EUROFUSION CP(15)05/109

J. Vicente et al.

Dynamics of Filaments in the Vicinity of the Separatrix During ELM Cycles

(22nd June 2015 – 26th June 2015)
Lisbon, Portugal

This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014-2018 under grant agreement No 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission.

Dynamics of filaments in the vicinity of the separatrix during ELM cycles

J. Vicente[1], G.D. Conway[2], L. Meneses[1], C. Silva[1], M.E. Manso[1], the ASDEX Upgrade Team[2], and JET Contributors*

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

[1]*Instituto de Plasmas e Fusão Nuclear, Instituto Superior Técnico, Universidade de Lisboa, 1049-001 Lisboa, Portugal*

[2]*Max-Planck-Institut für Plasmaphysik, 85748 Garching, Germany*

Introduction

Theory suggests that ELMs grow explosively by radial expansion and ejection of plasma filaments into the scrape-off layer (SOL). Filaments have been observed and studied in the past years, mainly in the SOL during the ELM crash phases. Despite the large amount of data collected in those late stages of the filament life-cycle (i.e. at the SOL) the early stages of filaments are scarcely documented due to the lack of diagnostics able to measure with high time and spatial resolutions in their birth and development regions. As a consequence, the role of filaments in the transport of particles and energy during ELMs is not yet fully understood. MHD simulations indicate that either conductive or convective losses (the later *via* ejection of plasma filaments) can become dominant loss mechanisms depending on the ELM size, which highlights the importance of filaments and opens possibilities for alternative ITER scenarios such as the Type-III ELMy H-mode.

Reflectometry Techniques

Reflectometry is a diagnostic technique able to probe broad regions of the plasma edge with good time/spatial resolutions. Electromagnetic waves launched into the plasma are reflected at a plasma cut-off layer determined by the wave frequency F for ordinary (O-mode) polarization, or bu both F and the local magnetic field for extraordinary (X) mode. According to the 1D geometric optics approximation the phase shift $\Delta\varphi$ of the O-mode reflected wave is proportional to the radial displacement Δr of the reflecting density layer, such that $\Delta r = \Delta\varphi c / 4\pi F$, where c is the velocity of light. For small radial displacements, such that the magnetic field changes are negligible, the above relation should also hold for X-mode polarization. Thus, for fixed probing frequency, the time derivative of the phase provides the radial velocity $V_r = \Delta r/\Delta t$ of the probed density layer, either in O- or X-mode.

*See the Appendix of F. Romanelli et al., Proceedings of the 25th IAEA Fusion Energy Conference 2014, Saint Petersburg, Russia

Using reflectometry, a technique for filament detection was developed based on the fast movements of density layers induced by filaments [2]. A V_r threshold criterion was employed with a typical value of $|V_r|$ > 1.2km/s, which was also suitable for this work.

Reflectometry Systems at AUG and at JET

At AUG two O-mode reflectometry systems operate in the Q (33-49.2 GHz) and V (49.4-72 GHz) bands respectively, using monostatic antennae configurations located on the low field side (LFS). The Q-band antenna is very close to the mid-plane and the V-band antenna is displaced downwards towards the X-point in lower single null magnetic configurations. At JET, a radial correlation reflectometer can be used in fixed frequency where two X-mode channels operate in the W band (73.4-110 GHz) sharing a bi-static antennae configuration. The antennae are located at the LFS close to the magnetic axis. The data acquisition rate for both the JET and AUG systems is 2 MHz.

The Type-I ELM Cycle at JET

The techniques developed for filament studies at AUG [2] were applied for the first time at JET in Type-I ELMy H-modes. In discharge #84704 the magnetic field at the flat-top phase reached B_t = 2.4T. The cut-off (density layer) for the lowest probing frequency (73.4 GHz) was located at the plasma edge, below the pedestal top, just inside of the separatrix. For higher magnetic field values the location of the cut-off would be further out. Filament detection was applied over a period of fairly stable plasma parameters [46.5-47.0s] and the V_r peak detections have been ELM synchronized (t_0=0 was taken at the ELM peaks observed in the Be emission line signal). In Fig. 1 it is displayed the probability distribution function (PDF) of the detection-times along the ELM cycle.

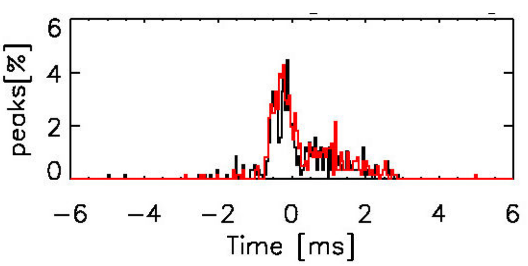

Figure 1: *Filament activity along the Type-I ELM cycle in JET. PDFs of detection times of positive (black) and negative (red) V_r peaks with probing F=73.44GHz.*

It is observed that the occurrence of filaments is largely enhanced at the ELM onset period, some hundred μs before the ELM peak (t_0=0). In Fig. 2 are displayed the signatures of filaments on the reflectometry signals (two closely spaced density layers were probed) during inter-ELM periods, obtained with conditional averaging.

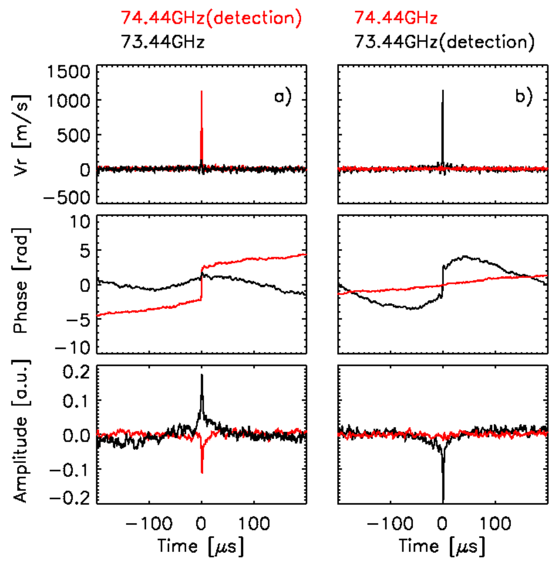

Figure 2: *Inter-ELM filament signatures on reflectometry signals at JET. Conditional averaging using detections from V_r signals at 74.44 GHz a) and 73.44 GHz b).*

Both channels were used to provide primary and secondary signals. It is observed that when performing detections using the signal reflected at the highest density, correlated amplitude peaks are observed in the signal reflected from the lower density layer. Since there is only a small smooth phase oscillation associated, it is likely that these signatures correspond to large (poloidally) filaments propagating with a dominant poloidal velocity. In general, the signatures in the detection channel, are similar to those obtained previously at AUG: V_r peaks associated with amplitude dips and jumps in the phase signals. This strengthens the suggestion that filaments display similar dynamics in both machines.

The Type-III ELM Cycle at AUG

In AUG discharge #27016, a period with 20 type-III ELMs was considered and filament detection was again ELM synchronized (t_0=0 taken at the ELM peaks in divertor currents). Li beam and Thomson scattering diagnostics allowed to locate the reflecting density layers of each channel operating at their lowest frequencies: $\rho_{pol} \approx 0.99$ (V-band) and $\rho_{pol} \approx 1.00$ (Q-band). Results in Fig.3 show the enhancement in filament activity at the ELM onset period as seen before in type-I ELMs at both JET and AUG.

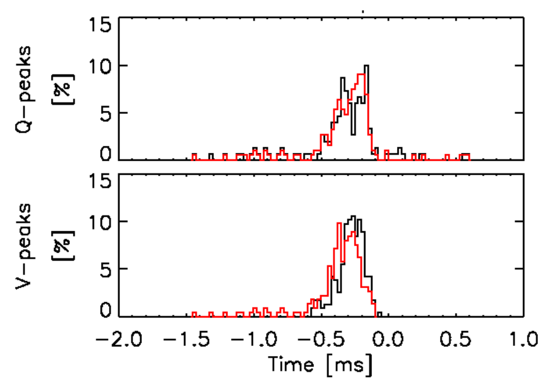

Figure 3: *Filament activity along the type-III ELM cycle at AUG. PDFs of times of detection of positive (black) and negative (red) V_r peaks with both the Q and V bands.*

After the ELM peak, filamentary activity is strongly reduced, contrary to what was observed in type-I ELMs where some activity remained for some ms (even if filaments displayed smaller size and/or amplitude). Differences in the PDF shapes from the two channels prevent a time delay analysis (between poloidally displaced measurements) as was the case for type-I ELMs, where a dominant poloidal velocity component of filaments at the ELM onset period was found [2].

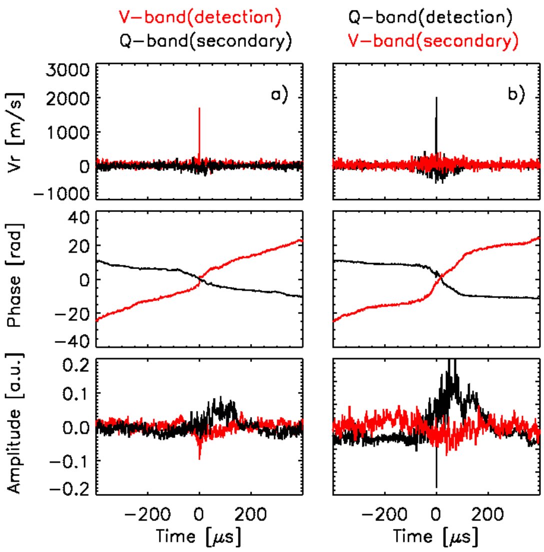

Figure 4: *Signatures obtained using the V-band a) and the Q-band b) signals for detection at AUG.*

The signatures obtained (see Fig.4) display large phase *jumps* (10-20 radians) anti-correlated in the two channels and an amplitude *hill* in the signal reflected from the lowest density probed layer. These features suggest that the density perturbations have large poloidal width (displacement between measuring spots is ≈20cm) and are likely propagating along a significant radial length.

Conclusions

Filaments were studied for the first time at JET in type-I ELMy H-modes using X-mode reflectometry. Results suggest that filament activity is enhanced at the ELM onset with dominant propagation in the poloidal direction, as seen before at AUG. Studies at AUG in Type-III ELMy H-mode reveal that at the ELM onset, filament activity is enhanced but does not display a preferred poloidal propagation direction and is suppressed more rapidly than in type-I ELMs (in JET or AUG).

Acknowledgments

This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014-2018 under grant agreement No 633053. IPFN activities also received financial support from “Fundação para a Ciência e Tecnologia” through project UID/FIS/50010/2013. The views and opinions expressed herein do not necessarily reflect those of the European Commission.

References

[1] G.T.A. Huijsmans and A. Loarte, Nucl. Fusion **53** (2013) 123023
[2] J. Vicente *et al.*, Plasma Phys. Control. Fusion **56** (2014) 125019