Plasma Facing Components Meeting
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Modeling & Analysis of Gas Puff Imaging Experiments

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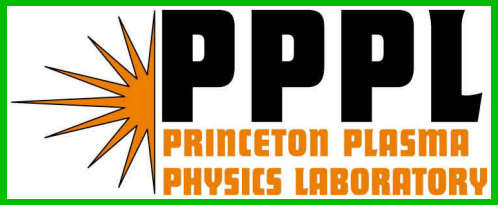
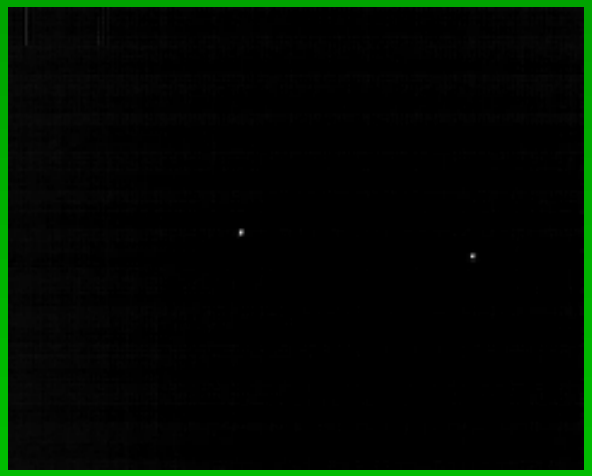


[1]Lodestar, [2]LANL

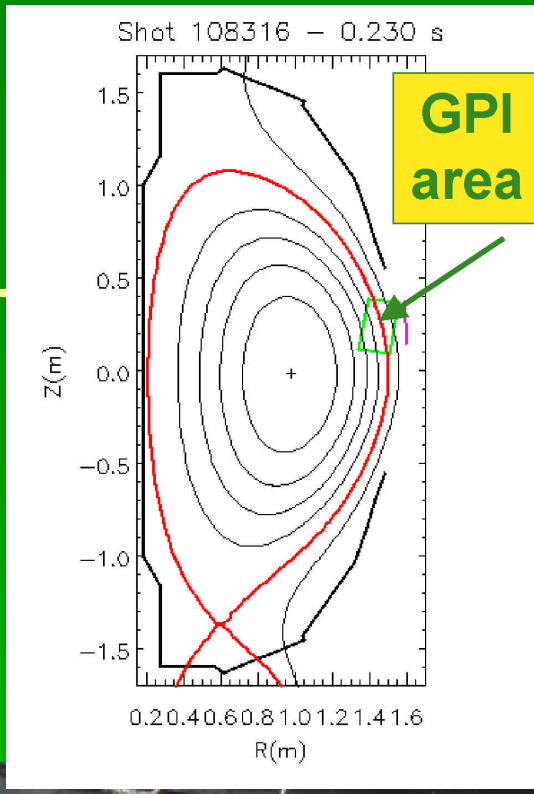
Introduction & Outline

- **Tokamak edge & SOL set boundary condition for core plasma,**
  - Until recently, transport has been assumed to be steady & diffusive,
  - Now, apparent that it may instead be intermittent & non-diffusive,
    - Particles & energy carried out by long, narrow filaments or “blobs”.
  - The nature of this transport also determines plasma-wall & plasma-material interactions,
    - May significantly impact ITER design decisions.
  - Gas Puff Imaging diagnostic designed provide high temporal & spatial resolution data on “blobs” for analysis & testing theories.
- **OUTLINE**
  1. Description of Gas Puff Imaging diagnostic,
  2. 3-D neutral transport modeling of GPI with DEGAS 2,
  3. Simulation of blob motion with reduced theoretical model.

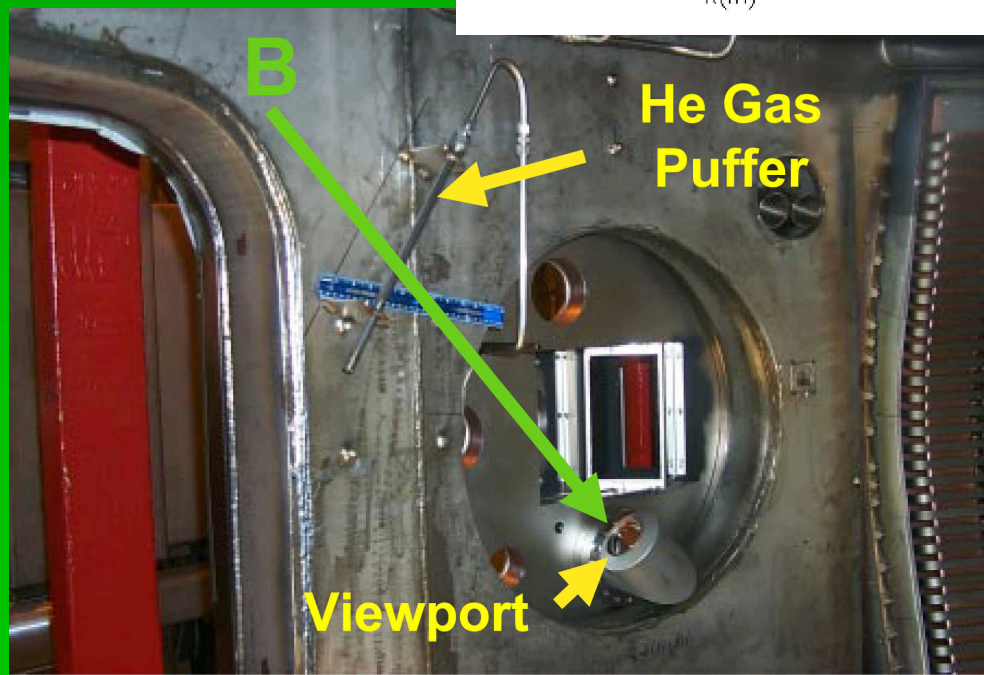


Gas Puff Imaging (GPI) Experiments Designed to Measure 2-D Structure of Edge Turbulence

- Puff neutral gas near outer wall,
- View with fast camera fluctuating visible emission resulting from electron impact excitation of that gas,
- Use sightline || to B to see radial & poloidal structure,
  - Compare with turbulence measured by probes,
  - And with output from plasma turbulence codes.

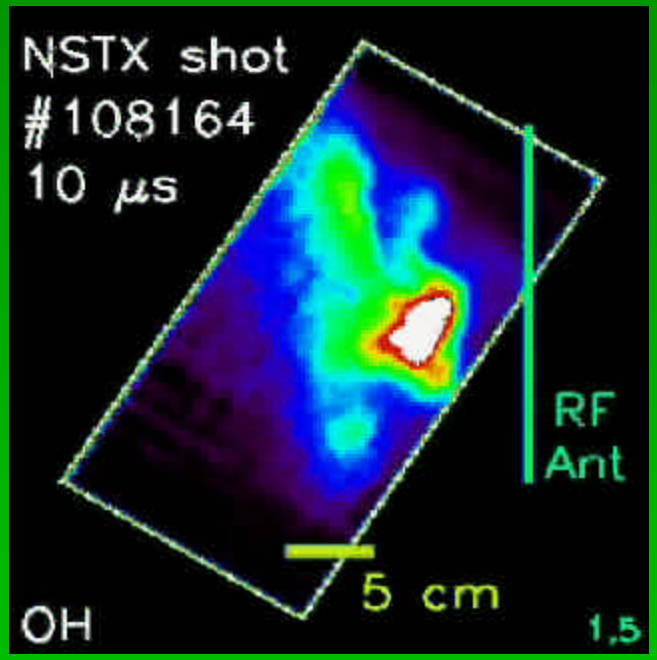


NSTX Configuration



Composite NSTX GPI Movie

10 μs / frame
28 frames



For more NSTX & C-Mod GPI movies, see
http://www.pppl.gov/~szweben

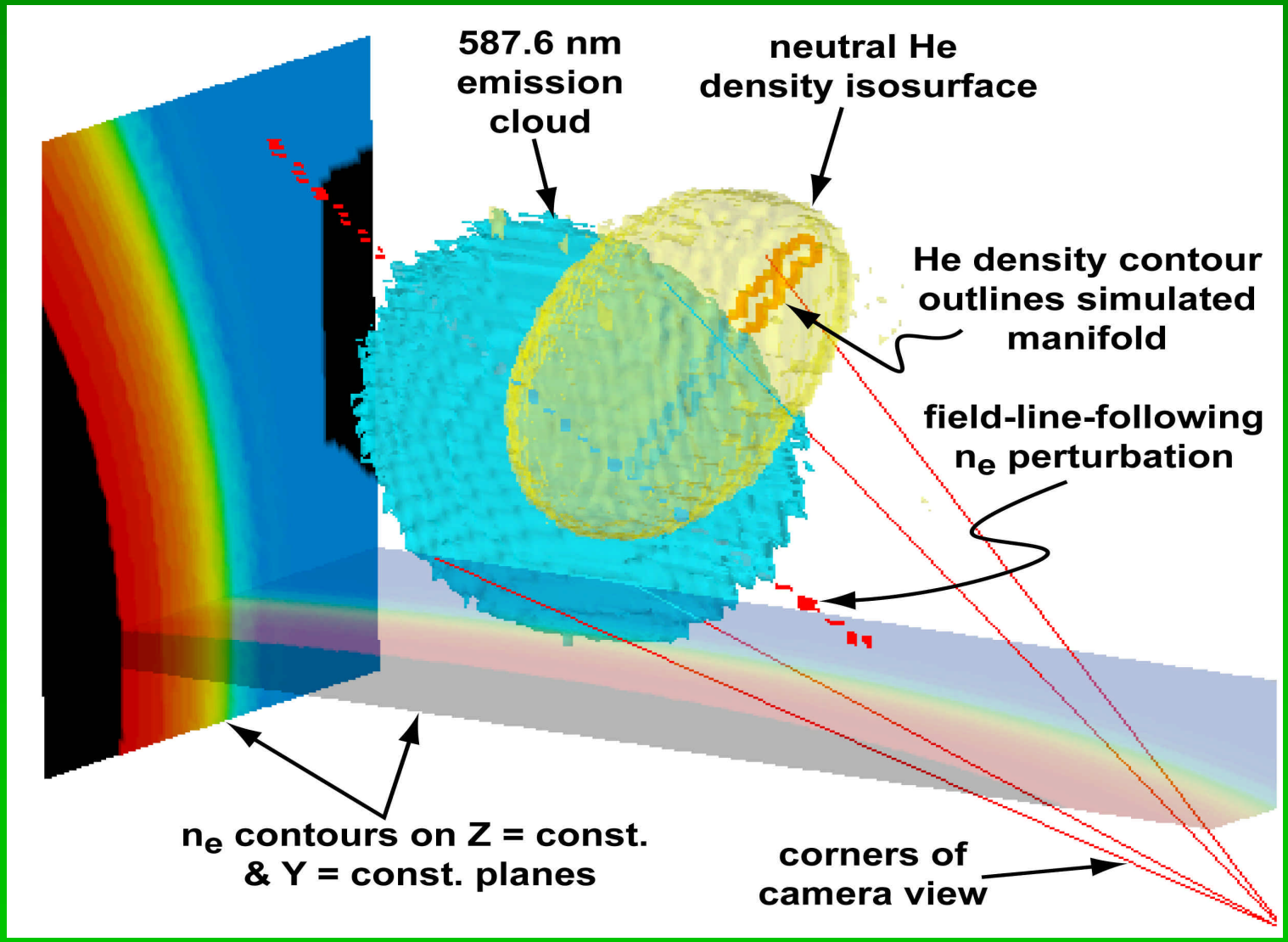
Summary of NSTX Results So Far

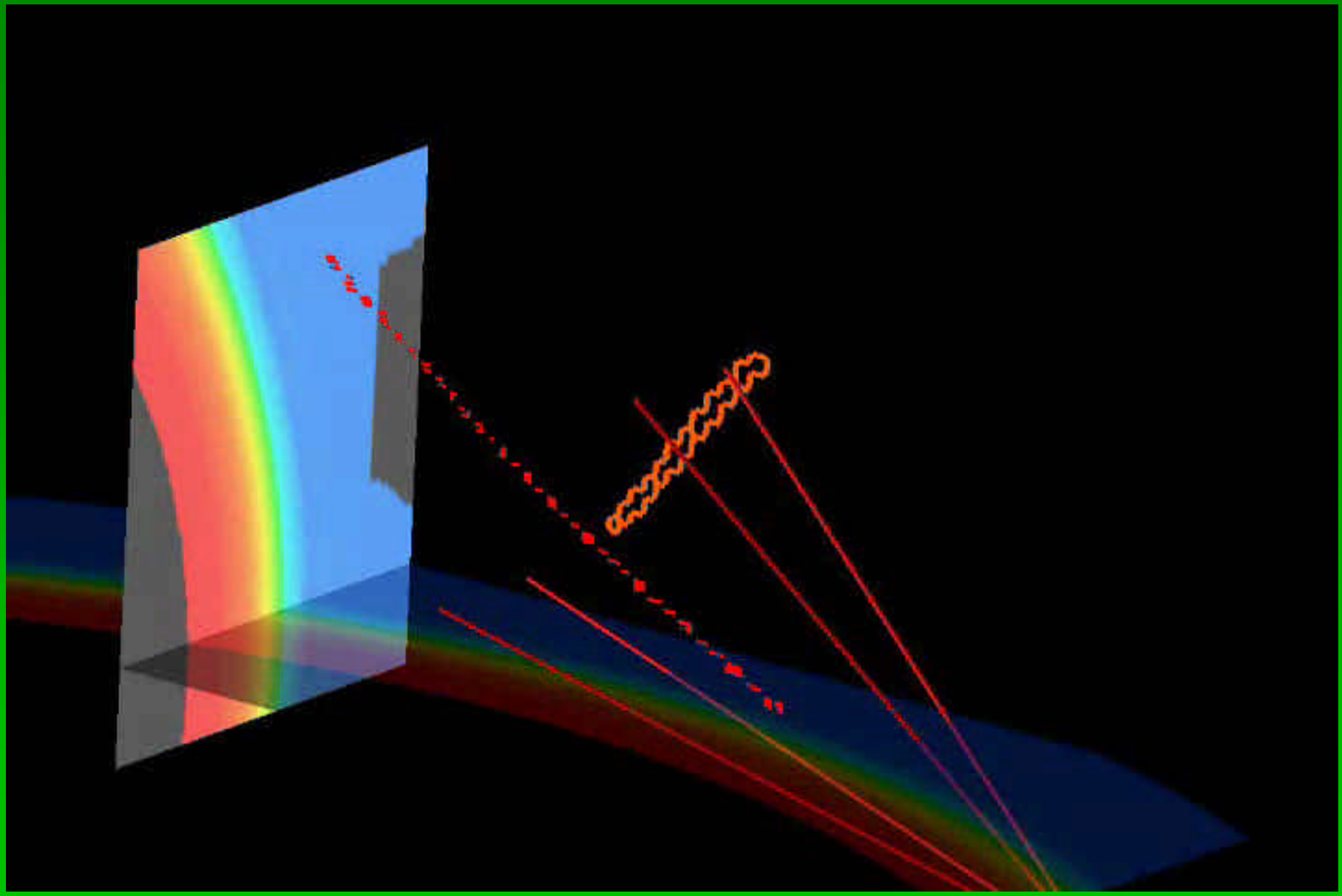
- Large, intermittent, transport events « blobs or filaments,
- Strong, non-Gaussian, SOL turbulence, consistent with previous measurements,
  - Large fluctuation level in edge
  - Broad frequency & k-spectrum,
    - Similar to probe & reflectometer,
  - Approximately isotropic structure ^ B
- Coherent structures move poloidally & radially at speeds ³ 10^5 cm/s.
- H-mode *generally* more quiescent than L-mode
  - Considerable variation in behavior

Neutral Transport Simulations of NSTX GPI

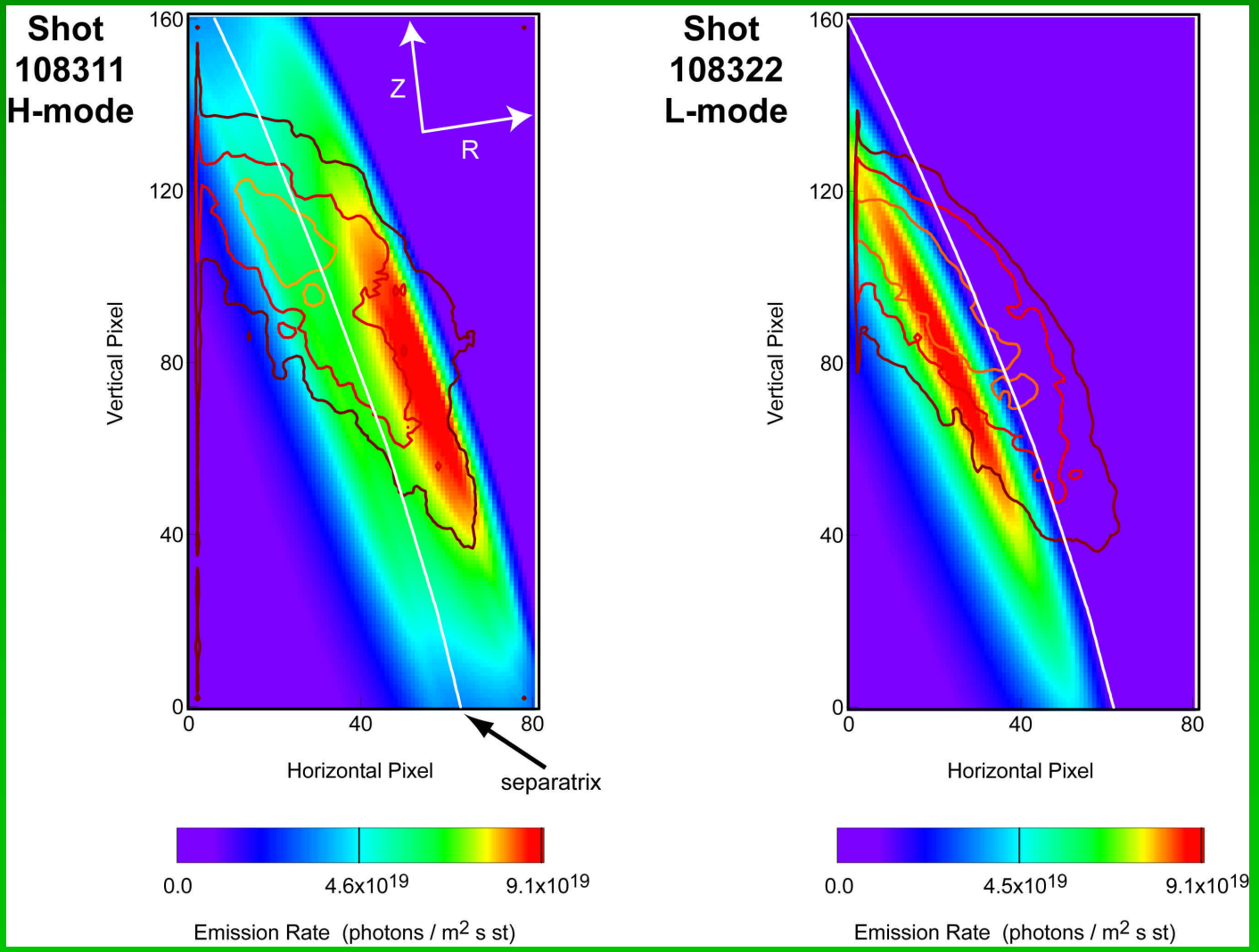
- **Detailed 3-D simulations of behavior of gas puff atoms facilitate interpretation & utilization of these results:**
  - **Understand spatial relationship of physical objects in experiment,**
  - **Assess consistency of available diagnostic data,**
  - **Provide neutral density data that can be used in inferring 2-D, time-dependent n_e, T_e from GPI data.**
  - **Done with DEGAS 2 Monte Carlo neutral transport code Þ detailed geometry & physics.**
    - **Includes toroidally extended gas puff & emulation of 81 x 161 pixel camera view.**
- **Plasma data must be input to DEGAS 2,**
  - **Only have single time, radial profiles of n_e, T_e.**
  - **Þ Assume constant on flux surface,**
  - **Do time-independent simulation & compare with time-average GPI emission.**

Spatial Relationships of Physical Objects Clarified by Visualization of 3-D DEGAS 2 Data





Observed & Simulated Emission Clouds in Rough Agreement

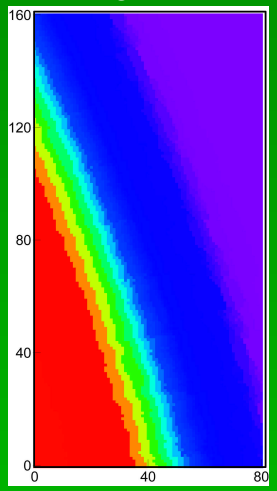


GPI Data Can Be Used to Test Theories of Blob Motion

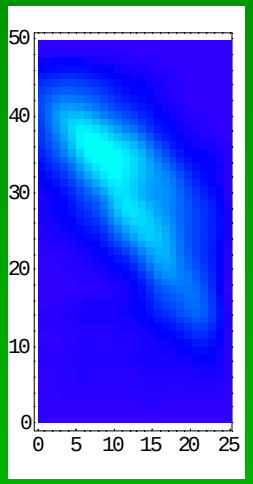
- Lodestar (J. Myra, D. D'Ippolito) 2-D nonlinear fluid simulation,
  - Takes GPI $n_e(x,y)$ blob as initial condition & computes evolution,
  - Compare with next frame.
- Availability of DEGAS 2 neutral density key to inferring needed time-dependent 2-D n_e & T_e from GPI data,
  - GPI intensity $I(x,y;t) = n_0(x,y)\, F[n_e(x,y;t), T_e(x,y;t)]$,
  - Get n_0 from DEGAS 2,
    - Assume n_0 = constant over turbulence timescale.
  - F « atomic physics (known function),
  - If know $n_e(T_e)$, can invert data to get 2-D n_e!
    - E.g., assume n_e & T_e passively convected together by interchange ExB turbulent motion.
  - Use DEGAS 2 simulation based on Thomson scattering profile,
    - Calibrate against average GPI image,
    - Shift & rotate n_0 to improve alignment.

Comparison of n_e and T_e for Equilibrium & Turbulent Frames

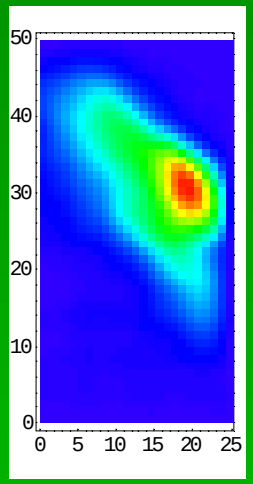
Input TS n_e



"Eq'm." GPI I

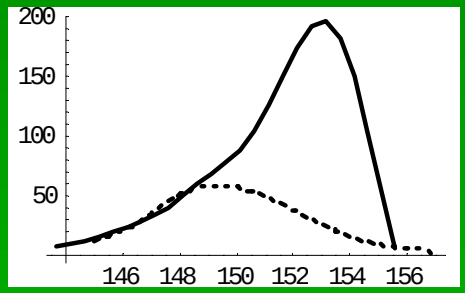


Blobby GPI I

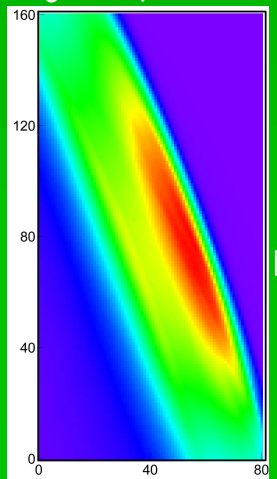


Radial Slices

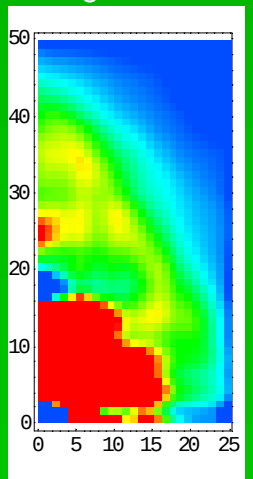
I



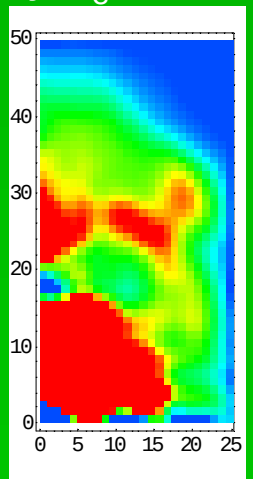
DEGAS 2
I & n_0



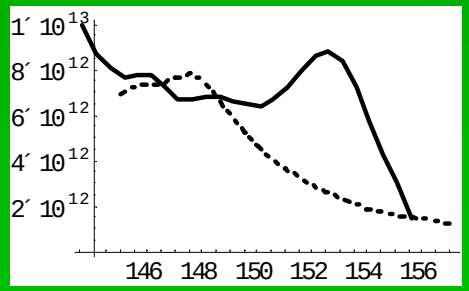
Inferred
"Eq'm." n_e



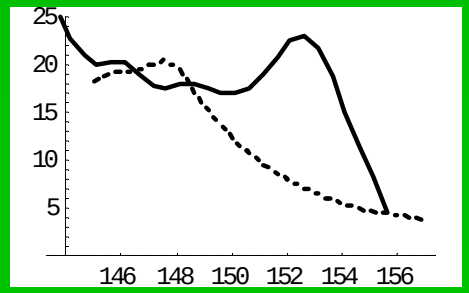
Inferred
Blobby n_e



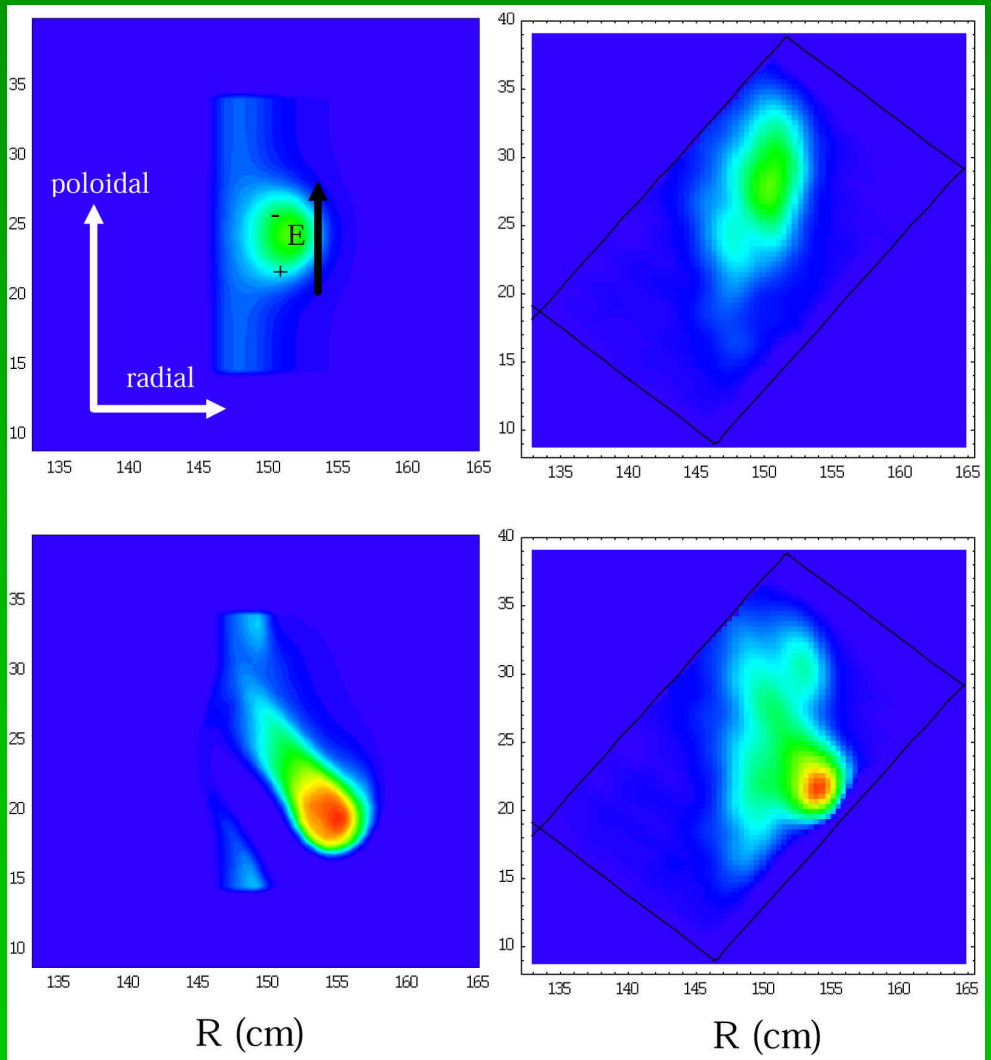
n_e



T_e



Simulated Blob Motion Similar to Observed Motion



CONCLUSIONS

- Collected large amount of GPI data from NSTX & Alcator C-Mod under different conditions,
  - Technique constantly being tweaked & improved.
- 3-D Neutral transport simulations with DEGAS 2 progressing,
  - Should provide accurate neutral density data.
- Initial Lodestar simulations reproduce some characteristics of observed blob motion,
  - Future work will assess:
    - Convective transport,
    - Divertor “short circuiting”,
    - Radial electric field in SOL,
    - Blob generation mechanisms.

References

- Zweben et al., *Nucl. Fusion* (to appear 2003),
  - NSTX GPI data analysis.
- Terry et al., *Phys. Plasmas* 10, 1739 (2003),
  - C-Mod GPI, comparison with theory & NSTX.
- Maqueda et al., *Rev. Sci. Instrum.* 74, 2020 (2003),
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- Stotler et al., J. Nucl. Mater. 313-316, 1066 (2003),
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- Stotler et al., PET 2003,
  - DEGAS 2 3-D simulations of NSTX GPI.
- Myra et al., APS 2003,
  - Analysis of blob motion in NSTX GPI.