Blob birth and transport in NSTX: GPI data analysis and theory

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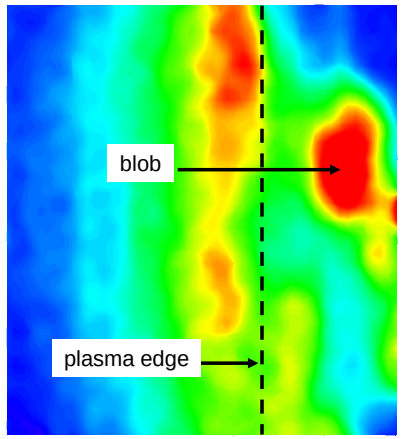
Basic goal: confront convective "blob" transport theory with gas puff imaging (GPI) data

- analytical blob theory
  - Krasheninnikov PoP 2001
  - D'Ippolito PoP 2002
  - Krasheninnikov J.PFR 2004
  - Myra PoP Plasmas 2005
  - …
- numerical simulation
  - Yu PoP 2003
  - Russell PRL 2004
  - Garcia 2005
  - …

- GPI experiments (Zweben, Maqueda)
  - blob parameters (size a_b, n_e, T_e)
  - DEGAS-2 using He 5876 emission (Stotler)
  - radial velocity v_x

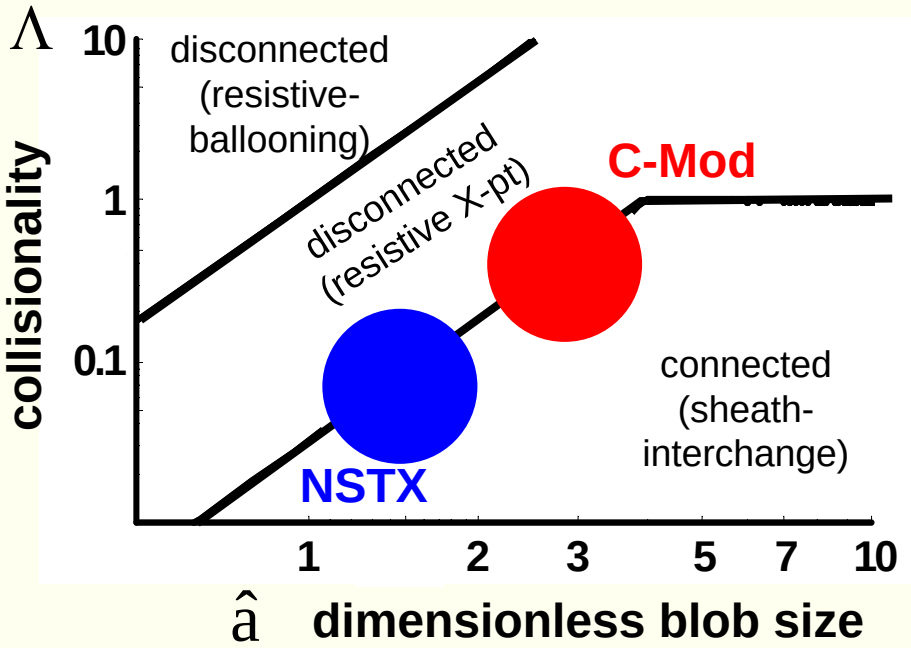


sample GPI frame

radial blob velocity v_x determines the competition between parallel and perpendicular transport

- plasma to the "wall" or to the divertor?

Theory predicts several characteristic regimes ⇒ blob velocities, & bounds



- NSTX and C-Mod explore different regions of parameter space (B ratio 20, n_e ratio 30 …)
- Observed v_{blob} similar
- Characteristic v_* is similar $v_* \sim 2$ km/s

Theoretical bounds on blob radial velocity

$$\frac{1}{\hat{a}^2} < \frac{v_x}{v_*} < \hat{a}^{1/2}$$

sheath

resistive bal.

Important parameters affecting blob speed

- blob parameters: blob scale size a_b, n_e, T_e, $\eta_{||}$
- geometry: $L_{||}$, [$q_{eff} = L_{||}/R$], X-pt shear
- amplitude above background $\delta n/n_{bkgd}$

$$\Lambda = \frac{\nu_{ei} L_{||}}{\Omega_e \rho_s} = 1.7\times 10^{14} \frac{n_e L_{||}}{T_e^2}$$

collisionality

$$\hat{a} \equiv \frac{a_b}{a_*} = \frac{a_b R^{1/5}}{L_{||}^{2/5} \rho_s^{4/5}} = 0.018 \frac{a_b B^{4/5} R^{1/5}}{L_{||}^{2/5} T_e^{2/5}}$$

dimensionless blob scale size

$$v_* = c_s \left(\frac{a_*}{R}\right)^{1/2} = 5.1\times 10^{6} \frac{L_{||}^{1/5} T_e^{7/10}}{B^{2/5} R^{3/5}}$$

characteristic radial convection velocity

GPI data analysis

- shot 112825
  - L mode 4.5 kG, 800 kA
  - 0.8 MW NBI
  - He puff (HeI filter)
- identify individual isolated blobs from the GPI movie
  - determine blob parameters
  - measure v_x from successive frames
  - compare with theoretical scalings

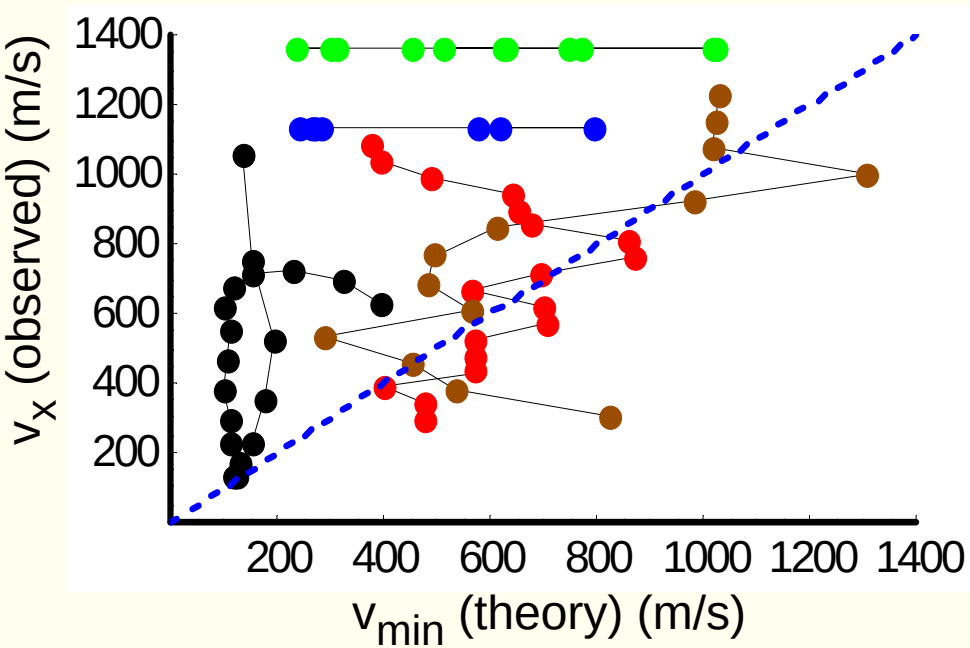
Observed blob velocity is bounded by theoretical minimum

- sheath-connected blobs have minimum v_x of all the regimes

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

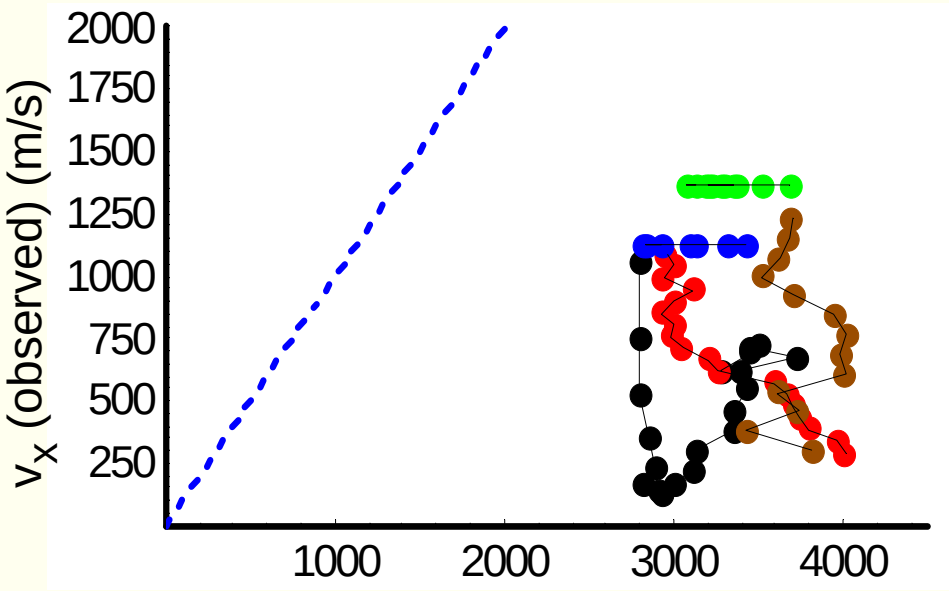
$f \sim \delta p/p \sim$ blob amp above background

- for spatial min set $q = L_{||}/R = 1 \Rightarrow v_{min}$



colors are individual blob "tracks"

Observed blob velocity is bounded by theoretical maximum



$$v_{max}(\text{theory}) \sim 6.9\times10^{5}\,\frac{a_b^{1/2}T_e^{1/2}}{R^{1/2}}\,f$$

- blob scaling in the resistive ballooning regime gives maximum v_x
- expect and confirm that observed $v_x << v_{max}$
- simple theoretical estimates bound the observed blob velocity

  $v_{min} < v < v_{max}$

Summary

- theory: identified the dependence of v_X on key blob parameters
- GPI data: observed blob v_X is bounded by theoretical estimates
- blob velocity is also influenced by effects outside scope of this study:
  - parallel blob structure?

Ongoing & future work

- application to more shots, and blob regimes
- numerical simulation with 2D turbulence code (D. Russell's SOLT code)
  - detailed blob dynamics
  - rate & statistics of blob generation
  - relation of blob size to $\gamma(k)$, nonlinear mode coupling

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