# ELM and inter-ELM electromagnetic filaments in the COMPASS Scrape Off Layer

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Filamentary structures have been observed in all magnetic configurations with very similar features despite the difference in the magnetic geometry: theory and experiments suggest they exhibit a radial convective motion across the SOL, and the interest in blob dynamics is further motivated by their interaction with first wall and divertor.

Despite their possible different generation mechanisms, turbulent structures and Edge Localized Mode (ELM) filaments share some common physical features, as the localization in the cross-field plane and the associated parallel current, with a convective radial velocity component somehow related to their dimension.

The electromagnetic (EM) effects on filament structures deserve particular interest, among the others for the implication they could have for ELM, related for instance to their dynamics in the transition region between closed and open field lines or to the possibility, at high beta regimes, of causing line bending which could enhance the interaction of blobs with the first wall. In this contribution the presence of ELMs and inter-ELM EM filaments will be investigated in the COMPASS tokamak, where a new probe head was recently developed and successfully commissioned [1]. The diagnostic, based on the U-probe concept [2], allows the simultaneous measurements of electrostatic and magnetic fluctuations, with high time resolution suitable for the identification of EM features of filaments, providing in particular the direct measurement of the current density associated to filaments.

The probe head was inserted at different radial positions in the SOL of D-shaped diverted discharges. The COMPASS experiment was operated in these discharges in ohmic H-mode, with the clear presence of different type of ELMs. The COMPASS tokamak [3] is a compact experimental device (R = 0.56 m, a = 0.2 m) operated in divertor plasma configuration with ITER-like plasma cross-section. Presently, COMPASS operates with plasma current up to 400 kA and toroidal magnetic field in the range 0.9 – 1.8 T and elongation 1.8. Two neutral beam injectors provide power of 2 x 0.4 MW at the beam energy of 40 keV for additional plasma heating. Recently, an Ohmic as well as NBI assisted H-mode has been successfully achieved on the COMPASS tokamak after application of boronization of the vacuum vessel interior.

The L-H transition is followed either by an ELM-free period or ELMs with frequency in the range of 80 – 1 000 Hz. During 2014 the system for application of magnetic perturbations at edge was successfully commissioned. In this paper the electromagnetic features of ELM and inter-ELM filaments observed in the Scrape Off Layer of Compass device are shown. In figure 1 the main plasma features of shot #9328 are shown. This shot was chosen as representative case, where an extended ohmic H-mode was obtained. In this case two H-mode phases are observed, from 1075 to 1120 ms and from 1170 to 1200 ms. As clearly seen in the $D_\alpha$ monitor, these phases are characterized by the sharp strong events with a frequency varying with time. In the right column of fig. 1 some quantities as measured by the Compass U-probe are shows. The probe is placed in a fixed position during the discharge in the bottom part of the device and at low field side. In this case the radial insertion of the probe head is 15 mm from the wall and corresponds to a distance of about 50 mm from the Last Closed Flux Surface (LCFS).

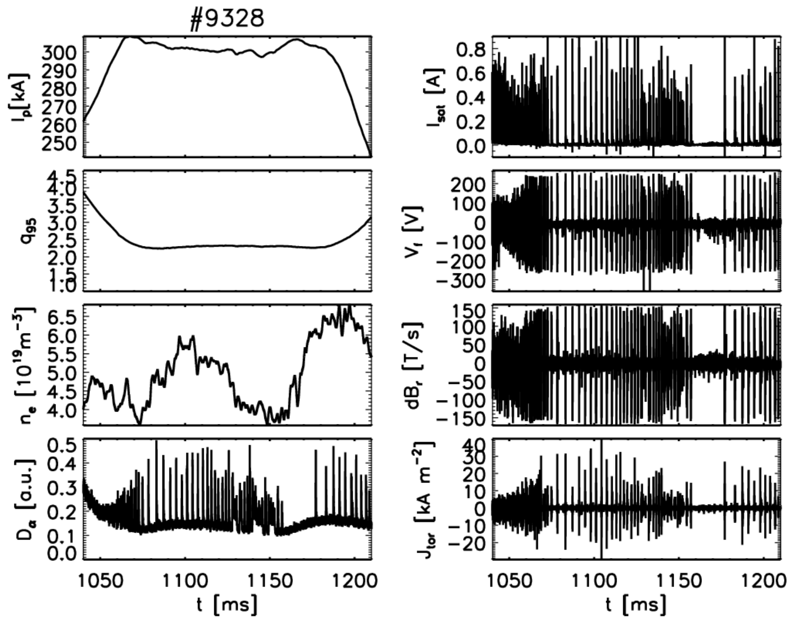


**Fig. 1** Time evolution of the main plasma parameters of shot #9328 (right column). Representative data from the Compass U-probe are shown in the left column.

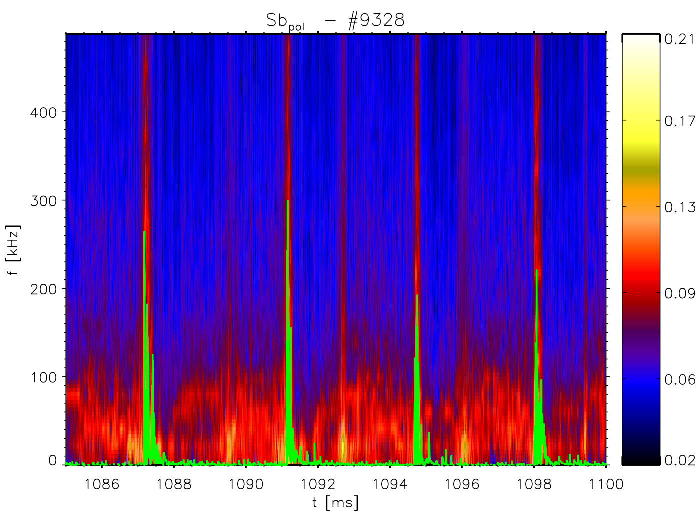


**Fig. 2** Spectrogram of 10 kHz high pass filtered $\delta b_{pol}$, during a ELMy phase. The local $I_{sat}$ [a.u.] measurement is overplotted for comparison (green line).

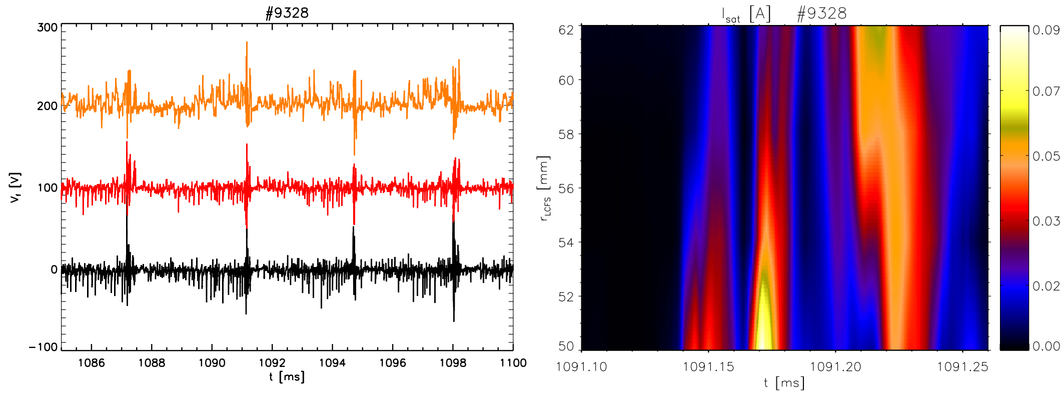


**Fig. 3** Time evolution during an ELMy H-mode phase of $V_f$ (left panel) measured at different radial positions (darker colors refer to outermost positions). $I_{sat}(r_{LCFS},t)$ during a single ELM event (right panel).

It can be observed that strong events on fluctuations of both $I_{sat}$ and $V_f$ are present and correspond to the $D_\alpha$ ELMs events. It is worth noting that also the magnetic fluctuations exhibit similar features, see the $dB_r(t)$ signals shown as representative, thus providing a clear indication of a EM feature of ELM filaments observed. The use of a 2D array of 3-axial coils allows also obtaining a direct monitor of the local parallel current density fluctuations, $J_{tor}$, measured along the whole discharge. It can be observed that strong events corresponding to ELMs are observed also in this case. In order to better explore this issue a focus on the ELMy phase is presented in the following. In particular, fig. 2 shows the spectrogram of the poloidal component of magnetic field fluctuation, $\delta b_{pol}$, during this phase. For comparison the local measurement of $I_{sat}$ time evolution is overlapped. Given that the strong $I_{sat}$ events, indicative of density bursts, can be considered as the signature of an ELM filament [4], it can be observed that also a clear magnetic activity is correlated to ELMs and is characterized by an abruptly spread spectrum. The dataset provided by the Compass U-probe includes also radially spaced information on $V_f$ and $I_{sat}$. Fig. 3 shows the time evolution, in the same phase seen in fig. 2, of $V_f$ measured in three different positions radially spaced by 8 mm. The ELM events involve all the $V_f$ signals, suggesting a radially extended potential structure. In the same figure the detail of the time evolution around a single event as seen by the radial

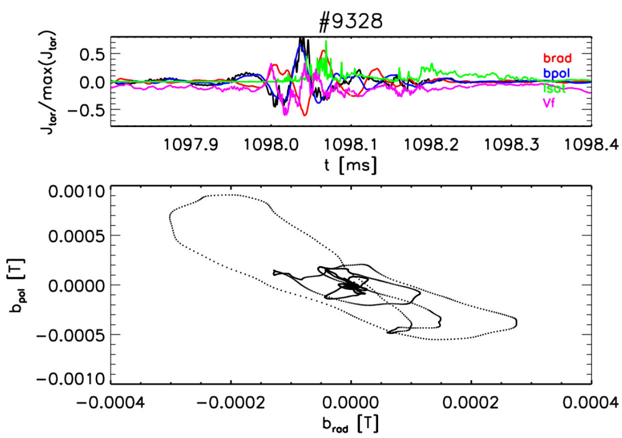


**Fig. 4** Time evolution during a single ELM event of $\delta J_{tor}$, $\delta b_{pol}$, $\delta b_{rad}$, $\delta I_{sat}$ and $\delta V_f$, normalized to their maximum value (top). Cross field pattern described by the $\delta b_{pol}$ and $\delta b_{rad}$ fluctuations during an ELM event (bottom).

array of $I_{sat}$ measurements is shown. In this case four measurements are used, radially spaced by 4 mm, the distance from the estimated position of the LCFS, $r_{LCFS}$, is shown. The revealed density structure associated to this event is complex: a radial extended structure appears at the beginning, then suddenly develops and radially propagates and exhibits multiple fragmentations. Fig. 4 shows details of a single ELM event according to locally measured magnetic and electrostatic quantities. The main $I_{sat}$ peak corresponds to a potential valley, furthermore, a main positive peak of parallel current density, $J_{tor}$, is observed. However, also negative secondary $J_{tor}$ peaks are evident, providing a nearly zero time integral of the $J_{tor}$ associated to the ELM filament. This behavior suggests a $J_{tor}$ current density pattern closing on itself. Its filamentary feature is confirmed by the closed patterns described by the $\delta b_{pol}$ and $\delta b_{rad}$ fluctuations in the cross-field plane [5,6], however a statistical analysis deserves in order to conclude on the detailed $J_{tor}$ topology. The ELM events result than characterized by a composite EM filamentary structure. A further detail can be provided by analyzing the inter-ELM phases. An example is shown in fig. 5, where the time behavior in between two ELMs is shown for $J_{tor}$, $I_{sat}$ and $V_f$ fluctuations. Several $I_{sat}$ events similar to the ELM ones are observed in these phases, but characterized by about one order of magnitude smaller amplitude and time scales. Also these inter-ELM events are characterized by associated $V_f$ valley and $J_{tor}$ filamentary structure. A zoom on one of them is shown as an example in fig. 5. Summarizing, ELM and inter-ELM electromagnetic filaments were measured during ohmic H-mode discharges in Compass device. Similar structures with different scales were observed in the two cases.

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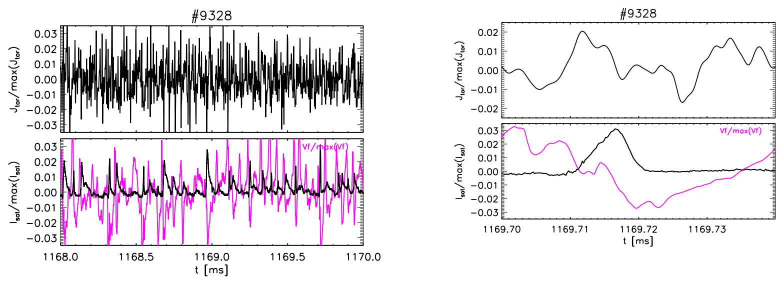


**Fig. 5** Time evolution during an inter-ELM phase of $\delta J_{tor}$, $\delta I_{sat}$ and $\delta V_f$, normalized to their maximum value (left), zoom of the same quantities on a single inter-ELM event detected on $I_{sat}$ (right).

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