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Experimental Validation of Universal Plasma Blob Formation Mechanism

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Anomalous plasma transport in the boundary region of a tokamak plasma is normally associated with density structures. These density structures are commonly termed as plasma blobs. Recently, a theory for a universal mechanism of plasma blob formation has been put forward that is based on a breaking process of a radially elongated streamer [1] in the presence of poloidal and radial velocity shear. The theory has been supported by numerical simulation results, but lacks experimental validation. In this work we report the first ever experimental validation of the universal mechanism by using NSTX and Aditya data to examine the dynamics of blob formation in that machines and comparing that to our theoretical and simulation results.

Figure-1(a)-(b) show snapshots of the formation of a plasma blob in one of the Ohmic L-mode plasma shots (shot #141745) in NSTX tokamak using images obtained from the gas-puff imaging (GPI) diagnostic [2]. The images have been superposed on quiver plots of the radial and poloidal velocities of the plasma obtained from velocimetry measurements [3,4]. It is to be noted that the visible images acquired by GPI are taken here as a proxy of the density contours as the intensity is mainly proportional to the density, and its temperature dependence has been neglected. The direction of the arrows indicates that the flow is sheared near the streamer structure in a manner such that the radially in and outward velocities can tear apart the plasma streamer structure. This is in accord with the theoretical picture of the universal mechanism of the plasma blob formation proposed in Ref[1]. Furthermore the mechanism requires that the following condition be satisfied,

$\frac{v_x^{'}}{\gamma} + \frac{v_y^{'} dx}{\gamma dy} \sim 1,$

where v_x' and v_y' indicate the radial gradients of the radial and poloidal velocities and γ indicates the linear growth rate of the interchange instability. We will also check the validity of this condition from the experimental data. In Fig-1(a) one sees the initial plasma blob formation phase where a poloidal compression of the streamer structure is taking place due to the presence of the positive and negative poloidal velocities. In this phase, two opposite directions of the radial velocities are seen (inner part of the streamer moves towards lower-R side and the outer part moves towards the local blob center) and at $x \sim 1465$ mm, $y \sim 273$ mm the plasma velocity is zero. This corresponds to the radial stretching as indicated in Ref.[1]. Similar behavior has also been seen in experimental shots of Aditya tokamak [5] and is analogous to our past numerical simulations where the velocity is seen to vanish at the point where the magnitude of the electrostatic potential of the mode is maximum. Fig.-1(b) shows a fully developed plasma blob phase. Here, the poloidal compression is not seen but the radial plasma motion is similar to Fig-1(a). From our analysis of the experimental data we find that the magnitudes of v_x' and v_y' over the plasma blob are $v_x' \sim 1 \times 10^4$/s and $v_y' \sim 3 \times 10^5$/s. These values along with $\gamma \sim c_s/\sqrt{RL_n} \sim 2 \times 10^5$/s and $dx \sim dy$ are found to nearly satisfy the universal condition given by above equation. An extended statistical validation of the universal condition carried out over a reasonably large blob data set is presently in progress and will be reported.

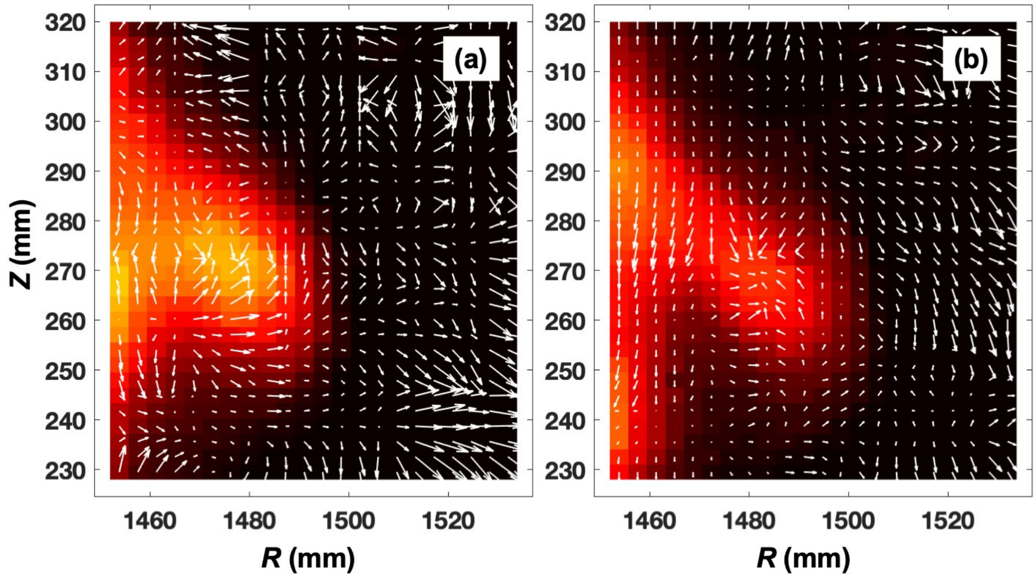

Figure 1: (a) and (b) are snapshots of the blob dynamics taken at the initial formation phase and fully developed phase respectively. These GPI images are superposed on quiver plots of the radial and poloidal velocities of the plasma. (a) and (b) are $5\mu s$ apart in time.

References

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