

Shear effect on edge turbulence during the L-H transition in JET and ASDEX Upgrade plasmas

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Introduction

The future fusion power devices are foreseen to operate in H-mode where the plasma particle and heat confinement efficiency is the best achieved nowadays. This improved confinement regime ensures the best fusion power efficiency. However, the transition from low to high confinement mode remains not clearly understood. L-H transitions are characterized by intermediate phases which may provide understanding about the triggering physics involved. We present two types of intermediate L-H transitions or ‘dithering H-modes’ such as the M-mode on JET [1] and the I-phase on AUG [2]. Intermediate L to H confinement states like M-mode and the I-phase exhibit similar behaviour [3]. Both appear to be dithering H-modes [4] and are obtained preferentially at rather low plasma densities as they are characterized by quasi-periodic transients with a coherent mode developing in the pedestal region at a frequency of about 1 or 2 kHz. The explanations differ from self-regulating turbulence via a predator-prey process involving zonal flows or more recently the I-phase bursts have been described as a type-III ELM [5]. The interest of studying such an intermediate state is to highlight the physical mechanisms involved in the L-H transition which generally occurs.

Measurement technique

Measurements were performed using the fast frequency swept X-mode reflectometry diagnostics installed on JET [6] and AUG [7]. JET system can be swept in 10 μ s with a dead time in between sweeps of 5 μ s thus providing a sampling rate of 66 kHz, while the system

installed on AUG can be swept in 1 μs with a dead time of 0.25 μs which provides a sampling rate of 800 kHz. These diagnostics are primarily dedicated to electron density profile measurements; however they can also provide information on the plasma density turbulence [8] regarding the fluctuation level, the wave number spectra and the frequency spectra. The latter is the purpose of this paper and one of the great advantages of the frequency swept systems over the hopping ones, despite their lowest signal to noise sensitivity, is the radial resolution as they continuously probe the plasma radially. Moreover, the same data for the frequency spectra and the density profiles are used providing a precise radial determination of the measurements.

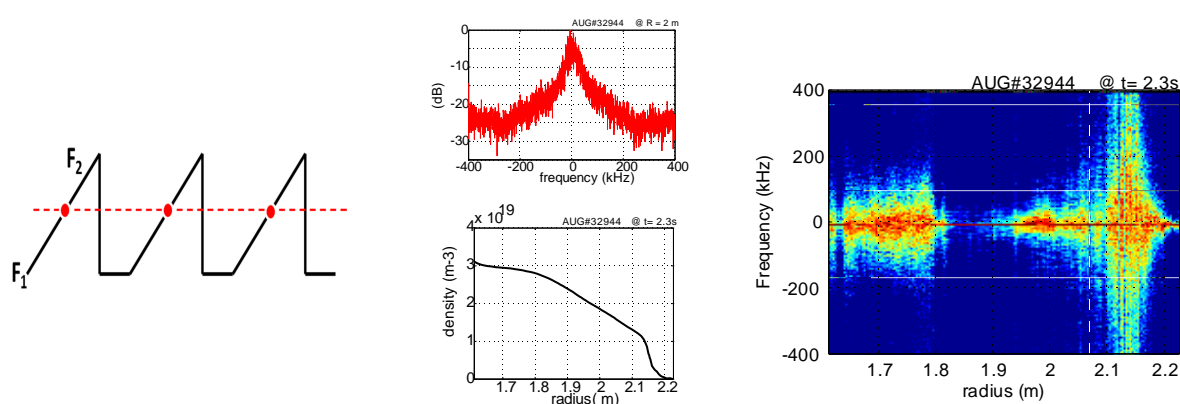


Figure 1 : Fixed frequency data processing of the reflected signals from repetitive frequency sweeps can provide the turbulent frequency spectra (with a sample rate of 66 kHz on JET and 400 kHz on AUG) at a given radius and the density profiles which provide the radial localisation of the spectra measurements. The continuous sweeping provides the radial dependence of the spectra.

Experimental results

Figure 2 is the example of an L-H transition obtained on AUG using ECRH additional heating power. The 250 ms time window corresponds to the record of 200 000 sweeps operated in one burst at a rate of 1 μs sweep time with a dead time of 0.25 μs . The coherent modes during the I-phase are clearly detected on the divertor shunt currents at 2.9 s with the frequency decreasing from 2 to 0 kHz at 3.07 s as the H-mode establishes.

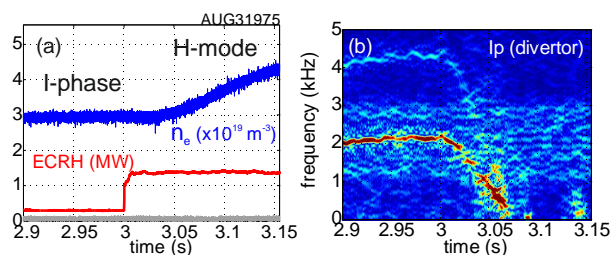


Figure 2 : (a) I-phase occurring before H-mode under ECRH additional input power. (b) time evolution of the edge coherent mode frequency recorded on the divertor current.

On figures 3, the turbulent frequency spectra in the top pedestal region turn locally from broadband to coherent modes due to the strong poloidal flow generated by the gradients. More strikingly, the frequency of this mode reverses sign from positive to negative at 2.12 m. This reversal occurs at the well of the radial electric field ($E_r \approx \frac{\nabla P}{e.n}$).

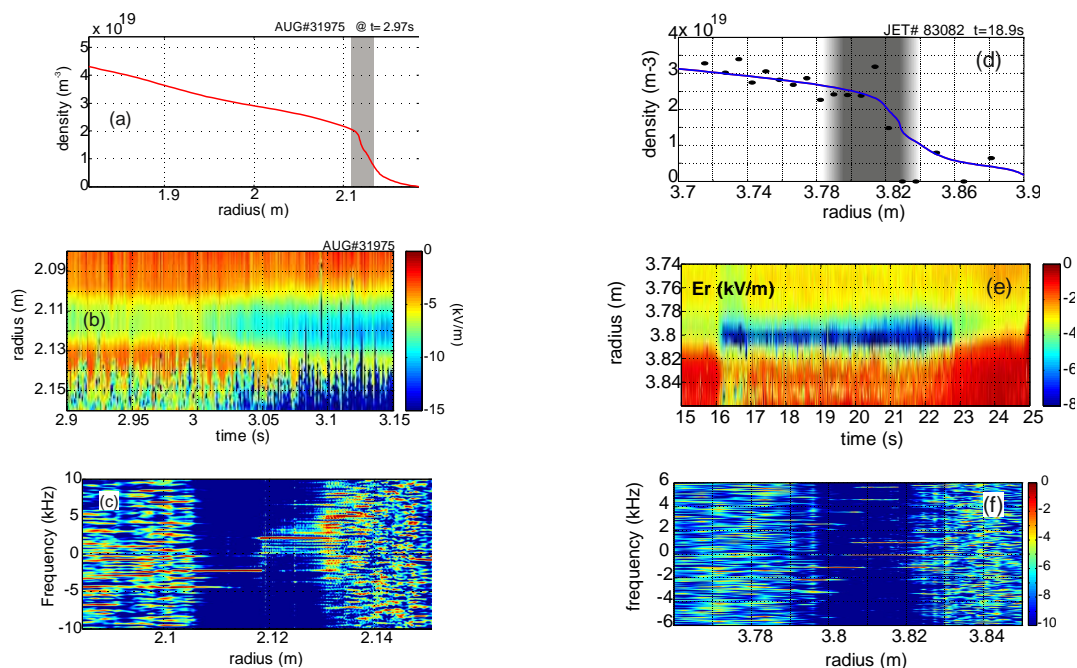


Figure 3 : (a) the vertical grey trace indicates the region where the turbulence changes from broadband to coherent modes. (b) time evolution of the diamagnetic contribution of radial electric field. (c) the radial evolution of the turbulent spectra exhibits the reverse sign of frequency of the 2 kHz mode at R=2.12m. Figures (d-f) account for the equivalent JET results.

Discussion

In order to explain first a one-sided frequency for the coherent mode, one may suggest a poloidal asymmetry of the turbulent structure. It would be a poloidal tilt angle of the turbulent structure, which under the effect of the poloidal rotation of the plasma would create

a Doppler frequency shift effect. The radial reverse sign of this frequency shift would then indicate a radial change of the tilt angle as draw in figure 4.

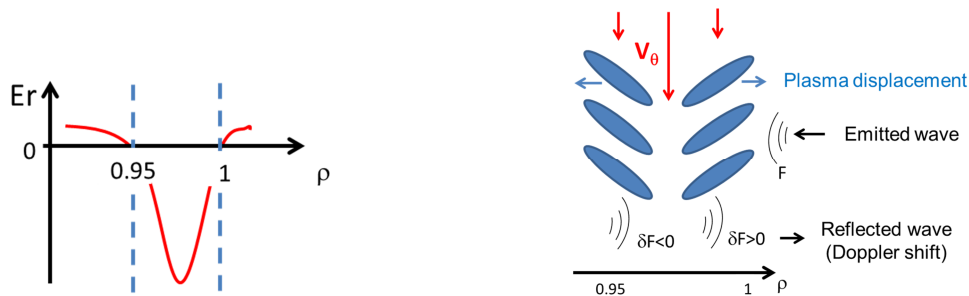


Figure 4 : During the L-H transition the E_r well provides a shear flow which could break the eddies and tilt them. This would be an explanation for the Doppler shifts of the reflected probing electromagnetic wave.

We observe a same behaviour between JET M-mode on JET and AUG I-phase plasmas. They present similar characteristics in the modifications of the turbulence frequency spectra, changing from broadband to coherent modes in the pedestal region along with the deepening of the diamagnetic contribution of the radial electric field well. A single side band feature is also observed at low frequency around a few kHz which reverses sign radially. A localized vertical plasma motion recorded by the magnetics [1] seems however insufficient to explain the reflectometry result so far which is interpreted here in terms of eddy tilting induced by the $E \times B$ shear flow. This would be consistent with previous observations [9] of eddy breaking and tilting by edge sheared flows and could account [10] for the observed particle transport reduction influenced by the turbulence via shear decorrelation mechanisms. Coherence between magnetics and reflectometry still has to be determined.

References

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