

## AN INTERPRETATION OF THE STRUCTURE OF ELMS AND THE H TO L TRANSITION ON JET

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### Introduction

Edge localised modes play an important role in H-mode confinement and stability /1/. Recent studies have identified precursors to the H to L transition rotating in the opposite direction to co-injected neutral beams /2/, and proposed that the H to L transition is triggered by a giant ELM /3/. Tearing modes driven by edge current density and ballooning modes driven by pressure gradient have been put forward as possible explanations for these precursors.

Initial studies on JET /4/ have described the characteristics of edge fluctuations in X-point plasmas and their effects on energy and particle confinement.

In this paper we perform a detailed magnetic analysis of ELMs and their precursors, and make a comparison with the H to L transition. These magnetic results correlate with those of other diagnostics such as the microwave reflectometer and X-point Langmuir probes. Localization of ELMs and H to L transition spike is determined with the soft X-ray camera, and particle transport estimated by an H-alpha detector. Finally possible theoretical explanations for ELMs are discussed.

### Structure of ELMs and precursors

The ELM structure is examined poloidally by two sets of coils (10kHz cut-off, 6dB roll-off) near the X-points and toroidally by lower frequency response coils (10kHz cut-off, 12dB roll-off).

Typical ELMs during an H-mode are presented fig(1a). ELMs are visible by all the diagnostics mentioned above. In addition a significant magnetic fluctuating toroidal component was observed (typically, larger than one tenth of the fluctuating poloidal component:  $\bar{b}_\theta/B_{pol} \approx 5 \cdot 10^{-4}$ ). The ELM spike has predominantly an  $n=0$  component with an  $n=1$  contribution of typically 30%. The poloidal component is predominantly  $m=1$ , with a phase inversion about the X-point for both single null and double null plasmas. In the single null case, the second phase inversion does not occur in a reproducible location.

ELMs are preceded by precursors and also often followed by postcursors (fig(1b)). Typically precursors start at about 0.5ms before the ELM, and postcursors stop 1ms after. Both are identical except that the amplitude of postcursors ( $\bar{b}_\theta/B_{pol} \approx 3 \cdot 10^{-5}$ ) is often two or three times higher than the amplitude of precursors.

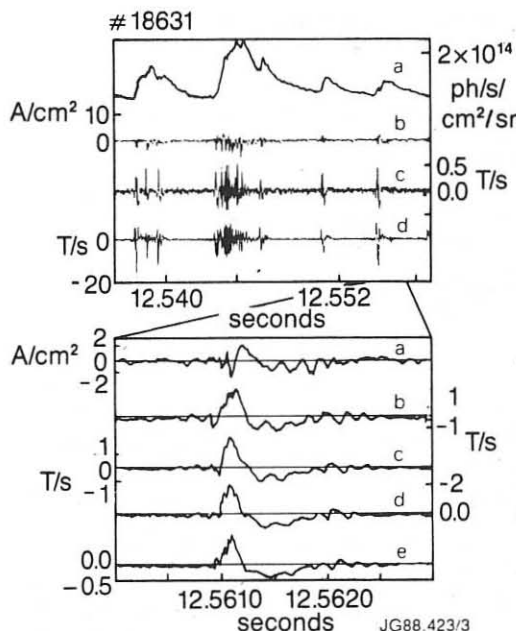


Fig 1a : ELMS for pulse 18631 ( $q$  at the edge : 9)  
 a) H-alpha channel viewing the X-point.  
 b) Langmuir probe signal.  
 c) Toroidal magnetic component near the X-point.  
 d) Magnetic coil near the X-point.

Fig 1b : Poloidal correlation of coils showing the propagation ( $m = 9$ ) of the oscillations before and after an ELM.  
 a) Langmuir probe.  
 b to e) poloidal array of coils near the X-point.

Because of this small amplitude they are only detected by the magnetics and the langmuir probe. Toroidal correlations show an  $n = 1$  component rotating opposite to the co-injected neutral beam direction with a frequency of about 6 to 8kHz. The frequency of precursors has been found to be close to the electron diamagnetic drift frequency calculated in the high shear region ( $\approx 10$ kHz). Poloidal mode numbers in the range of 5 to 10 have been estimated for the ELM precursors. Such high  $m$  ( $n = 1$ ) modes are resonant very near the separatrix in the high shear boundary region.

Soft X-rays have verified  $1/4$  that ELMs originate near the edge, and also exhibit an inversion radius at about 5 to 10 cm inside the plasma indicating the enhanced particle and energy transport in this region when ELMs occur. To explain this large transport during the ELMs the island width has been calculated in the high shear region for two neighbouring surfaces, assuming a tearing mode model for the precursors. Within the range of uncertainties over the edge shear and poloidal mode number of the precursors, overlap appears possible for the measured amplitude of ELM ( $b/B_{pol} \approx 5 \cdot 10^{-4}$ ), thus leading to a stochastic field topology and enhanced transport. To support this interpretation, reflectometry measurements of  $n_r$  near the inversion radius have been made during and in between ELMs. Preliminary results show at all frequencies an increased level of density fluctuations (by a factor two or three) during ELMs.

Differences have also been noticed on toroidal correlations, but more complete analysis is required.

#### Comparison with the H to L transition

A similar magnetic analysis has been carried out for the H to L transition (fig(2)). Unlike ELMs, the spike that occurs at the H to L transition has dominantly an  $n=1$  structure with a strong  $n=0$  contribution of about 40%. The poloidal structure is also  $m=1$  predominantly but the phase inversions does not occur at the X-point. However this  $n=0$   $m=1$  component is probably due to the fast displacement of the plasma ( $\sim 1$ cm radially,  $\sim 2$ cm vertically) when the transition occurs.

In addition, the H to L transition is also often preceded by precursors for about 1ms. They again rotate in the electron diamagnetic drift direction with a frequency of 6 to 8 kHz, and exhibit a predominantly  $n=1$ , and  $m=5$  to 10, structure, indicating that they are localized near the separatrix.

The edge localization of the H to L transition is corroborated by the soft X-ray reconstruction shown fig(3). The spike of the transition does not affect the center of the plasma, and is a much faster phenomenon ( $\sim 100 \mu\text{s}$ ) than the ELM spike ( $\sim 0.5$  ms).

Given the identical precursors observed before the ELMs and the H to L transition, it seems that they may both have the same underlying cause. However, a decisive conclusion cannot be drawn due to differences in the modes structure and the duration.

#### Interpretation and conclusion

As the ELMs during H-modes are accompanied by  $n=1$   $m=5$  to 10 precursor structures, high  $n$  ballooning activity would seem to be precluded as an explanation of their origin. It seems likely that in the high shear edge region,  $n=1$  instabilities with a broad spectrum of coupled poloidal harmonics are destabilized. The observed rotation of the precursors in the electron diamagnetic drift direction with approximately the electron diamagnetic drift frequency is in agreement with the tearing theory /5/.

The magnetic fluctuation level during ELM spikes may be sufficient to give island overlap in the high shear region. This overlapping could lead to ergodization of field lines and enhanced edge transport /4/, reducing the edge pressure gradients. Thus, tearing modes are a possible candidate to explain the precursors and would lead to stochastic transport during ELMs.

The H to L transition spike is preceded by similar precursors, but its different mode structure and shorter duration make it difficult to identify the transition as a giant ELM.

#### References

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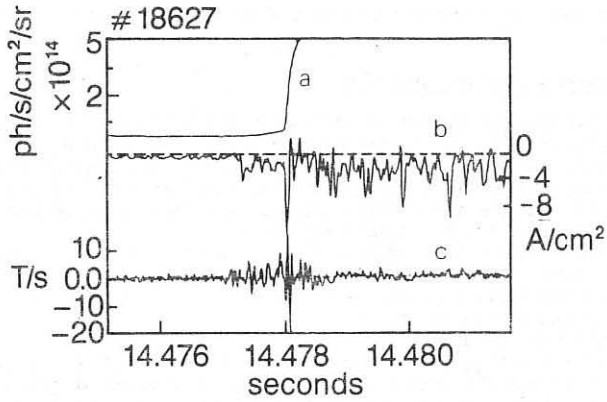


Fig 2 : H to L transition showing the precursors.  
 a) H-alpha channel viewing the X-point.  
 b) Langmuir probe signal near the X-point.  
 c) coil near the X-point.

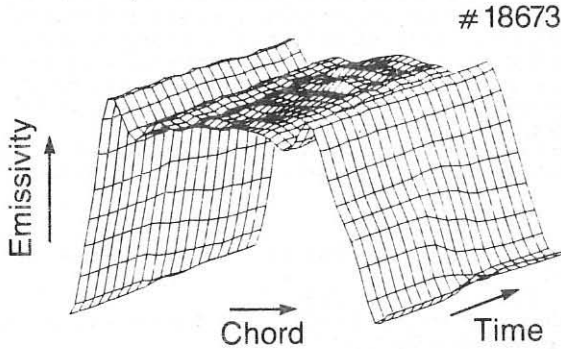


Fig 3 : Reconstructed X-ray emissivity of an H to L transition spike over 0.5ms along the vertical chord ( $Z = -1.6$  to  $Z = 1.6$ ).