

# Quiet Periods in Edge Turbulence Preceding the L-H Transition in NSTX

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*What triggers the L-H transition in NSTX ?*

also thanks to: R. Bell, C.S. Chang, E.D. Fredrickson, T.S. Hahm, S. Kubota,  
B. LeBlanc, K.C. Lee, D.A. Russell, S. Sabbagh, and K. Tritz

# Outline and Summary

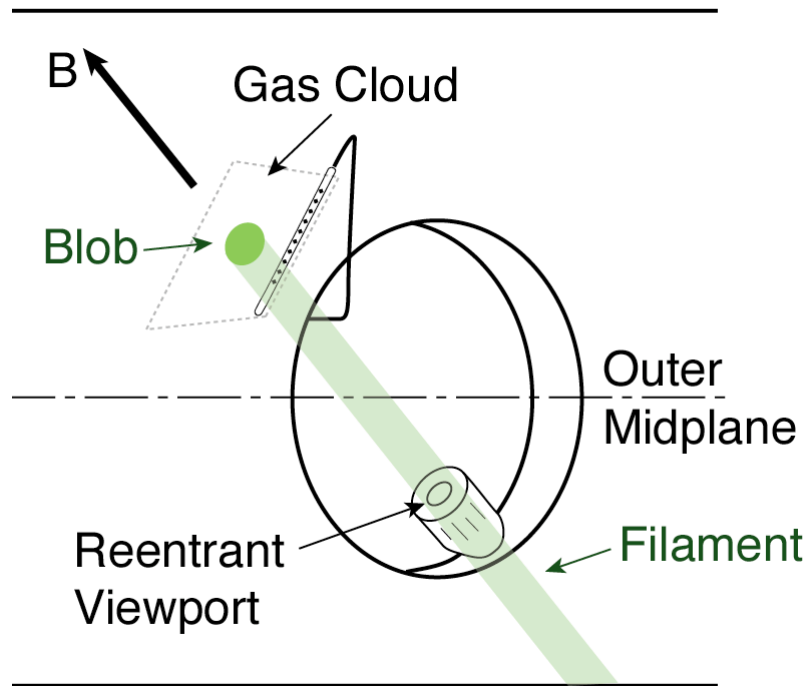
- Ultra-fast GPI movies of L-H transition (XP #929)
- Quiet periods observed preceding L-H transition
- Estimate of poloidal shear flow from turbulence
- Theory and directions for further data analysis

=> the 'quiet periods' do *not* appear to trigger L-H transition

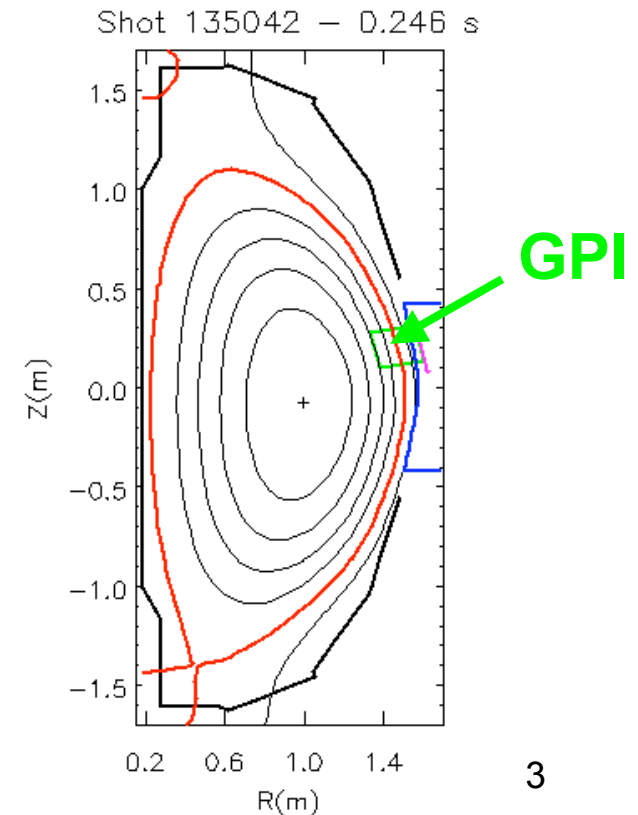
=> local shear flow does *not* appear to trigger L-H transition

# Gas Puff Imaging Diagnostic on NSTX

- Views  $D_\alpha$  light along B to get 2D radial vs. poloidal view
- Turbulence structure and motion derived using  $D_\alpha(n, T_e)$

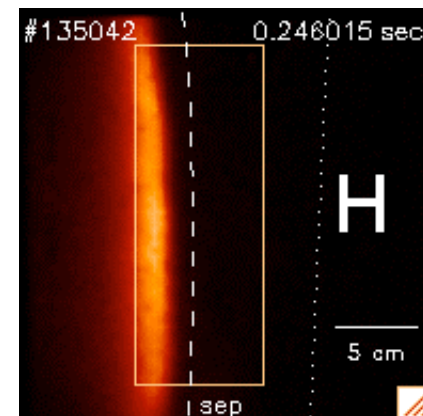
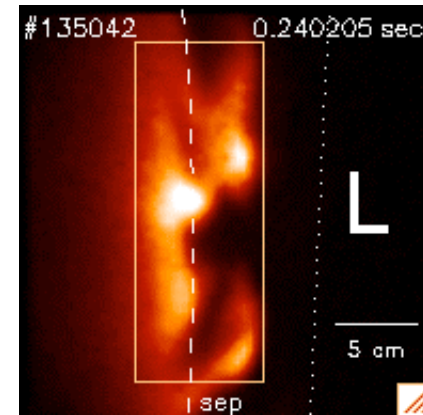
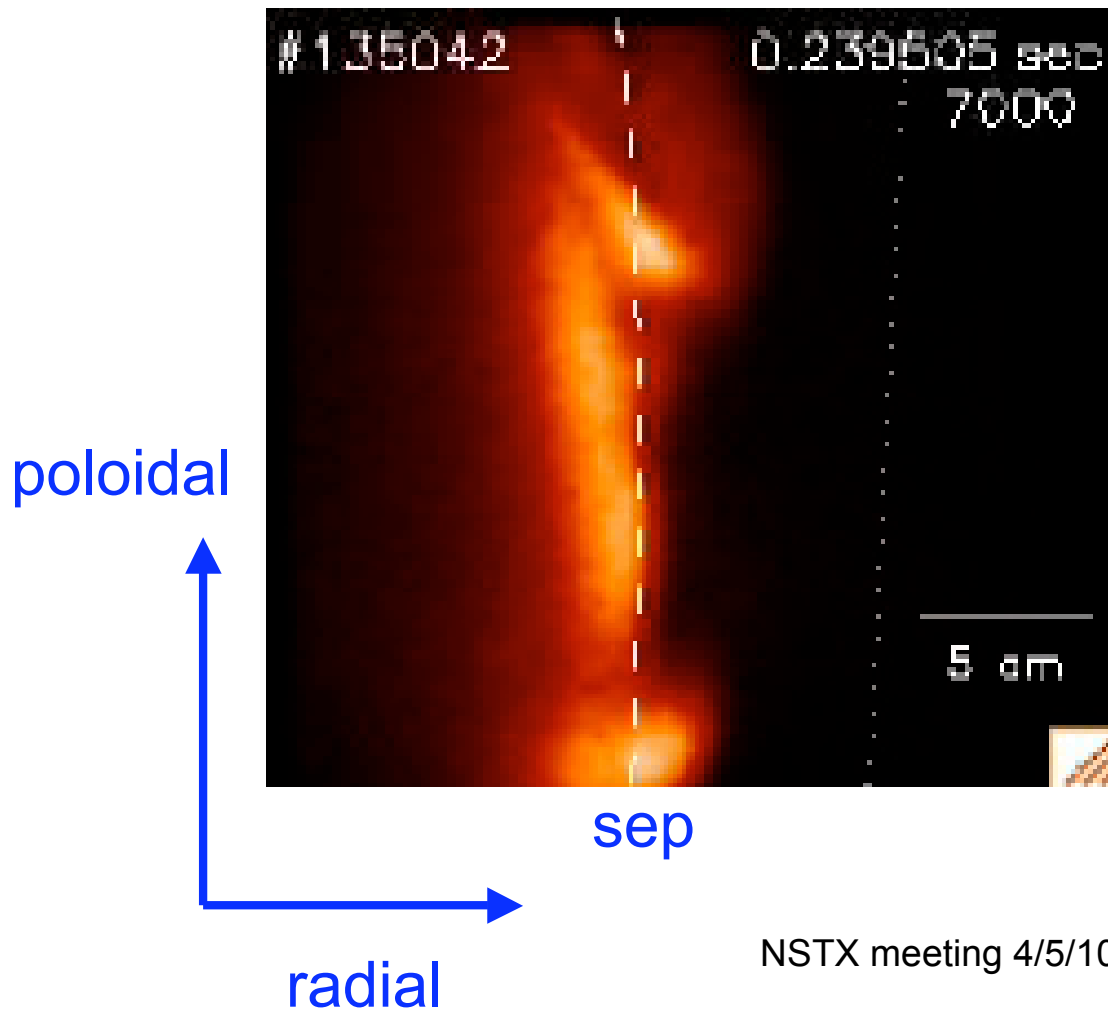


NSTX meeting 4/5/10



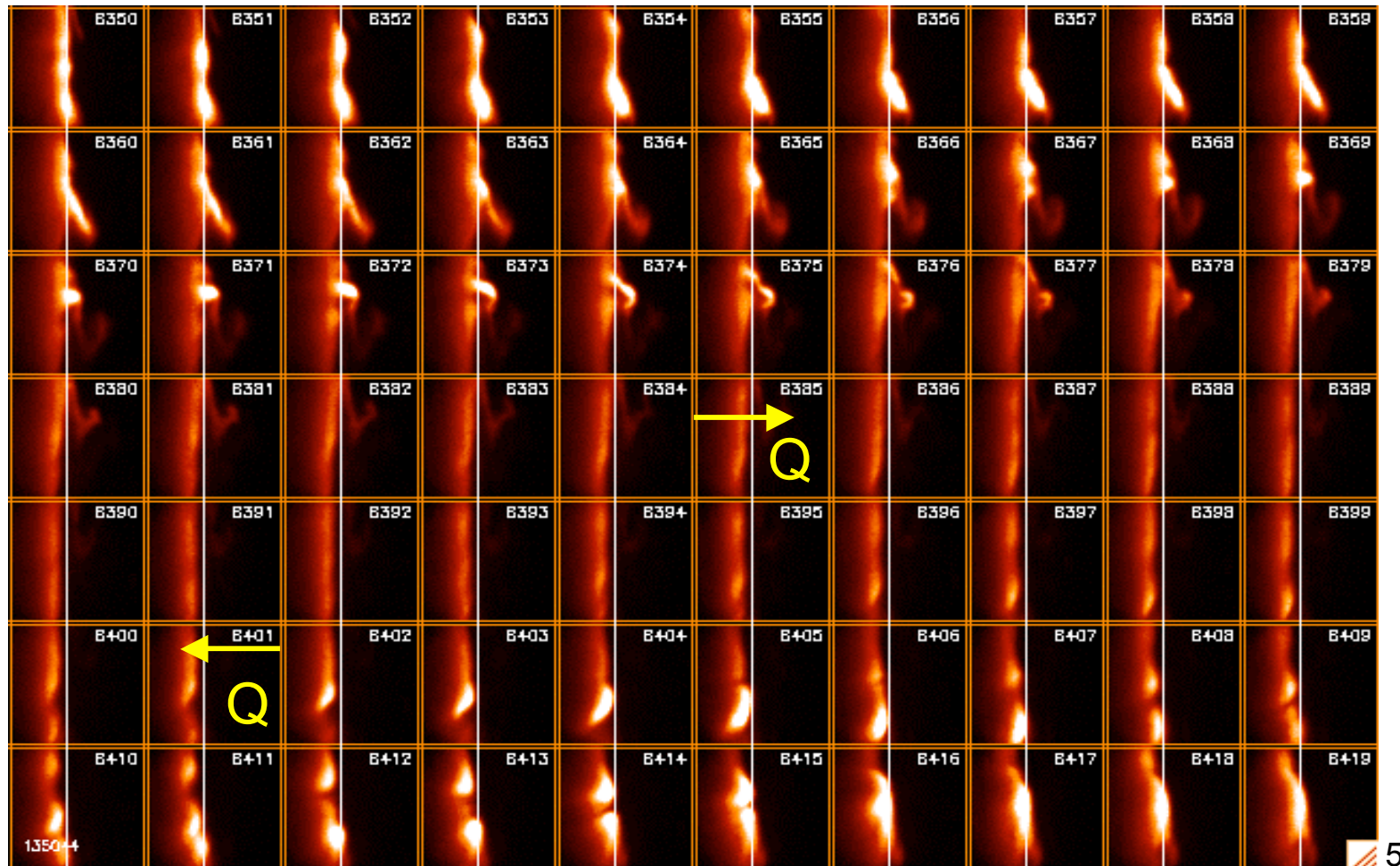
# GPI Images Across L-H Transition

~100  $\mu\text{s}/\text{sec}$  (285,000 frames/sec)



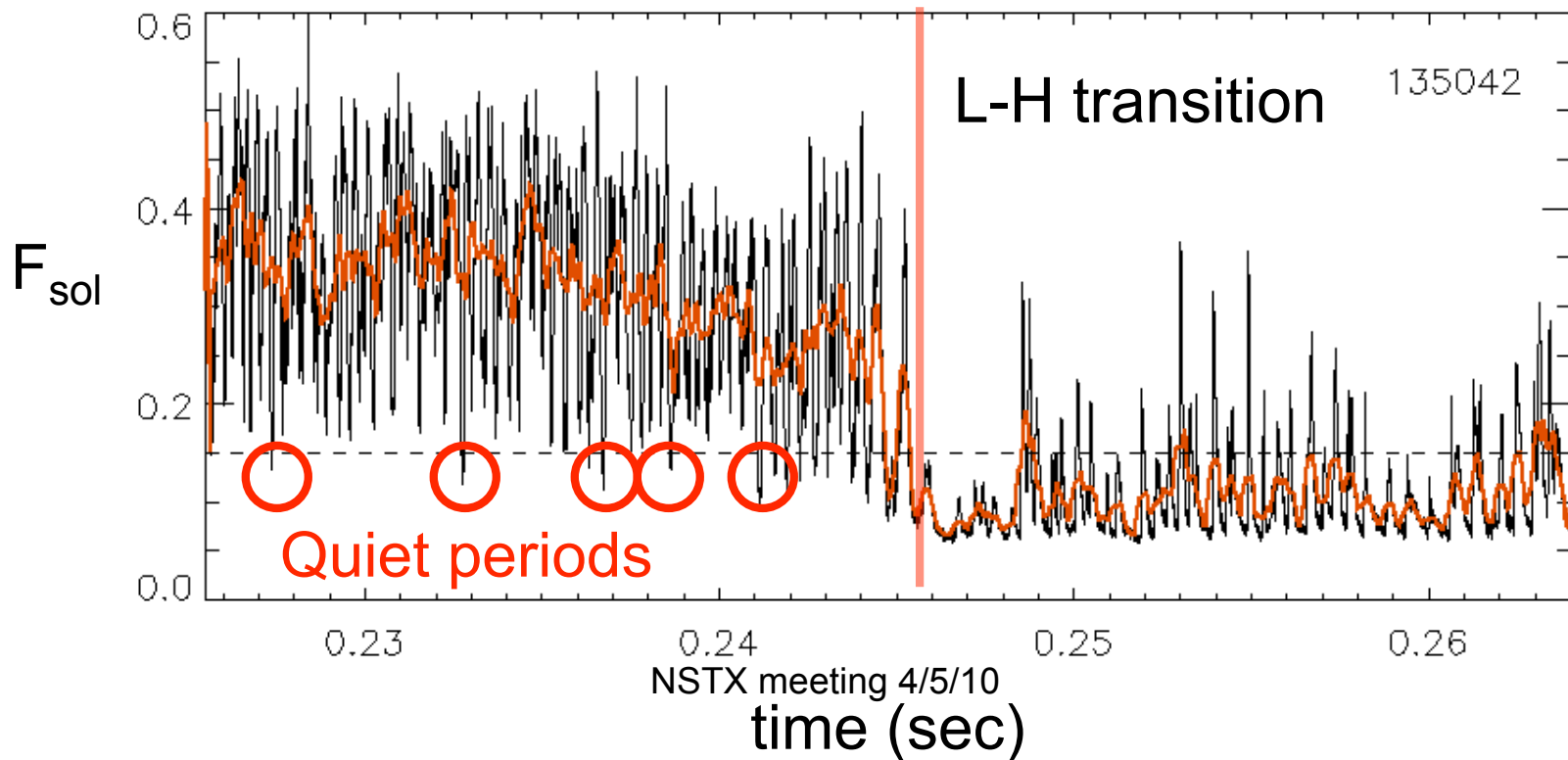
# Quiet Periods Preceding Transition

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



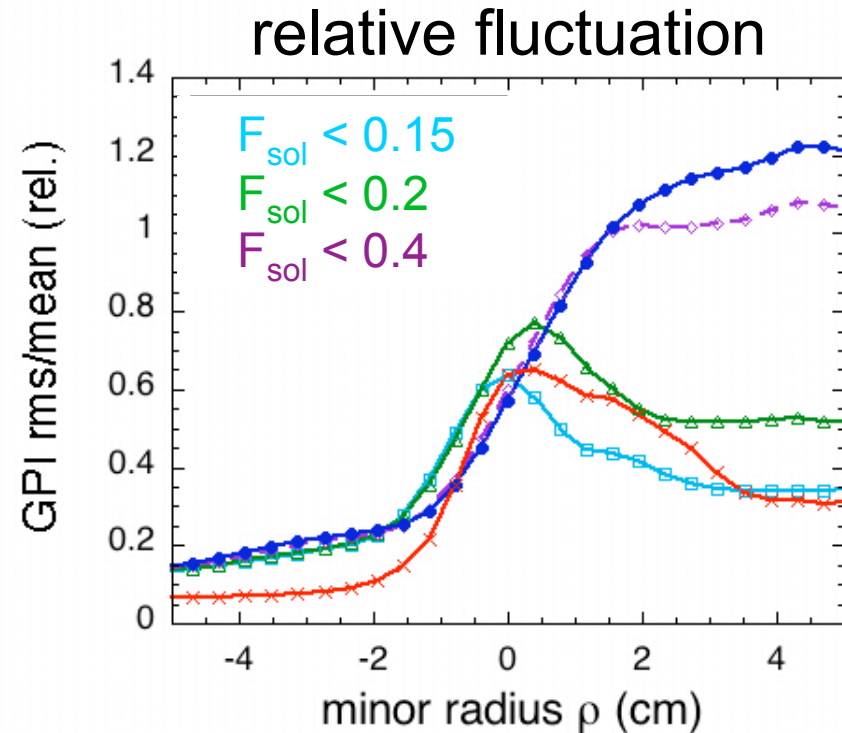
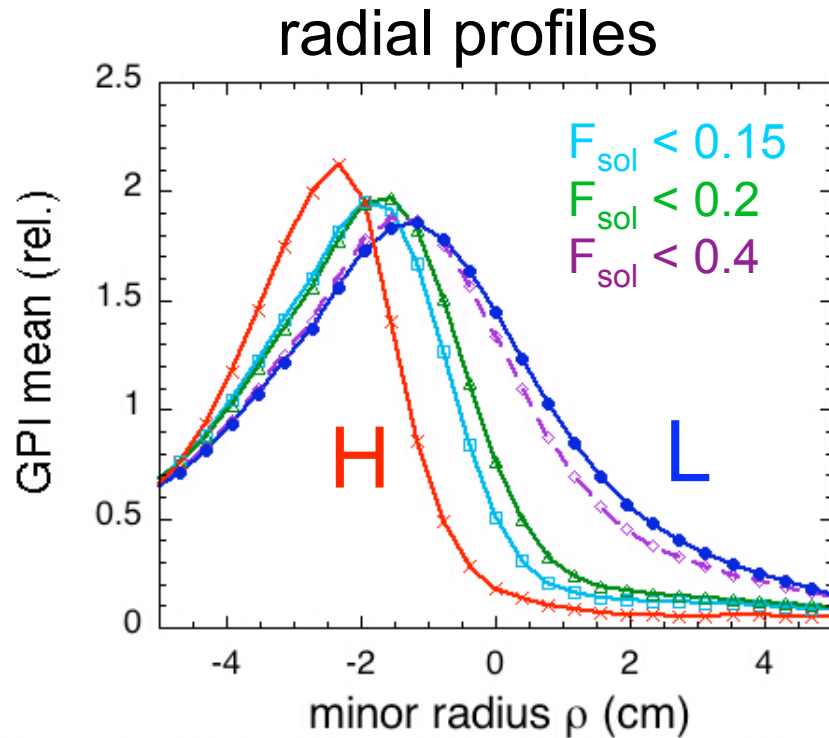
## Define “Scrape-off Layer Fraction”

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



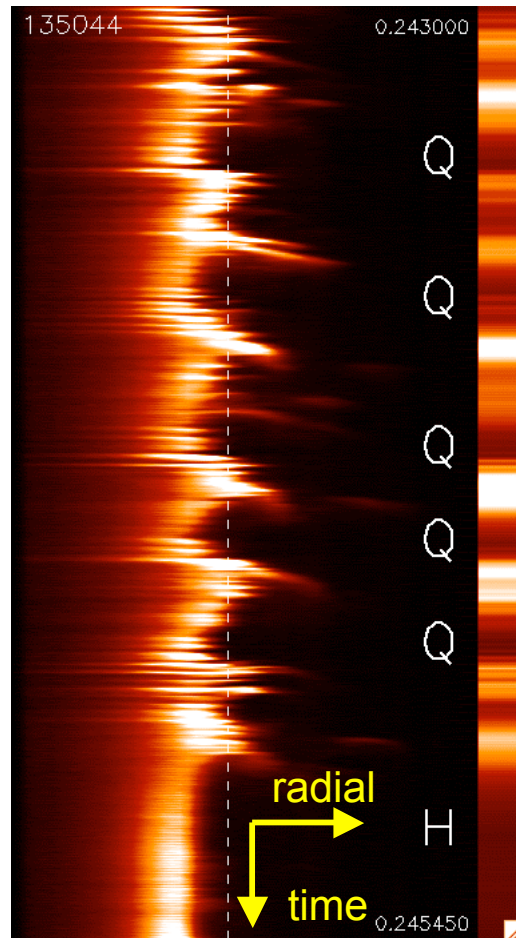
# Radial Profiles vs. $F_{sol}$

- GPI radial profiles and relative GPI fluctuation levels in L-mode for  $F_{sol} < 0.2$  look like those in H-mode

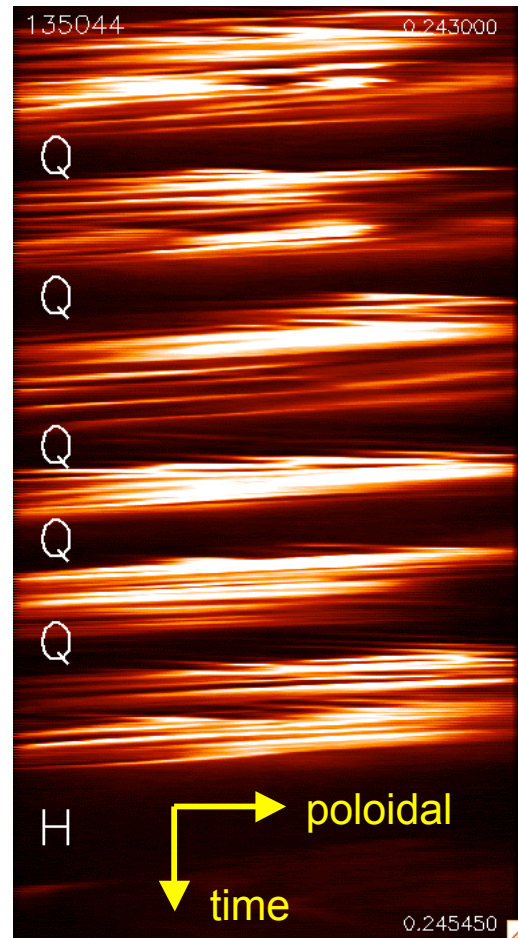


# Quiet Periods Across L-H Transition

(a) radial profile vs. time



(b) poloidal profile vs. time

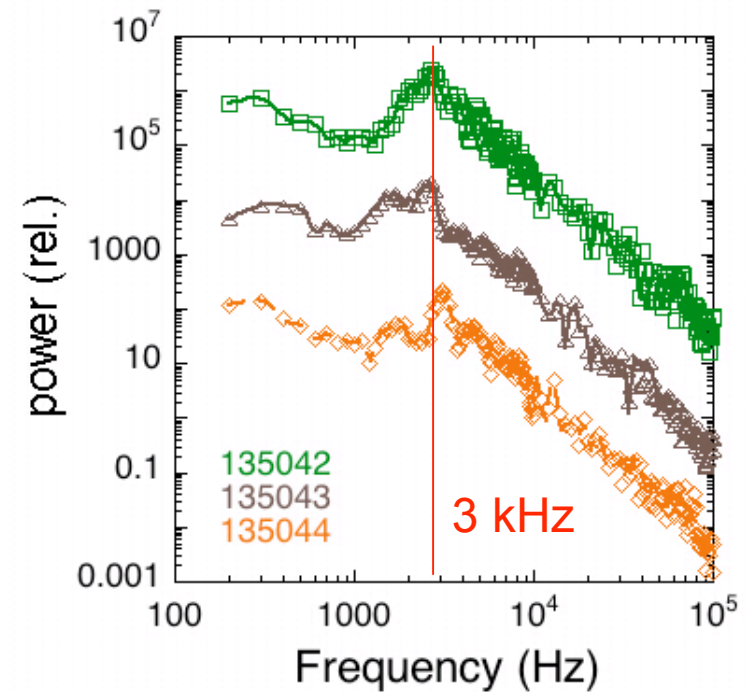
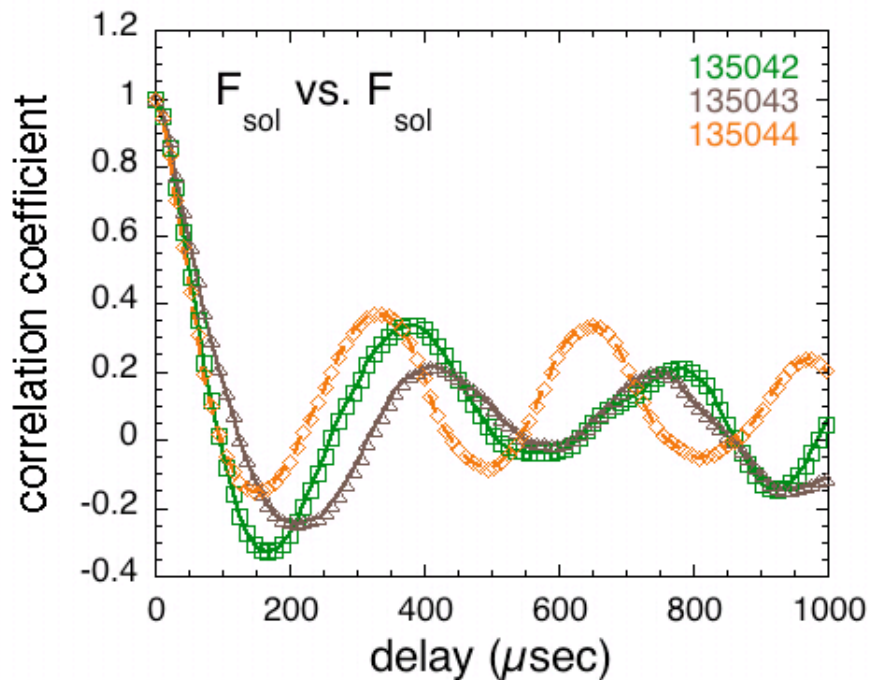


2.5 msec



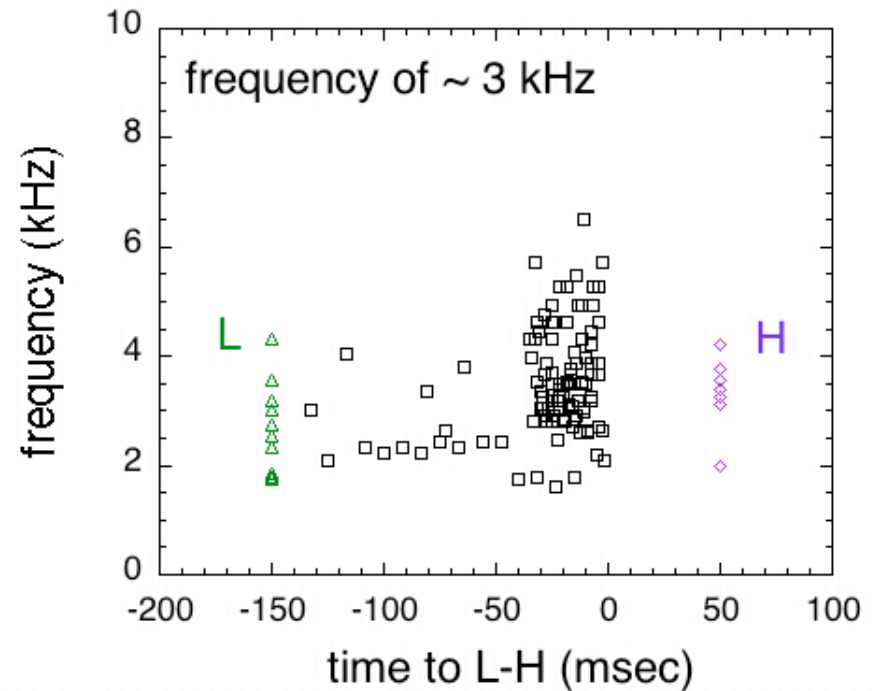
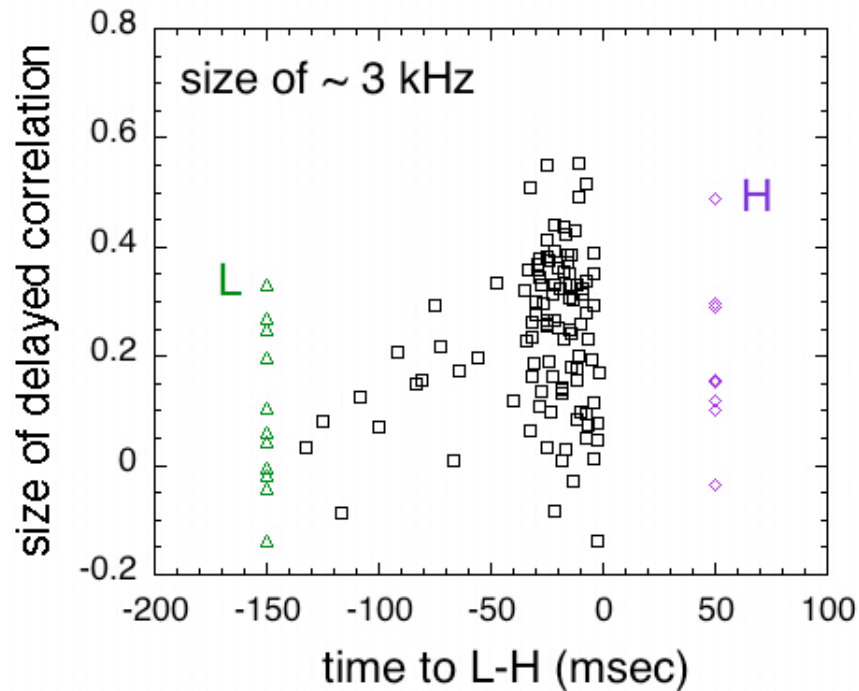
# Frequency of Quiet Periods

- Autocorrelation of  $F_{\text{sol}}$  shows quasi-periodicity of  $\sim 300 \mu\text{s}$
- Quiet periods have frequency of roughly  $\sim 3 \text{ kHz}$



# Duration of Quiet Periods

- Size and frequency of quiet periods is not changing before L-H transition, so does not appear to trigger transition



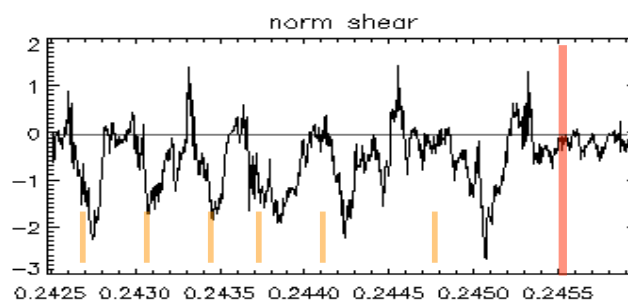
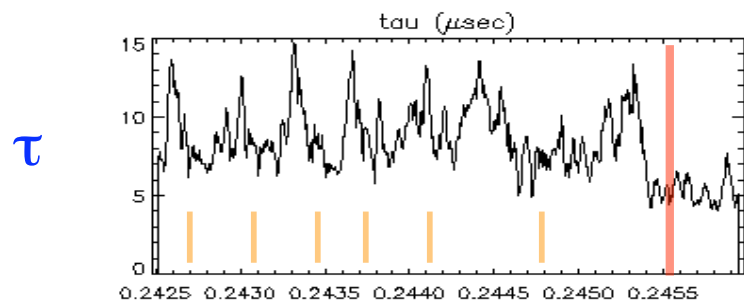
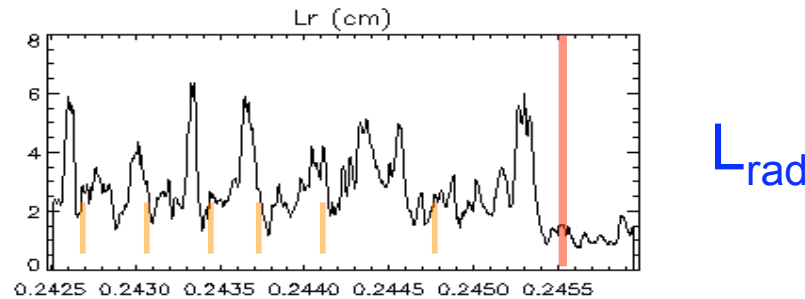
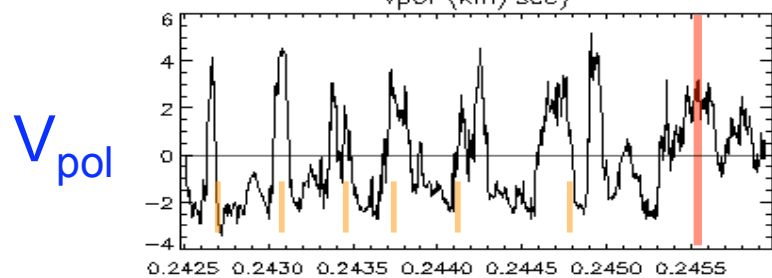
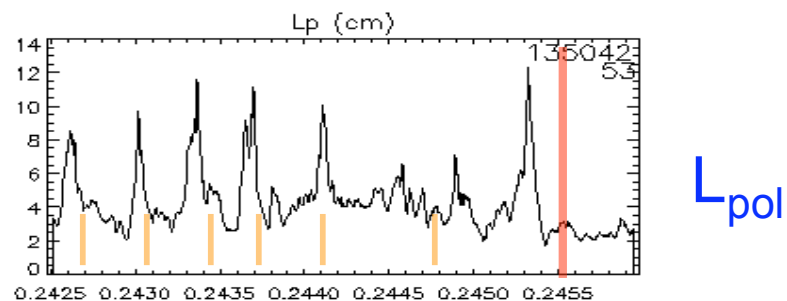
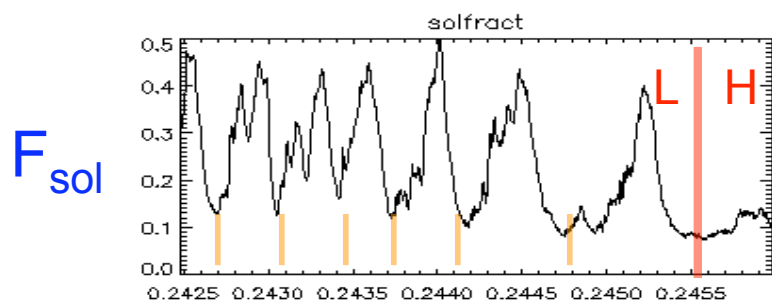
## Estimate of Shear Flow from GPI

- Dimensionless shear:  $S = (dV_{\text{pol}} / dr) (L_{\text{rad}} / L_{\text{pol}}) \tau$
- Scale lengths and times derived from correlation functions
- Poloidal velocity from delayed-time cross-correlations
- Average over  $\sim 40 \mu\text{sec}$ , and  $\sim 1.5 \text{ cm}$  radial for  $dV_{\text{pol}} / dr$
- $L_{\text{rad}} \sim 3 \text{ cm}$ ,  $L_{\text{pol}} \sim 4 \text{ cm}$ ,  $\tau \sim 8 \mu\text{sec}$ ,  $dV_{\text{pol}}/dr \sim \pm 10^5 \text{ sec}^{-1}$

$\Rightarrow S \sim \pm 1-2$  (interesting coincidence !?)

# Shear Preceding Transition ( $\rho \sim 0$ )

- $V_{\text{pol}}$  and  $S$  reverse sign during quiet periods ( $F_{\text{sol}} < 0.2$ )

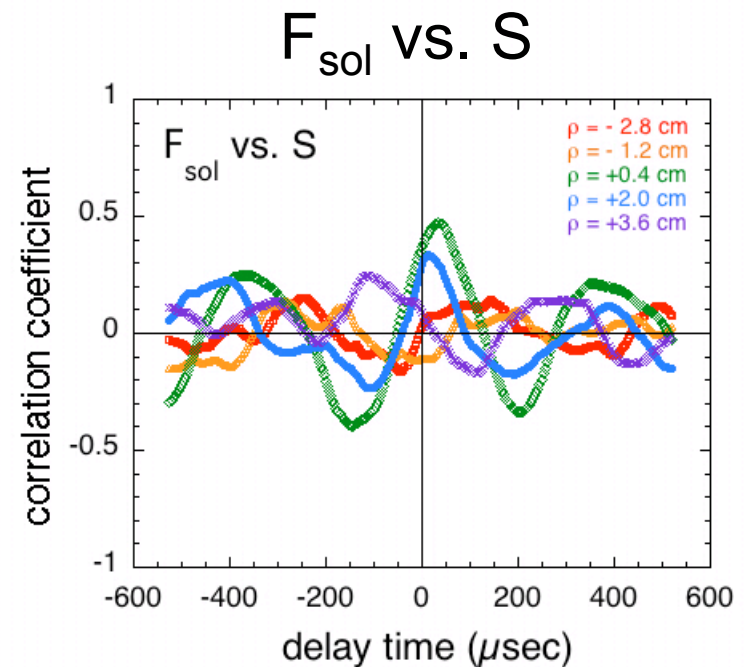
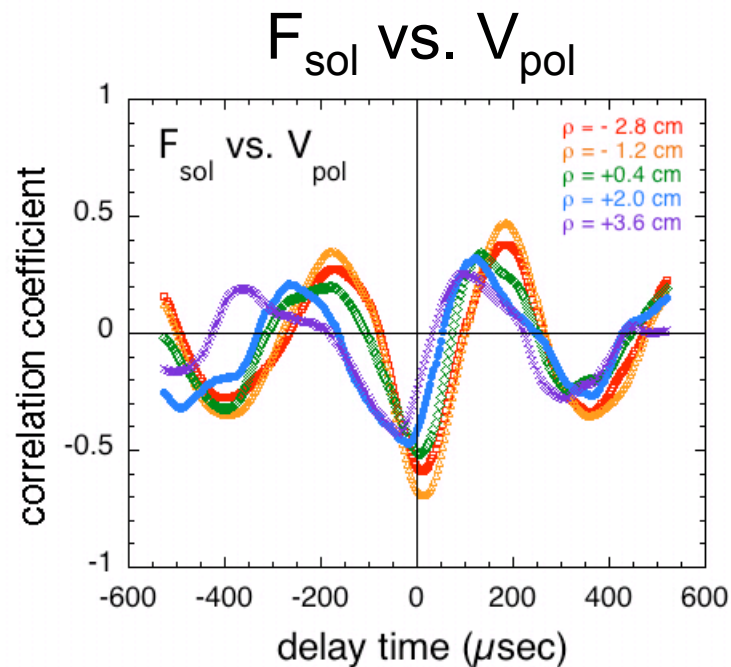


time

time

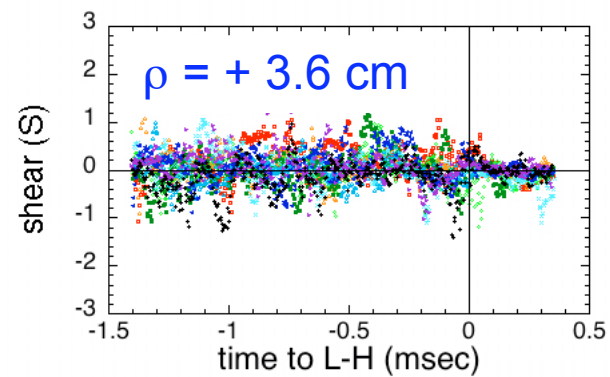
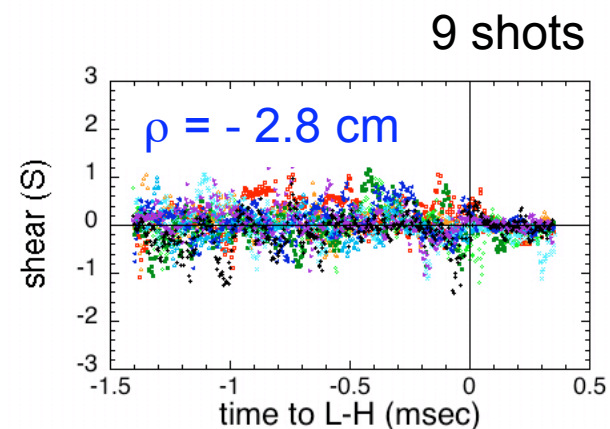
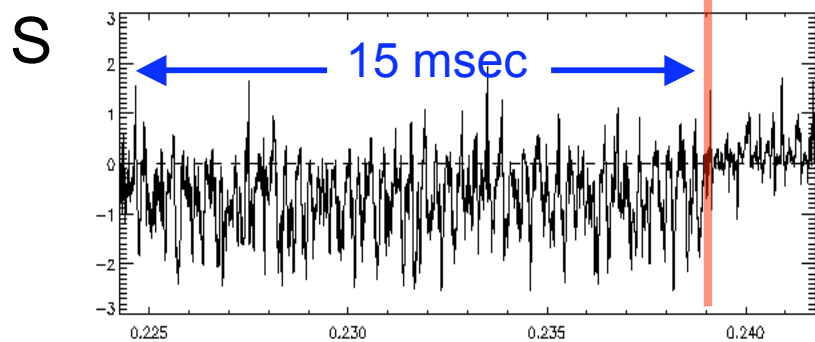
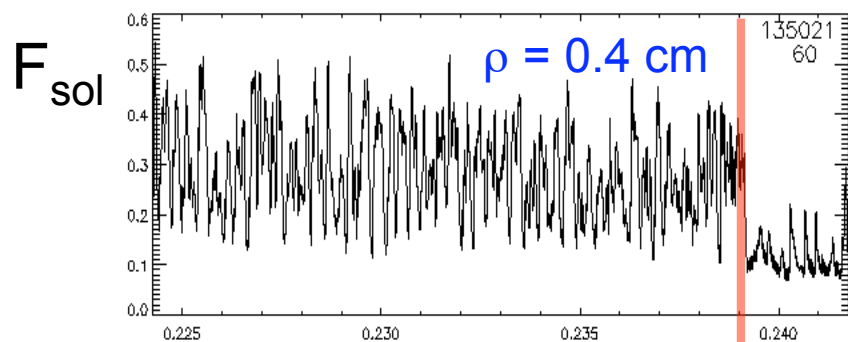
# Correlation of $F_{\text{sol}}$ with $V_{\text{pol}}$ and $S$

- $V_{\text{pol}} \sim 50\%$  correlated with  $F_{\text{sol}}$ , phase varying with radius
- $S \sim 40\%$  correlated with  $F_{\text{sol}}$ , but mainly near  $\rho \sim 0-2$  cm



# Shear Preceding Transition

- Turbulence shear  $S$  is not changing before L-H transition, so does not appear to trigger transition



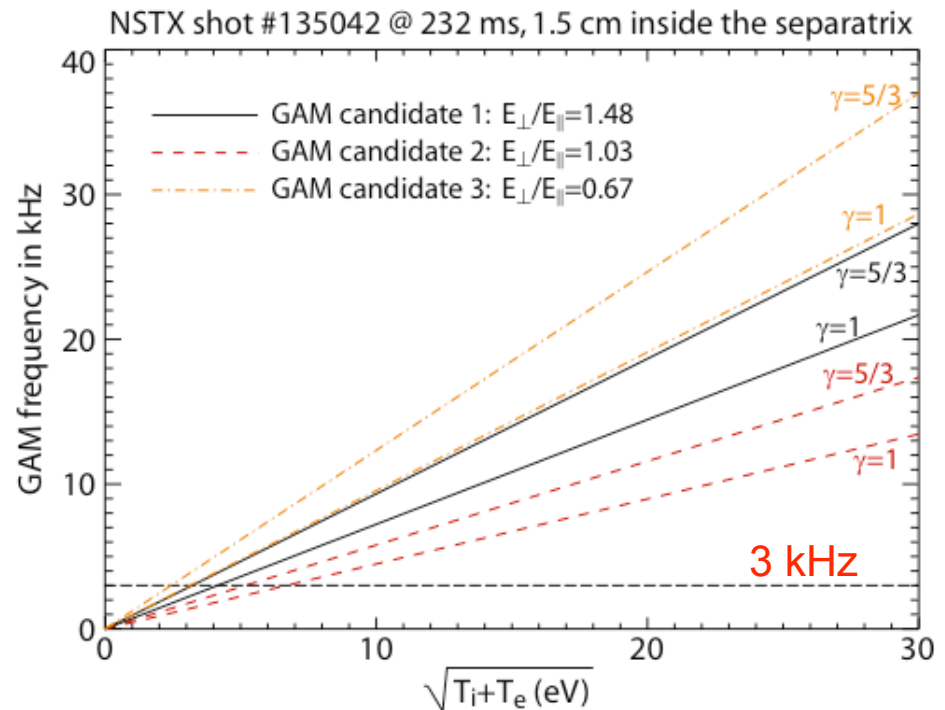
# Geodesic Acoustic Mode (GAM) Analysis

*R. Hager, K. Hallatschek, IPP Garching*

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

- linear simulations show three GAM candidates for NSTX #135042

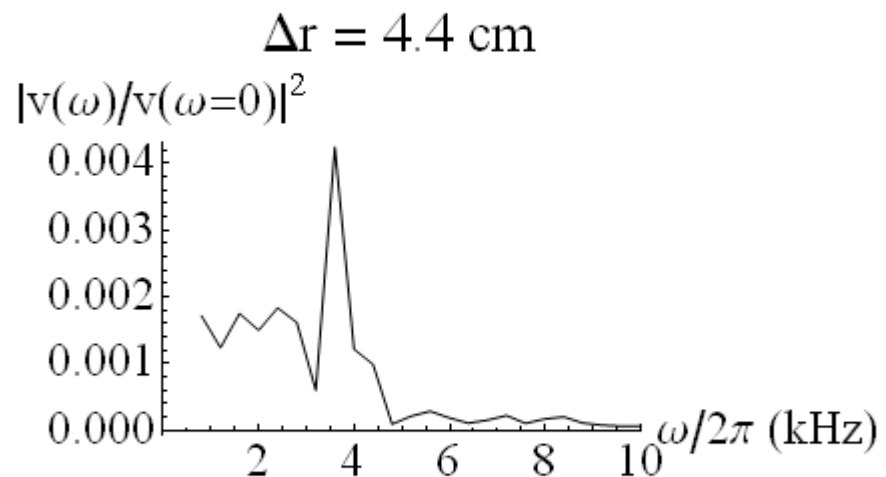
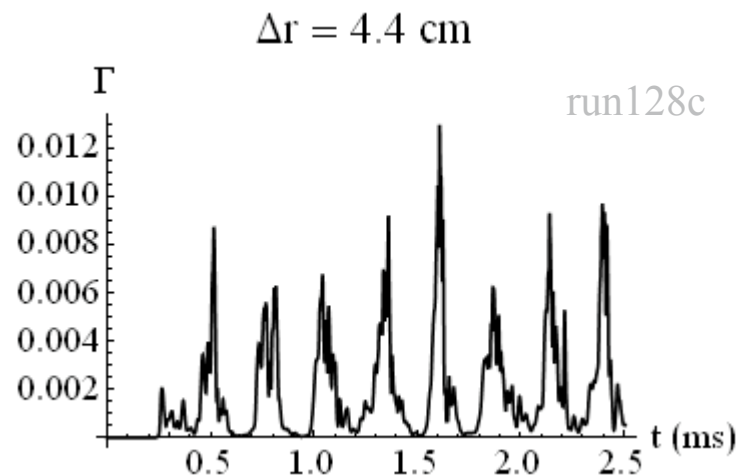
- nonlinear simulations show low frequency mode (red) excited at  $\sim 6.3$  kHz for  $T_i + T_e \sim 100$  eV



# Edge Zonal Flow Analysis

*T.S. Hahm, PPPL, D.A. Russell, Lodestar*

- Zonal flow expected from theory at  $f \sim v_{ii}(R/a) \sim 3$  kHz (assuming  $n=10^{13}$  cm<sup>-3</sup>,  $T_i=50$  eV,  $\mu=2$ )
- SOLT 2-D simulation of NSTX shows ‘bursty’ behavior in SOL quasi-periodic  $V_{pol}$  modulation at  $\sim 4$  KHz (D.A. Russell et al Phys. Plasmas 16, 122304 (2009))

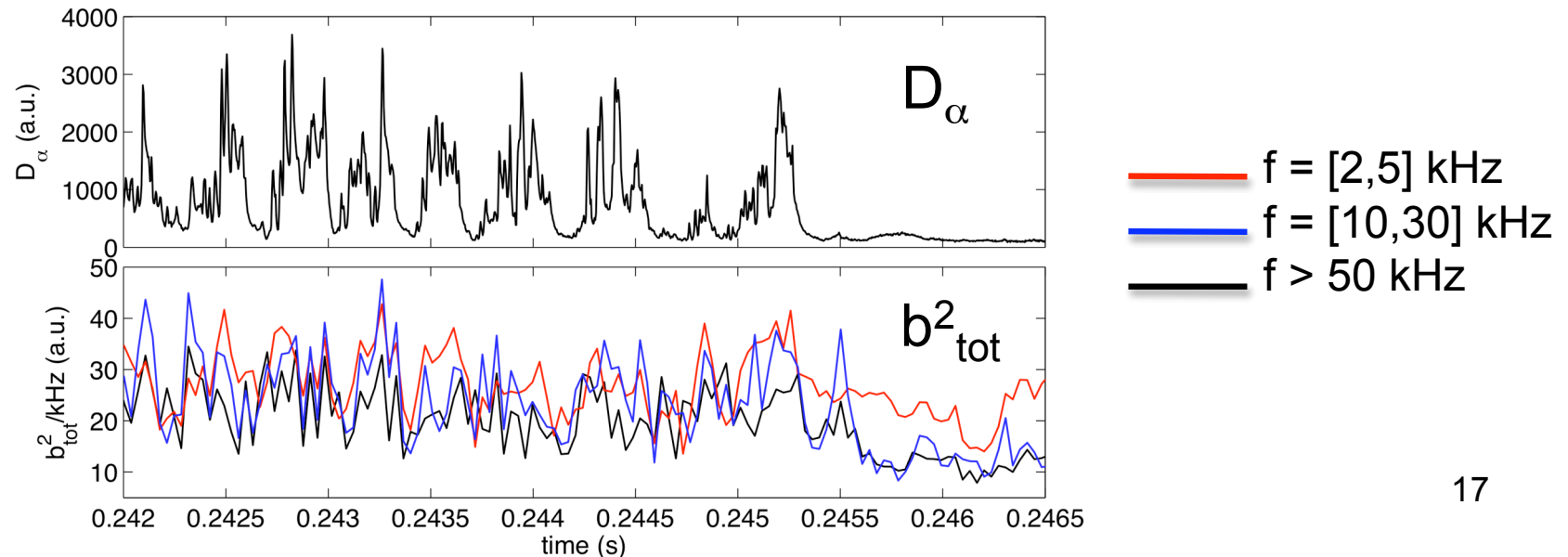




# Nonlinear Bicoherence Analysis

*F.M. Poli, U. Warwick*

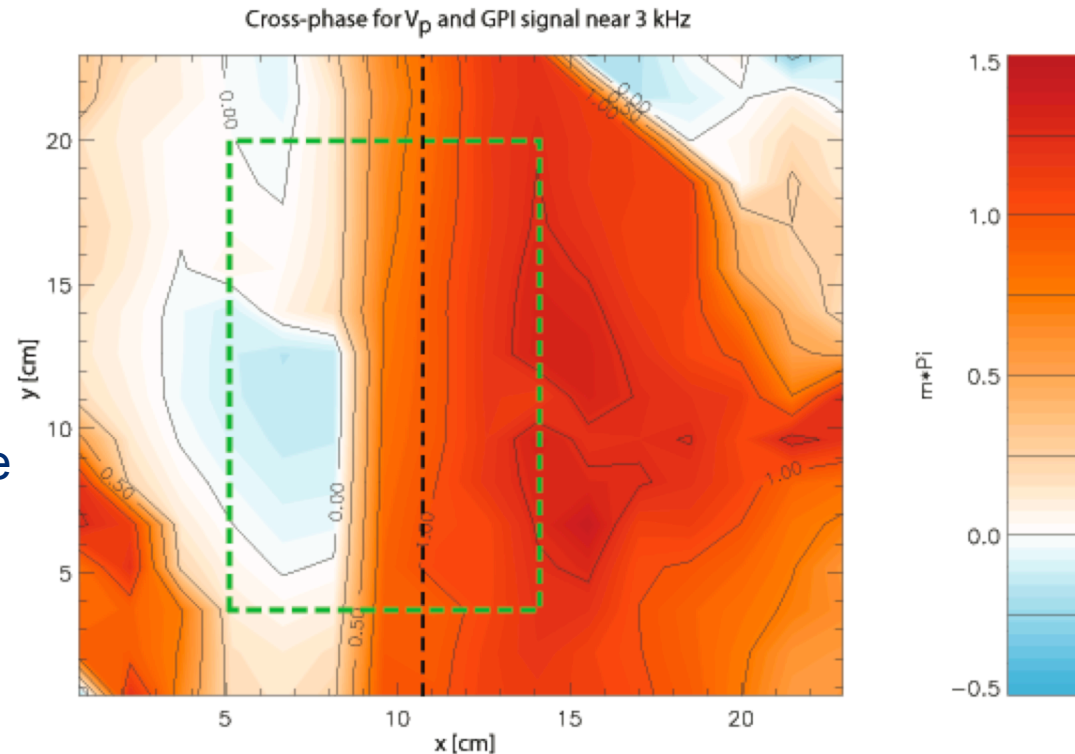
- Total bicoherence  $b^2_{\text{tot}}$  has minima during quiet periods in all frequency ranges until 2 ms before L-H transition
- Total bicoherence slightly increases  $\sim 0.5$  ms before transition in the low- to intermediate- frequency range



# Velocimetry Analysis

*Y. Sechrest, T. Munsat, U. Colorado*

- Advanced Pattern Matching Technique
  - Optimizes “error function” of correlation between local subsections of sequential GPI image pairs
- Able to study 2-D structure of time resolved turbulent flow
- Characterize properties of turbulent flow
  - Reynolds stress
  - Flow shear
  - Possible zonal flows
  - Vorticity and moments of flow



# Conclusions

- So far: “the role of turbulence in triggering the L-H transition must be considered open.” [G.R. Tynan et al, PPCF (2009)]
- Possibilities:
  - L-H transition is triggered by slow or slight changes
  - the trigger is non-local, i.e. outside GPI field of view
  - creative data analysis might yet identify the trigger