Blob physics and analysis from Gas Puff Imaging in the National Spherical Torus Experiment (NSTX)

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It is well known that the cross-field transport in the edge of tokamaks has a substantial, if not dominant, contribution from intermittent convective processes [1]. Filamentary structures, with a long parallel scale length relative to the magnetic field, have been measured in many experiments. In the National Spherical Torus Experiment (NSTX) the radial vs. poloidal cross section of these filaments, known as 'blobs', is imaged with high spatial and temporal resolution with a diagnostic known as Gas Puff Imaging (or GPI)[2]. In this diagnostic, a local gas puff is used to increase the contrast and brightness of the blobs while observing the emitting gas cloud (approximately) parallel to the local magnetic field.

The 'blob' phenomena are observed to be born from edge turbulence which is, in turn, most likely due to drift wave and/or curvature-driven instabilities. In general, in NSTX, both turbulence and blobs are substantially reduced during H-mode respect to the Ohmic or L-mode (lower confinement) regimes. An example is shown in Fig. 1 in which images from a ~23 cm x 23 cm radial vs. poloidal portion of the edge just above the outer midplane are shown. The characteristics of the H-mode turbulence and blobs in NSTX present a continuum from a turbulence level just above that measurable (a "quiescent" H-mode as in Fig. 1(b)) to that approaching L-mode level (an "active" H-mode, Fig. 1(c)), at least for brief periods of time. The H-mode blobs observed in NSTX seem to be highly localized and are not the same as small (type V) ELMs.

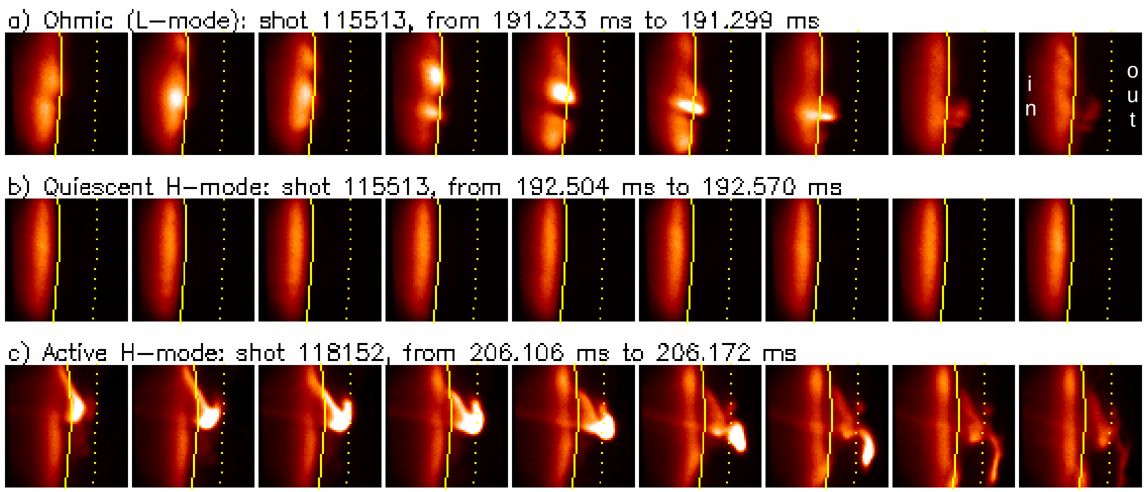

Fig. 1 Blob regimes in NSTX. Sequence of images obtained at 120000 frames/s with each image exposed for 3 μs. A deuterium puff is injected from the right and D_α light is imaged. Each image corresponds to ~23 cm x 23 cm (solid line: separatrix, dotted line: antenna limiter shadow).

The turbulence giving rise to the blob phenomena has been characterized in NSTX as having poloidal correlation lengths of 4-9 cm, radial correlation lengths of 2-6 cm, poloidal velocities of up to 5 km/s (in the ion diamagnetic drift direction) and radial velocities of up to 2 km/s (radially outwards). The measured k spectra structure is consistent with the usual drift wave scaling of $k_{pol}\rho_i \approx 0.2$. Nevertheless, despite the general reduction in (light) turbulence levels between L-mode and H-mode, the radial and poloidal correlation lengths of the turbulence are not significantly different between L-mode and H-mode (Fig. 2), and the average radial gradient of the poloidal velocity of the turbulence is smaller in H-mode than in L-mode plasmas, at least within the region measured. The most significant change in the turbulence from L-mode to H-mode is a decrease in the fluctuations in the poloidal velocity of the turbulence, as if the flow was more 'frozen' in H-mode.

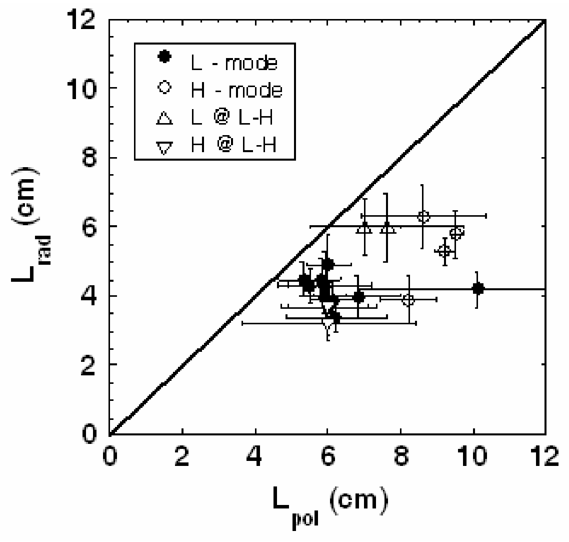

Fig. 2 Radial vs. poloidal correlation lengths inferred from camera images for a set of discharges of various types. There are no statistically significant variations between L-mode and H-mode correlation lengths in this data set.

Bicoherence analysis of time series of the light from ~2 cm diameter "spots" within the emitting gas cloud have been performed. Previous experiments using bicoherence to study L-H transition dynamics have been carried out in other devices [3] and the results have found that the coupling between high frequency and low frequency fluctuations inside the separatrix increases substantially just prior to the L-H transition. In NSTX, no significant increase in the amount of nonlinear coupling between high frequency and low frequency fluctuations was observed just prior to (or after) the L-H transition. These results indicate that during the L-H transitions the turbulence is not coupling to poloidal flows in the edge of NSTX at least in the region across the separatrix and just above the outer midplane where the GPI diagnostic is located.

Finally, the measured blob radial velocity in the scrape-off layer appears to be bounded by theoretical limits [4]. On the lower side (minimum velocity) this limit is imposed by the "sheath-connected" regime and, on the upper side (maximum velocity), the limit is set by the "resistive-ballooning" regime.

Analysis in these and other areas, as well as additional experimental activities, continue and will be presented at this conference.

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