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The Poloidal Distribution of Avaloids and ELMs perturbations in the Scrape-off layer of MAST

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Introduction

Plasma in the scrap-off layer of tokamaks in L and H-mode is caused by radial transport caused by either turbulence [1] or/and ELMs [2]. The transport of hot and dense plasma outside the last closed flux surface (LCFS) can cause the temperature of the first wall to rise leading to a high level of sputtering and probably to ablation and/or melting. This is the reason why it is crucial to understand and quantify the role of each of the two phenomena, especially for the next generation of fusion devices. This paper presents a comparison of the scrape-off layer (SOL) fluctuations in L and H-mode in MAST. We deduce that while avaloids are localized in the poloidal plane, ELMs are not, and strong coherence is detected between different poloidal angles. Only ohmic heating was used to get the H-mode, hence, ELMs that are studied here are of type III.

To highlight the motivation of this work, Fig. 1 shows the ion saturation current at the mid-plane at about 5 cm away from the separatrix in L (shot 6864) and H-mode (shot 6865) plasmas with similar main plasma parameters. Note that the amplitude of the current density hitting the probe is approximately the same in the two cases. However, avaloids are approximately at least 100 times more frequent then ELMs.

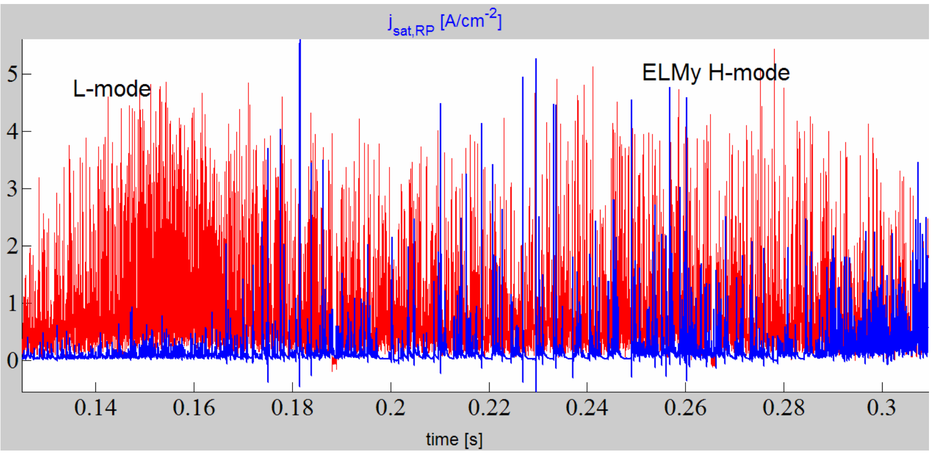

Fig. 1: The ion saturation current as a function of time for two discharges in MAST taken with the same mid-plane Langmuir probe. The probe is approximately at the same distance from the separatrix.

Results from fast imaging

We use a Phantom V4 camera with shutter time equal to 10 µs. The time between frames is about 150 µs. We image approximately one-half of a cut through the poloidal plane. A typical image is shown in Fig. 2 on the far right. The detected light is dominated by D_α. In order to extract the fluctuations in the SOL we select a curve (shown in black) and plotted the fluctuations as a function of the poloidal angle and time. It is clear from Fig. 2 that ELMs affect the whole SOL whereas avaloids are local in the poloidal plane reflected in individual bumps occurring more or less randomly as a function of the poloidal angle.

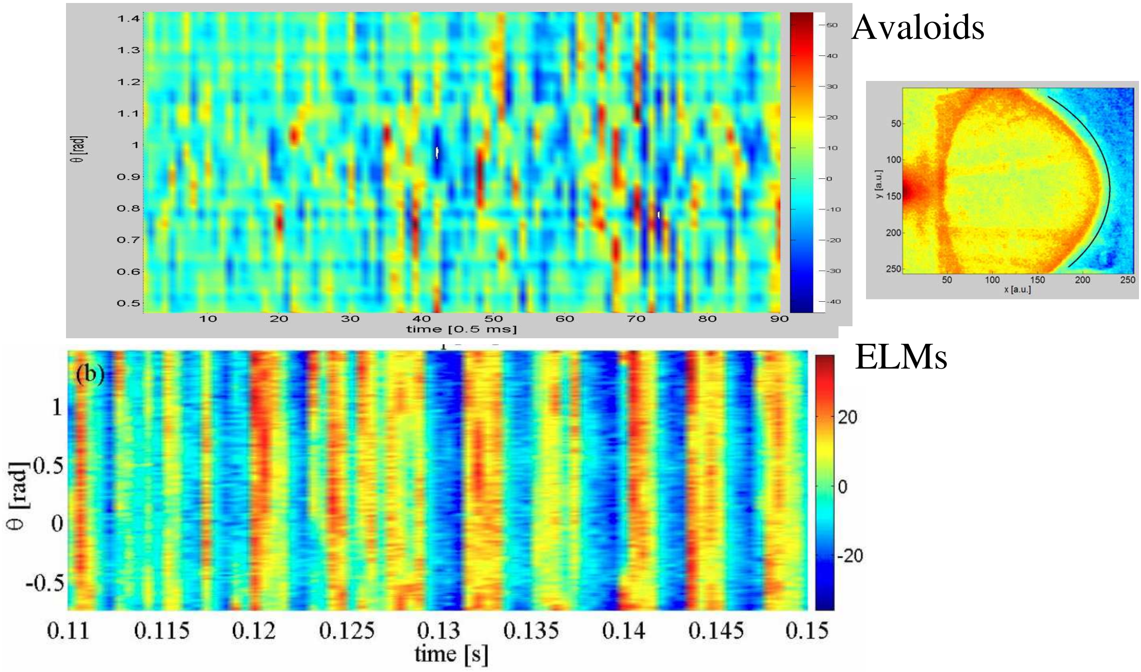

Fig. 2: density fluctuations caused by ELMs (bottom) and avaloids (top) as a function of the poloidal angle and time. The far right-hand image shows a typical image of the plasma with the center stack on the left-hand side.

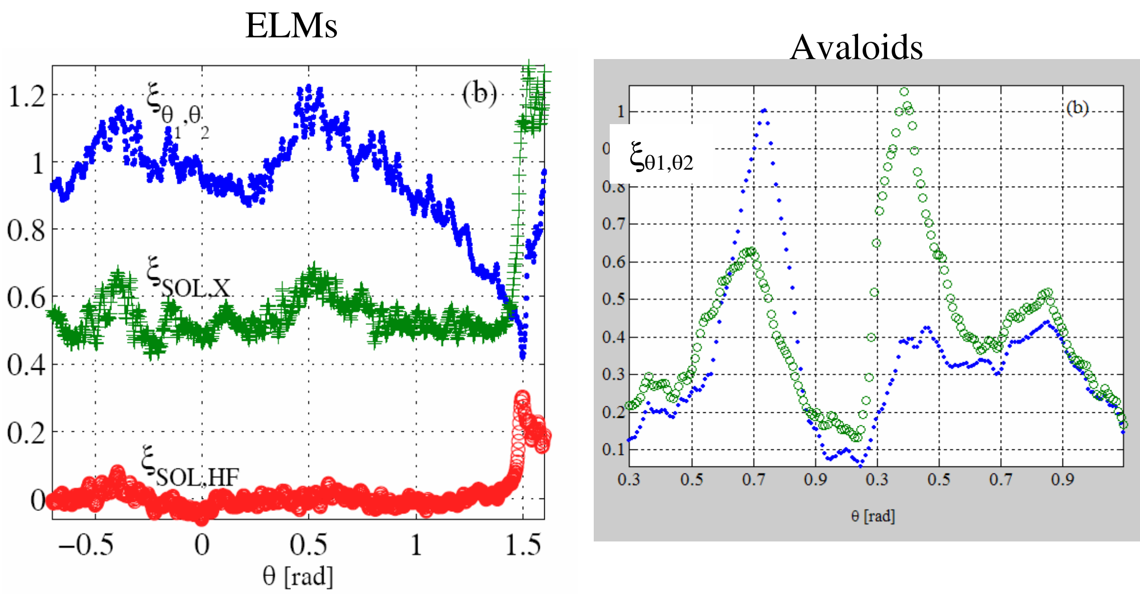

Fig. 3: The slope of the cross-correlation among different points of an image taken from a movie with 300 frames. Note that the cross-correlation is strong at all poloidal angles for ELMs whereas it is localized for avaloids. When the two points are in the SOL, the slope is $\xi_{\theta 1,\theta 2}$. When one is in the SOL and the other around the X-point it is $\xi_{SOL,X}$, and when they in the low and high field SOL it is $\xi_{SOL,HF}$.

Quantifying the correlation in the poloidal plane

In order to obtain Fig. 3, we plot the fluctuations of light coming from the SOL at one point in the image as a function of another point in the image for a whole movie formed of 300 images. Then, we perform a fitting where ξ denotes the slope. If the slope is about 1, it means that the two points are strongly correlated; if it is around 0, it means that the two points are not correlated. A value of 0.5 would mean intermediate correlation. The result shown in Fig. 3 clearly indicates that for ELMs the perturbation occurs at all poloidal angles on the low field SOL and that they are strongly correlated. The correlation between the low field SOL and the X-point is intermediate probably because of a time delay between the perturbations at these two points. Fig. 3 also shows that there is no correlation between the low and high field perturbation in the SOL. For avaloids, the result is quite different where the correlation is spatially localized around the point where the correlation is being performed, that is around 0.7 and 0.4 rad.

Radial cuts of images in L and H-mode

Fig. 4 shows the radial cut through images taken in L-mode and ELMy H-mode with and without ELMs. Several points are to be emphasized. In L-mode turbulence leads to a relaxation of the profile on both sides of the separatrix. In H-mode, ELMs lead to a modification of the profile outside the separatrix whereas inside, it seems little affected. Moreover, notice that the edge gradient in L-mode is about the same as in the case of ELMs. Accordingly, it is expected that turbulence would arise where an ELM occurs. This might explain the filamentary structures observed in some of the images shown in MAST [3].

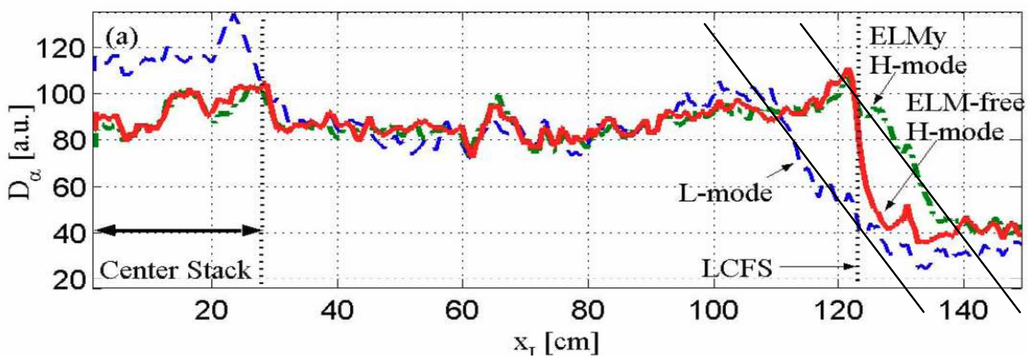

Fig. 4: Radial cut through images of plasma in L-mode (dashed) and H-mode (solid, without ELMs and dash-dotted during an ELM.

Comparison using Langmuir probes at different poloidal locations

The purpose now is to confirm some of the results showed above using *Langmuir probes* that are located at the targets near the top and bottom low-field strike points. Moreover, the mid-plane Langmuir probe is used. The signals of the ion current density is shown in Fig. 5(a) where it is rather clear that despite the large distances among the various probes ELMs are detected on all of them. This fact is quantified in Fig. 5(b), where we plotted the cross-correlation coefficient of the ion saturation current taken at the top, bottom and mid-plane. The cross-correlation amplitude between top and bottom reaches 0.8 indicating strong correlation between the two distant regions of the plasma. The correlation between the top or bottom and mid-plane is about 0.4. This decrease of the cross-correlation amplitude may be attributed to the presence of turbulent fluctuations that are ballooning in nature. This is in agreement with the above observation that radial profiles in L-mode and during an ELM are of the same order leading to instabilities and turbulence fluctuations to grow. Moreover, one can notice a time shift where maximum cross-correlation occurs. This time shift is consistent with a propagation of the ELM perturbation in the SOL at the sound speed between the different positions of the probe. Accordingly, at least for these type-III ELMs, the perturbation starts at the top and then propagates to the bottom of the tokamak.

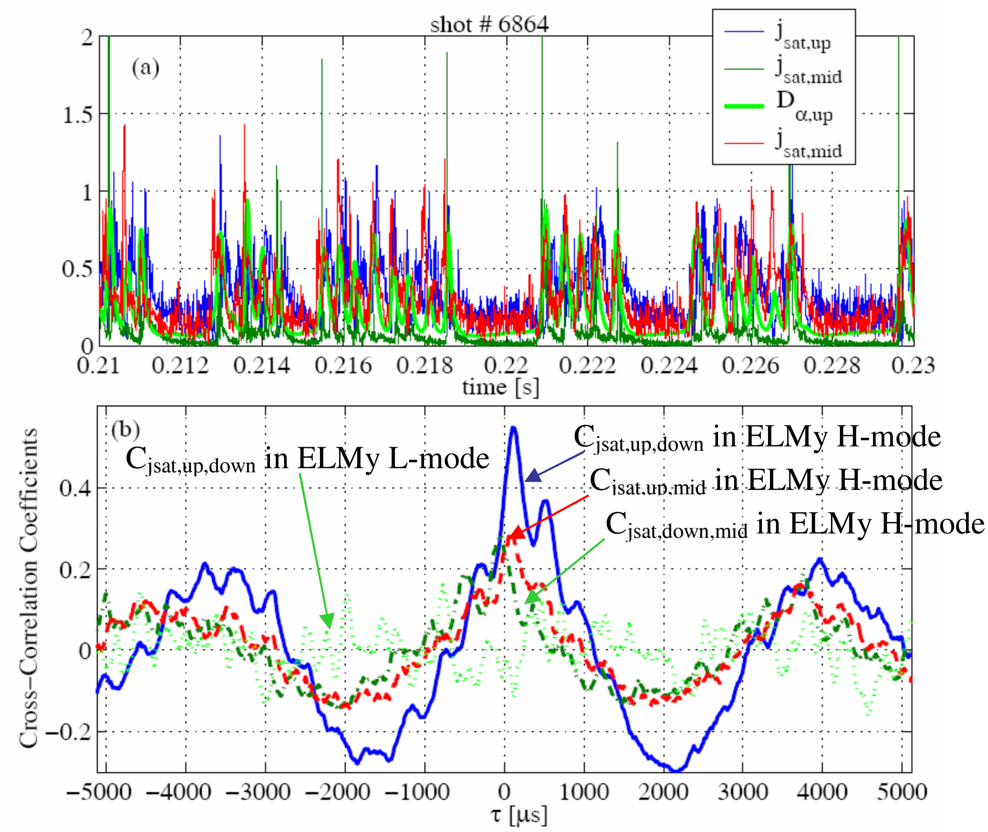

Fig. 5: (a) shows the ion saturation current density taken at the top, bottom and mid-plane as well as the D_α light coming from the top of MAST. (b) shows the cross correlation of the different ions saturation currents. Note that the amplitude of the cross-correlation is about 0.8 between the top and bottom, whereas it drops to 0.4 when it is determined between top and bottom with the mid-plane fluctuations. Also is shown in green that the cross-correlation amplitude is equal to 0 for the L-mode case.

Conclusion

Several conclusions can be drawn. (1), even though ELMs and avaloids lead to more or less the same particle flux at the wall, they are very much different with respect to their poloidal and toroidal extent. ELMs affect the whole SOL, whereas avaloids are localized structures. However, this fact does not exclude that the *origin* of ELMs may be a localized perturbation. (2), strong correlation is observed between the top and bottom of the tokamak, weaker correlation between top or bottom and the mid-plane. This is partly because of the onset of turbulent fluctuations, which are strongest at the low-field mid-plane leading to the signals de-correlation. (3), for the next step devices, it is important to study not only ELMs but also avaloids (or blobs) as they both transport matter from inside the separatrix towards the SOL, and in addition avaloids are roughly 100 more frequent than ELMs.

References:

[1] G. Y. Antar et al,. Physics of Plasmas, **12**, 032506 (2005).
[2] G. Y. Antar et al., submitted to Phys. Rev. Lett.
[3] A. Kirk et al., Plasma Phys. Control. Fusion, **47**, 315 (2005).