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D.I. Refy et al.

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Comparative analysis of density profile and magnetic signals during the JET M-mode and ASDEX Upgrade I-phase phenomena

D. I. Réfy[1], E. R. Solano[2], N. Vianello[3], S. Zoletnik[1], D. Dunai[1], B. Tál[1], M. Brix[4], R. Gomes[5], G. Birkenmeier[6], E. Wolfrum[6], F. Laggner[6], E. Delabie[7], the ASDEX Upgrade Team, the JET Contributors and the EUROfusion MST1

EUROfusion Consortium, JET, Culham Science Centre, Abingdon, OX14 3DB, UK

*[1]Wigner RCP, Budapest, Hungary, [2]LNF, CIEMAT, Madrid, Spain, [3]Consorzio RFXPadova, Italy, [4]CCFE, Abingdon, United Kingdom, [5]IPFN, Instituto Superior Técnico, Universidade de Lisboa, Lisboa, Portugal, [6]MPI for Plasma Physics, Garching, Germany, [7]ORNL, Tennessee, USA, *See the Appendix of F Romanelli et al., Proc. 25th IAEA Fusion Energy Conference 2014, St Petersburg, Russia*

Introduction

An ELM-free H-mode confinement regime with clear density pedestal has been observed both at JET [1][2] and ASDEX Upgrade (AUG) [3] tokamaks, usually identified by a low frequency (~1 kHz), m=1, n=0 magnetic oscillation (LFO). The phenomenon at JET is referred to as M-mode while at AUG as I-phase. A comparative analysis of these phenomena in terms of the density and temperature pedestal properties and the high frequency magnetic and density oscillations will be presented in this paper.

Li-BES measurements

Lithium beam emission spectroscopy (Li-BES) and reflectometer measurements at JET and AUG shows that the above phenomena modulates the plasma edge density. The investigation of the density profile dynamics during these phenomena became possible with the upgraded Li-BES as the diagnostic is capable of density profile measurements up to the pedestal top with ~1cm spatial and 50-100µs temporal resolution [4][5]. The analysis presented in this paper were done for JET pulse 90482, 55.4-55.95s, M-mode frequency 1.2kHz, ~600 M-mode periods; AUG pulse, 29302, 3.5-3.68s, I-phase frequency 1.5kHz, ~250 I-phase periods.

High Frequency Band power modulation

A high frequency band (10-100kHz) power modulation of the poloidal magnetic field is also detected during these phenomena. The HFB power modulation signal is calculated by taking the square of the signal after filtering with a 10-50 kHz bandpass digital FIR filter, which gives the time evolution of the HFB power in the signal. *Figure 1* shows the spectrogram of the magnetic signal in the low (a) and the high frequency (b) range, and the spectrogram of the HFB power modulation (c). The time evolution of the LFO and the HFB power modulation frequency is identical, the signals also show high coherence in the low frequency range. The phase distribution of the HFB power modulation is symmetrical both poloidally and toroidally, thus ideal as a reference signal. These properties are observed on both machines.

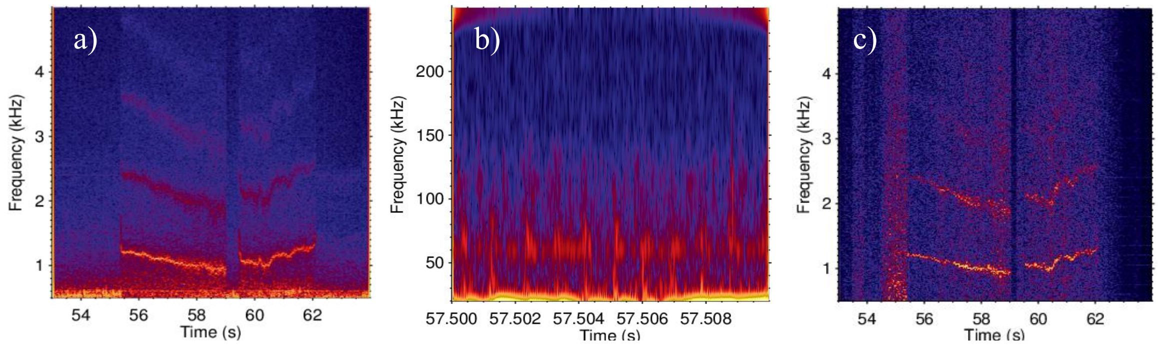

Figure 1.: Spectrogram of B_{pol} low frequency range (a), high frequency range (b) and B_{pol} HFB power modulation (c). (JET, shot 90482, Mirnov coil: C1M-I803)

Density pedestal modulation

The density profile is calculated from Li-beam data using a Bayesian algorithm [6]. Modulation related to the studied phenomena is analysed in terms of coherence spectra of a magnetic HFB power modulation signal as reference (JET: C1M-I803, AUG: C09-23) and the time evolution of the reconstructed density at different radial locations along the Li-beam. *Figure 2* shows the general density profile behavior of the phenomena: the top and the bottom of the pedestal is mostly modulated (2 maxima at these positions), and the relative phase between the top and bottom of the pedestal fluctuation is π, while the middle of the pedestal is less affected, which indicates that the gradient is modulated. The relative fluctuation amplitude is 1-5%. The phase of the pedestal bottom density relative to the HFB power modulation of the magnetics is +0.3π which means that the flattening of the pedestal is

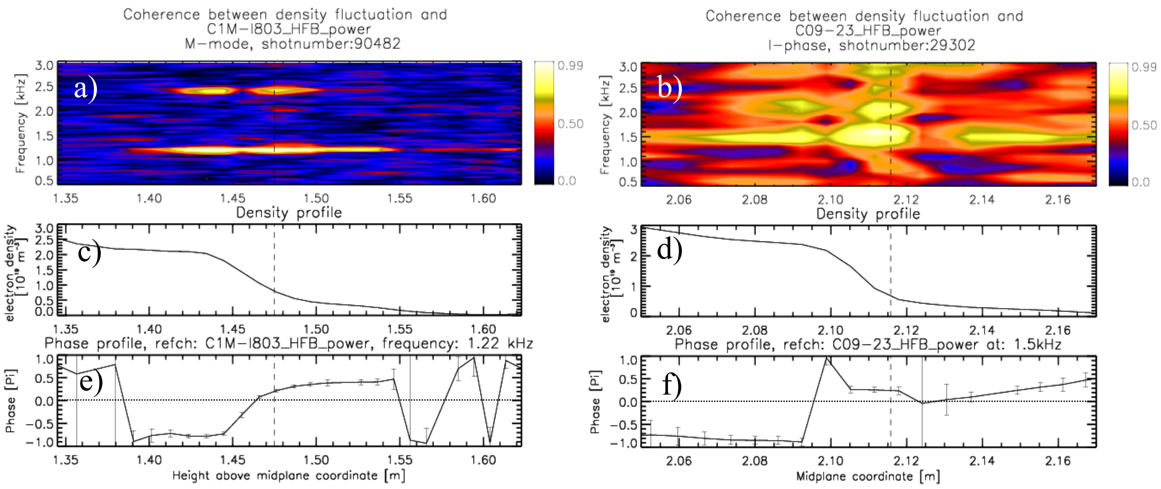

Figure 2.: M-mode (a) and I-phase (b) coherence of the HFB power modulation of the magnetics and the LFO of the electron density; M-mode (c) and I-phase (d) averaged density profile; M-mode (e) and I-phase (f) phase profile at the relevant frequency range relative to the HFB pulsation of the magnetics. Vertical dashed line indicates the LCFS position, horizontal dotted line shows the phase of the reference signal (0 phase line).

preceded by the HFB pulse in the magnetics by ~120µs. A radially outward propagating density perturbation in the SOL is also related to the phenomena, indicated by the clear phase delay outwards in the SOL. Note, that these results are fairly similar for the M-mode and the I-phase.

Temperature pedestal characterization

The temperature profile fluctuations were investigated at JET with the same technique. The temperature data was taken from the KK3 ECE radiometer, the investigated shot and time range is the same as for the density analysis (90482, 55.4-55.95s). The coordinates of the channels were mapped to the BES coordinates to make them comparable, and were shifted to match the pedestal positions. *Figure 3* shows that the edge temperature profile is also modulated by the M-mode at its characteristic frequency. The low spatial resolution and sensitivity of the ECE at the edge does not allow us, to draw conclusions about the phase relative to the density modulation.

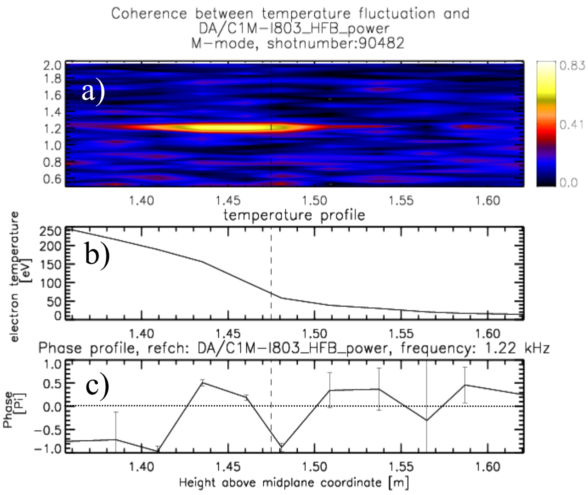

Figure 3.: M-mode temperature LFO characterization: coherence of the HFB power modulation of the magnetics and the LFO of the electron temperature (a); averaged temperature profile (b); phase profile at the relevant frequency range relative to the HFB pulsation of the magnetics (c). Vertical dashed line indicates the LCFS position, horizontal dotted line shows the phase of the reference signal (0 phase line).

Density HFB power modulation

The Li-BES diagnostic measures the light emission of an accelerated Lithium beam, and the fluctuation of the beam emission is proportional to the local density fluctuation, within certain constraints. The low signal to noise ratio (~5-10) of JET and AUG BES measurements does not allow us to directly detect the density fluctuations related to the HFB magnetic signal. However, the characteristic frequency of the HFB power modulation enables us to localize radially the HFB activity using correlation techniques. The HFB power modulation calculation was carried out on the raw BES signals, and it was carefully checked that beam effects and noise modulation does not play a significant role. *Figure 4* summarizes the results: the HFB power modulation of the BES signal is localized at the pedestal region, and its phase is 0 relative to the HFB power modulation of the magnetic signal, which means, that these events are simultaneous. Note, that these results are fairly similar for the M-mode and the I-phase.

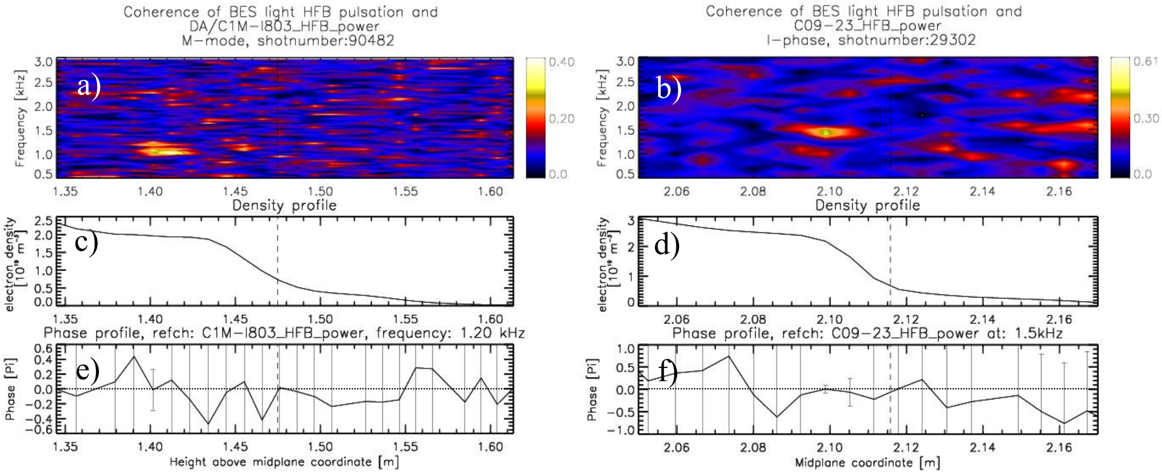

Figure 4.: M-mode (a) and I-phase (b) coherence of the HFB power modulation of the magnetics and the HFB pulsation of the BES light emission; M-mode (c) and I-phase (d) averaged density profile; M-mode (e) and I-phase (f) phase profile at the relevant frequency range relative to the HFB pulsation of the magnetics. Vertical dashed line indicates the LCFS position, horizontal dotted line shows the phase of the reference signal (0 phase line).

Summary

Our analysis revealed that the M-mode phenomena at JET and the I-phase phenomena at AUG have very similar dynamics, thus their physical background is likely the same. The density profile periodically flattens, preceded by a burst of fluctuations in the poloidal magnetic field and density at the pedestal region. The data shows that the temperature profile is also modulated but the phase relative to the density is uncertain. The flattening of the pedestal profiles is followed by a radially outward propagating density pulse in the SOL.

Acknowledgments

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