Motion of Edge Turbulence in NSTX

S.J. Zweben

NSTX PAC 2/23/06

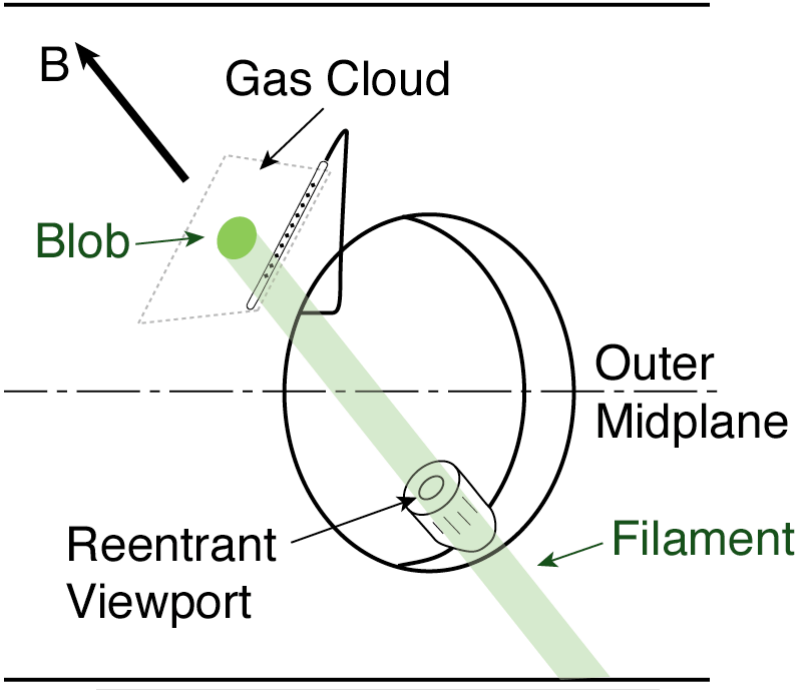
- Gas puff imaging diagnostic (GPI)
- GPI fluctuation data from NSTX
- Images from L-H transition
- Analysis via 2-point cross-correlation function
- Results on structure and motion
- Work in progress

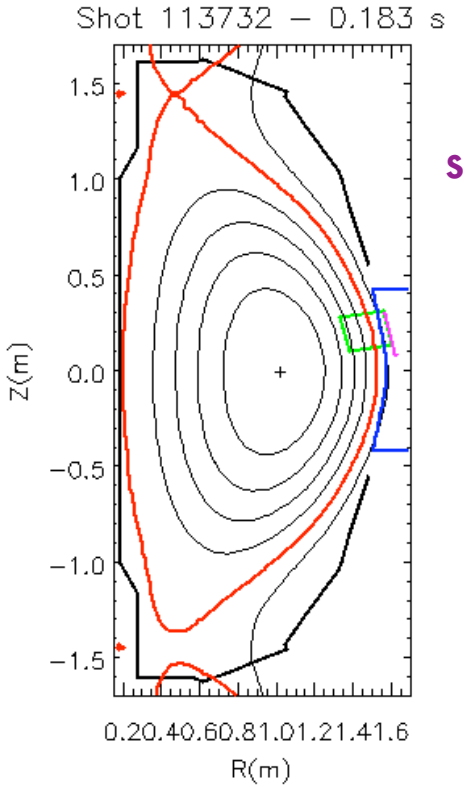
=> note: this analysis gives only *turbulence* flow,
not background plasma (ExB) flow !

Gas Puff Imaging (GPI) Diagnostic

- Looks at D_α line of neutral deuterium from a gas puff
- View ≈ along B field line to see 2-D structure ⊥ B

view from center column





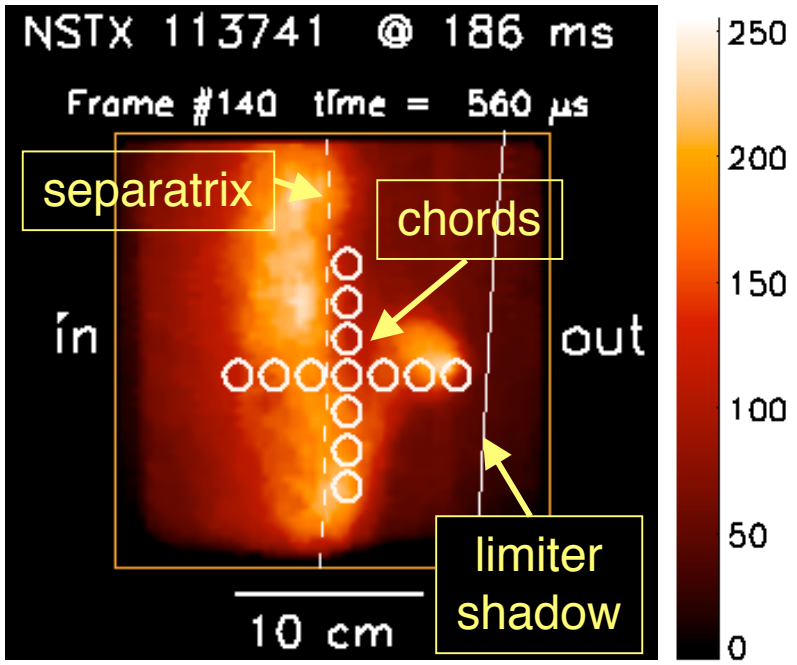
viewing area
≈ 25x25 cm
spatial resolution
≈ 1-2 cm

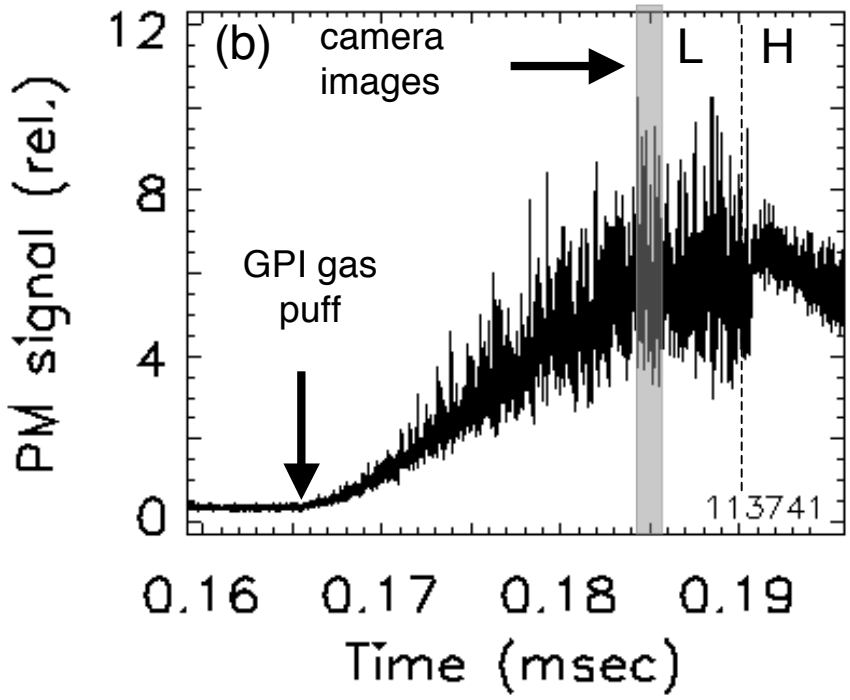
see: R.J. Maqueda et al, Rev. Sci. Inst. 2003

GPI Fluctuation Data in NSTX

- PSI-5 camera records 300 frames at ≤ 250,000 frames/sec with 64x64 pixels / frame => 1.2 msec of data per shot

- Additional PM tube array digitized radial vs. poloidal array at 500,000 Hz => 64 msec of data per shot





GPI Images During L-H Transition

L-H Transition

NSTX #113732

B=3.0 kG, I=780 kA, 2.0 MW NBI

$\langle n \rangle = 2.2 \times 10^{13}$ cm^{-3}

250,000 frames/sec

- large data set of images from 2004 run (≥ 300 shots)
- many on web: http://www.pppl.gov/~szweben/NSTX04

Analysis of Structure and Motion

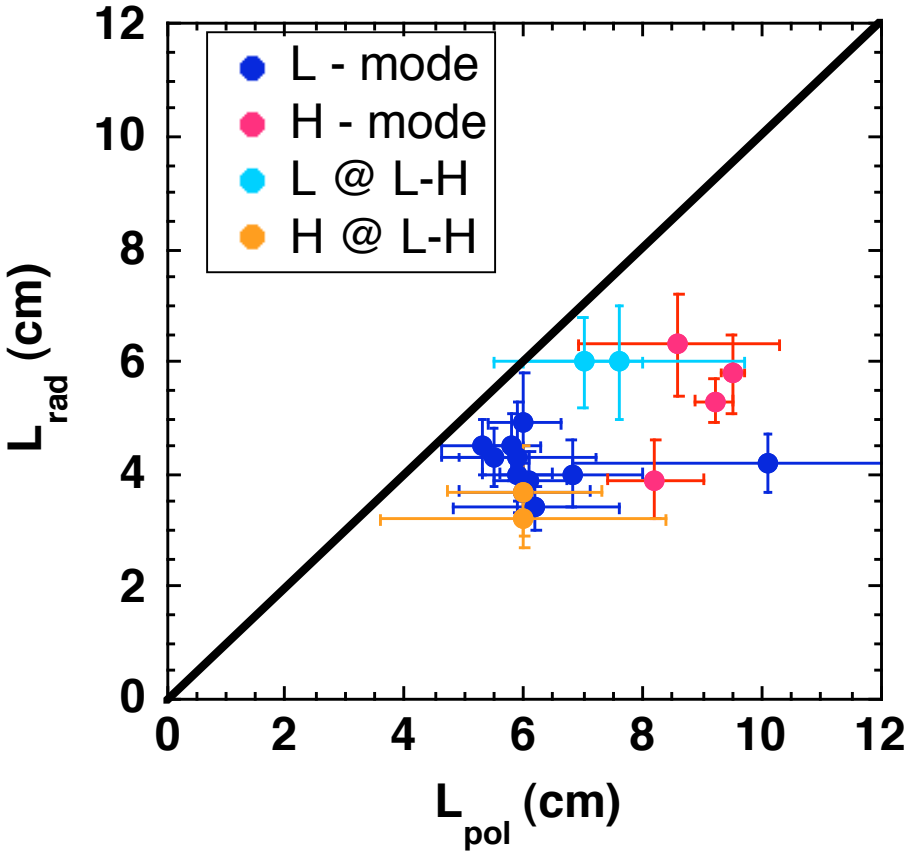
- Use simplest analysis via 2-point cross-correlation function of fluctuations in GPI light signals vs. space and time:

$$C(\Delta x, \Delta t) = \sum_{t} \tilde{S}_0(t)\, \tilde{S}_{\Delta x}(t+\Delta t)$$

- Correlation length from FWHM of $C(\Delta x, 0)$ [$\approx 1.6 \times \sigma_{Gaussian}$]
- Velocity from time the delay of the peak in $C(\Delta x, \Delta t)$ vs. Δx
- $C(\Delta x, \Delta t)$ averages over space and time spectrum of signals

2-D Turbulence Structure

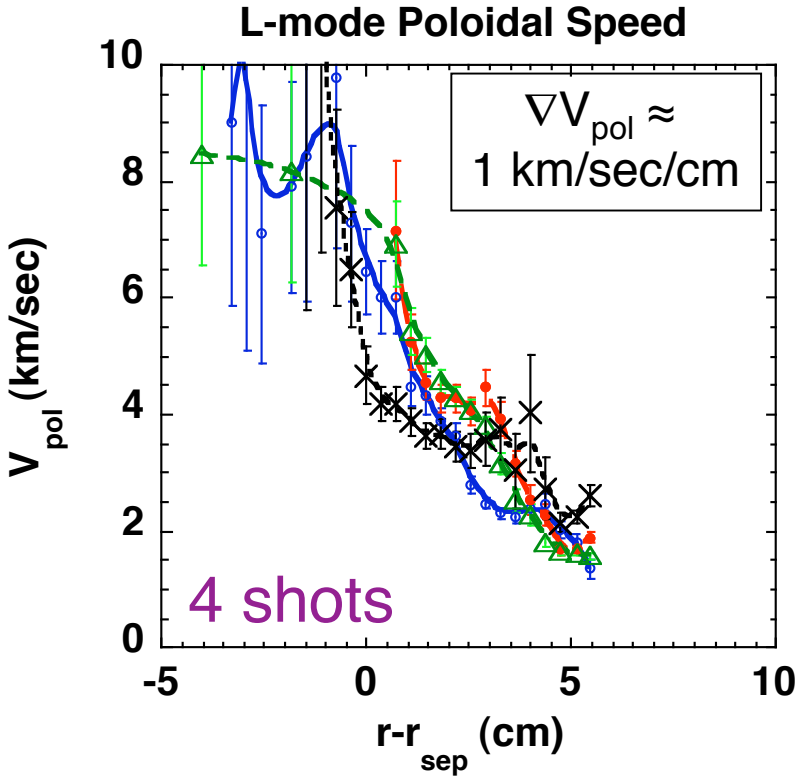
- Evaluated near radial peak of GPI signal ~ separatrix
- No statistically significant changes from L- to H-mode

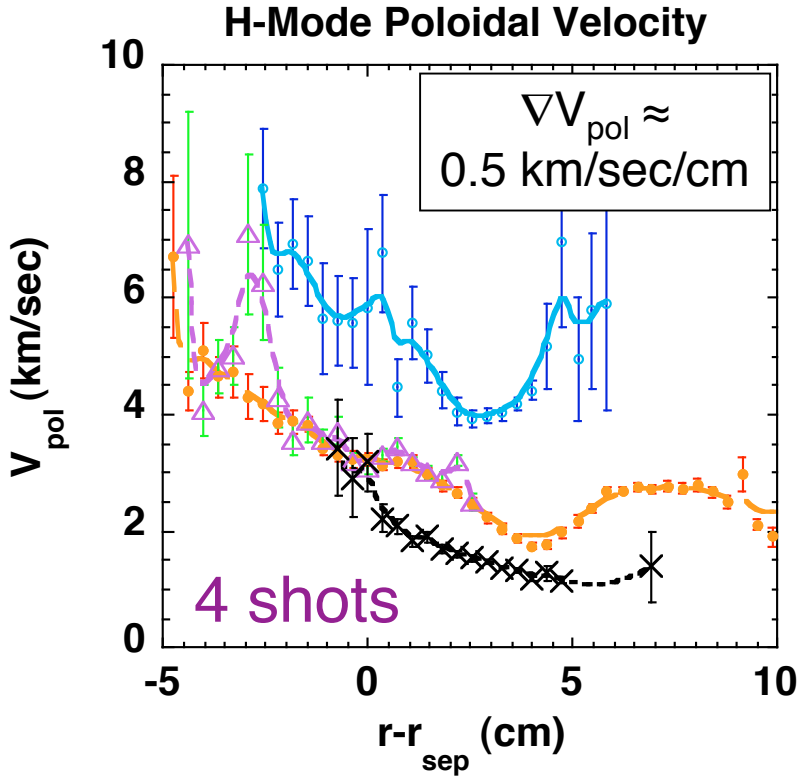


	L_{rad} (cm)	L_{pol} / L_{rad}
L	4.2±0.4	1.5±0.4
H	5.3±1.0	1.9±0.4

Poloidal Turbulence Motion

- Average flow is generally in ion diamagnetic drift direction
- V_{pol} gradient tend to be lower for H-mode than L-mode

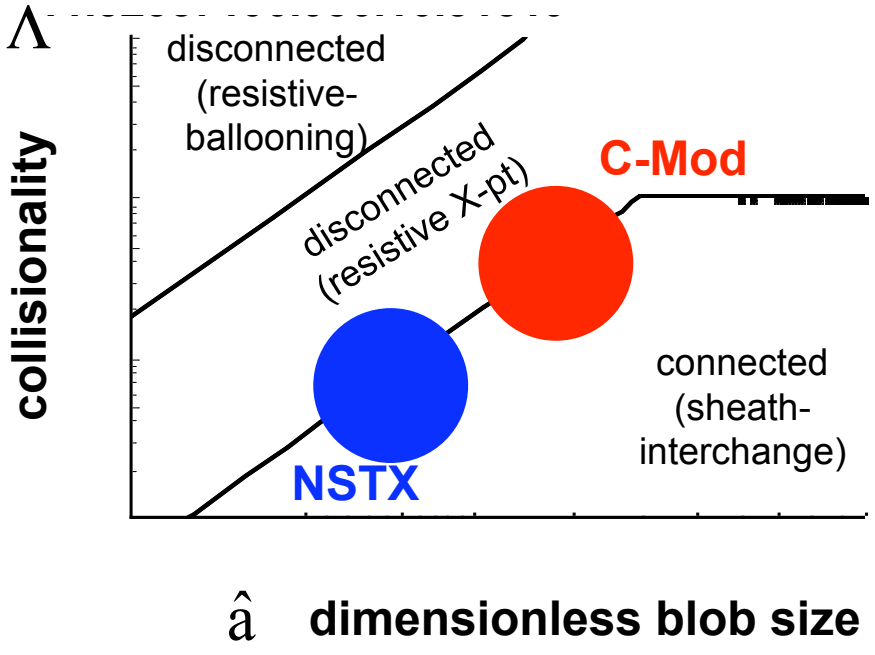




S.J. Zweben et al, to be published in Phys. Plasmas (2006)

Comparison with "Blob Model"

- Model for dynamics of isolated structures in SOL
- Explains similar radial velocity on NSTX and C-Mod



$$V_{rad} = 5.1\times10^{6}\,\frac{L_{\|}^{1/5}T_e^{7/10}}{B^{2/5}R^{3/5}}$$

~ 2 km/s in both
C-Mod & NSTX

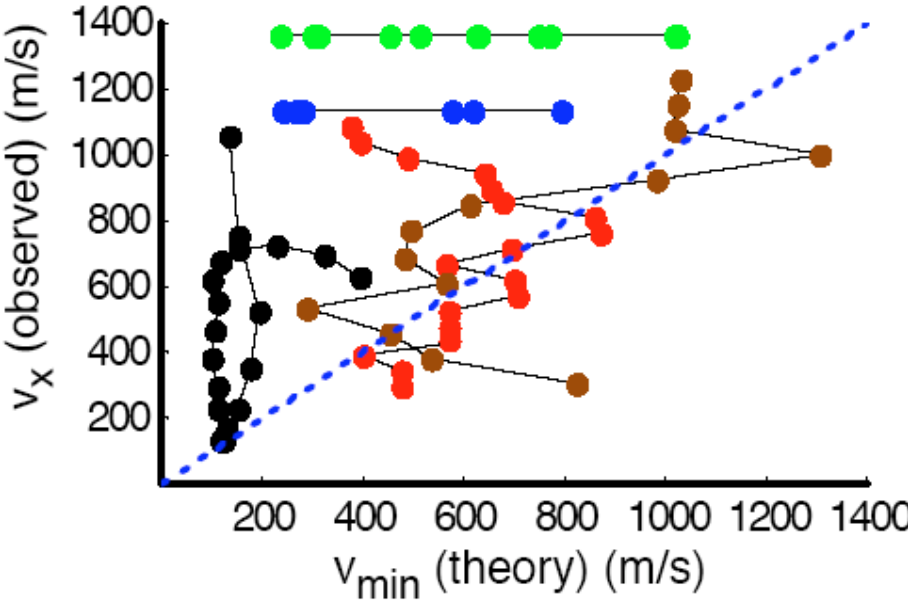
Myra et al, Poster RP1.00019
Thursday PM (NSTX)

Lodestar

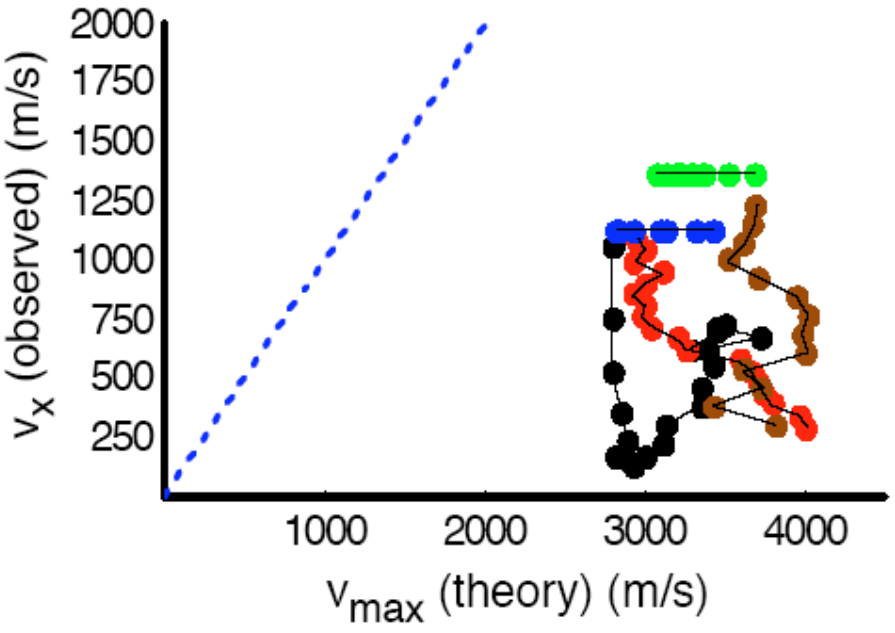
Comparison with NSTX Data

- Measure radial blob speed vs. time for one typical NSTX shot
- Compare with theory using some assumptions (Myra APS '05)

sheath-connected regime



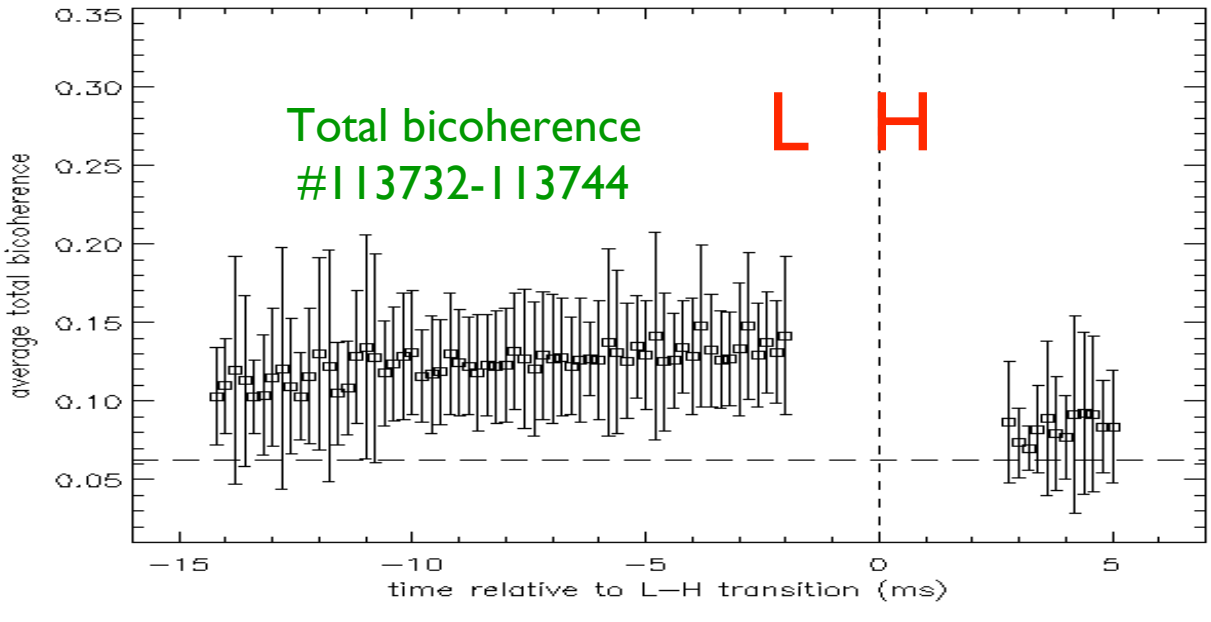
resistive ballooning regime



Bichoherence at L-H Transition

- An increase in total bicoherence, suggesting an increase in coupling between low frequency flows and high frequency turbulence, was seen at L-H transition DIII-D (Moyer 2001)

- The same analysis was applied to NSTX chord data, but no significant increase in bicoherence was observed at L-H.



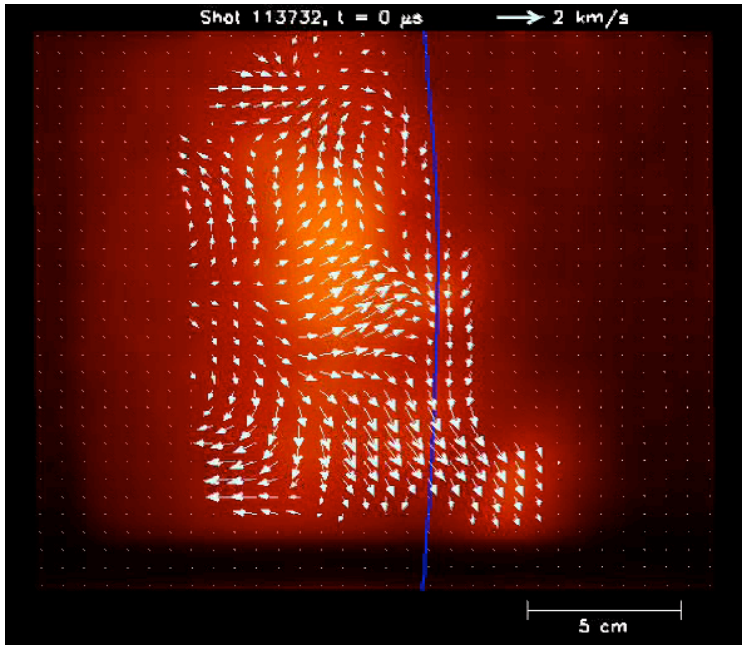
Anne White (UCLA)
APS DPP '05

Work in Progress

- Analysis of 2-D turbulence velocity fields vs. time
- Tracking motion of coherent structures (blobs)
- Getting new and better data from GPI on NSTX
- Comparisons with theory and simulation
- Comparisons with other experiments

2-D Turbulence Velocity Fields

- Munsat (Colorado) has written codes to derive local velocity fields from images using ‘optical flow’ and ‘2-D tiling’
- But needs more work to complete comparison with 1-D CCF method (proposals not funded)
- Stoltfus-Dueck (PPPL) trying alternate technique based on PCA (in progress)
- Terry (MIT) wrote code to find 2-D time-averaged velocity fields (will apply to NSTX)



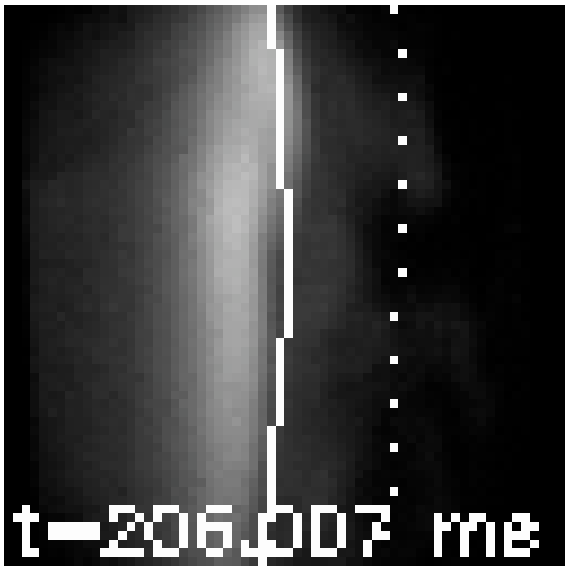
Tracking Motion of Blobs

- Tracking blob motion is *not* the same as determining local turbulence velocity fields (blob tracking may be more relevant for determining radial transport)
- Myra (Lodestar) has done tracking of local maxima of blobs in GPI images in a few shots ('by hand')
- Maqueda (FP&T) has written a code to automatically track blobs with certain (arbitrary) selection criteria
- Kamath (LLNL) is writing Sci/Dac/SAPP proposal to apply 'advanced' image processing and coherent structure algorithms to NSTX data

New Data from GPI on NSTX

- Maqueda has new GPI camera which can record ≥ 100,000 frames/shot at up to 120,000 frames/sec

- New tangential view near lower divertor should allow us to determine if blobs form there, and if so, which way they move (out in r or R ?)



- New XP's this year will focus on GPI measurements during density scan (Boedo) and Ohmic density limit (Williams)

Comparisons with Theory

- Detailed comparisons of analytic 'blob model' with GPI images from specific shots (Myra et al, Lodestar)

- Attempt to understand origin of blobs from first principles (Krommes, Stoltfus-Dueck, PPPL)

- Attempt to compare GPI results with turbulence simulations
  - BOUT (Umansky, Xu, LLNL)
  - ESEL (Garcia, Naulin, Riso and Grulke, Greifswald)
  - GEM (Scott, Garching)

- Plan to compare with CPES (Chang) and ESL (Cohen)

(GPI data is available to compare with any theory or simulation)

Comparisons with Other Experiments

- Alcator C-Mod - very similar diagnostic and generally similar results, as reported at APS, IAEA (Terry)
- TJ-II stellarator (Madrid) - collaboration on developing GPI diagnostic and analysis of images (Hidalgo)
- RFX (Padova) - collaboration starting this summer on GPI diagnostic and analysis (Scarin, Antoni)
- JET (possibly) - discussions of GPI diagnostic and fast edge imaging (Gonsalves, Hidalgo)

(many other collaborations/comparisons possible)