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ABSTRACT

A new snake-like MHD mode localised at the plasma edge has been found in ELMy H-mode discharges with type-I ELMs on JET. The mode occurs in a wide range of plasma parameters and is excited by the perturbation of the ELM. It is located at the $q = 3$ surface and the magnetic spectrum consists of many harmonics. The mode numbers are $n = 1, 2, 3, \ldots$ and $m = 3, 6, \ldots$. The mode is radially localised within $\Delta R \approx$ 2-3cm , a poloidal localisation can be seen from the non-sinusoidal modulation of the edge ECE signal. A possible explanation is that this mode is a remnant of an island which is created by the edge ergodisation due to the ELM event.

1. PHENOMENOLOGY OF PALM TREE MODES

The first observation of the new mode has been in Argon seeded radiative mantle discharges in the ELMy H-mode regime. An inspection of many ELMy H-modes in various configurations revealed that this mode is a frequent phenomenon and occurs in a wide range of plasma parameters. Approximately 100 discharges from the 2000/2001 campaigns on JET showing this mode have been identified.

The mode is detected by magnetic pick up coils and Fig. 1 shows a spectrogram where three palm tree modes following type-I ELMs are visible. (The signal at 11kHz and the harmonic at 22kHz are due to a continuous 1/1 mode.) The modes are obviously triggered by the preceding ELM, and an ELM occurring during the lifetime of the mode seems to stop it abruptly. Not every ELM is followed by a mode oscillation, i.e. during the stationary phase of a discharge ELMs with and without a following mode can be found. In some discharges a lot of palm tree modes are found during the type-I ELM phase, other discharges show only very few of these events. It lasts for typically 10ms to 40ms and the mode frequency increases in time. The measured amplitude of the magnetic perturbation decreases quickly: although the signal is the product of the rising frequency and the mode amplitude, it saturates and decays.

The mode frequency may be used to indicate some properties of the edge during the ELM, namely that the plasma rotation in the edge seems first to be stopped during the ELM and then later starts rotating again. In the example shown here the mode frequency at onset is zero, in other discharges the mode may start at a finite frequency and show only a moderate increase in time. The palm tree mode seems to be naturally stable and is only excited because the ELM creates a large perturbation.

2. MODE NUMBERS

The analysis of the mode using magnetic measurements (Fig. 2) gives the poloidal mode number $m = 3$, the toroidal mode number is $n = 1$, and the harmonics have increasing toroidal ($n = 2, 3, 4, 5, \ldots$) and poloidal ($m = 6, \ldots$) mode numbers. This indicates that this mode is poloidally well localised and is associated with $q = 3$.

3. RADIAL AND POLOIDAL LOCALISATION

The palm tree mode is observed on the edge ECE and SXR measurements as well. The poloidal and radial localisations can be seen on the ECE time traces, which show a strongly anharmonic modulation in time and only very few neighboring channels are modulated by the mode, similar to the signatures of a snake. Figure 3 shows the time trace of an ECE channel measuring at R = 3.84 m . The mode is visible only on this trace and the adjacent channel at R = 3.83m . This determines the radial extent of the mode to be about R ≈ 2-3cm .

The mode is radially located a few cm inside the separatrix well within the region which is strongly influenced by the ELM. The poloidal localisation is indicated by the non-sinusoidal modulation of the signal.

The spikes seen in Fig. 3 have a higher temperature and a typical width of 15% of the modulation period. This gives an approximate poloidal width of the mode of $l_\Theta \approx$ 30-40cm . The strong localisation of the mode suggests an explanation in the form of localised magnetic islands connected by two Y-points and a neutral line rather than a usual X-point.

The new mode resembles the “snakes” which where found to be strongly located at the q = 1 surface [1] and to occur also at the q = 2 surface [2]. A snake-like mode at q = 3 has been reported to appear in optimised shear discharges (“picket fence mode”) when the edge is in L-mode, but this mode disappears at the L-H transition [3]. In contrast, the snake-like mode reported here appears only in Type-I ELMy H-modes. As will be shown next, there is at present no clear dependence on global plasma parameters which favor the appearance of palm tree modes.

4. GLOBAL PLASMA PARAMETERS

Figure 4 shows several plots of the global plasma parameters of ELMy H-modes with type-I ELMs where observations of palm tree modes have been made. The plasma current and the toroidal magnetic field can vary as long as the q_{95} is near 3, i.e. the mode is associated to the q = 3 surface being near the separatrix in a region which is perturbed by the ELM. The confinement quality, the normalised beta and the total heating power can vary over a large range. The radiated power, power across the separatrix, effective charge and the Greenwald number do not show any particular dependence either.

5. WHAT IS A PALM TREE MODE?

Unfortunately, this question can not be answered yet. In some respect the palm tree mode can be regarded as an ELM postcursor. A possible hypothesis to explain the experimental observations might work as follows. The ELM creates a magnetic perturbation of the plasma edge. This perturbation leads to ergodisation of the magnetic structure in the edge. This can help to explain the fast outflow of heat and particles during the ELM event. On the other hand, it is well known that in regions of incomplete stochastisation islands do exist. The modelling of the edge structure, which is anticipated when the Dynamic Ergodic Divertor (presently under construction) will be operational at the TEXTOR tokamak, shows typical examples for ergodic regions in which chains of islands are created [4]. The confinement within the islands is better than outside the islands, i.e. the heat transport is slower [5, 6]. This leads to a peaked temperature within the island after the perturbation, consistent with the measurement. The palm tree mode is therefore explained as the remnant of an 3/1 island which was created during edge ergodisation by the ELM.

The observed stabilisation of the palm tree modes within several tens of ms might be explained as follows. The enhanced temperature in the islands decreases the resistivity which causes a locally increased plasma current. The higher current flows in the O-point and com-pensates therefore for the loss of current which is required to form the island.

6. OPEN QUESTIONS

Although a likely explanation of the phenomenon has been given, some questions arise which should be answered by further investigations.

- What are the global or local plasma parameters leading to destabilisation of that mode?
- What is the difference between ELMs triggering that mode and those which do not?
- Is the mode structure of the palm tree mode related to the mode which causes the type-I ELM?
- Is the power outflow modified when palm tree modes occur?
- Is there any relation of this mode to a change in edge transport?
- Can this mode be used to test ELM models, especially models which are based on field line ergodisation [7]?
- Is this mode observed on other divertor tokamaks (e.g. Asdex Upgrade, DIII-D)?
- Are similar modes excited when other integer q surfaces are located close to the plasma edge?

SUMMARY AND CONCLUSION.

The palm tree mode is observed for a wide range of plasma parameters in type-I ELMy H-modes provided the $q = 3$ surface is located in the edge region perturbed by the ELM. It is a snake-like mode located at the $q = 3$ surface. A possible explanation for this mode is that it is the remnant of a 3/1 island which was created by edge ergodisation due to the ELM.

ACKNOWLEDGMENT

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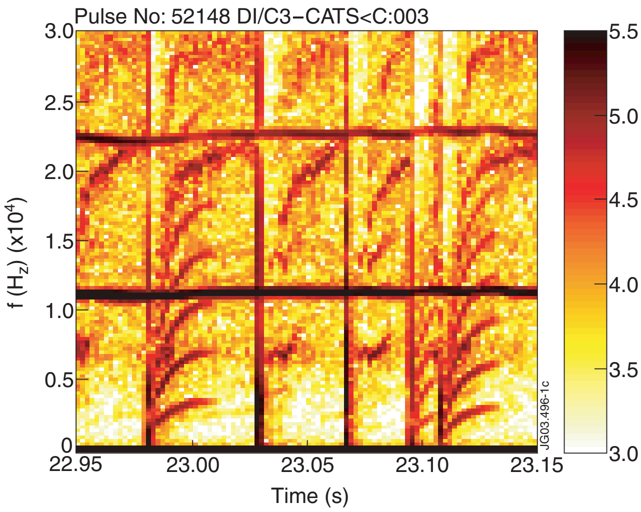

Figure 1: Magnetic spectrogram with palm tree modes in JET Pulse No: 52148.

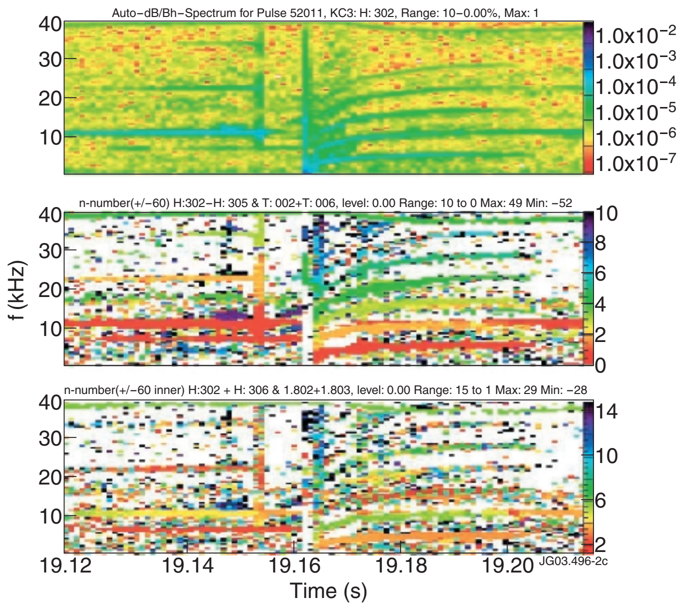

Figure 2: Mode number analysis of a palm tree mode using the CATS diagnostic.

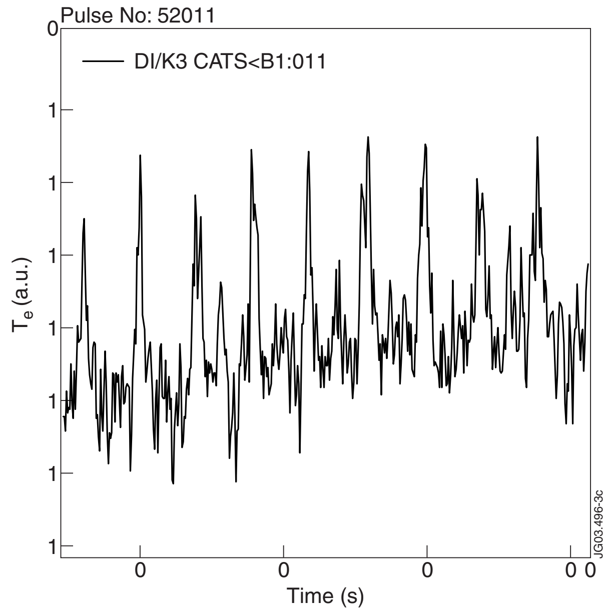

Figure 3: ECE signal at R = 3:84 m.

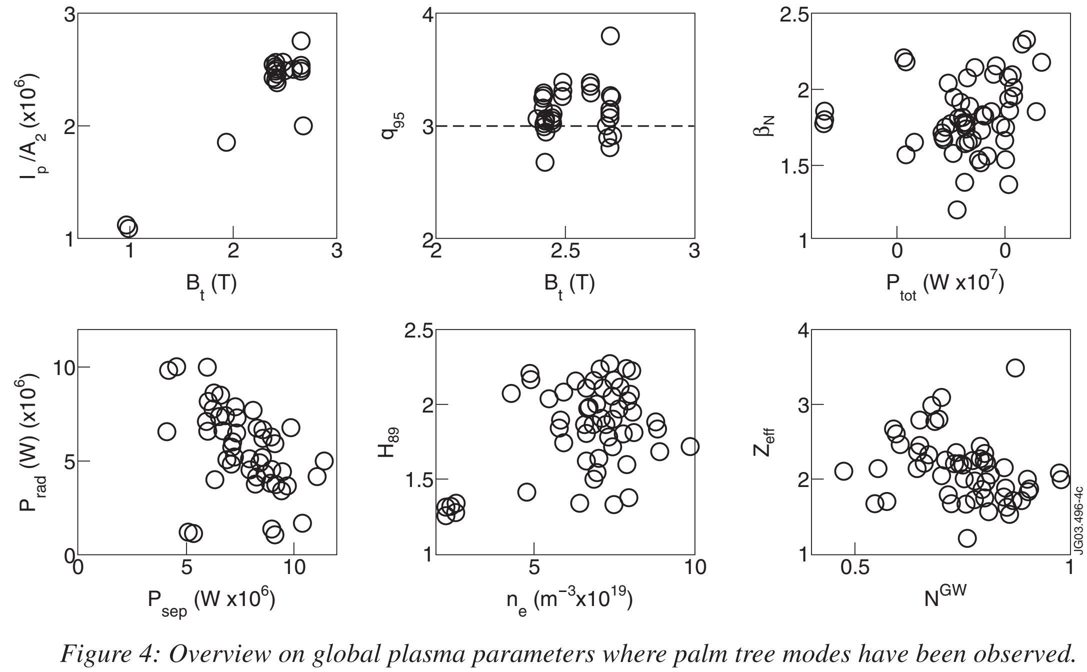

Figure 4: Overview on global plasma parameters where palm tree modes have been observed.