Gas puff imaging of fluctuations

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Edge Turbulence Studies Objective

- Understand physics of edge turbulence to gain access to: anomalous transport, H-mode physics, transport outside last close flux surface, diffusion of toroidal current from edge to core, etc.

Approach

- Measure visible emission from the plasma edge.
- Use localized, controlled gas puffs to de-couple emission from natural recycling phenomena.
- Use intensified imaging camera to view gas puff, i.e., **Gas Puff Imaging**.
- Correlate structures seen on edge emission with electron density filaments/eddies.
- Complement scale length studies from imaging with fast (~200 kHz) discrete chord measurements of gas puff emission.
- **Interactive comparison with numerical modeling.**

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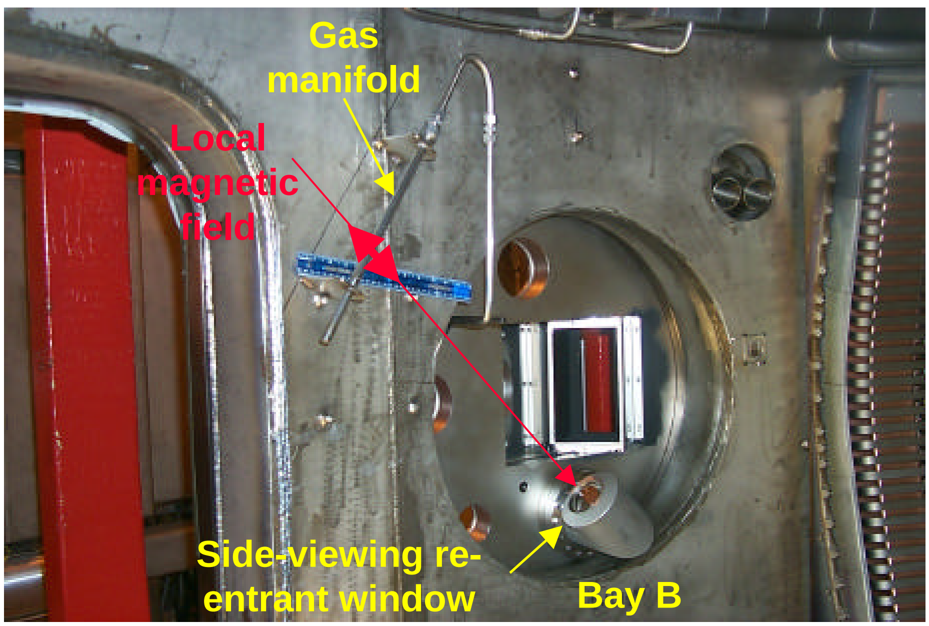
GPI Implementation on NSTX

- Use Kodak EM1012 fast-framing intensified camera for 2-D imaging
  - 10 μs exposure time
  - 1000 frames/s at 239x192 8-bit pixels
  - He gas puff and HeI line filters at 587.6 nm
- View gas puff along B field line: (radial vs. poloidal)



- Supplement with fast time series
  - 7 fiber-optic chords, ~2 cm diameter each, obtained "radially" on puff
  - light detected by photomultiplier tubes
  - frequency response to ~200 kHz

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XP-34: Edge turbulence measurements, comparison with simulations

Goal:

Characterize the cross-field scale-length and frequency spectrum of this turbulent filaments, and compare the experimental results with those of the **BOUT** and **BAL** codes.

- **BOUT** is a *Bou*ndary Plasma *T*urbulence Code
  X. Xu, W. Nevins, LLNL
- **BAL** is a linear eigenvalue stability code
  J. Myra, D. D'Ippolito, Lodestar Research

• Codes have predicted/observed that the scale-size, frequency and growth rate of the turbulence depend on the toroidal field and plasma current, with some characteristics invariant for constant edge q.

• Growth rate in inner wall limited discharges is smaller than in double null discharges.

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BOUT simulation for NSTX

BOUT is a *Bou*ndary Plasma *T*urbulence Code

X. Xu, W. Nevins, LLNL

- 2-fluid 3D Braginskii equation turbulence code with:
  - realistic geometry
  - open and closed flux surfaces
  - background and turbulence evolution in time

- BOUT possesses many sources of turbulence, most important one appears to be **resistive ballooning**.

- Input to the code is provided from experimental data:
  - plasma current and magnetic equilibrium data
  - edge electron and ion temperatures (estimates)
  - edge electron density (estimate)

- Turbulence results from the numeric simulation are compared with experimental turbulence results.

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BAL results

J. Myra, D. D'Ippolito, Lodestar

- **BAL** is a linear eigenvalue (stability) code.
- Code can treat both the closed and open flux surface regions.
- Physics of pressure driven modes and divertor flux plate sheaths are included.
- Code employs the same magnetic geometry mode and input files that are used by BOUT.
- BAL has been important in understanding the unstable modes in X-point geometry and the corresponding turbulence seen in BOUT.

- As q in increased (constant B) , scale size increases, frequencies are smaller and growth rate doesn't change much.
- As B and Ip are reduced (constant q), scale size gets larger, frequencies are similar and growth rate decreases.
- Growth rate in inner wall limited discharges is smaller than in double null discharges.

July 2001 XP-34 experiments

Topology comparison:

Ohmic 700 kA, 0.3 T shots:
- Inner Wall Limited
- Lower Single Null
- Double Null

Current/field scan:

IWL->LSN with 1 source NB “prelude”
- 0.3 T and 0.45 T at 1.0 MA
- 0.2 T, 0.3 T, and 0.45 T at 0.7 MA.

Puff strength scan:

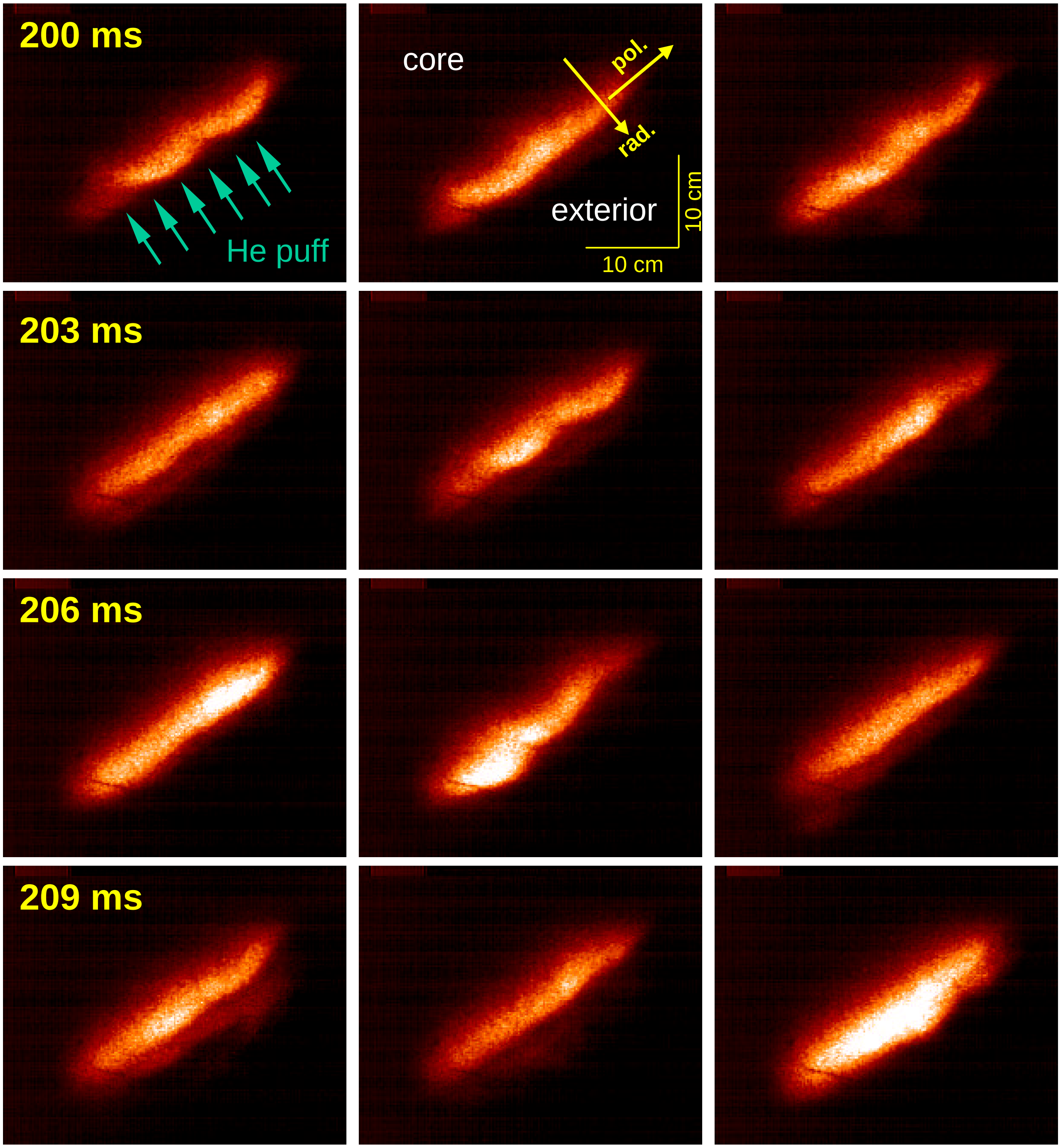
Helium puff strength varied a factor 7 (net amount of gas injected) in 1.0 MA, 0.3 T discharges.

Main initial result:

Most striking differences observed during current/field scan, relative to topology and puff strength scans.

1.0 MA, 0.3 T

He puff on D_2 discharge, HeI filter, 10 μs exposure



Shot 105766

Click here for MPEG clip

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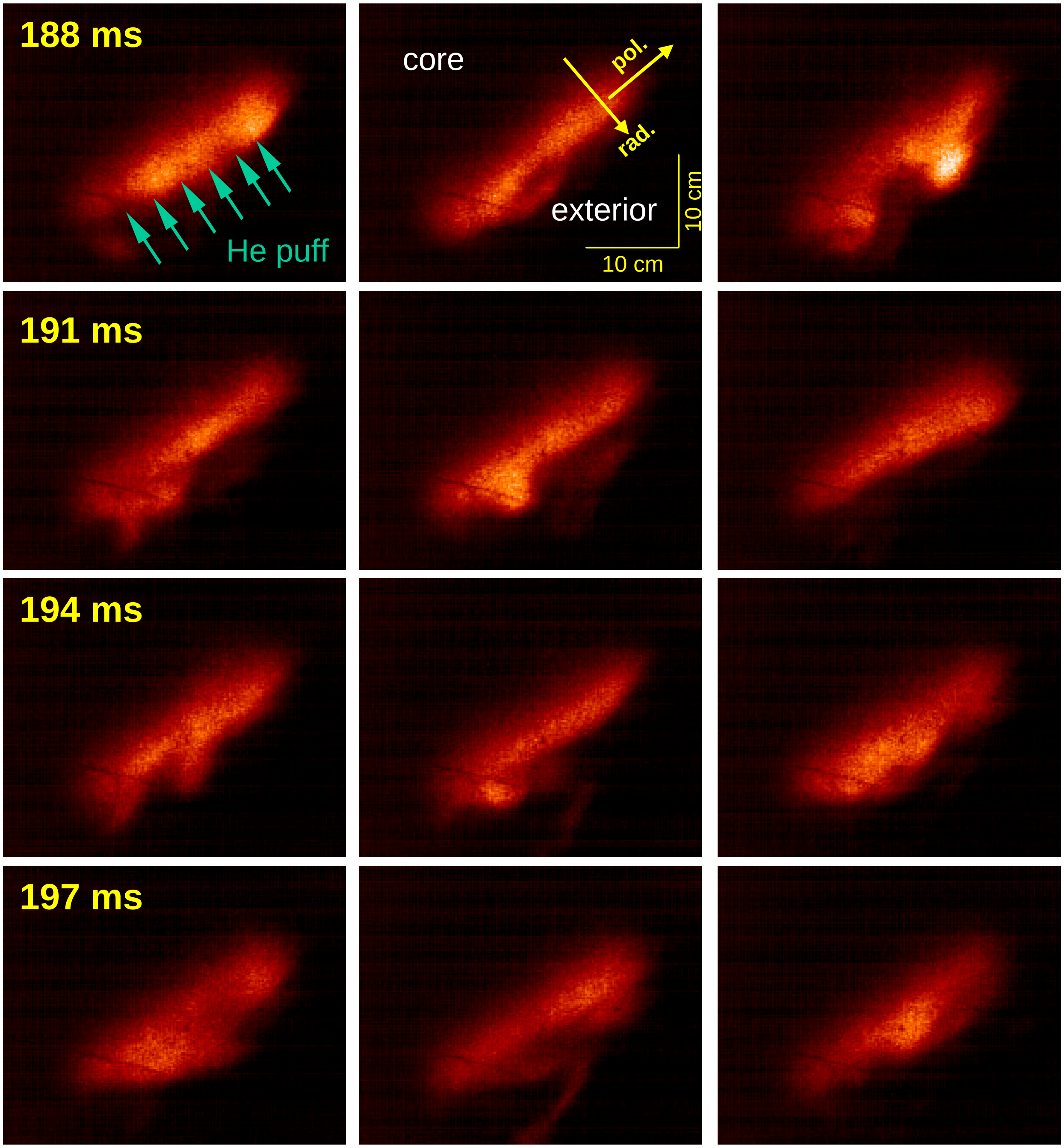
1.0 MA, 0.45 T

He puff on D_2 discharge, HeI filter, 10 μs exposure



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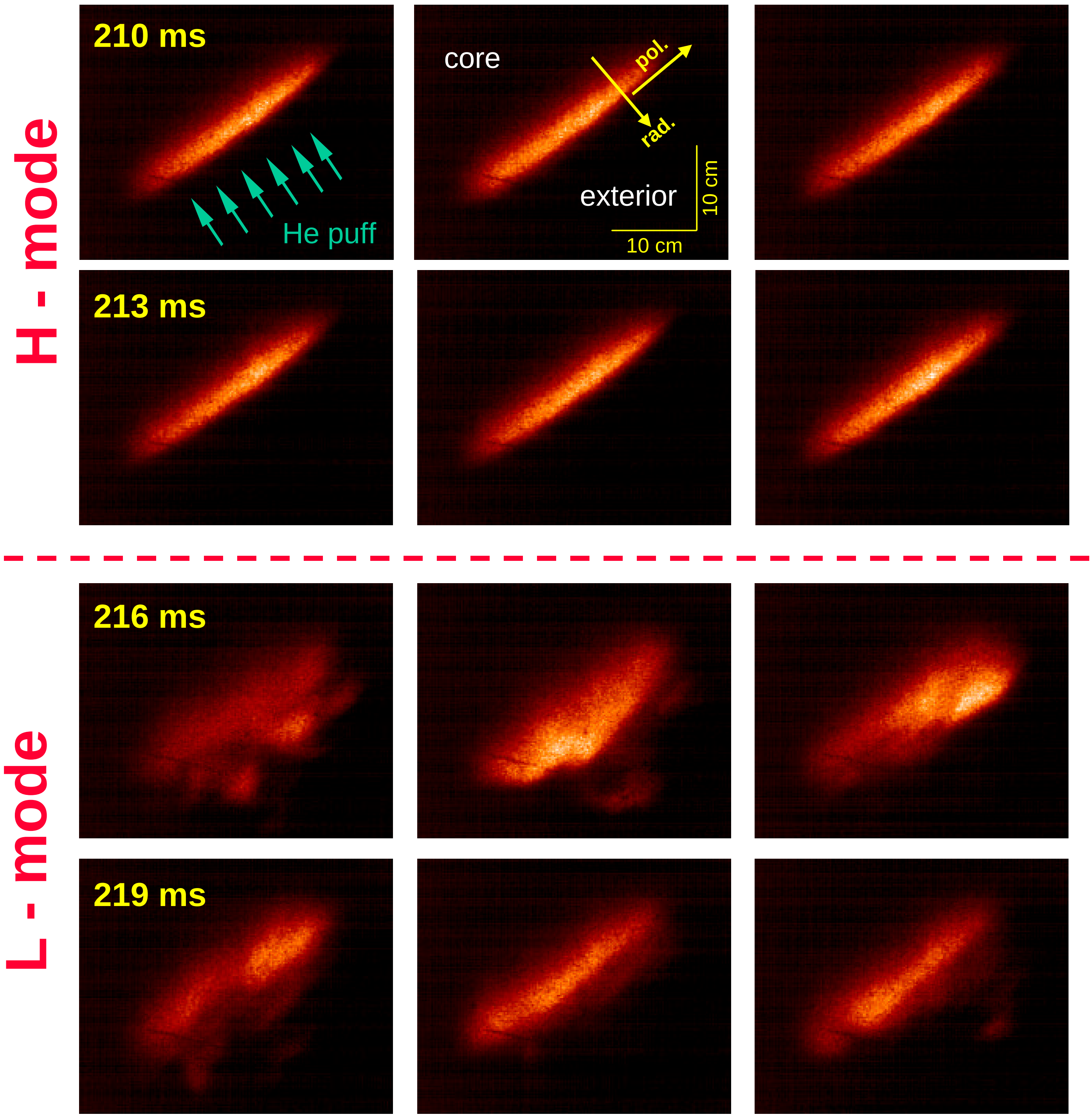
H - L transition
1.0 MA, 0.45 T

MPEG clip

He puff on D_2 discharge, HeI filter, 10 μs exposure



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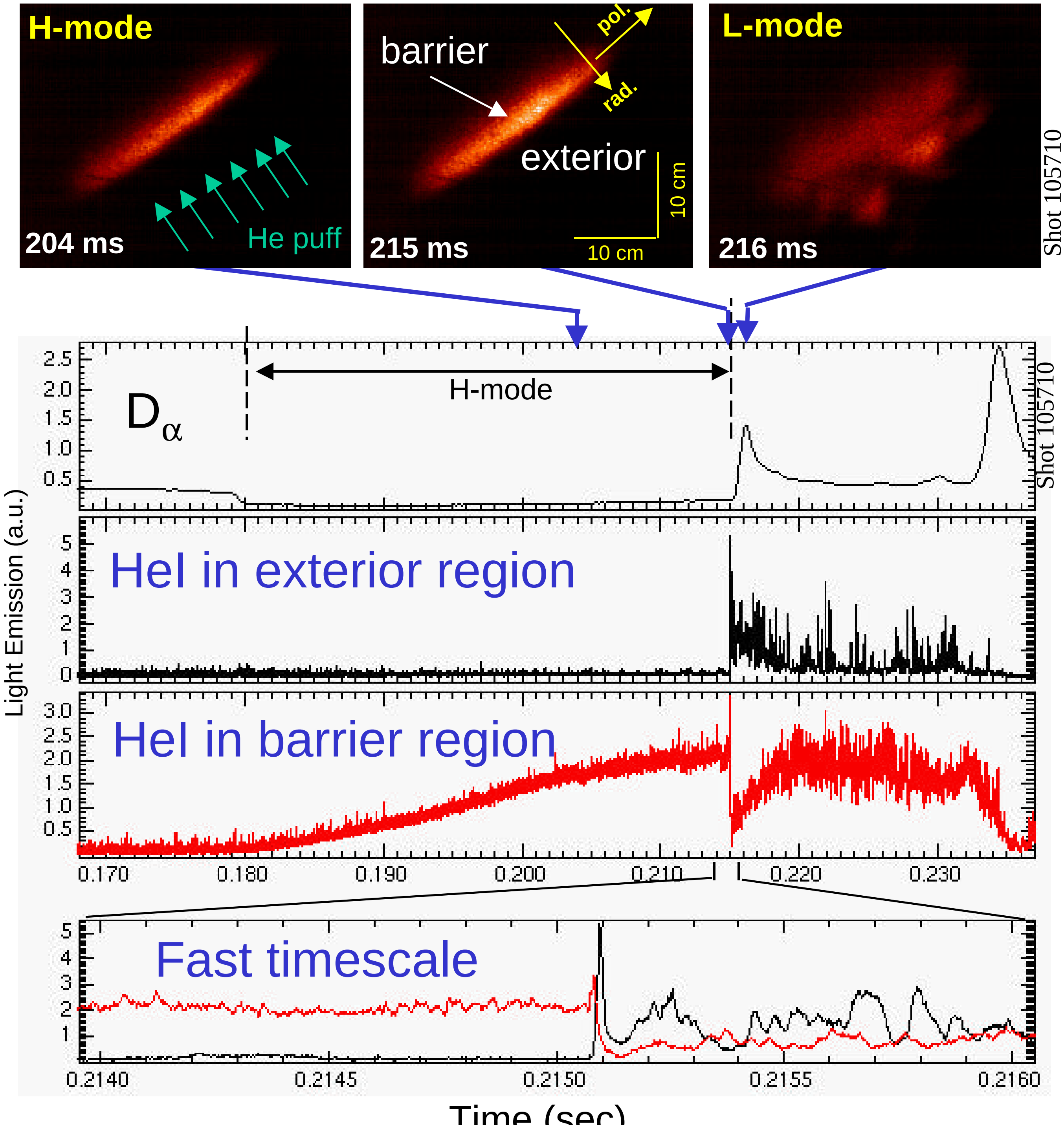
Differences in edge turbulence observed between H and L modes



Timescale for H-L transition is similar to auto-correlation time: 20-30 µs.

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Time series analysis

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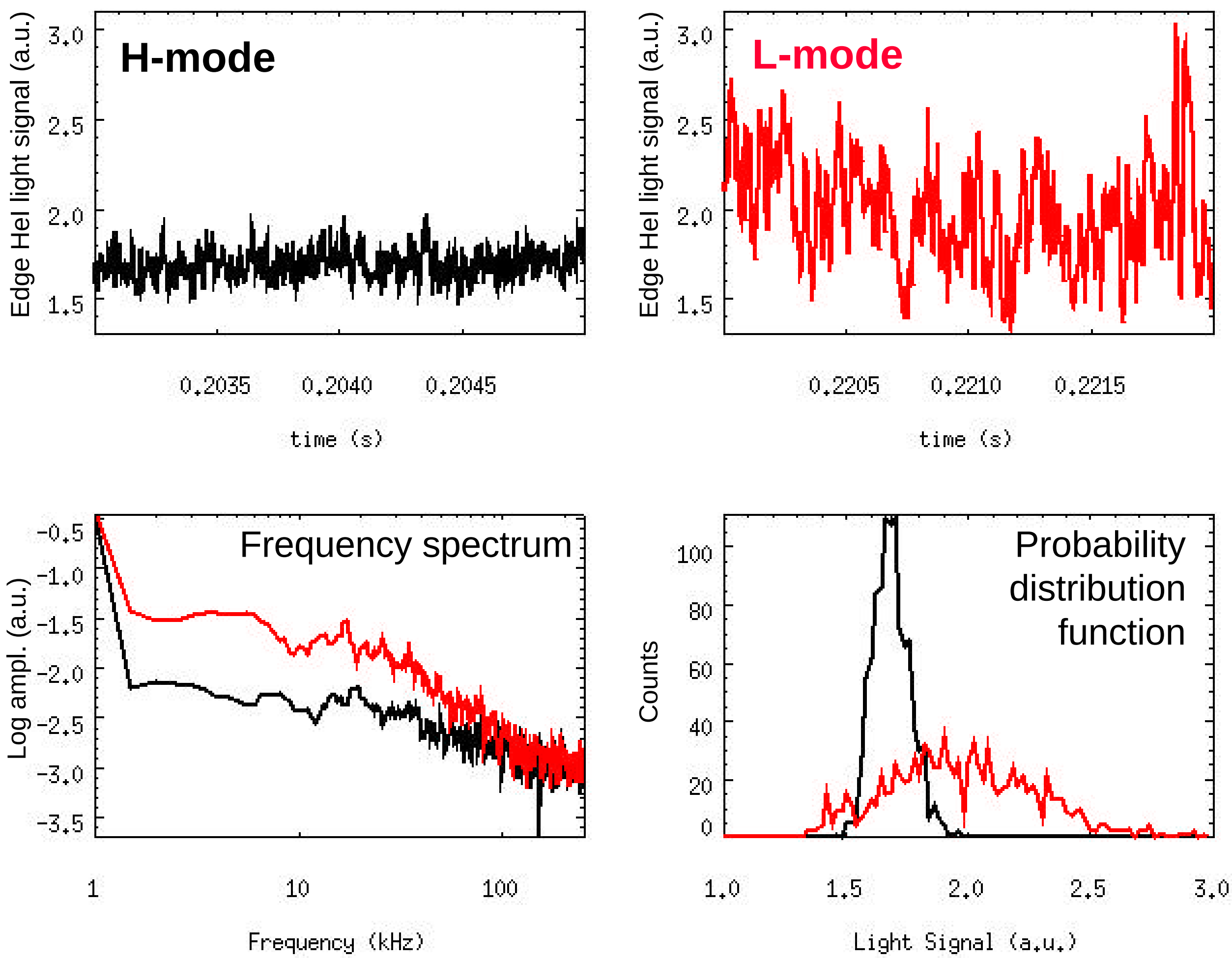

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Summary

Results

- Valuable gas puff imaging data obtained in a number of plasma conditions. Topology was varied between inner wall limited, lower single null diverted and double null. Toroidal field varied between 0.2 and 0.45 T with plasma currents of 0.7 and 1.0 MA.
- Current/field variations resulted in the more pronounced differences between shots, relative to topology (and gas puff strength) variations.
- **Most notable are the differences observed between H and L mode confinement regimes, with strong suppression of turbulent eddies in H-mode.**

Ongoing work

- Calibration of imaging system (in-vessel).
- Modeling of edge atomic physics.
- **Interactive comparison with numerical modeling.**