FLUCTUATIONS AND CONFINEMENT IN JET

P A Duperrex[+], P Cripwell[×], A W Edwards, R D Gill, R S Granetz, A Hubbard[×], M Malacarne, G Matthews[*], F Simonet[ι], J Snipes, A Weller[°]

JET Joint Undertaking, Abingdon, Oxfordshire, OX14 3EA, UK
On attachment from: [+] CRPP, Lausanne, Switzerland,
[×] Imperial College, London, UK
[*] Culham Laboratory, Abingdon, Oxfordshire, UK
[ι] CEA, Cadarache, France
[°] IPP, Garching, FRG

ABSTRACT

Fluctuation measurements in JET are presented and their correlation with the confinement is discussed for limiter and X-point discharges.

I INTRODUCTION

Measurement of turbulence in tokamak is motivated by the fact that anomalous transport is often attributed to micro-instabilities. The results presented here concern fluctuations analysis in JET using different diagnostics: edge located pick-up coils for poloidal magnetic fluctuations ($\tilde{b}_\theta$), diodes for fluctuations of soft X-ray and visible light emission, a reflectometer for density fluctuations and Langmuir probes for electrostatic fluctuations.

II LIMITER DISCHARGES

Magnetic pick-up coils in JET detect the usual Mirnov activity ($f \sim 0.3 \rightarrow 7$ kHz) [1], events linked with the internal disruption (the so-called gong [2]) and fluctuations [3]. The signal is either recorded with relatively fast ADC (sampling frequency: 40 kHz) or monitored by 8 hardware band-pass filters (from 5 to 56 kHz). The amplitude decreases with frequency: $\tilde{b}_\theta \propto f^{-1.5 \pm 0.5}$ above 2 kHz. The total normalised amplitude is typically: $\tilde{b}_\theta/B_\theta \sim 10^{-4} - 10^{-5}$. Cross correlation techniques have been used to determine the spatial characteristics of these fluctuations. Two different types of activity can be observed in the frequency range 0 to 20 kHz. The first, dominant at frequencies up to 10 kHz, is observed to propagate in the electron diagmagnetic drift velocity direction (also with Neutral Beam Injection). On the contrary, the second type (dominant from 10 kHz) appears to be stationary even during NBI with n=1 and m equal to the outermost integral q_ψ value. Both types are strongly correlated along a direction parallel to the equilibrium magnetic field (B_o) (fig. 1). The corresponding correlation length is larger than the major radius (R). The phase shift between 2 magnetic probes along this direction is very close to zero for all frequencies indicating $\underline{k} \cdot \underline{B}_o \sim 0$ for the broadband spectrum.

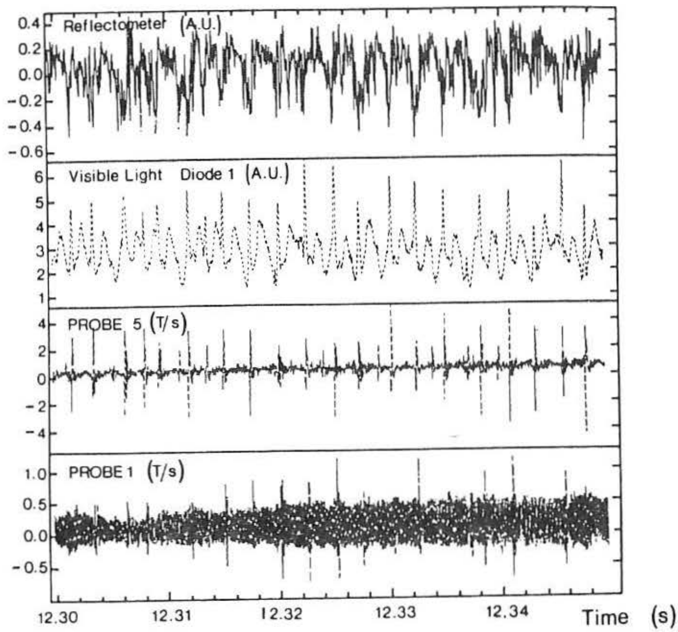

Fig. 3: "spike" activity at the edge during the L phase prior to an H mode transition. # 10850

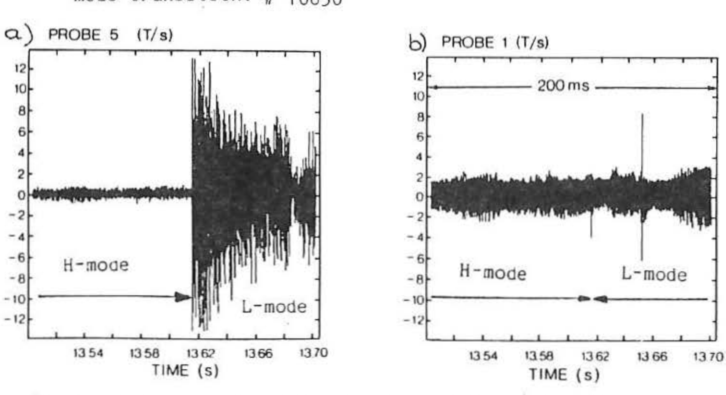

Fig. 4: Magnetic signals at the H-L transition. # 10789

a) probe 5 near the X-point for which edge fluctuations signal dominates.

b) probe 1 behind the limiters, dominated by coherent oscillations resonant deeper inside the plasma.

The $\tilde{b}_\theta$ level depends strongly on the plasma-probe distance and increases when additional heating is applied. This enhancement is observed for all pick-up coils and therefore is not due to a simple shift of the plasma. It also increases with I_p and decreases with B_T though it is not possible to determine if it is a genuine enhancement or is due to the closer location of the resonant layer at lower $q_\psi(a)$. However, taking these effects into account by multiplying $\tilde{b}_\theta$ by $q_\psi(a)$ (or B_T/B_p) the normalised level is shown in Fig. 2 (for f = 40 kHz in this example) to increase with τ_E^{-1} (τ_E = energy confinement time).

Fluctuations from visible light emission were measured by 2 arrays of soft X-ray diodes without foils. Tomographic reconstruction confirms that the measured emission is essentially located at the plasma edge. Cross-correlation analysis shows the presence of high m wave numbers. In the frequency range 15-20 kHz the measured m numbers are about 25 - 35 and for the frequency range 40-60 kHz the corresponding m numbers are m ~ 70-100.

Density fluctuations have been measured with a reflectometer. Coherent oscillations are sometimes seen which correlate well with the magnetic signals. However no correlation between broadband density and magnetic fluctuations has yet been found. Langmuir probes in the scrape-off layer can also detect fluctuations in the range 0 to 20 kHz. Preliminary results indicate that the correlation length is shorter than the distance (10 cm) between the 2 probes. No correlation has been obtained either with the magnetic or the reflectometer data as far as the broadband spectrum is concerned.

III FLUCTUATIONS DURING X-POINT DISCHARGES

During X-point discharges, visible light fluctuations are seen to correlate with the first type of magnetic activity (the propagating type) measured with a coil which is near the X-point and very close to the plasma for this configuration, whereas the n=1 low m magnetic standing fluctuations do not have any visible counterpart.

A new type of edge activity in JET has also been observed. Perturbations appear to dominate in the phase preceding the transition from a low confinement regime (L-mode) to a high confinement regime (H-mode) (fig. 3): regular spikes are observed on the magnetic, reflectometry (when probing the edge density) and visible light emission signals. They are correlated with a sudden flattening of the soft X-ray emission at the edge. The repetition frequency of these spikes is slowed down by sawtooth disruptions, one of which often marks the final transition to the H-mode. In contrast H-L transitions (which are preceded by a large increase of edge radiation) are characterised by a sudden burst of broadband (turbulent) activity with $m \geq 6-8$ and $n \geq 1$, (fig 4a). Coherent oscillations resonant on surfaces deeper inside the plasma are apparently unaffected by the transitions (fig 4b). The X-ray emission drops at the edge and H_α radiation from the single X-point region shows a large increase; very often spikes reappear after this initial burst. During the H-mode, edge turbulent fluctuations are still present, though at a much lower level.

IV DISCUSSION AND CONCLUSION

Turbulence up to 50 kHz has been observed with different diagnostics. Magnetic fluctuations have a very long correlation length ($\gtrsim R$). This could confirm that the magnetic connection length is of the order of ~ qR.

No correlation has yet been found between the broad-band fluctuations of the different diagnostics for limiter discharges. During X-point discharges the light emission exhibits some correlation with a magnetic coil near the X-point for which edge fluctuations dominate the signal. The enhancement of $\tilde{b}_\theta$ during additional heating proportionally to τ_E^{-1} points out a possible link between $\tilde{b}_\theta$ and the anomalous transport. Edge perturbations appear to play an important role in the physics of the high confinement regime (H-mode).

REFERENCES

[1] Snipes J et al: EPS Schliersee 1986, Vol I, p152.

[2] Duperrex P A, Keller R, Malacarne M, Pochelon A: EPS Budapest 1985, Vol I, p126.

[3] Malacarne M, Duperrex P A: JET Report JET-P(86)31.

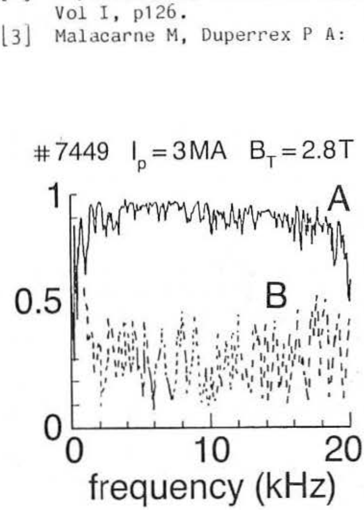

Fig. 1: Coherence spectrum between 2 magnetic coils A) along $\underline{B}_0$, B) across $\underline{B}_0$.

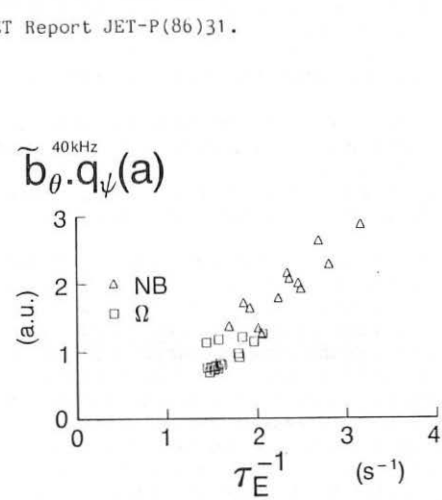

Fig. 2: Normalised level $\tilde{b}_\theta$ (at 40 kHz) versus τ_E^{-1}. Ip = 2, 3, 4 MA, B_T = 2.5, 2.8, 3.4 T.