Recent Progress in SOL Turbulence Simulations

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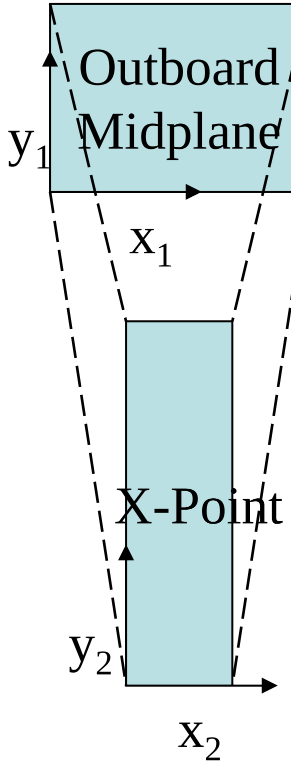
Introduction

- **This talk describes recent results obtained with a SOL turbulence simulation code (SOLT-TRM, D. Russell, 2005)**
- **Linear theory, analytic blob theory and 3D simulations show that mode structure parallel to magnetic field is important**
- **The two-region model (TRM) is the simplest and fastest way to do simulations with parallel structure (reduced 3D)**
- **The simulations address the following issues:**
  - effect of **parallel physics and magnetic geometry** (fanning, shear) on turbulent transport
  - **role of blobs**
    - blob birth zone and velocity scaling
    - blob source rate and "packing fraction"
  - **statistical properties** of turbulence

Two-Region Model (TRM)



1. **Solve vorticity and density eqs in two planes in midplane and divertor regions**

   (2D turbulence simulation in each plane, coupled by parallel transport terms,

   e.g. effect of parallel resistivity)

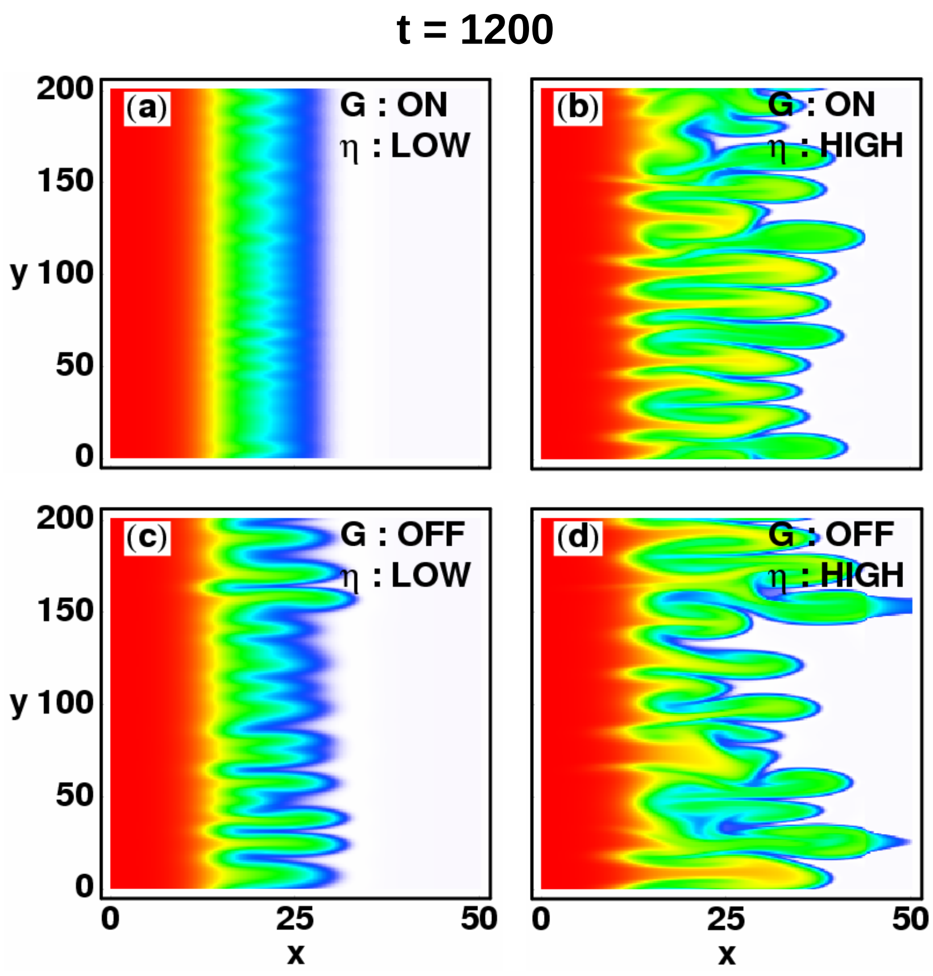
2. **Include X-point geometry by magnetic mapping between the planes**

$$\begin{pmatrix} dx_2 \\ dy_2 \end{pmatrix} = \begin{pmatrix} 1/f & 0 \\ \xi & f \end{pmatrix} \begin{pmatrix} dx_1 \\ dy_1 \end{pmatrix}$$

$$f = \text{fanning} \quad , \quad \underline{\xi = \text{shear}} \qquad \text{(new)}$$

TRM model: Myra, Russell, D'Ippolito, Phys. Plasmas 13, 112502 (2006)

Compare n(x,y) at outer midplane for four cases (vary magnetic geometry and parallel resistivity)



Geometry ON:

$f = 1/4, \ \xi = 4$

Geometry OFF:

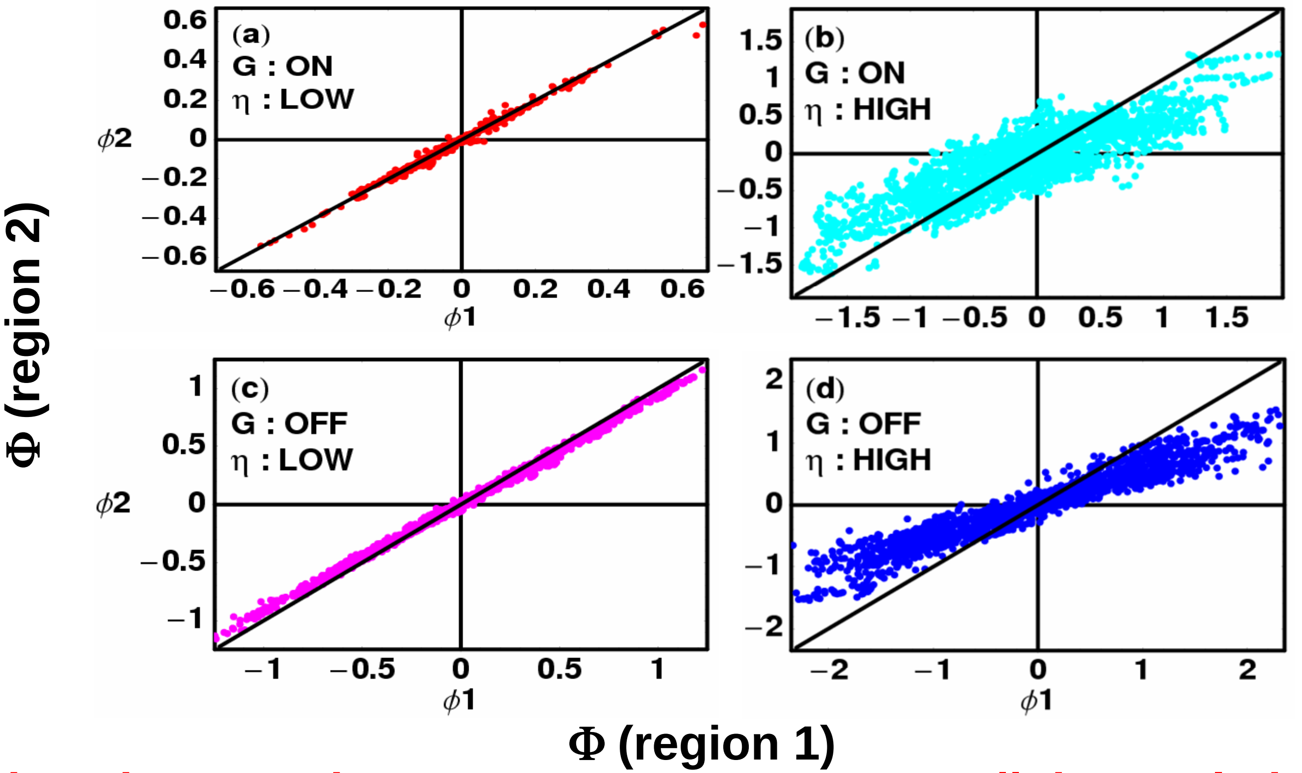
$f = 1, \ \xi = 0$

LOW $\eta = 10^4$

HIGH $\eta = 10^5$

Disconnection for high η
⇒ larger growth rate and faster transport

Parallel disconnection and decorrelation



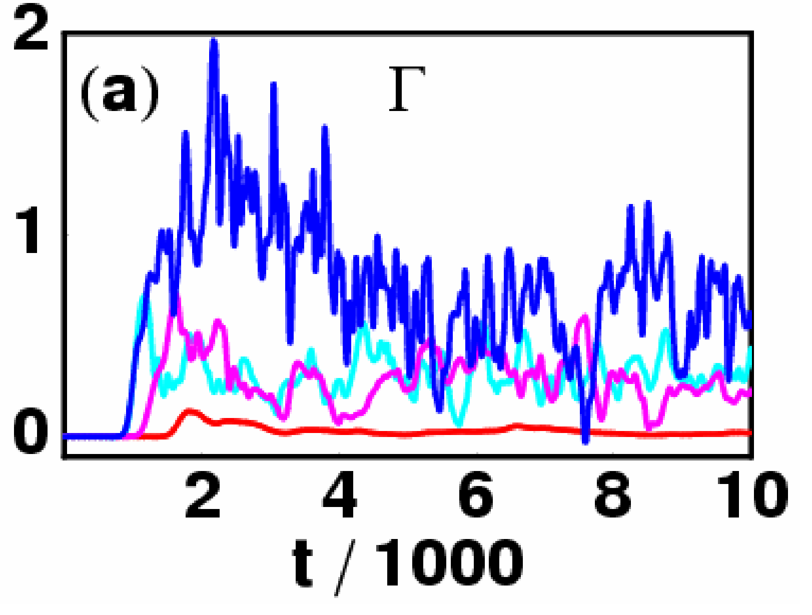
reduced connection ($\Phi_2 < \Phi_1$) for high η

|| decorrelation due to X-pt geometry

Turbulent particle flux

- G: OFF, low η
- G: OFF, high η
- G: ON, low η
- G: ON, high η

Γ(t) at x = 30 at outer midplane



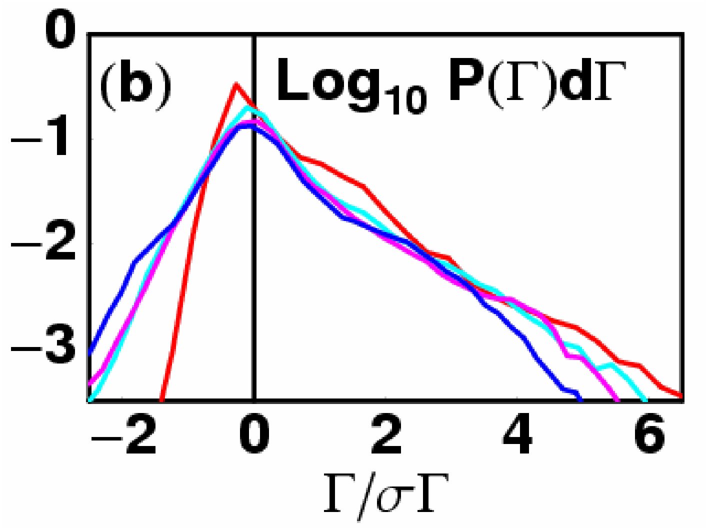
$$\Gamma \equiv <\Gamma>_y \uparrow \quad \text{as} \quad \eta \uparrow$$

$$\Gamma \downarrow \quad \text{for} \quad G:ON$$

Note: temporally intermittent

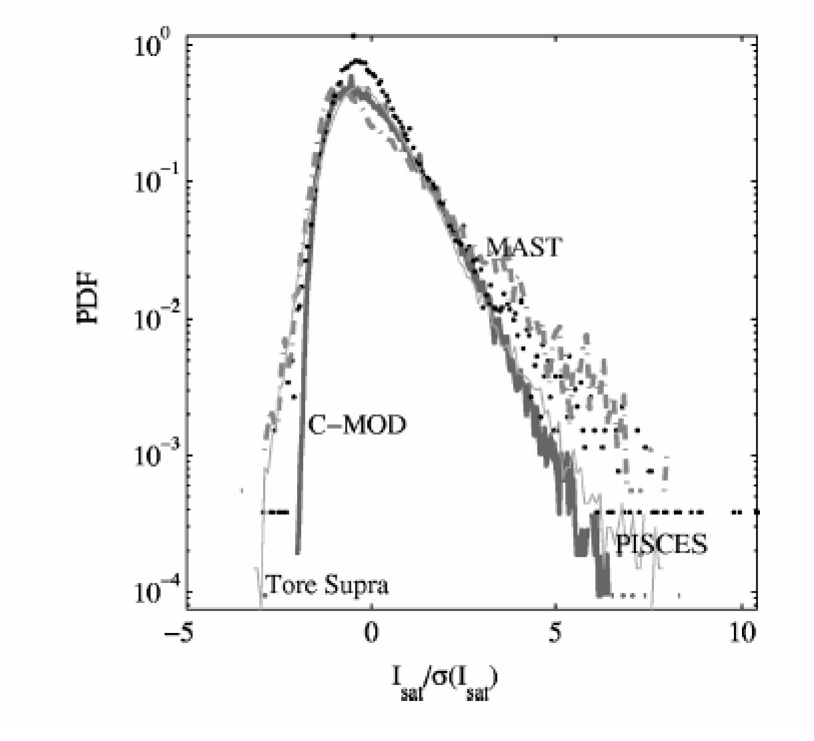
SOL Turbulence has non-Gaussian pdf

simulated "probe data" for TRM turbulent particle flux



PDF of flux at x = 30 with Geom. and η: non-Gaussian, insensitive to case , similar to exp. data

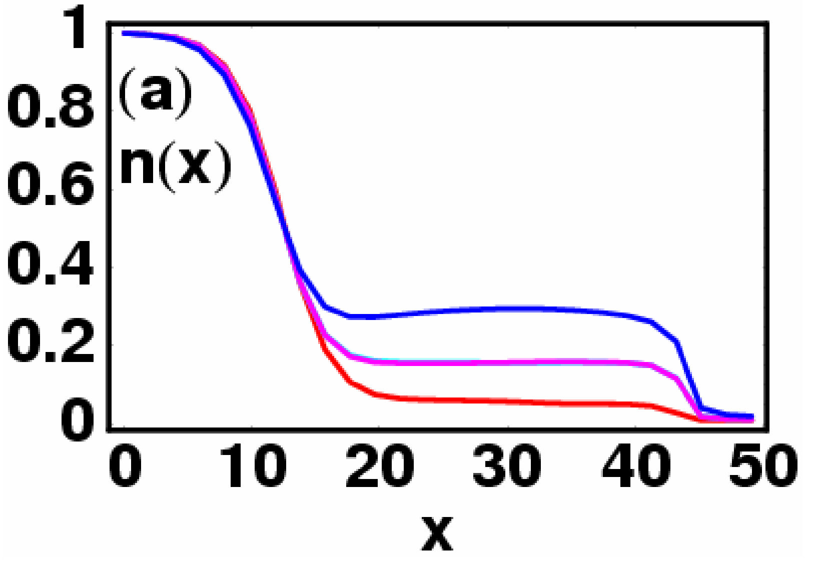
Experimental data (I_{sat})



Antar, PoP 2003

Turbulent (blob) transport flattens SOL profile

- G: OFF, low η
- G: OFF, high η
- G: ON, low η
- G: ON, high η



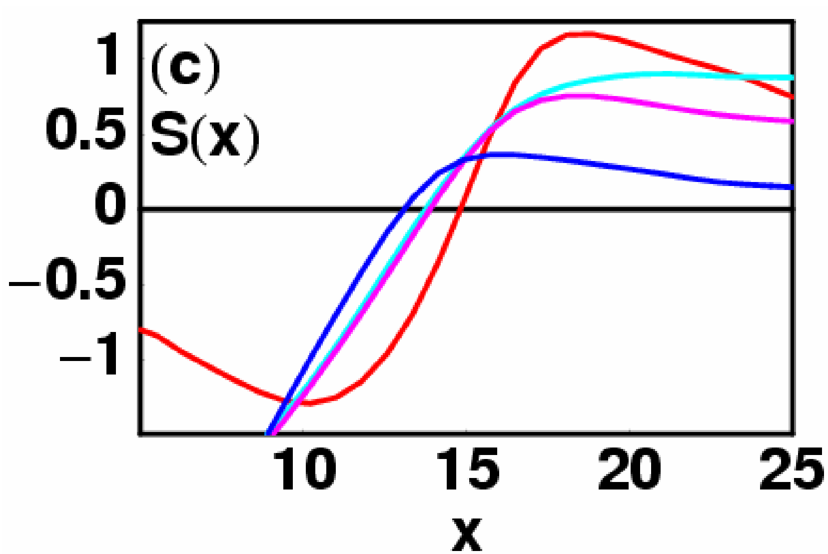
Where are blobs generated?

What is the scaling of the blob generation rate?

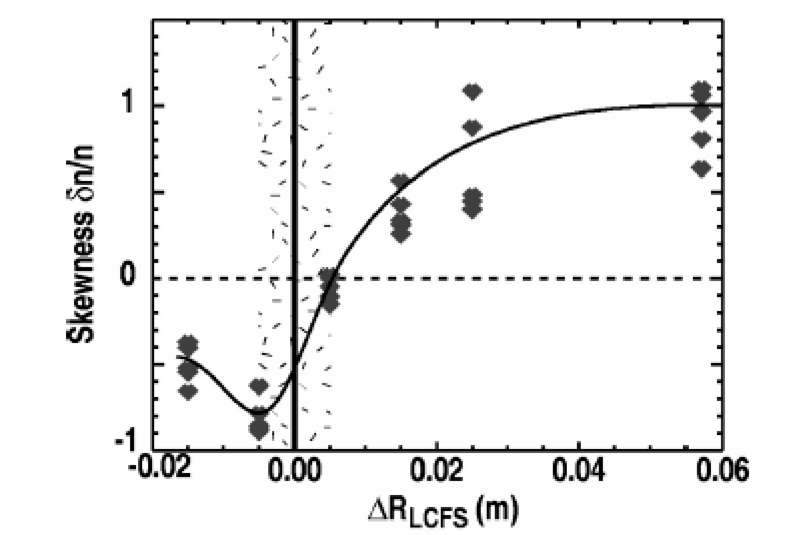
Skewness profile S(x) in simulations resembles experiment

• Skewness **S(x) = <S>$_{y,t}$** measures intermittency of turbulence

SOLT-TRM code

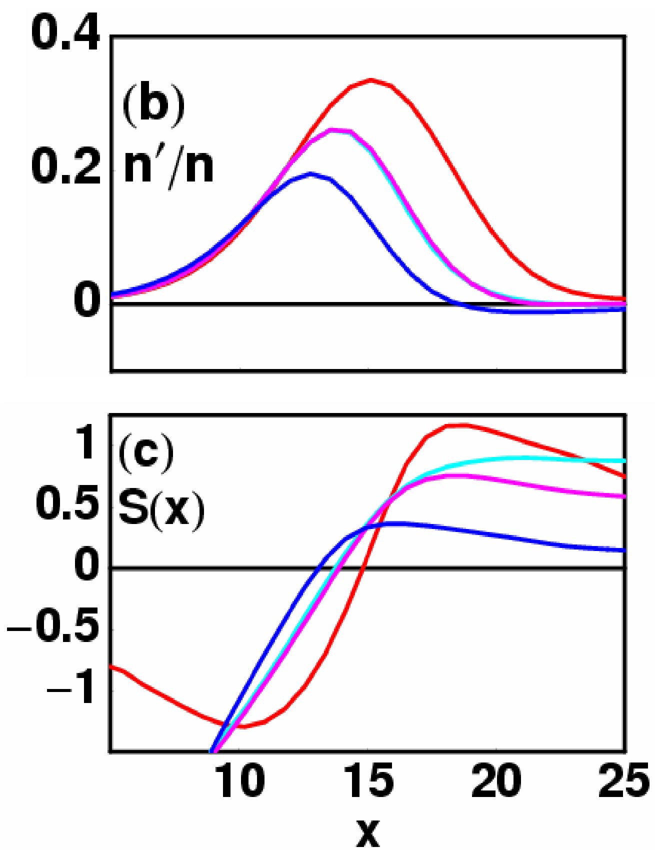


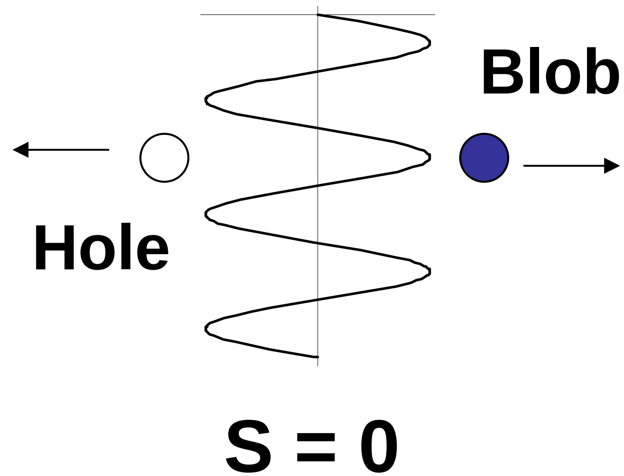
DIII-D BES data



Boedo, PoP (2003)

Blob creation zone is location of maximum linear growth rate





Similar behavior for all 4 cases:

- **blobs created near point where S = 0**
- **coincides with maximum linear mode growth, $\gamma \propto n^{-1}\, dn/dx$**

Blob creation rate

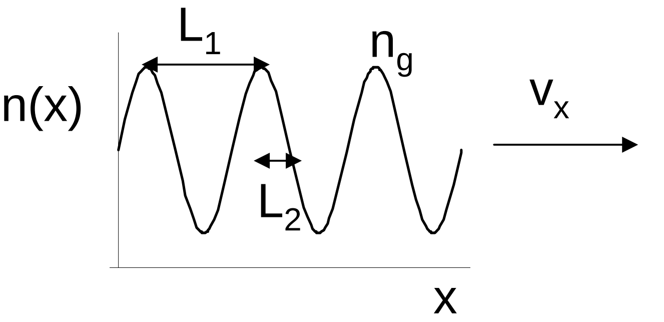
Particle flux due to blob transport ∝ blob creation rate, which can be related to a "packing fraction" $0 \le f_p \le 1$ defined by

$$\Gamma(x) = f_p\, n_g\, v_x(x) \Rightarrow$$

$$\boxed{f_p(x) = n(x) / n(x_g)\,,}$$

$$S(x_g) \equiv 0$$

$f_p = 2L_2/L_1$



The packing fraction can be inferred from the turbulent Γ(x) and n(x). Results for our 4 reference cases at x = 30 show that the packing fraction f increases with η:

- **G: OFF, low** η: $f_p = 0.43$
- **G: ON, low** η: $f_p = 0.21$
- **G: OFF, high** η: $f_p = 0.65$
- **G: ON, high** η: $f_p = 0.41$

Summary - 1

- The SOLT-TRM code (SOL Turbulence with Two-Region Model) is a useful tool for studying turbulent transport physics including physics || to **B**
  - magnetic shear decorrelation
  - fanning of flux tubes near X-points
  - collisional disconnection from divertor sheaths

$$\Gamma\downarrow \text{ for } G:\text{ON}$$

$$\Gamma\uparrow \text{ as } \eta\uparrow$$

- Both “probe” diagnostics of fluctuations and “wavelet” analyses of blob propagation have been used with various filtering schemes. Some specific results:
  - ➢ parametric dependence of *total* turbulent flux (probe data) is similar to that of *blob* contribution to the flux (wavelet data).
  - ➢ flux pdfs are insensitive to geometry and collisionality

Summary - 2

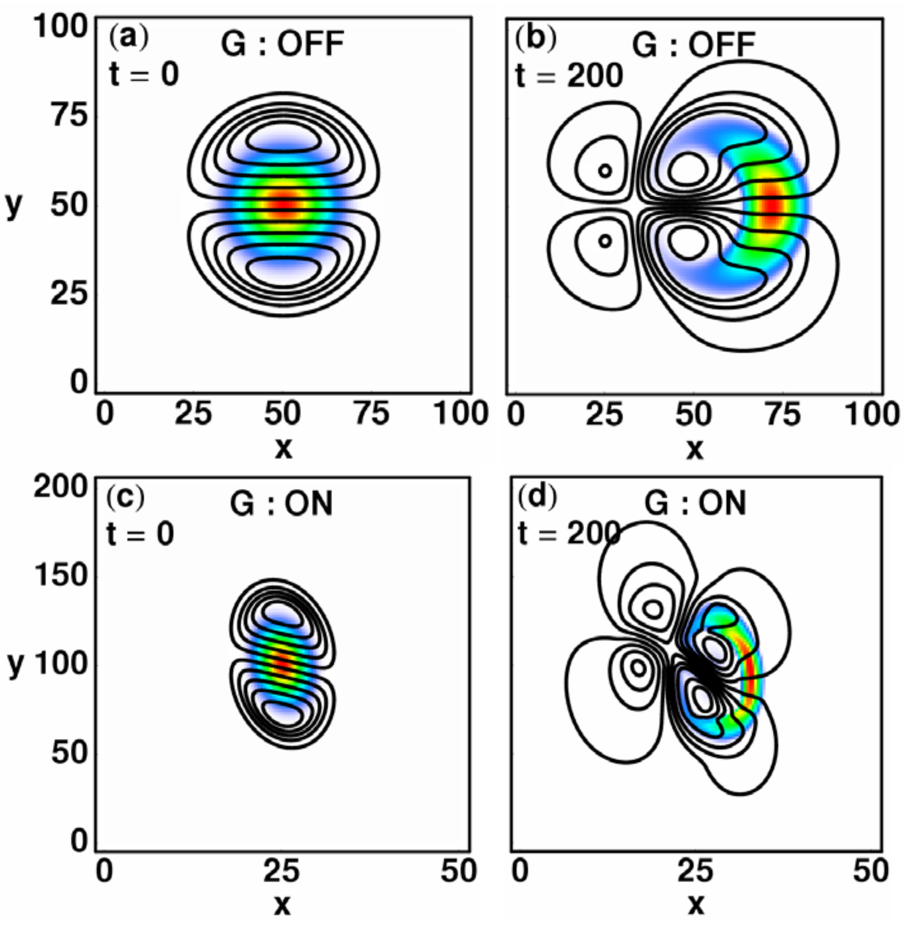
- pdfs are similar in simulation and in experiments, e.g. blobs with $\Gamma > 2\,\sigma_\Gamma \Rightarrow$ 40% of flux (similar to DIII-D data)

- blobs are created where the skewness $S = 0$ (at the location of the maximum linear growth rate)

- blob creation rate (f_p) and velocity v_x both increase at high η (consistent with C-Mod flux data)

• Further studies of turbulent blob creation (size distribution) and the relation of the observed transport to analytic theory predictions is in progress.

Effect of geometry on initialized blobs



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