Theory and modeling of blobs and gas-puff-imaging experiments in the NSTX boundary plasma

J.R. Myra, D.A. D'Ippolito, D.A. Russell (Lodestar),

S.J. Zweben D.P. Stotler, (PPPL),

R. Maqueda, (Nova Photonics)

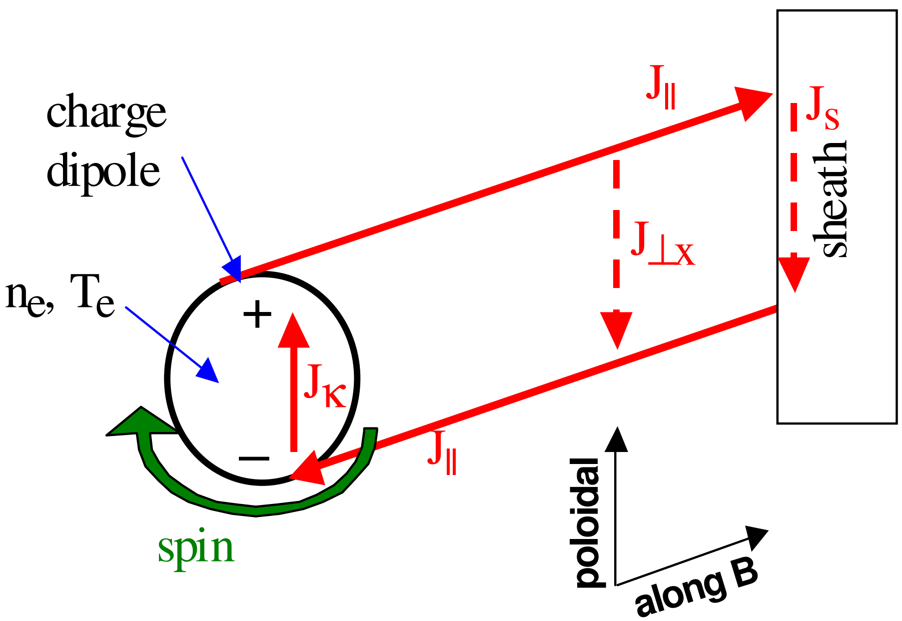
acknowledgements:
the NSTX Team

experiment • theory • modeling • simulation

Outline of talk
- theoretical framework
- data analysis and modeling

Motivation
- basic experiment/theory comparisons
- PFC damage, recycling, SOL width & v_X

Introduction to blob physics

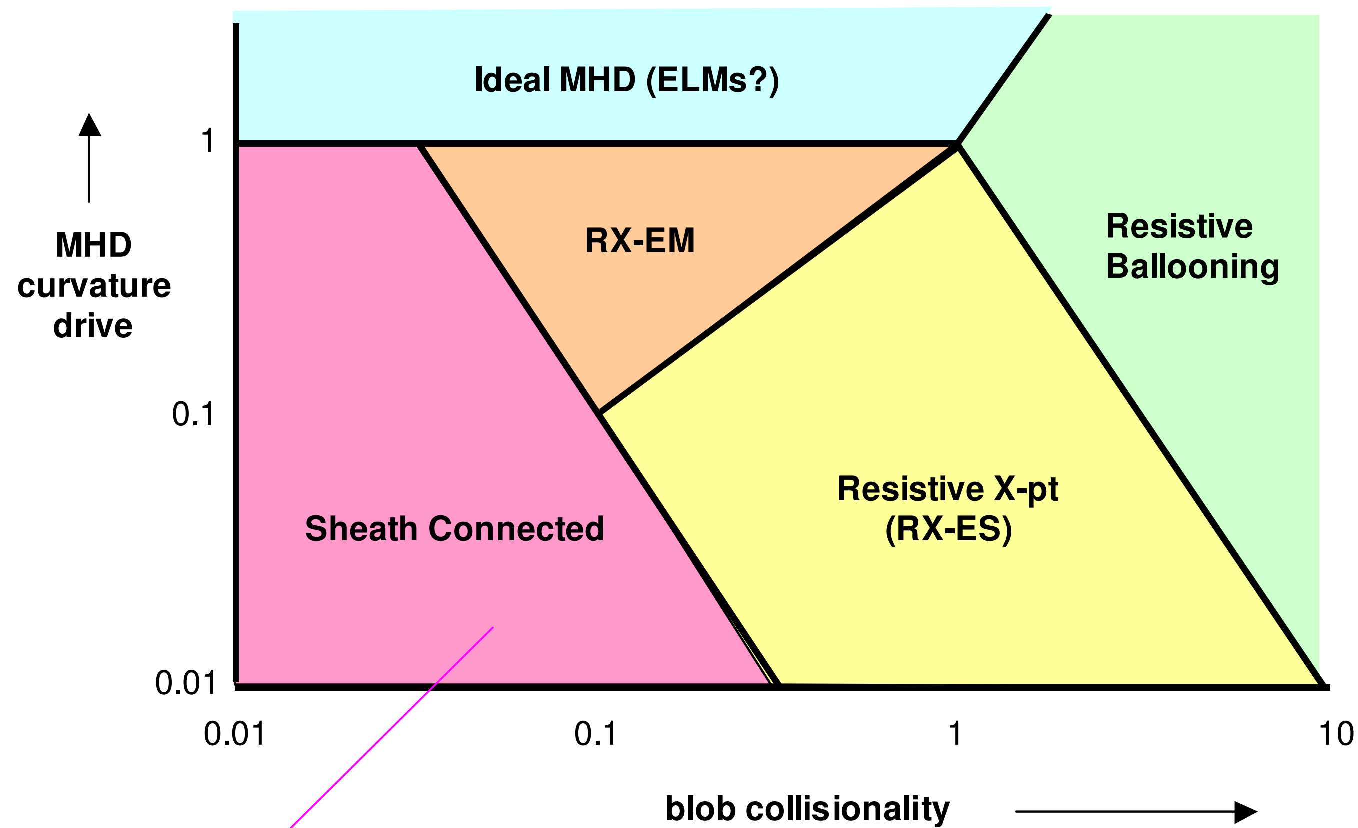


- blob = flux tube with excess plasma
- charges
  - separate by curvature drift
  - drain by $J_\parallel$
  - mix by spin

- effective circuit resistance determines Φ
- internal blob E gives $v_{E\times B}$ that propels blob outward in R

Blob regimes and linear mode regimes are closely related

$\gamma \rightarrow c\Phi/a_b^2 B$ where a_b = blob radius (E×B drift time scale)



$$v_x \sim 2.9\times10^{10} \frac{qT_e^{3/2}}{a_b^2 B^2}$$

each regime has a characteristic magnitude and scaling of blob radial velocity $v_x(n_e, T_e, a_b; B, q, R)$

Challenge questions

- Can we understand the dynamics of an individual blob with known properties?
- What properties are blobs created with and why?

Data analysis

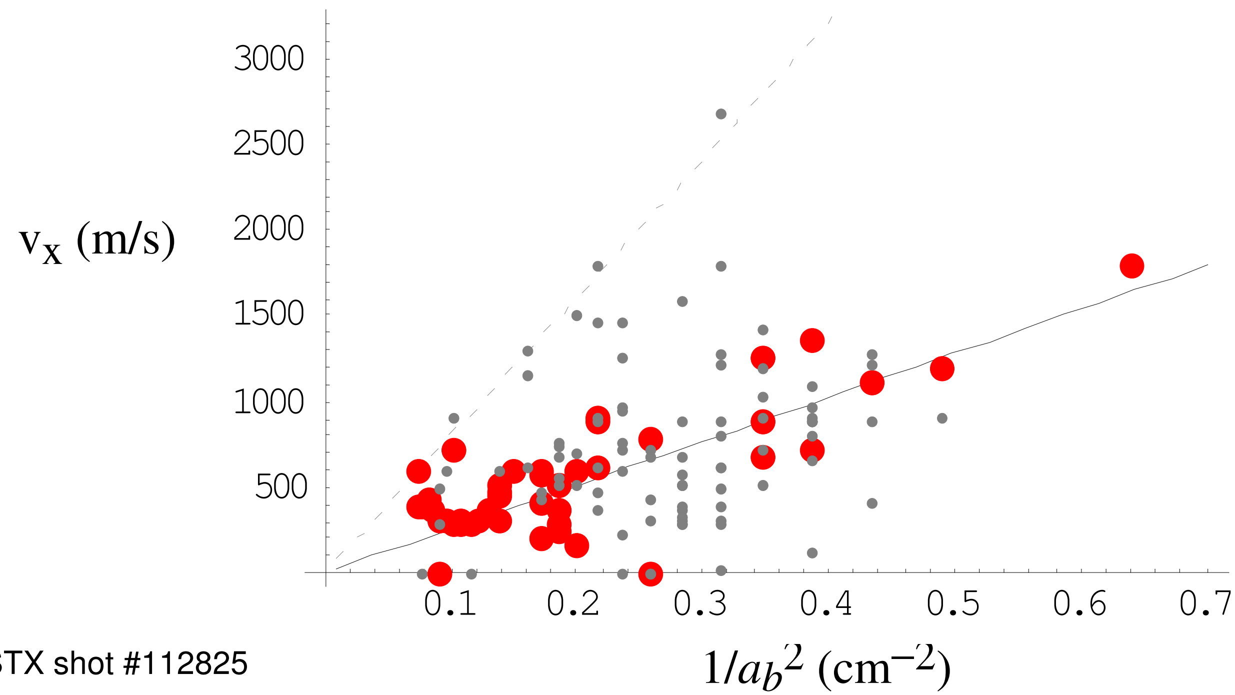
- synergy with tools used to analyze LLNL BOUT turbulence code output
- examples of analysis techniques and what we can learn from them
- preliminary results that will need follow-up …

- mostly L mode with 0.8 MW NBI, He puff with (HeI filter). 4.5 kG, 800 kA

Track blob max, determine evolution of properties as it propagates

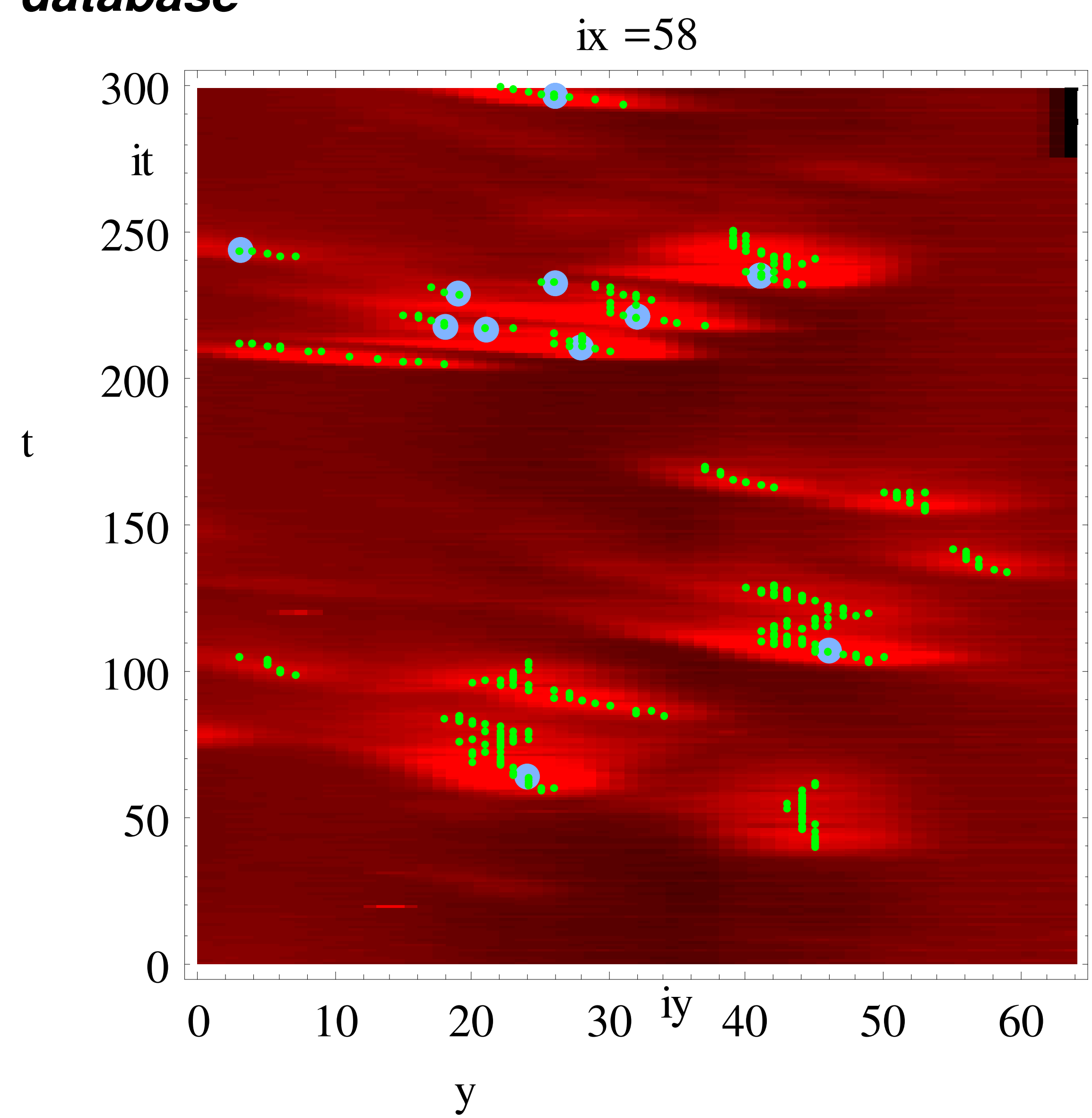
$\{x, y, t, v_x, v_y, a_b, \delta I, I_0\} \Rightarrow$ blob database
works well (with some human intervention) for blobs that are bright and well isolated

Preliminary Result:
blobs that are not too bright (hot and/or dense) show sheath-connected scaling



NSTX shot #112825

Wavelet clustering algorithm automates generation of a blob database

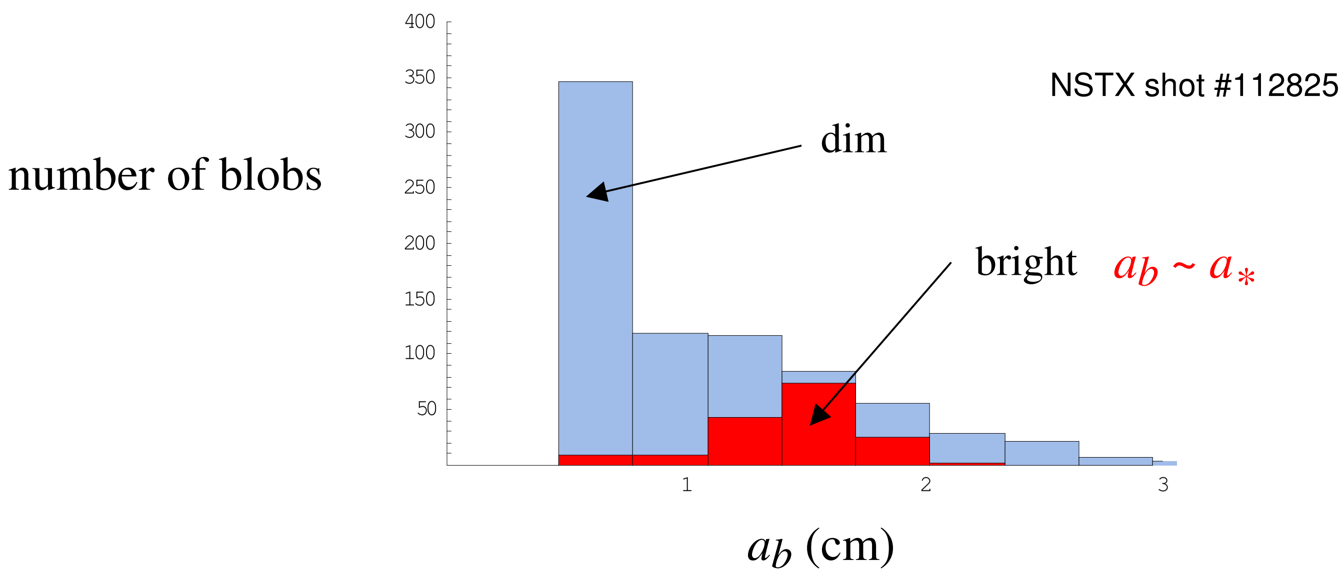


- watch patterns go by a particular radius x
- wavelet analyze in y-t plane to define a "blob"
- extract local properties: $\{x, y, t, v_x, v_y, a_b, \delta I, I_0\}$ $\Rightarrow$ blob database

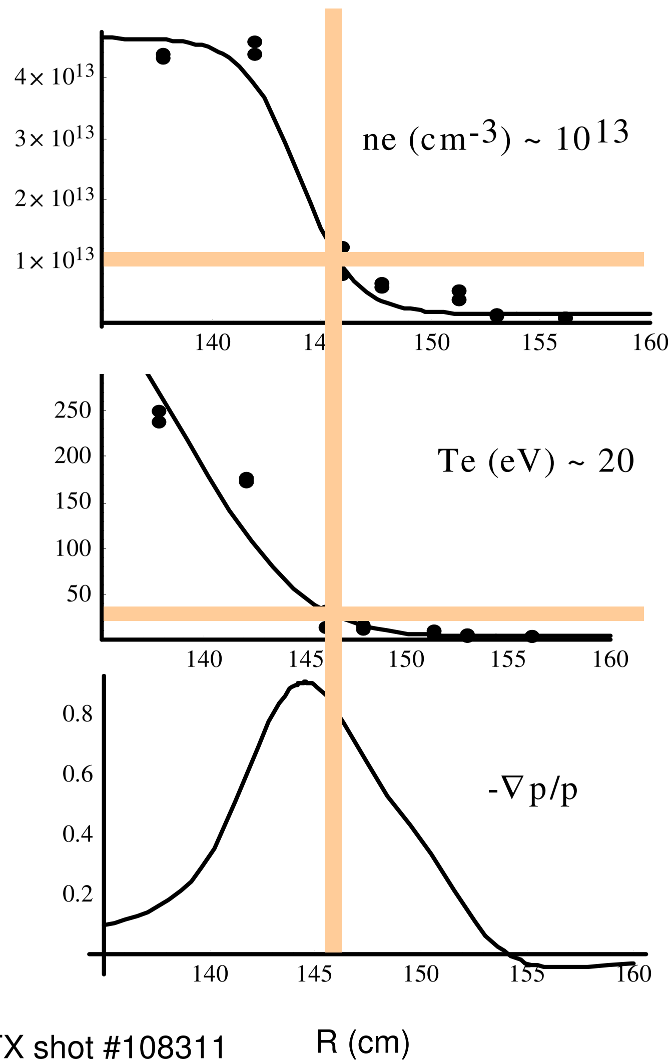
NSTX shot #112825

Distribution of blob sizes shows peaking at dimensionless parameter â ~ 1 (preliminary, for this shot)

- dimensionless $\hat{a} = a_b/a_*$ arises from balancing 3 terms in the vorticity equation:
  - charge separation by curvature drift
  - charge loss by parallel current flow to sheaths
  - charge (vorticity) advection (non-linear dual cascade)



Atomic physics calculations "invert" emission intensity, I to n_e,T_e



NSTX shot #108311

- DEGAS-2 Monte Carlo neutral calculations (Stotler)
- assume: at birth blob passively convects n_e and T_e together
  - map n_e,T_e $\leftrightarrow$ I using equilibrium profile (calibrated by Thompson scattering)
  - inverse mode radiation calculation

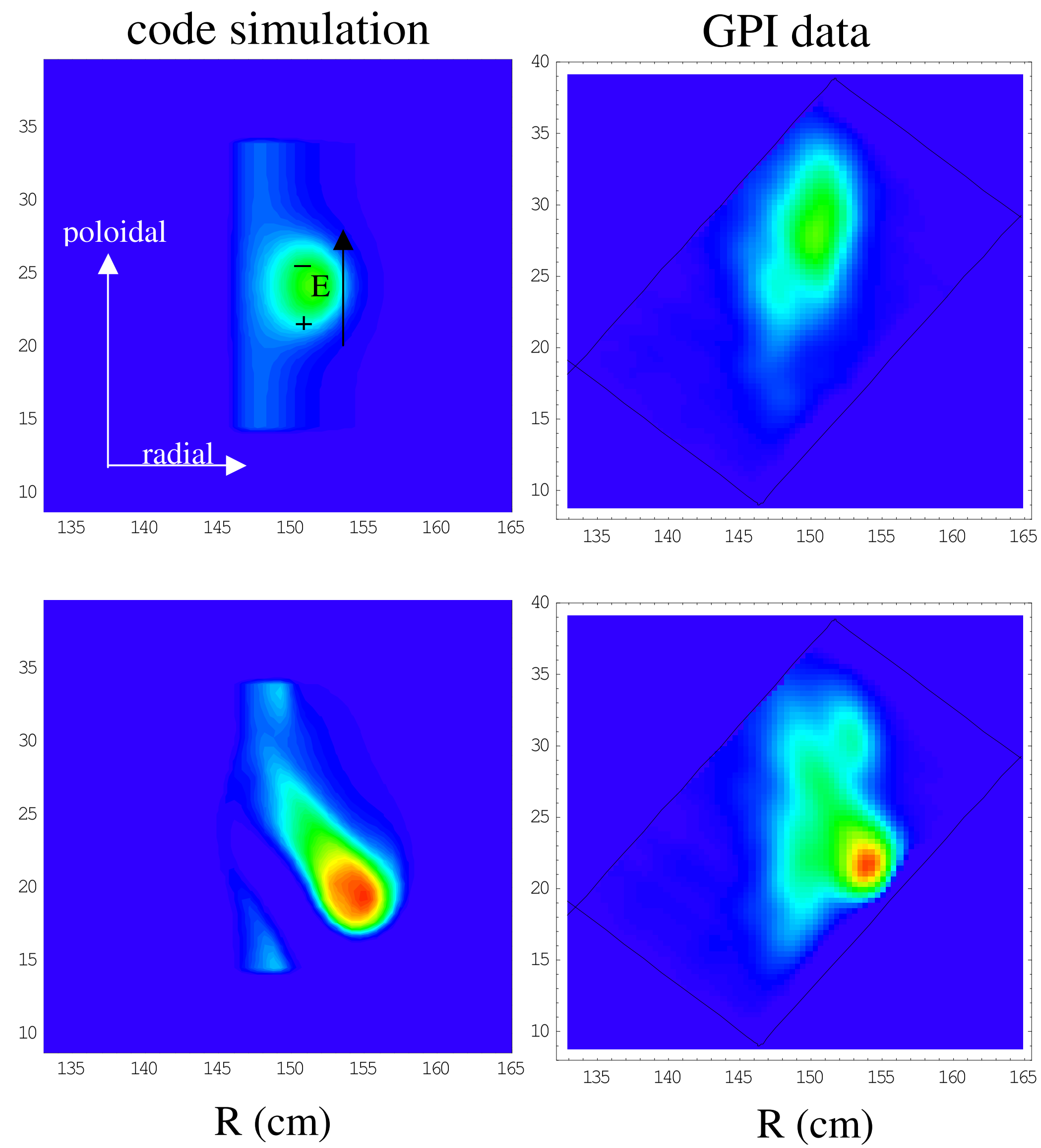
- blob(s) appear to form near the region of max linear $\gamma(x) \sim \nabla p/p$
- n_e, T_e characteristic of local plasma at x
- from last year's run, repeat

2D fluid simulations can reproduce some dynamical features

radial motion
poloidal motion
wake

$t = 0\ \mu s$

$t = 40\ \mu s$



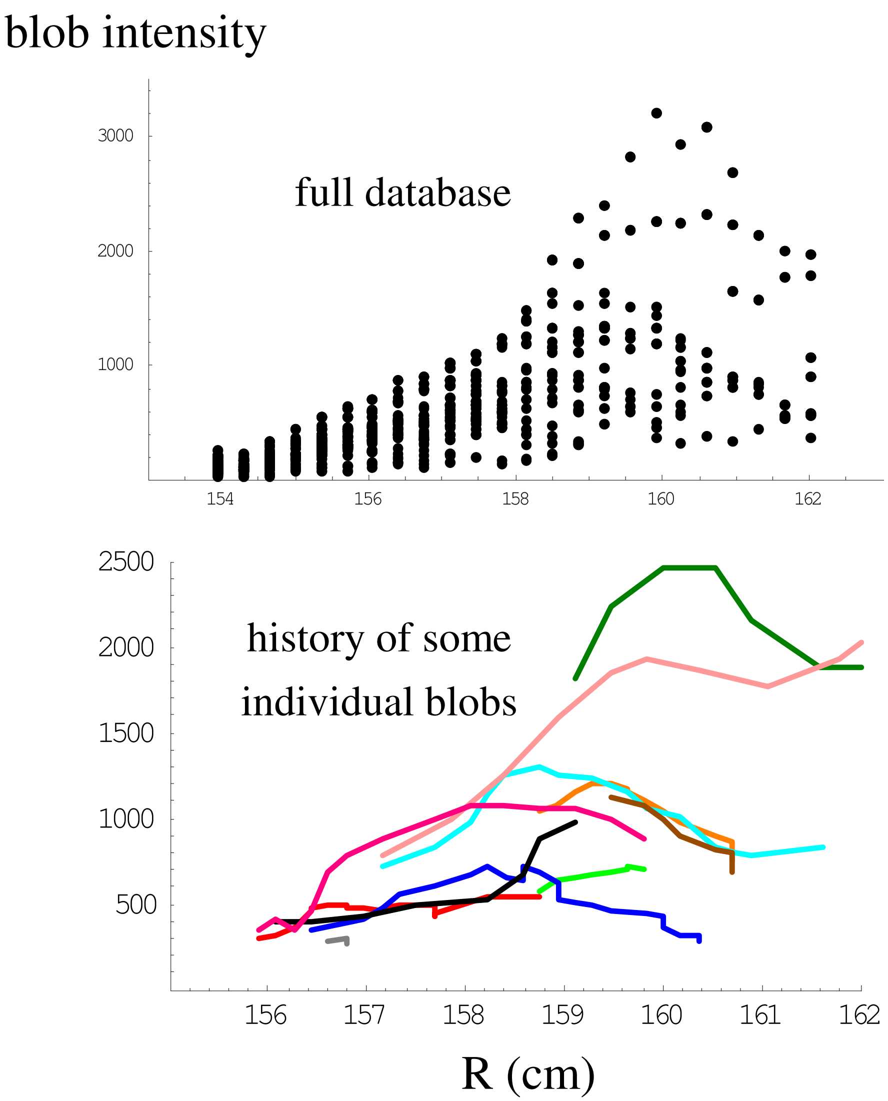
#108311
H mode

neutral and atomic physics simulations from DEGAS-2 (Stotler et al.)

forward mode

NSTX shot #108311

GPI blob images typically intensify then decay



NSTX shot #112825

- intensification from increasing $n_0(x)$
- decay from cooling and radiation function.
  - parallel energy conduction
- information on blob's n_e and T_e

Summary

- edge turbulence produces coherent propagating structures
- preliminary evidence (limited data analysis) suggests:
    - dynamics of these structures is consistent with simple theoretical models
    - e.g. radial blob velocity arises from blob charge polarization and $E \times B$ convection
    - several blob regimes may exist
- synergy between analysis tools for simulations and data can be exploited
- much more work remains
    - ideas and tools in place to address some fundamental questions
    - theory and data are rapidly improving