XP Proposal: Ultra-high speed GPI measurements of the L-H transition

S.J. Zweben, R.J. Maqueda, T. Munsat, S. Kaye et al

T.S. Hahm, B.D. Scott

Goals: Obtain ultra-high speed images of on edge turbulence before and through the L-H transition (ITPA priority)

=> Look carefully for “trigger” of L-H transition

Run time: 1-2 hours of a typical L-H transition shot with GPI to get ~5-10 good transitions

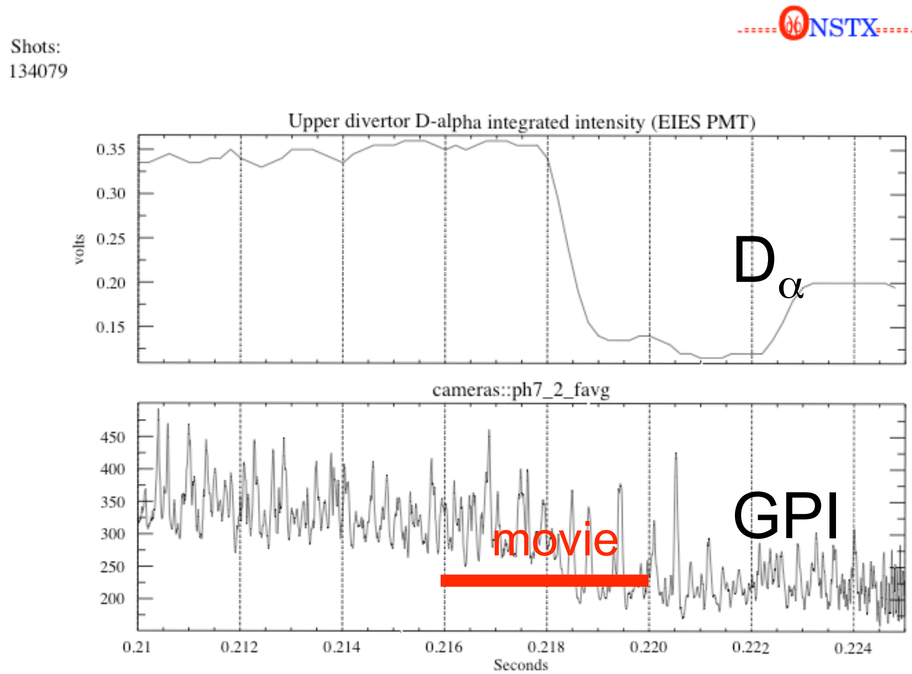
Motivation

- "I would suggest that we make the H-mode transition physics again part of our experimental programme. There are still many open issues, the time scales, the actual transition trigger, the role of the SOL and the high edge poloidal Mach numbers...", F. Wagner, "A quarter-century of H-mode studies", PPCF 2007

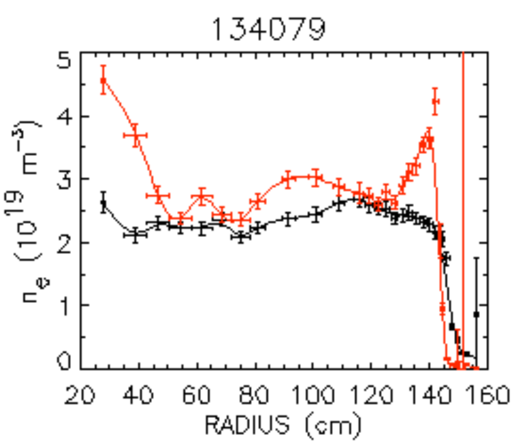
- Ultra-high speed GPI on NSTX is now one of the the best diagnostics to probe the L-H transition trigger physics

  - two Phantom cameras viewing same GPI image
  - framing rate up to 300,000 frames/sec @ 4 μs/frame
  - can record thousands of frames around transition time

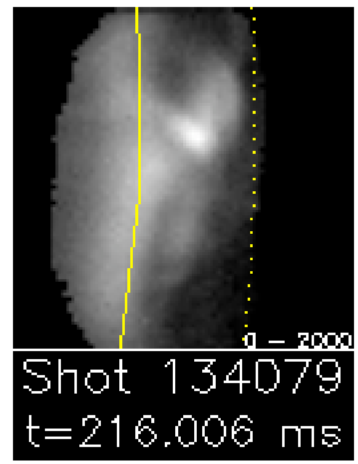
Ultra-high Speed Movie of L-H



density
before &
after this
transition



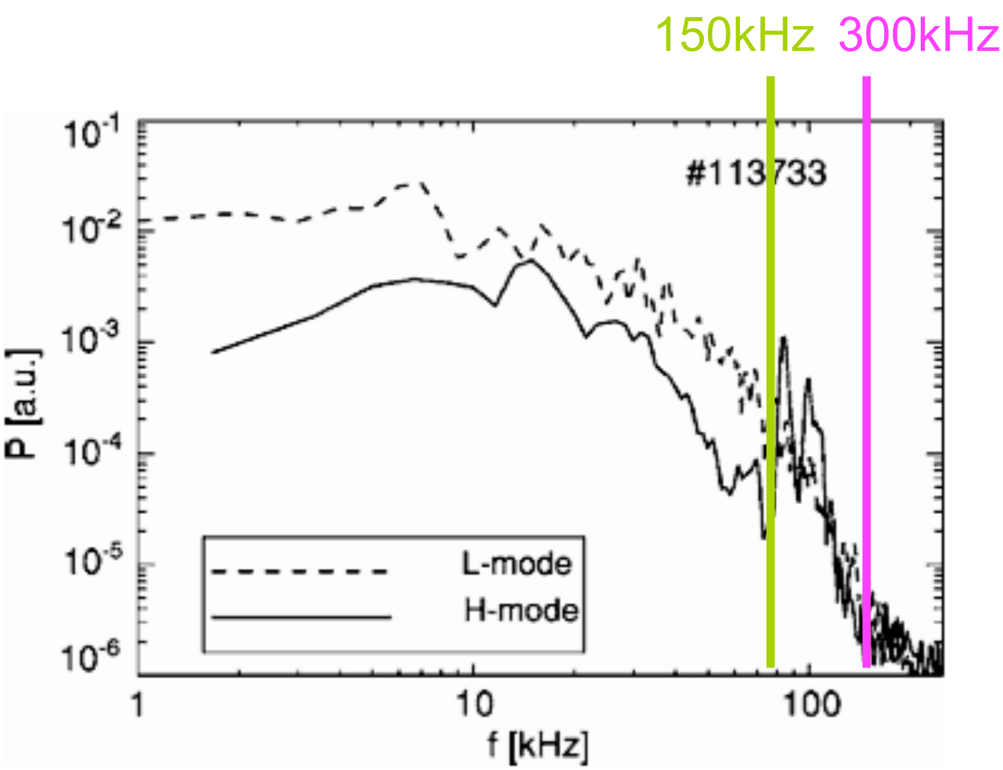
Phantom 7.3+7.1
(Maqueda)



234k frames/sec
4 μs/frame
64 x 64 pixels
20 cm x 20 cm

Sampling in Frequency Space

- Camera at 150 kHz is somewhat "under-sampling"
- Cameras at 300 kHz should be adequately sampling



M. Agostini, S.J. Zweben et al

"Study of statistical properties of edge turbulence in NSTX with the gas puff imaging diagnostic"

Physics of Plasmas 102305 (2007)

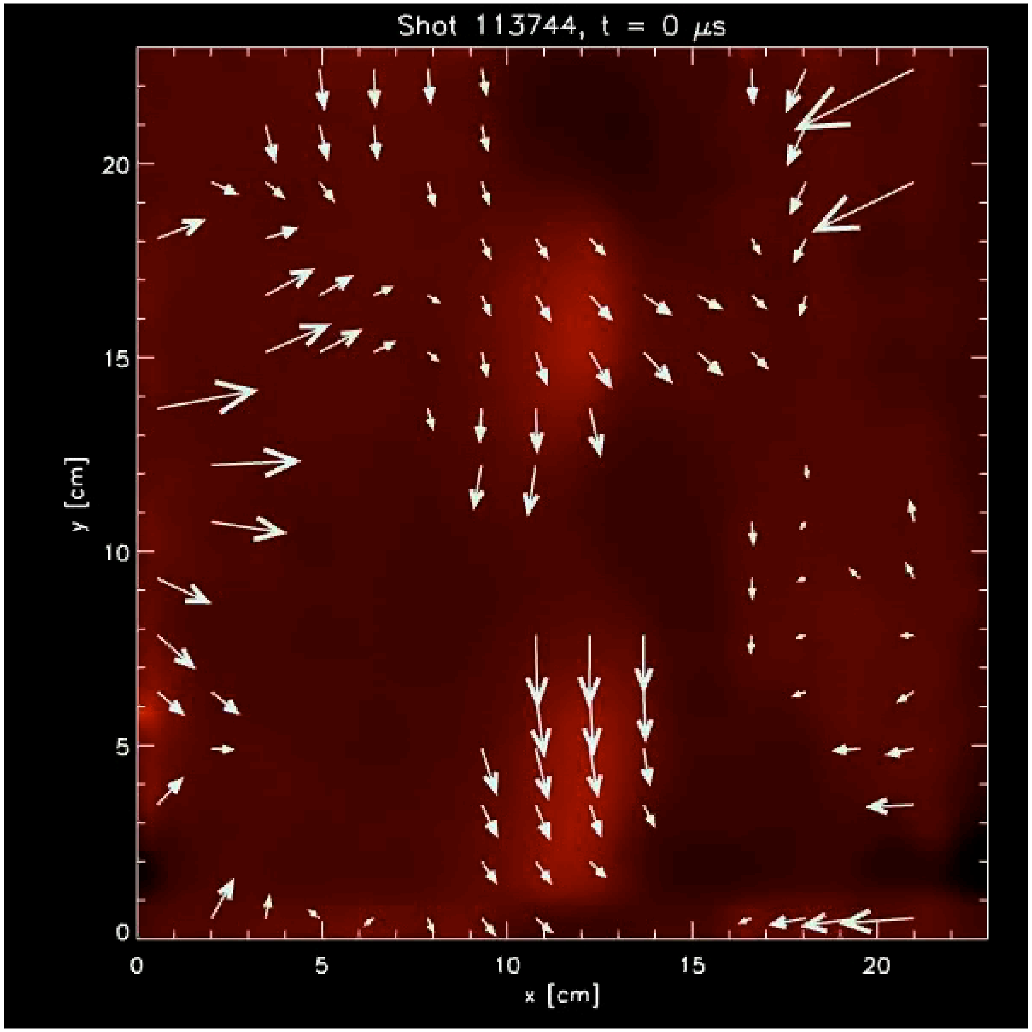
Analysis of Images

Can analyze with (~ 4 μs, 1 cm) resolution over GPI grid:

- Fluctuation level vs. radius (in D_α ~ ñ/n)
- Radial and poloidal correlation lengths
- Autocorrelation times and spectra
- Local turbulence flow velocity in 2-D
- Zonal flows and/or GAMs (if present)
- Local shearing criterion (all terms !)
- Nonlinear mode coupling (bicoherence)
- Shapes of structures (e.g. tilting, shearing)
- Turbulence radial propagation (≥ r/a ~ 1)

2-D Velocity Field Analysis (Munsat)

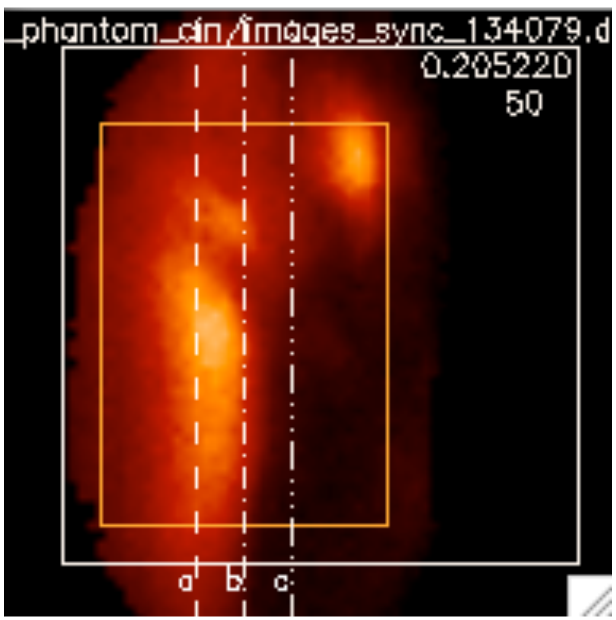
- Combination of **Optical Flow** and **Pattern Correlation** techniques used to derive velocity fields from image frames
- Match structure evolution, trajectories, etc. to evolving models
- Characterize turbulent plasmas and assess intermittent transport
- Derive higher-order statistics from dense flow fields

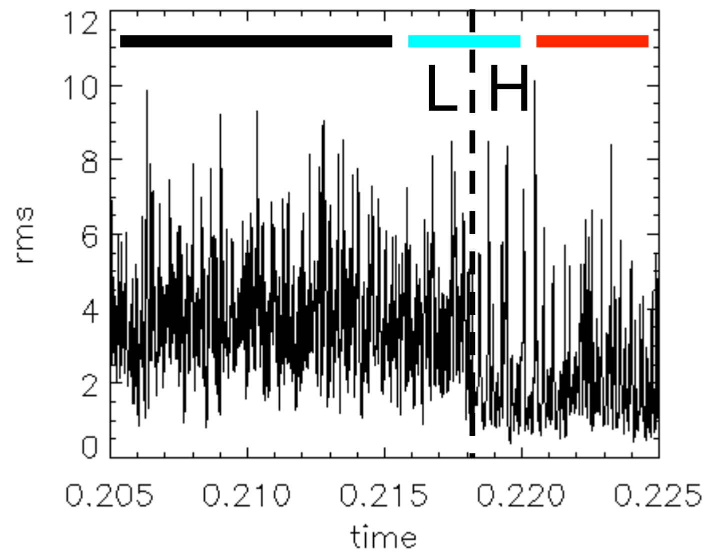


Preliminary Analysis of Shear

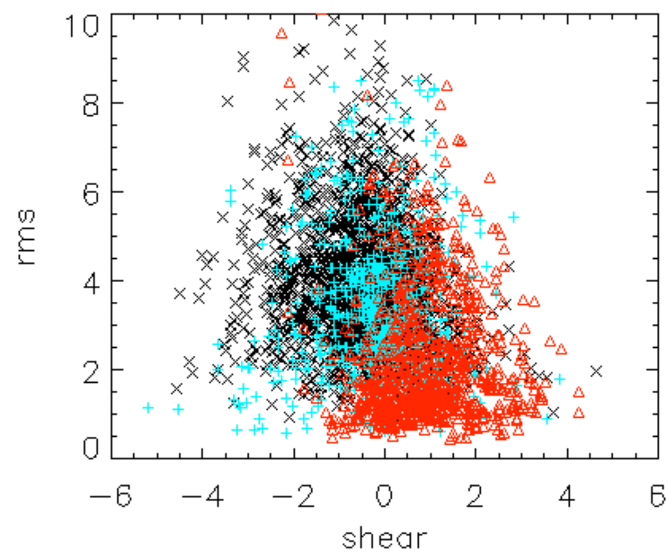
shear = $(dV_p/dr)\,(L_r/L_p)\,\tau$

evaluated at each radius





r = b



r = b

XP Idea and Plan

- Use optical beam splitter to look at same image with two Phantom 7.3 cameras, one delayed by 1/2 frame, to get x2 the present framing rate ~300,000 frames/sec
- Repeat same shot (#132959) to capture ~ 10 transitions
- Vary only the GPI puff strength (as needed for clarity)
- Piggyback all fast diagnostics (reflectometer, FireTip, USXR, magnetics, IRTV etc)
- Get as much edge profile data as possible (ERD, CHERS, bolometry etc)