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On the properties of edge localised density fluctuations observed in quasi-double null identity experiments in JET

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Introduction Small ELM regimes combine benign heat depostion with good confinement. A whole range of fluctuations has been observed in these regimes (also varying with the particular type of scenario run), whose role is not always clear. To understand their physics and the extrapolability to ITER, it is important to identify which of these modes are indeed sustaining the regime (e.g. giving rise to enhanced transport across the separatrix). Here we study in more detail the characteristics of a type of density fluctuation that was observed, among other phenomena, in a first set of identity experiments performed on JET [1, 2].

Identity Experiments The experiments were designed to match, in terms of dimensionless parameters, ASDEX Upgrade discharges exhibiting type-II ELMs. The plasmas had $q_{95} \sim 4$, $\beta_{\mathrm{pol}} \sim 0.9$, $n_e/n_{\mathrm{GW}} \sim 1$ and were run in a highly shaped configuration ($\delta_{\mathrm{up}} = 0.50$, $\delta_{\mathrm{low}} = 0.38$) close to double null. At low current and field (0.86MA, 1.15T), long time intervals (up to 6-8 energy confinement times) free of type-I ELMs with stationary pedestal density and temperature (figure 1) were found. Attempts to push this regime to higher field and current have not been not successful. Discharges run at 1.2MA/1.6T still had some shortlived phases without type-I ELMs, but at 1.5MA/2.0T regular type-I ELM activity was encountered.

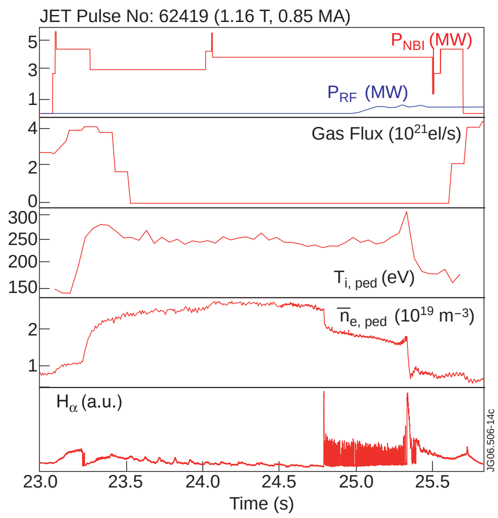

Figure 1: JET pulse 62419.

Compared to earlier type-II ELM approaches, the stationary pedestal density was a novelty. The earlier attempts had managed to reduce the type-I ELM frequency, but failed to suppress them completely because the edge density still kept increasing between ELMs [1]. In those experiments the reduction in type-I ELM frequency was associated with a type of edge turbulence that is called on JET the washboard mode [3, 4]. While having an effect on the edge temperature, washboard modes were found unable to control the edge density [3]. Hence, the newly observed constant density requires the presence of some other edge instability.

*See the Appendix of M. L. Watkins et al., Fusion Energy 2006 (Proc. 21st Int. Conf. Chengdu, 2006) IAEA, (2006)

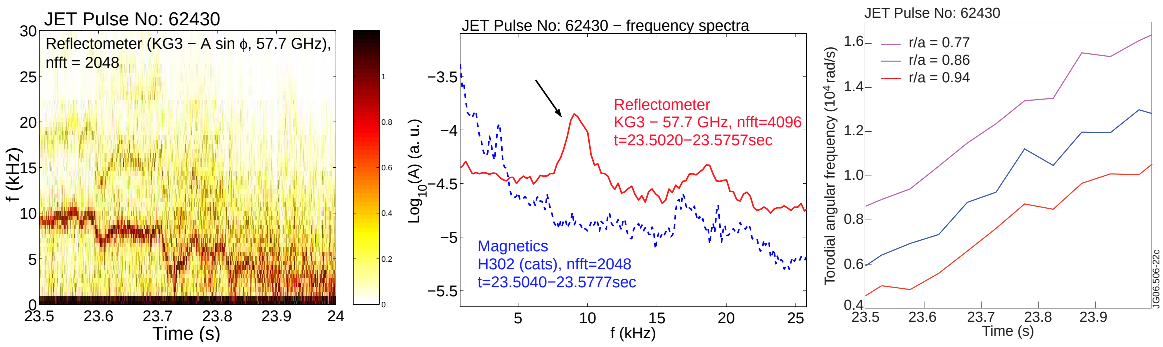

Figure 2: (a) Spectrogram from reflectometry showing narrowbanded density fluctuations, (b) comparison of frequency spectra from reflectometry and fast magnetics. The density fluctuations are not detected on the magnetic fluctuation signal. (c) Time evolution of the edge plasma rotation, obtained by charge exchange recombination spectroscopy.

It is noted that in these experiments the shape match to the ASDEX Upgrade reference discharge (which had $\delta_{\rm up} = 0.35$, $\delta_{\rm low} = 0.45$) was not perfect. More recent experiments with better shape match [5] show a different edge behaviour, with more bursting activity (here the activity is continuous). It is therefore not clear whether the regime considered here and the one in [5] are indeed the same.

Fluctuations The density fluctuations under consideration have low frequency, typically less than 20 kHz (figure 2a). They have been detected near the plasma boundary on the low field side through reflectometry and a vertical chord of JET's far-infrared interferometer. For this plasma shape the chord crosses the horizontal midplane 8 cm inside the separatrix, a few cm inwards of the pedestal top. The mode is not found on any of the magnetic fluctuation signals (figure 2b). This implies that the fluctuations are either electrostatic, or that they have very high mode numbers.

The temporal frequency behaviour of the mode is singular. Although the edge plasma rotation is accelerating (figure 2c), the frequency of the mode keeps decreasing (figure 2a). This indicates that the mode is propagating against the bulk plasma rotation (hence, in the direction of the electron diamagnetic drift). In addition, there are much sharper (transient) drops in mode frequency (figure 2a at 23.60s, 23.71s, and 23.82s). These are coincident with the arrival of sawtooth heat pulses at the plasma boundary.

The O-mode reflectometer system comprises ten channels with fixed frequency probing densities between 0.43 and 6.01e19 m^{-3}, thus providing coverage for different regions within the pedestal. It is found that the density fluctuations are preferentially detected on channels probing near the pedestal shoulder (figure 3).

Induced particle losses Figure 4a shows data for a time window of discharge 62433. The discharge was run at 2.0T/1.5MA and had more or less frequent type-I ELMs (no long periods free of type-I ELMs, as at low current). Despite this, occasional shortlived phases of density fluctuation activity could still be found (see the time interval 22.49-22.53s). Comparing phases with and without the fluctuations gives further physics insight. When the density fluctuations

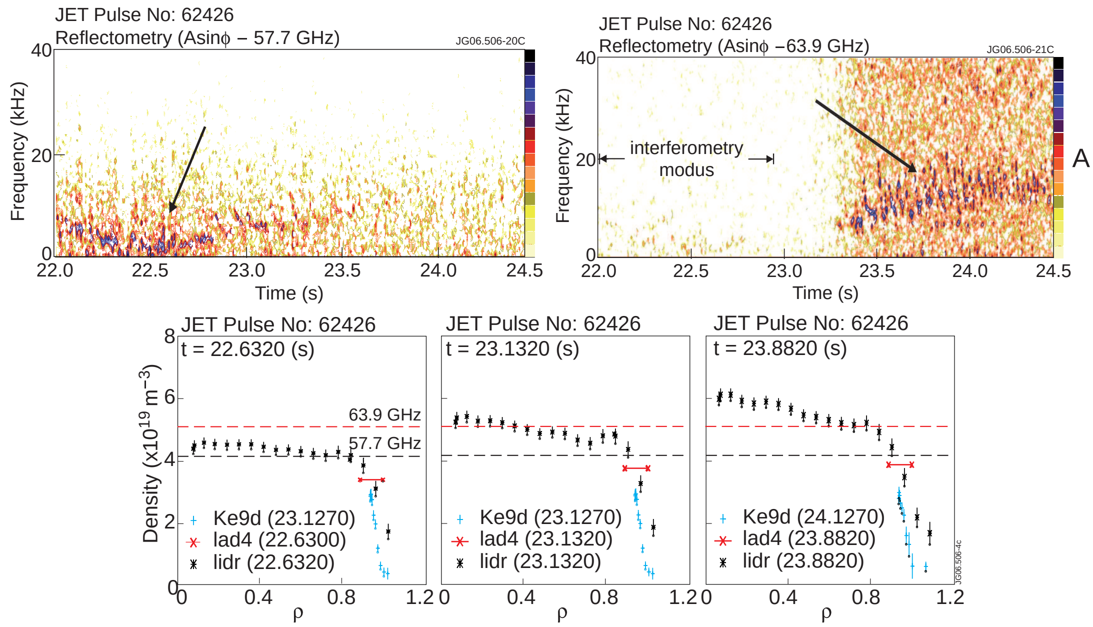

Figure 3: Spectrograms of $A\sin\phi$-signals for two reflectometer channels with $n_{e,cutoff} = 4.13e19$ m^{-3} (top left) and 5.07e19 m^{-3} (top right) during a density ramp up. The density fluctuations switch channels at $t = 23.3$s. A sequence of density profiles for three different times is shown below, together with the respective cut-off positions of reflectometry (horizontal lines), indicating radial locations of spectrogram observations. Until ~22.9s the 63.9 GHz channel is in interferometry modus (reflection at inner wall).

are absent, the edge density increases between the ELMs. On the contrary, when the edge fluctuations are present, the edge density increase is reduced or even stops. This demonstrates that the density fluctuations are able to contribute to the edge density control through enhanced particle losses. Unfortunately, the electron cyclotron emission is in cut off and we have therefore not been able to determine in how far the edge temperature is also affected by the mode.

It can also be seen that the H_α emission is higher when the fluctuations are present (a similar enhancement has also been observed for C-III emission). This effect has been identified on chords monitoring the outer divertor, the inner divertor and the main chamber. Time lags for the onset of enhanced emission at different poloidal locations (figure 4b) are interpreted in terms of the finite parallel transit time of ions in the SOL [6]. The time lags are consistent with the particles being released near the low field side midplane. These time lags are approximately a factor three higher than the ones observed for nearby type-I ELMs (e.g. for the inner divertor 1.3 ms (mode) versus 400 μs (type-I ELM)). Because the transit time of ions is inversely proportional to the square root of temperature, this implies that the temperature of ions released by the density fluctuations is nearly an order of magnitude smaller than those expelled by the type-I ELMs.

Contrary to what one might expect, the ELM repetition rate is not seen to decrease, despite the additional particle losses. Instead, on the H_α trace the ELM periods with fluctuations are ended by smaller and more shortlived spikes (presumably still attributable to type-I ELMs)

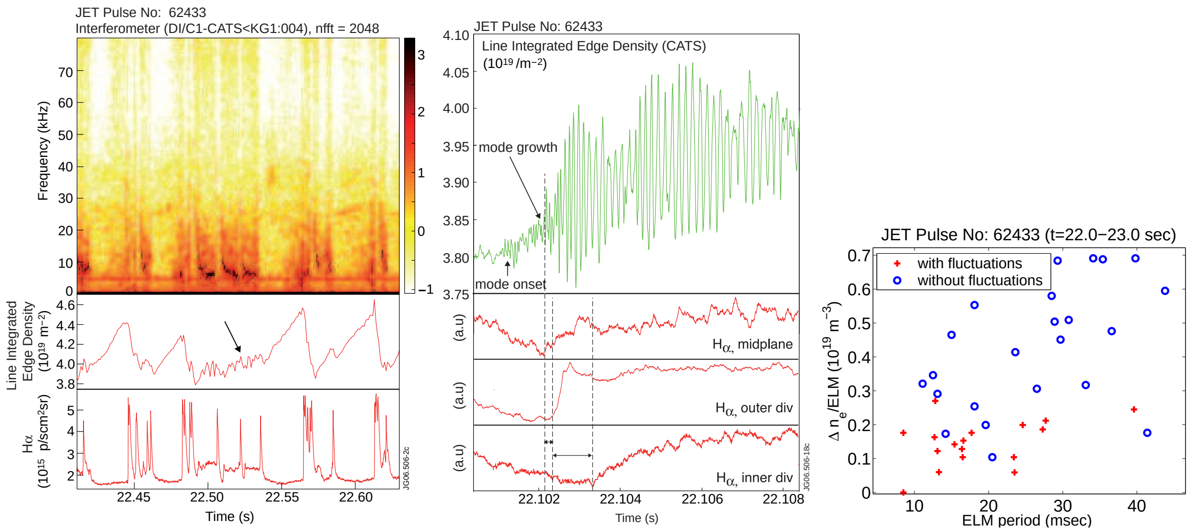

Figure 4: (a) Spectrogram of the edge chord signal of the FIR interferometer, showing isolated phases with density fluctuations between some type-I ELMs. Also shown are the line-integrated edge density and the H_α emission in the outer divertor. (b) Timings for onset of enhanced emission at various locations(c) comparison of ELM-induced particle losses for ELM periods with and without the density fluctuations

compared to the ELM periods without fluctuations. Figure 4c shows ELM statistics done for a wider time window of the same discharge. It shows that for a given ELM period the particle losses per ELM go down if the ELM was preceded by the density fluctuations, while the time between two consecutive ELMs remains largely unaffected (or perhaps even decreases sligthly).

Discussion The properties found for this type of fluctuation make it a good candidate to explain the steady density in the long type-I ELM-free phases obtained. Somewhat unexpectedly, many of the features of this mode are reminiscent of the quasi-coherent mode of Alcator C-Mod [7], opening the possibility of a link between this regime and the EDA H-mode. When found in type-I ELMy H-modes, the fluctuations do not result in a reduction of the ELM repetition frequency. Instead, the ELM particle losses (and presumably also the overall ELM size) become smaller. Other types of edge localised activity have been observed as well, whose role is being assessed.

[1] Saibene G *et al* 2005 *Nucl. Fusion* **45** 297
[2] Stober J *et al* 2005 *Nucl. Fusion* **45** 1213
[3] Perez C P *et al* 2004 *Plasma Phys. Control. Fusion* **46** 61
[4] Smeulders P *et al* 1999 *Plasma Phys. Control. Fusion* **41** 1303
[5] Nunes I *et al*, "Small ELMs in quasi-double null plasmas at JET", P5.137, this conference
[6] Loarte A *et al* 2004 *Phys. Plasmas* **11** 2668
[7] Mazurenko A *et al* 2002 *Phys. Rev. Lett.* **89** 225004

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