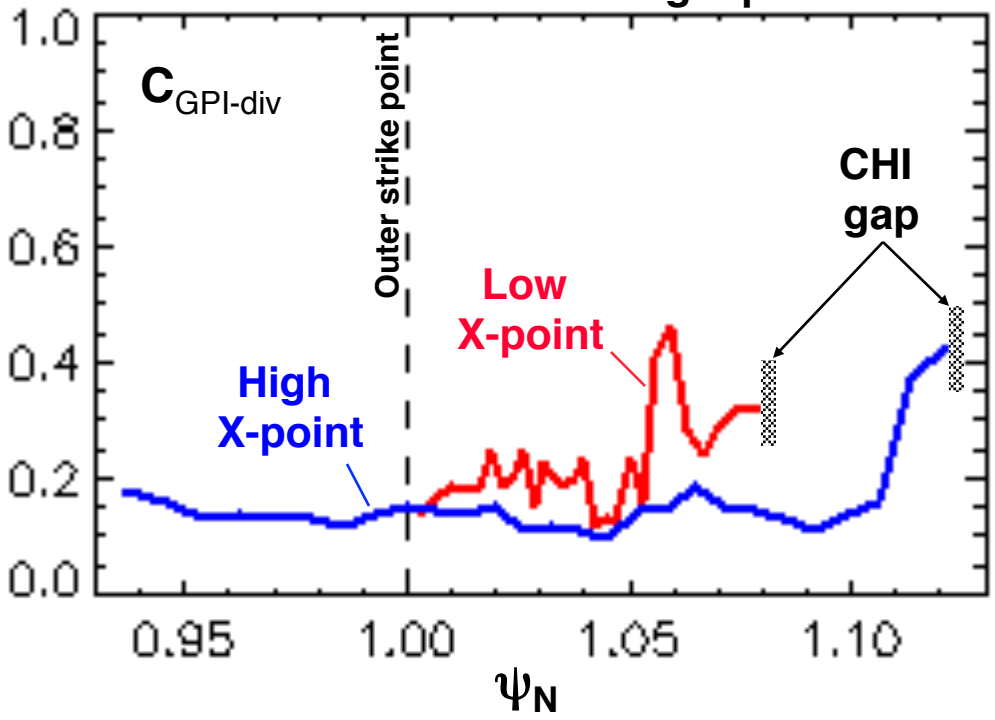
Good correlation observed down to $\psi_N \sim 1.04$, in low X-point case



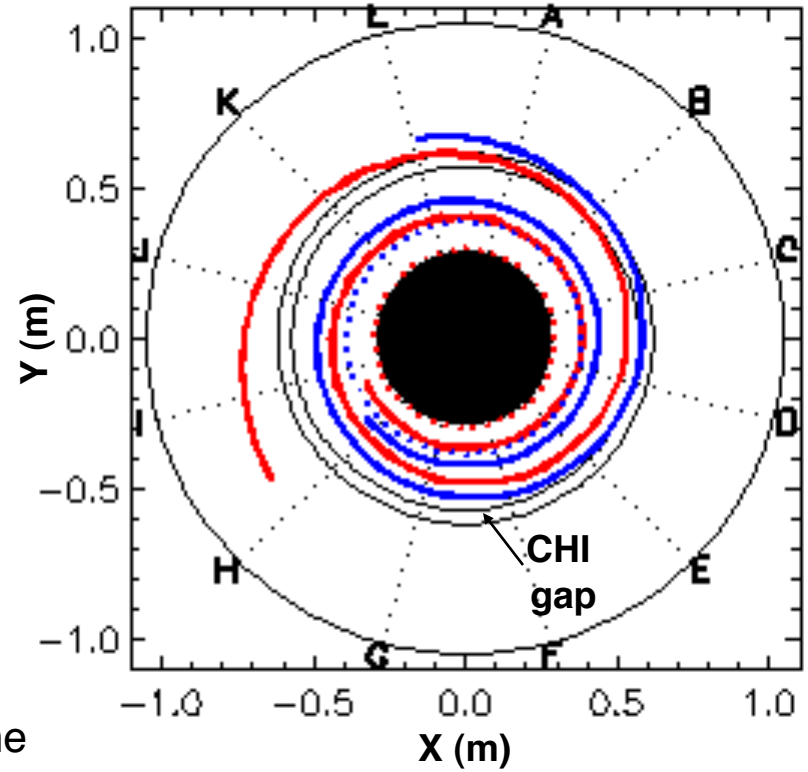
- Allowing correlation to "early" (within 100 ms) divertor events, correlation can be obtained in extended regions of the top-down images.
- In the case of a low X-point an "early" band of correlation at $\psi_N \sim 1.04$ appears, corresponding to the striation going one whole turn around the center column (insert).
- No improvement is seen at small ψ_N in the case of a high X-point.

Striations close to outer strike point are not related to midplane blobs

Correlation between midplane GPI and inner divertor target plate



Footprints of 3 cm diam. midplane blobs



- No correlation seen between divertor and midplane GPI at low ψ_N, even though footprints should "spiral" around center stack.
- Striations at low ψ_N consistent with toroidally symmetric fluctuations (i.e., non-spiral).

Summary and conclusions

- Quiet periods in edge turbulence and SOL intermittency appear un-related to L-H transition.
- Quiet periods may be related to Geo-Acoustic Modes (GAM).
- Turbulence shear not changing just prior to L-H transition.
- Fast-moving striations observed on the divertor target plates which correspond to “footprints” of midplane blobs.
- The correlation between the GPI diagnostic (blobs) and divertor light (neutral lithium) is remarkable, but only obtained if the two observation regions are mapped along field lines.
- Good correlation (filament “connection”) between the midplane and the divertor target plate can be observed down to ψ_N~1.04 in the case of a low X-point.
- Striations at low ψ_N (<1.04) not related to midplane blobs and are consistent with toroidally symmetric fluctuations (circular rather than spiral).