Experimental Study of Long-lived Saturated Mode in EAST ELM-free H mode Sawtoothing Plasma

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Intoduction Tokamak plasmas are observed to be highly sensitive to a variety of large-scale instabilities which can degrade the plasma confinement. However, long-lived 1/1 “snake” modes with superb particle confinement attracted extensive attention since found at Joint European Tours [1] in 1987. A second type, the accumulation of impurities induced LLMs is also observed in C-Mod [2, 3] and EAST [4]. In this paper, we report the formation of impurity LLMs and dynamic of LLMs in EAST sawtoothing plasma.

Experiment results As shown in figure1, the impurity LLMs can persists for a surprisingly long time, shown by surviving tens to hundreds of sawtooth cycles. And the LLMs located inside q=1 region.

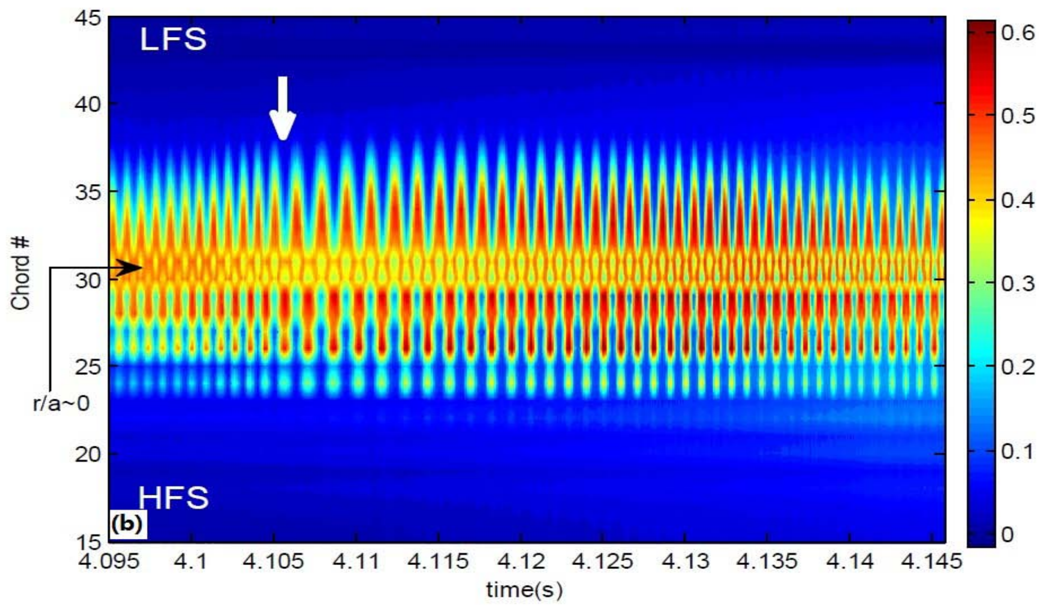
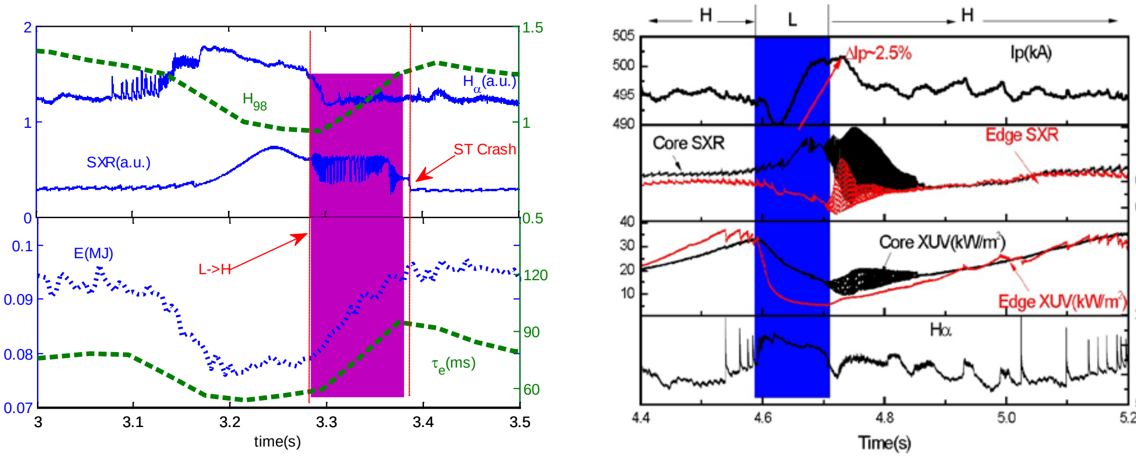


Fig.1 SXR brightness time history profiles of the impurity LLMs in EAST. The white arrow indicate the timepoint of sawtooth crash. LFS –Lower Feld Side, HFS-Higher Field Side.

Impurity LLMs can persists for a surprisingly long time, with superb particle confinement, and the mode do not degrade the plasma confinement. As shown in Figure2 (a), the increase of H_{98}, energery confinement time, and also stored energy are unhindered by 1/1 LLMs. Furthermore, the increased of core SXR radiation is due to the high-Z impurities accumulation. The ramp of plasma current (Fig.2 (b)) is beneficial to the generation and transport of impurities.



(a) (b)

Fig.2 Energy confinement time increase in H-mode plasma, energy confinement do not pollute by LLMs (a) and plasma current ramp up just before the formation of LLMs.

As the typical features of impurity LLMs, it is commonly found that on-axis peaking of radiation profile before the formation of LLMs, as shown in Fig.3. And good agreement between LLMs and impurity emissions are also observed in EAST, shown in Fig.4 (a,). Moreover, it is also found the intensity of impurity profile become flat in the core region during LLMs process, as shown in Fig.4 (b).

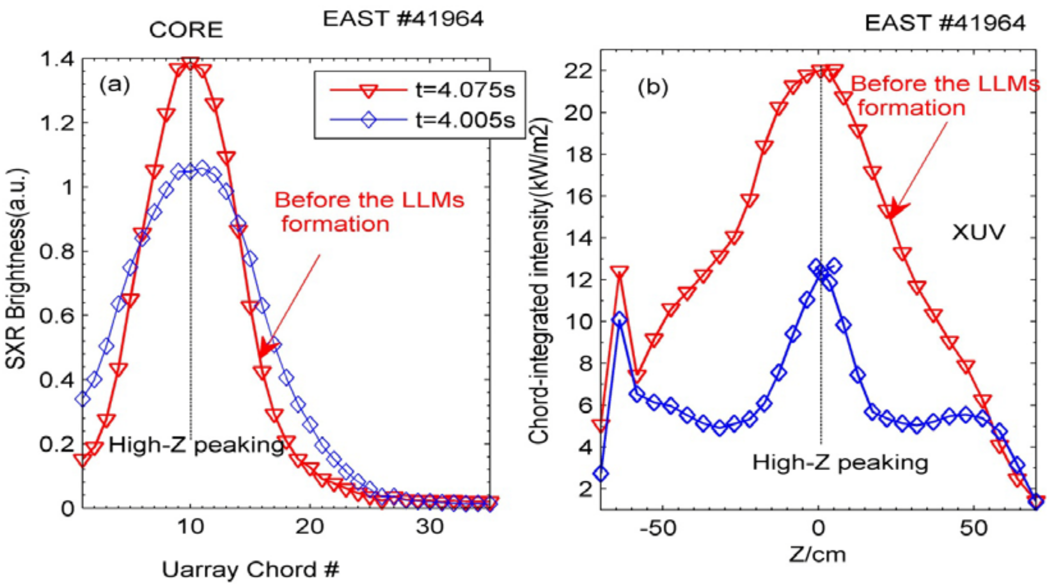
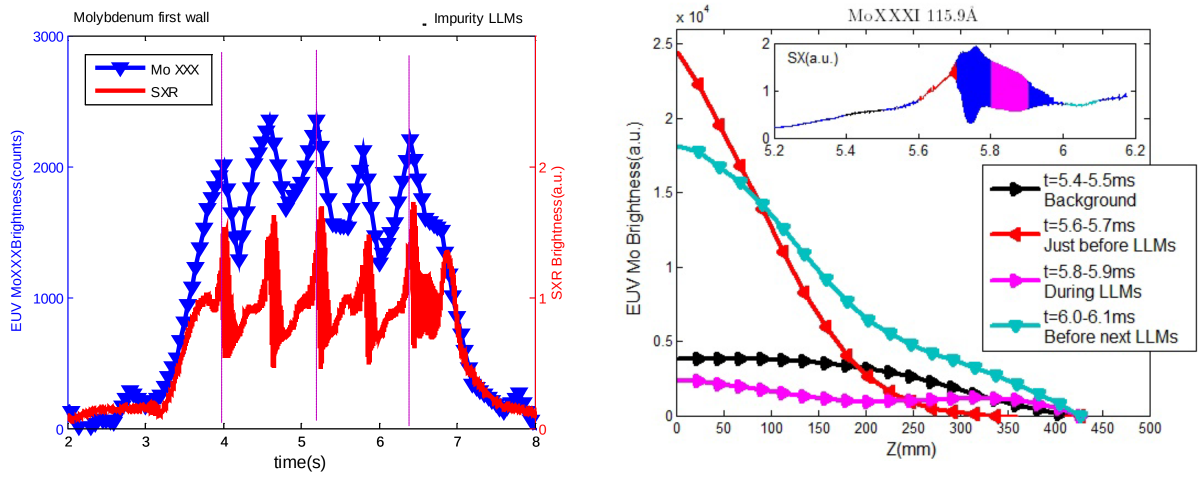


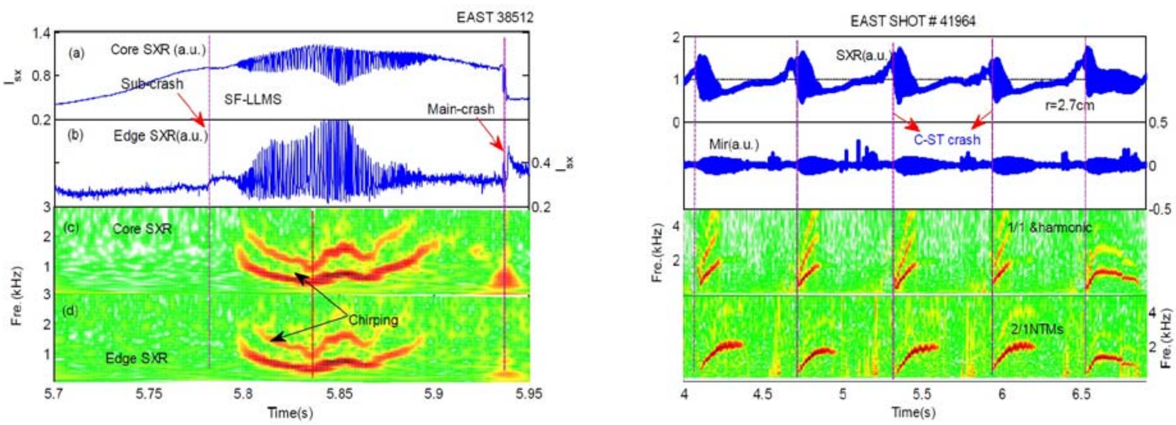
Fig.3 on-axis peaking of radiation profile before the formation of LLMs. (a) Soft x-ray emissions and (b) XUV radiation.



(a) (b)

Fig.4 Features of LLMs. (a). Good agreement between LLMs and MO emissions. MOXXXI emissions from EUV spectrometer. (b) Time evolution of MO emission profile.

The LLMs always coexist with compound sawtooth instability in EAST ELM-free H mode plasma. Based on the difference of compound sawtooth behavior, two types of LLMs are classified in EAST. One is SF-LLMs, ideal-like kink mode like which damp before larger sawtooth crash, as shown in Fig.5 (a). The other one is C-LLMs which coexistence with compound sawtooth and final damping by sawtooth crash, as shown in Fig.3 (b). An interesting result shown in Fig.5 (b) is that the strong coupling of C-LLMs and 2/1 TMs can lead a forced magnetic reconnection process during ST crash [5], hence, give a seed island for 2/1 NTMs.



(a) (b)

Fig.5 Two kinds of LLMs in EAST. (a) SF-LLMs, frequency chirping is clear in SF-LLMs. (b) C-LLMs, 2/1 NTMs triggered by strong mode coupling under sawtooth crash.

In EAST, we also find the frequencies of LLMs are related to the toroidal rotation, as shown in Fig.6. And same phenomenon is reported in TCV, the rotation of sawtooth precursor is corresponding to plasma toroidal rotation [6].

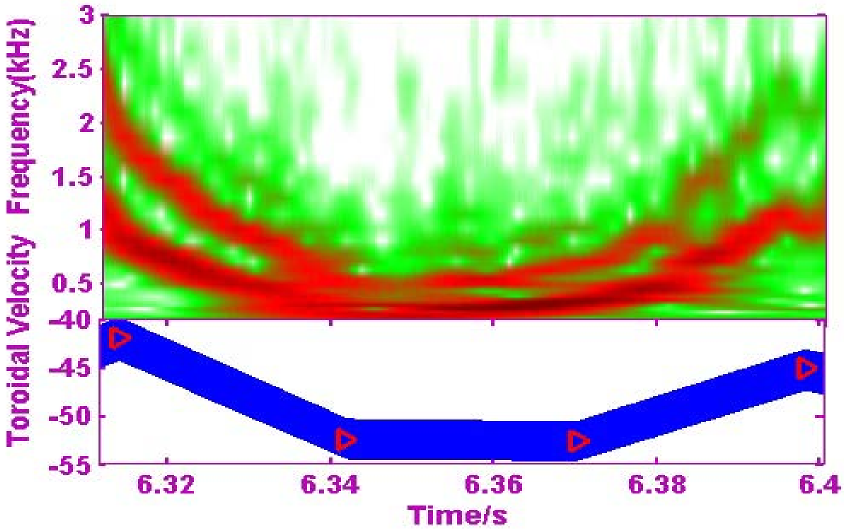


Fig.6 The rotation of LLMs related to the plasma toroidal rotation. The plasma rotation data from XCS.

Conclusions In summary, transient bursts of LLMs are frequently observed in EAST ELM-free intermittent H mode plasma. In consideration of the complex relationship between compound sawtooth and LLMs, two types of LLMs are classified. Many questions regarding LLMs formation, long-term survival, interaction with other instabilities (with EHOs, electron fishbone) remain. The role of strong $E \times B$ flow to the excitation of LLMs, and the q profile (magnetic shear) to the stability of LLMs is still need to further study.

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