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Ch. Maszl, V. Naulin, M. Brix, T.W. Versloot, R. Schrittwieser
and JET EFDA contributors

Palm Trees and Islands – Current Filaments in the Edge of JET

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Ch. Maszl[1,*], V. Naulin[2], M. Brix[3], T.W. Versloot[4], R. Schrittwieser[1]
and JET EFDA contributors*

JET-EFDA, Culham Science Centre, OX14 3DB, Abingdon, UK

[1]Association EURATOM/ÖAW, Institute for Ion Physics and Applied Physics,
University of Innsbruck, Austria
[2]Association EURATOM/RISØ DTU, Danish Technical University, Roskilde, Denmark
[3]EURATOM-CCFE Fusion Association, Culham Science Centre, OX14 3DB, Abingdon, OXON, UK
[4]Association EURATOM/FOM, FOM Institute Rijnhuizen, Nieuwegein, The Netherlands
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ABSTRACT.
It is now well known that ELMs lead to the ejection of a number of filamentary structures into the Scrape Off Layer (SOL). ELMs thus generate structures with excess energy and density. Recent results show also that the ELM filaments carry current. Furthermore it can be conjectured that ELM blobs leave corresponding holes behind. If such a hole is able to reach a resonant surface it closes on itself and increases its lifetime significantly. We presume that the Palm Tree Mode (PTM) is a signature of such an event. Understanding PTMs therefore enhances thus our knowledge of ELM and edge physics and contributes to the verification of ELM models.

1. INTRODUCTION

High confinement mode (H-mode) operation is the standard operational scenario for ITER [2]. This mode is prone to Edge Localized Modes (ELMs). Understanding ELMs is therefore of fundamental importance for the success of future fusion reactors. A profound insight into the underlying physics is the key for successful ELM mitigation and control. This contribution is focused on a special ELM post-cursor, the so-called Palm Tree Mode (PTM) (Fig.1). We believe that the PTM can shed more light on ELM physics and its understanding will contribute to the further verification of ELM models.

The PTM is a special MHD phenomenon, which has so far been only detected in JET type-I ELMy H-mode plasmas for which as the rational $q = 3$ surface is located in the ELM-perturbed region. The PTM is radially and poloidally well localized and has a toroidal mode number $n = 1$ and a poloidal mode number $m = 3$. The mode propagates in the ion diamagnetic drift direction. The signature of the mode can be found and studied as electron temperature fluctuation in the ECE diagnostic and as magnetic perturbation in the in-vessel magnetic pick up coils [3].

We suggest that the genesis of the PTM can be explained by a blob/hole creation mechanism. Blob-like transport was observed first by Zweben in 1985 during studies of edge density turbulence in the Caltech research Tokamak using an array of Langmuir probes biased to ion saturation [4]. Zweben described coherent magnetic field aligned structures of higher or lower plasma density and called them consistently blobs and holes. With the advent of fast camera diagnostics the occurrence of localized filamentary blob-like structures has been shown to occur as a consequence of the ELM istability, but, with much smaller structures, also during L-mode regimes [5].

It is now well known that ELMs lead to the ejection of a number of filamentary structures into the scrape off layer [6,7]. It can therefore be conjectured that ELMs also leave corresponding holes behind. The aim of this study was to check whether or not this assumption is valid and to gain more insight into the physics of the PTM.

2. EXPERIMENTAL RESULTS AND DISCUSSION

The dynamics of the PTM were studied by means of the in-vessel magnetic pick up coil arrays of JET (Fig.2). The JET JPF signals of these arrays were multiplicated with calibration factors and afterwards filtered by a 2nd order Butterworth high pass filter with a cut-off frequency of 1kHz. In a last step the signals were integrated in order to compute the magnetic field B. The so calibrated signals were used to reconstruct the helical structure of the mode (Fig.3). Data from all available coils were evaluated in the poloidal/toroidal plane. A simulated current filament on a $q = 3$ surface was synchronized with the mode onset and the propagation of the measured signals and the simulated signals from coil to coil was studied.

From this we found the helical structure of the PTM (Fig.3). It appears that the PTM is a closed current filament on a rational surface. Charge interchange imbalance is therefore short-circuited by parallel currents and the mode is radially trapped. The trapped filament is no longer in contact with the whole flux surface, its life time is therefore significantly increased.

Edge Localized Modes eject energy and particles. In addition angular momentum is lost, which is restored by NBI power immediately after the ELM crash [8]. Cross correlations were used to calculate the time lag between toroidally separated coil pairs at the same poloidal position and henceforth the toroidal angular frequency of the PTMs (Fig.7). A linear dependence of total NBI power on the maximum toroidal angular frequency of different PTMs (Fig.4) suggests that the frequency increase of the mode is correlated with the recovery of edge rotation after ELM induced momentum losses. Therefore comparisons with edge rotation measurements took place (Fig.5). The ratios of initial and final rotation frequencies of the PTM, measured by the in-vessel coils, and of the edge measured by CXRS are close to unity (Fig.6). The PTM is therefore co-rotating with the ambient edge plasma. The spin up of the mode is approximately one order of magnitude faster (Fig.7) than that of the edge plasma. An possible explanation for this discrepancy could be that CXRS measure carbon impurity ion velocities.

Palm Tree Modes are, if not interrupted by subsequent ELMs, long-living structures. Lifetimes up to 60ms can be observed. The average lifetime is around 23ms. In principle the lifetime should be influenced by parallel resistivity and perpendicular transport into the filament. Localisation of the mode is therefore important in order to study these effects and was done by the ECE diagnostic. The PTM was found to live on top of the pedestal. The measured electron temperature is inverse proportional to the Spitzer resistivity. Therefore pedestal temperatures at the beginning (blue), in the middle (orange) and at the end of the mode (green) were taken and correlated with the lifetime (Fig. 8). The obtained data is strongly scattered. A lack of data between 35ms and 45ms prevents conclusive statements about the role of resistivity on the life time of the PTM. Nevertheless linear trends can be fitted to the data cautiously indicating the role of resistivity on the evolution of the mode.

CONCLUSION

First steps were done to test the hypothesis whether the genesis of the PTM can be explained by a blob/hole creation mechanism. JET in-vessel magnetic pick up coils allowed the reconstruction of the helical structure of the mode. PTMs were found to be a closed hole current loop, born on rational surfaces.

The dynamics of the mode has been studied. The PTM is co-rotating with the ambient edge plasma although the spin up after ELM induced momentum losses is one order of magnitude faster. ECE as used to localize the mode. The mode is located on top of the pedestal. A comparison of mode life times and pedestal temperatures indicate the role of resistivity. Further research and modeling is necessary to get more insight into the underlying processes. A detailed study of the genesis and decay of the PTM will be presented elsewhere.

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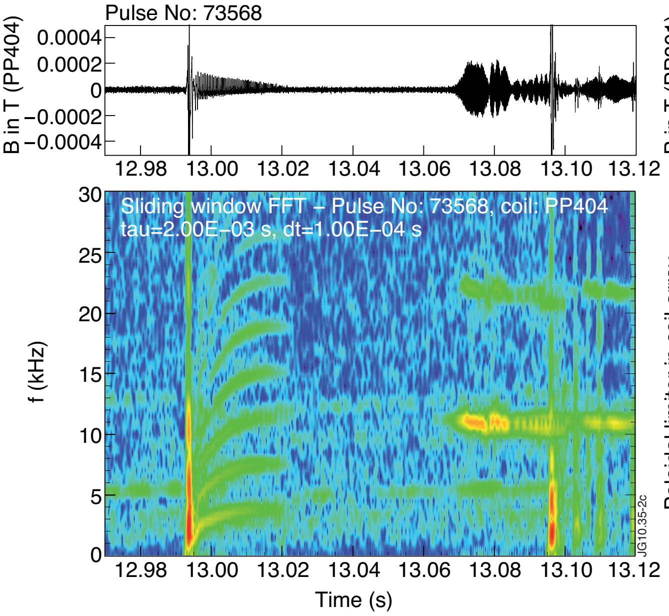


Figure. 1: Spectrogram of the signal of coil C1M-PP404 at the outboard limiter of JET (JET Pulse No: 73568). The characteristic pattern inspired the name.

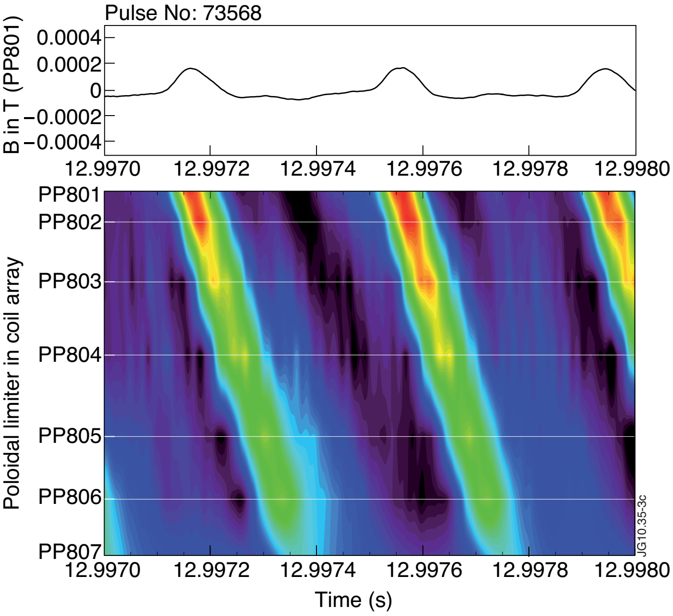


Figure. 2: Passing of the mode as seen by the poloidal limiter coil arrays (JET Pulse No: 73568).

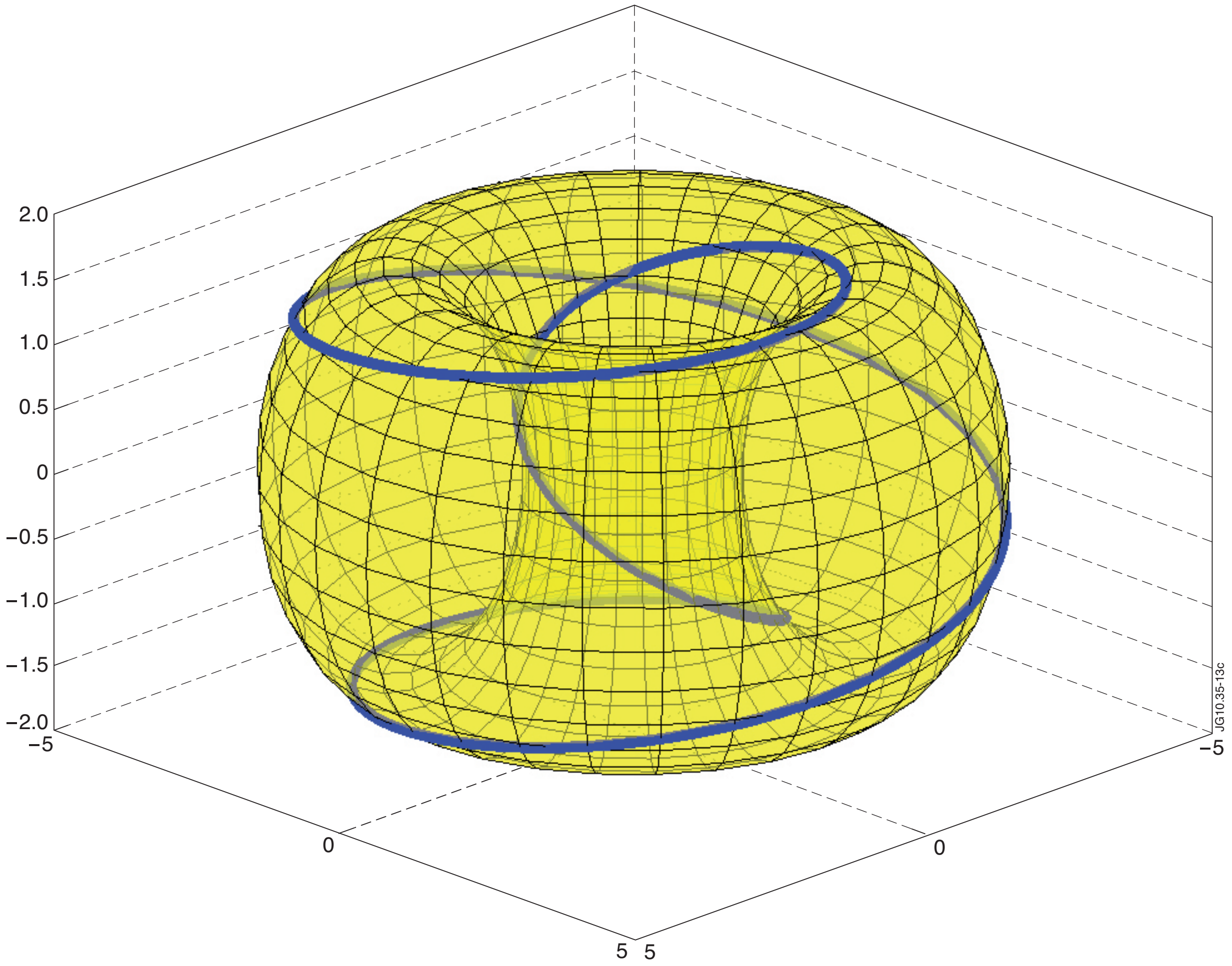


Figure. 3: Visualization of the PTM filament on a q=3 surface. PTM filament seems to be a closed 1D structure on a 2D surface.

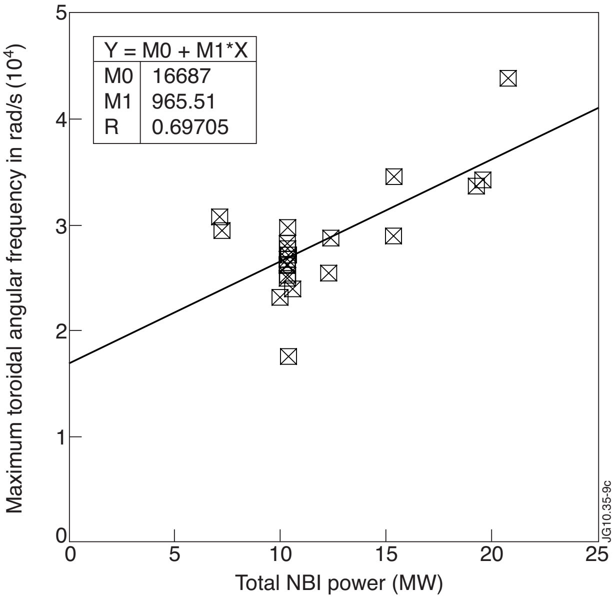
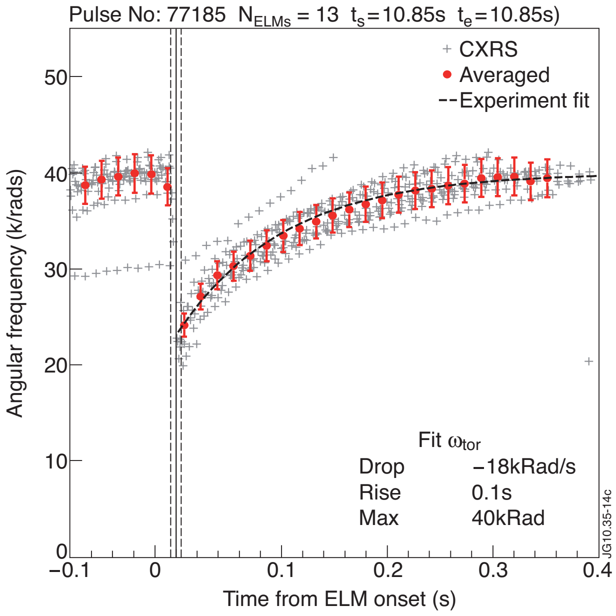


Figure. 4: Maximum mode frequencies vs NBI powers



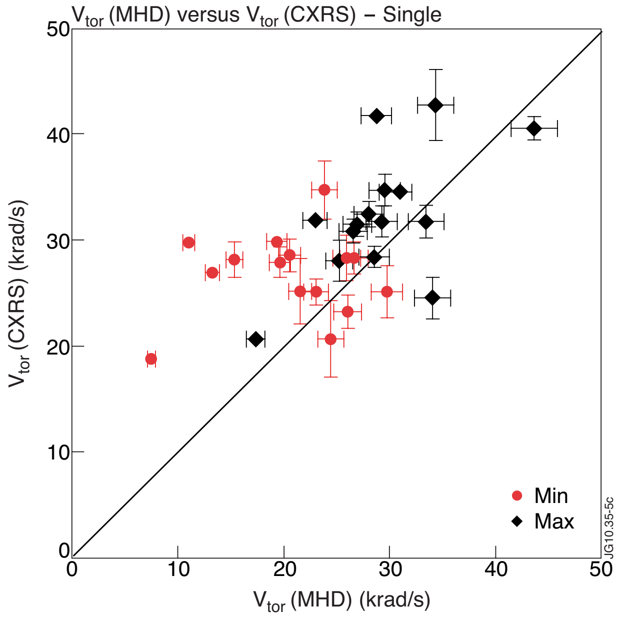
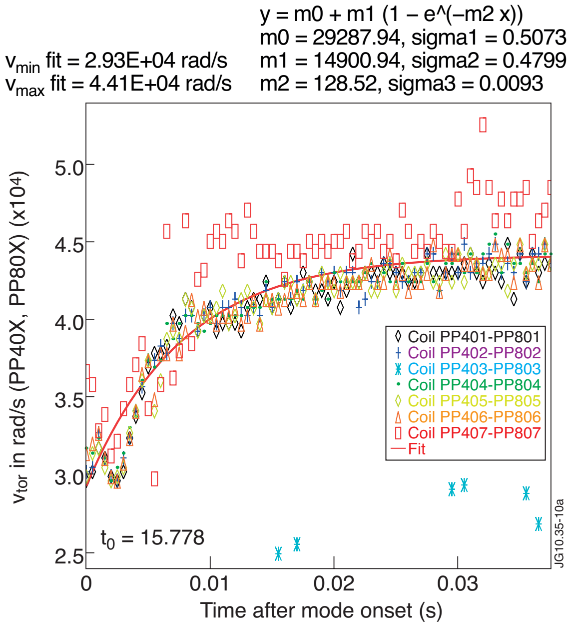


Figure. 5: Edge rotation as measured by CXRS. Recovery of edge rotation after ELM induced momentum losses (vertical line) can be observed (JET Pulse No: 77185).

Figure. 6: Comparison of initial and final velocities of PTM (MHD) and edge frequencies (CXRS).



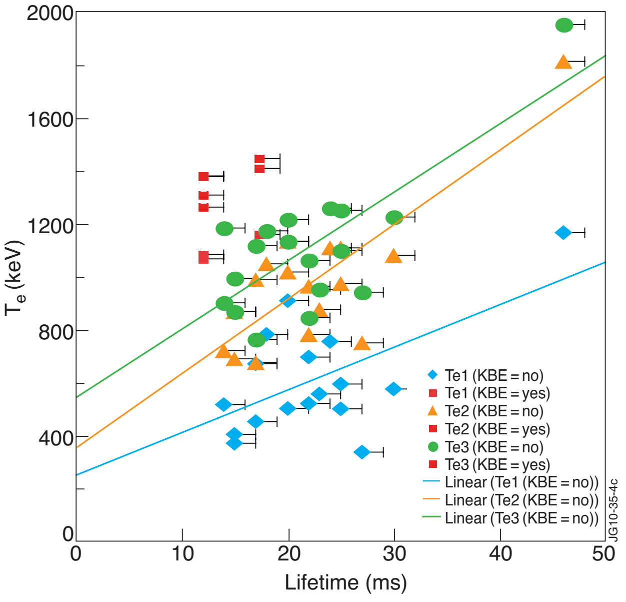


Figure. 7: Toroidal rotation frequencies of the PTM (JET Pulse No: 77185).

Figure. 8: Pedestal temperatures vs lifetime at beginning, in the middle and at the end of various PTMs. The red squares represent PTMs interrupted by a subsequent ELM.