Experimental Validation of Universal Plasma Blob Formation Mechanism

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Abstract

- Plasma blob formation is due to the breaking process of a radially elongated streamer due to the poloidal and radial velocity shear [1].
- In this work, we report the first ever experimental validation of this universal criterion by testing it against NSTX data on blobs obtained using the gas-puff imaging (GPI) diagnostic [2].
- The criterion is widely satisfied in most L-mode discharges and may explain the predominance of blobs in such a regime compared to the H-mode.
- We also validate the theoretical criterion using Aditya Langmuir probe data taken in the edge and SOL regions in L-mode plasma.

Background

- Anomalous plasma transport in the boundary region of a tokamak plasma is normally associated with density structures. These structures are commonly termed as plasma blobs [2-5].
- Studies on the plasma blob formation is important so that one can identify the cause for the blob formation and can control the anomalous transport in tokamak.
- The blob formation theory is well supported by two-dimensional (2D) and three-dimensional (3D) numerical simulation results [1,3] but lacks experimental validation.

Theory of plasma blob formation

- A radially elongated streamer structure generates blob when it breaks in the presence of the shear of the electric fields (E_x' and E_y').
- The breakup happens when the shearing time (τ_s) due to the differential stretching is smaller or of the order of the radial convection time ($\delta_x/v_x \leq \tau_s$).
- If the linear growth rate $\gamma \sim c_s/\sqrt{RL_n}$ the condition for breaking :

$$\frac{E_y'}{B\gamma} + \frac{\delta_x}{\delta_y}\frac{E_x'}{B\gamma} \geq 1$$

where δ_x and δ_y are radial and poloidal widths of the streamer, respectively. In terms of velocity shear the condition is:

$$\frac{v_x'}{\gamma} + \frac{\delta_x}{\delta_y}\frac{v_y'}{\gamma} \geq 1$$

Validation of theory from gas-puff imaging data of NSTX

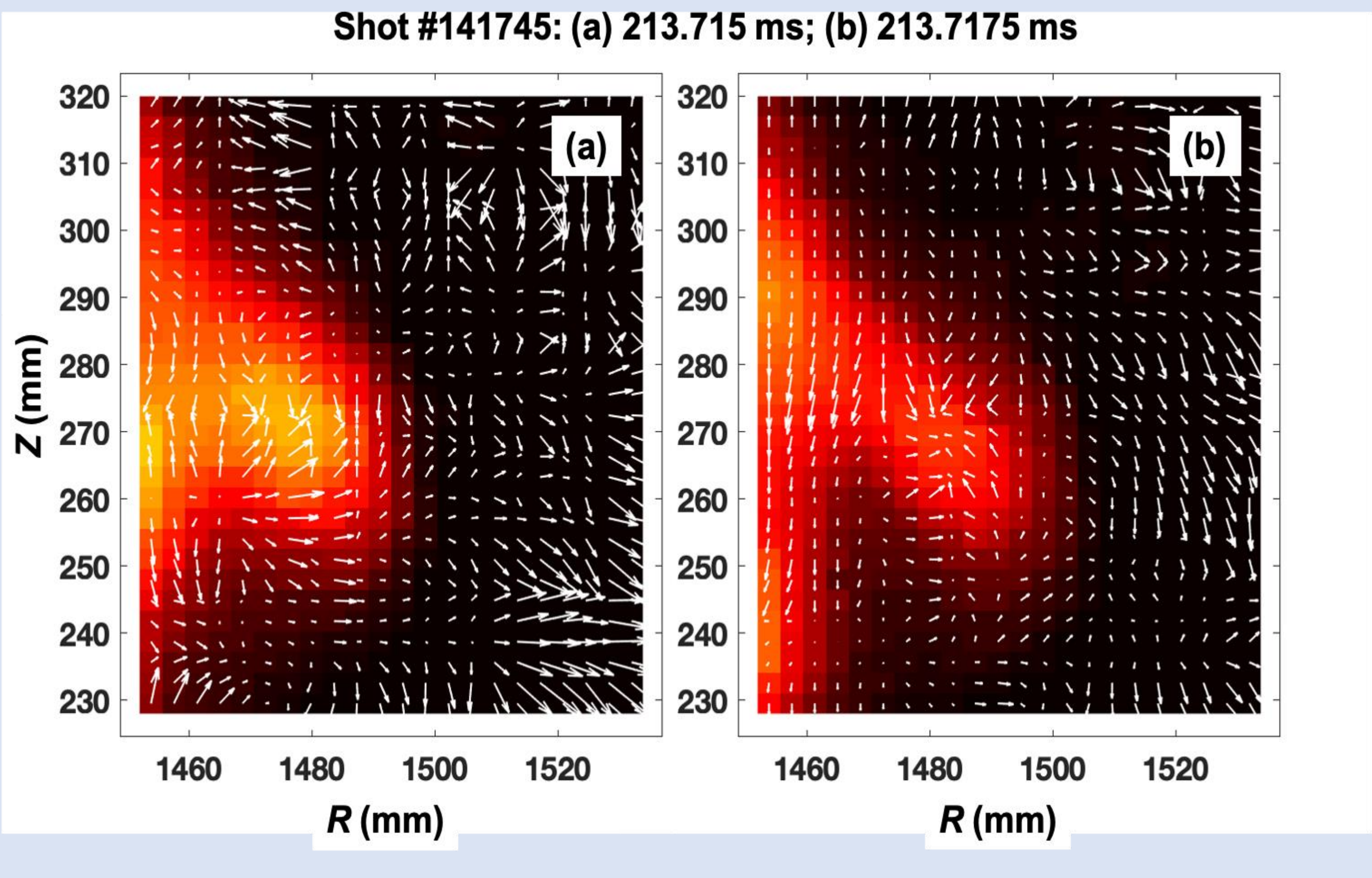
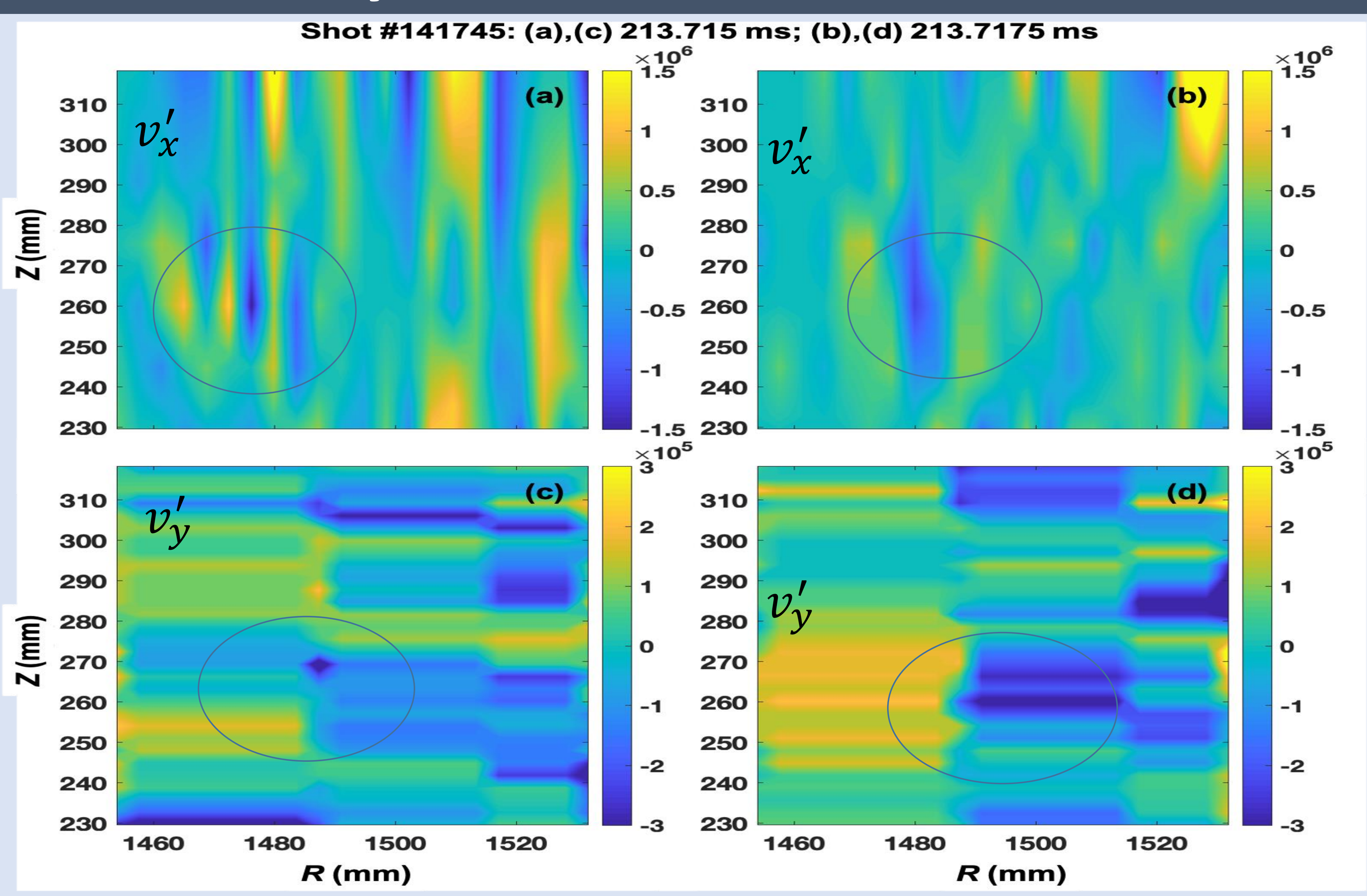


FIG. 1: Blob dynamics. These GPI images are superposed on quiver plots of the radial and poloidal velocities of the plasma. (a) and (b) are 5 µs apart in time. The separatrix is at 1445 mm that is beyond the left edge of the figure

NSTX velocimetry data



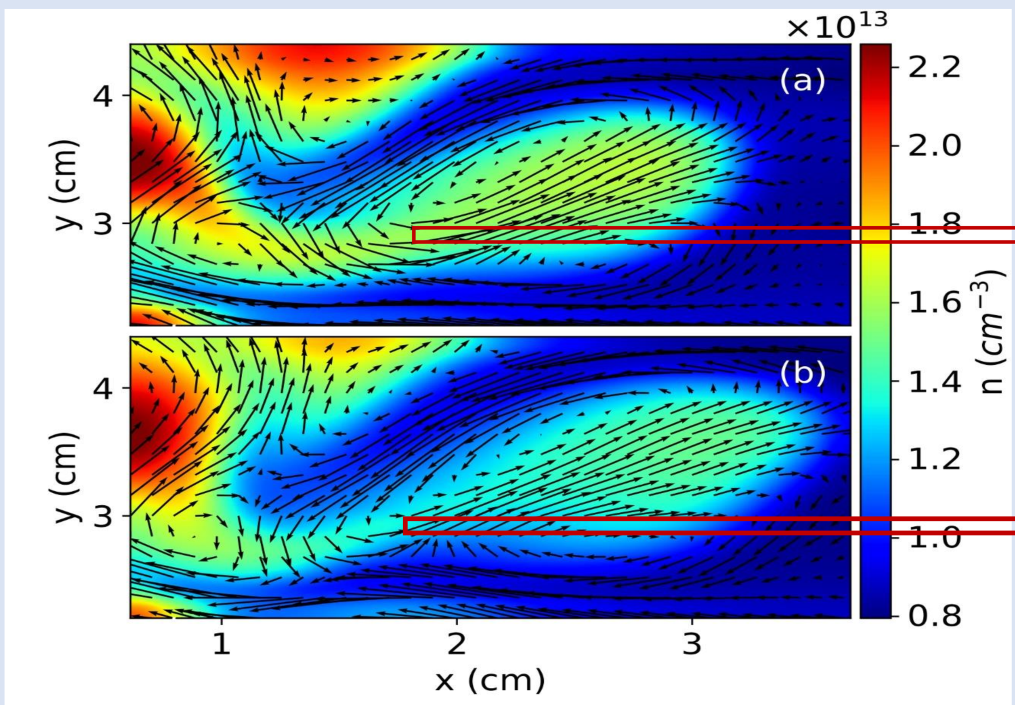
$v_x' \sim 1 \times 10^6/s$

Ellipses represent Position of the blob

$v_y' \sim 1 \times 10^5/s$

FIG.2:(a)-(b) indicate v_x' and (c)-(d) indicate v_y'at the same instant of time as Figs.1(a) and (b). These plots obtained from NSTX gas-puff imaging data.

Numerical simulation data

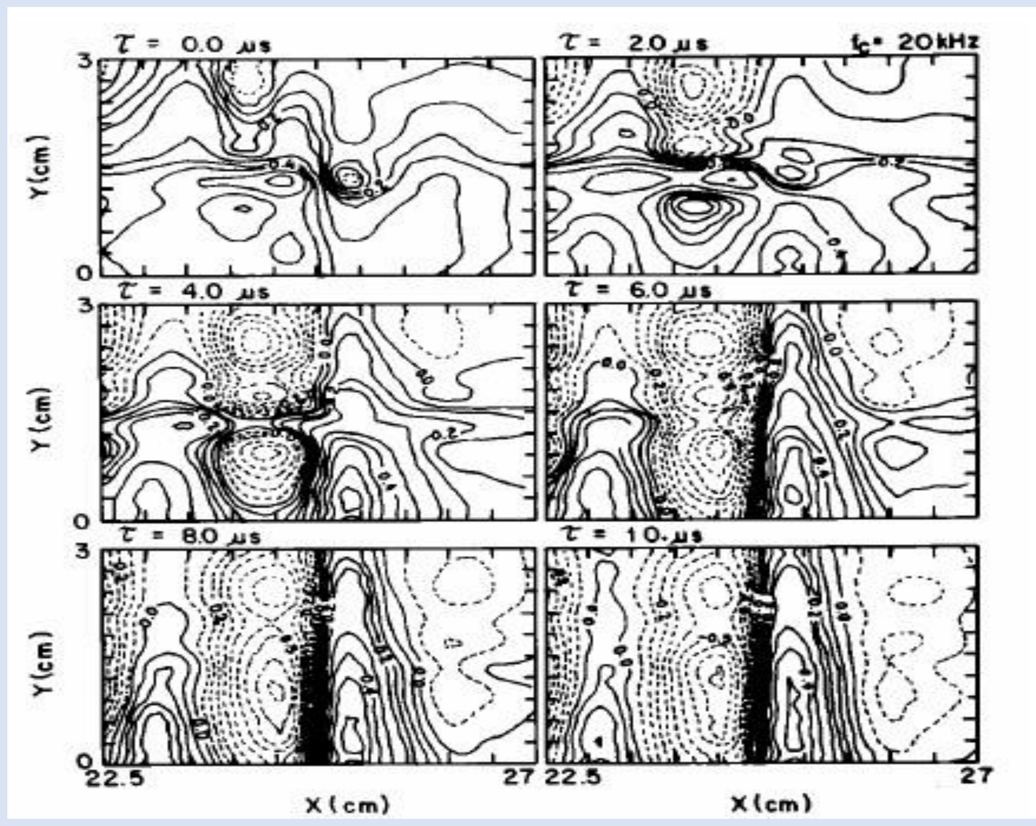


Initial phase of the blob formation. Poloidal width is higher.

After blob formation. Poloidal width is narrower Than the initial phase

Fig.3 Simulation data, behavior is similar to the sequence as in Fig.1

Blob formation from Langmuir probe data (shot #2009)



Data indicates:

$v_x' + v_y' \sim 3 \times 10^5/s$
and $\gamma \sim 2.8 \times 10^5/s$
γ has been estimated from Aditya tokamak data $T_e = 16eV$, $R = 1.0m$, $L_n = 0.02m$.
LCFS is at x=25 cm.

FIG. 3: Iso-potential structures for blob formation from Aditya probe data

Conclusions

- The NSTX velocimetry data from gas-puff imaging: $v_x' \sim 1 \times 10^6/s$ and $v_y' \sim 1 \times 10^5/s$ .These values along with $\gamma \sim 2 \times 10^5/s$ and $\delta_x \sim \delta_y$ are found to satisfy the condition. In L-mode, the condition is widely satisfied.
- For Aditya Langmuir probe data $v_x' + v_y' \sim 3 \times 10^5/s$ and $\gamma \sim 2.8 \times 10^5/s$ satisfy the formation criterion of blob. The condition also satisfies from Aditya tokamak for L-mode plasma.
- Blob formation in H-mode will be investigated in future.

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