Modeling of Blob Formation in NSTX Edge Turbulence

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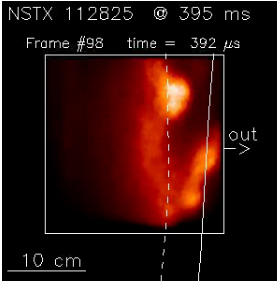
Blob Formation

- Blob propagation: significant understanding
- Blob formation: still poorly understood



- Goal: Study blob formation with reduced turbulent models
  - Numerically simulate simplified 2D, three-field models
    - Analyze results with coherent structure analysis techniques borrowed from fluid turbulence
  - Carefully examine structural properties of further-reduced models, including a novel one-field closure

Parallel coupling

- Inside the separatrix, magnetic field lines cover surfaces
  - $k_{\|} = 0$ generally not allowed, except for zonal modes
- Electron parallel force balance exerts a controlling influence
  - seeks $\nabla_{\|}(\tilde{n} - \tilde{\varphi}) = 0$
- $\tilde{\varphi} = \tilde{n}$ fluctuations very *ineffectively* coupled along field lines, except indirectly through $\tilde{\varphi} \neq \tilde{n}$ fluctuations

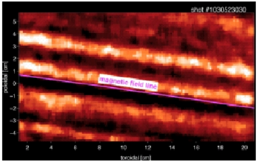


Figure: Effectiveness of parallel coupling, shown in GPI data.

Importance of nonadiabatic fluctuations

- $\tilde{\varphi} \neq \tilde{n}$ fluctuations tend to be small but very important because:
  - major dissipation channel
  - determine gradient drive

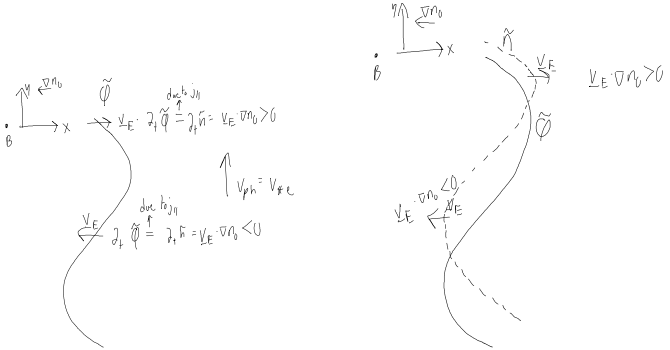


Figure: Phase relations for the drift wave. Left: $\tilde{\varphi} = \tilde{n}$: wavelike, no growth. Right: $\tilde{\varphi}$ trails $\tilde{n}$, growth.

Parallel electron physics

- Drift wave nonlinearities and curvature drive stir up nonadiabatic fluctuations
- Ohm's Law dissipates them
  - If turbulence is resistive, nonadiabatic fluctuations damp with parallel diffusion $D_{\|} = v_{te}^2/\nu_e$
  - If turbulence is electromagnetic, physics is Alfvén wave with slow damping $\propto \nu_e k_\perp^2 \sigma_0^2$
- Nonadiabatic drive/damp balance sets turbulent drive rate

$$\hat{\beta}\partial_t \tilde{A}_{\|} + \hat{\mu} d_t \tilde{j}_{\|} = \nabla_{\|}\left(p_e + \tilde{p}_e - \tilde{\varphi}\right) - C\tilde{j}_{\|}$$

Parallel electron physics in NSTX

$$\hat{\beta}\partial_t \tilde{A}_{\|} + \hat{\mu} d_t \tilde{j}_{\|} = \nabla_{\|} \left(p_e + \tilde{p}_e - \tilde{\varphi}\right) - C\tilde{j}_{\|}$$

Quantity	Edge	Separatrix	SOL
$\hat{\epsilon}^2 \doteq \left(k_{\|} c_s / \left(c_s/L_\perp\right)\right)^2 \sim \left(L_{\|}/L_\perp\right)^2$	1600	1600?	1600?
$\hat{\beta} \doteq \beta_e \hat{\epsilon}^2 = \left(\left(c_s/L_\perp\right)/k_{\|} v_A\right)^2$	14	0.3	.04
$\hat{\mu} \doteq \left(m_e/M_i\right)\hat{\epsilon}^2 = \left(\left(c_s/L_\perp\right)/k_{\|} v_{te}\right)^2$	0.5	0.5	0.5
$C \doteq 0.51 \frac{m_e}{M_i} \frac{\nu_e}{c_s/L_\perp} \hat{\epsilon}^2 = 0.51 \frac{c_s/L_\perp}{k_{\|}^2 v_{te}^2/\nu_e}$	0.1	1.1	3.3

- NSTX mostly electromagnetic in edge, electrostatic in SOL
  - even in near SOL, behavior electromagnetic for larger perpendicular scales
- Near SOL has $\nu^*_{SOL} \doteq \lambda_{mfp}/L \sim 10^{-16} n_u L / T_{su}^2 \gtrsim 10$, probably sheath-limited