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Intermittent Fluctuation Property of JT-60U Edge Plasmas

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1. Introduction

Intermittent convective plasma transport, so-called "blobs" has been observed in edge plasmas of fusion devices, which plays an important role for cross-field plasma transport in SOL. In this paper, we will report a statistical analysis of intermittent edge plasma fluctuation of ion saturation currents I_{sat} measured with probes in JT-60U[1-3]. In JT-60U, the reciprocating Mach probes are installed at the low field side (LFS) mid-plane and just below the X-point as shown in Fig. 1[4]. We obtained time evolution of I_{sat} with a high time resolution by the Mach probe to investigate the electrostatic fluctuation property. Cross and parallel transports of intermittent density bursts including ELM events[5, 6] are also discussed by comparing the spatiotemporal behavior of the fluctuations in I_{sat}.

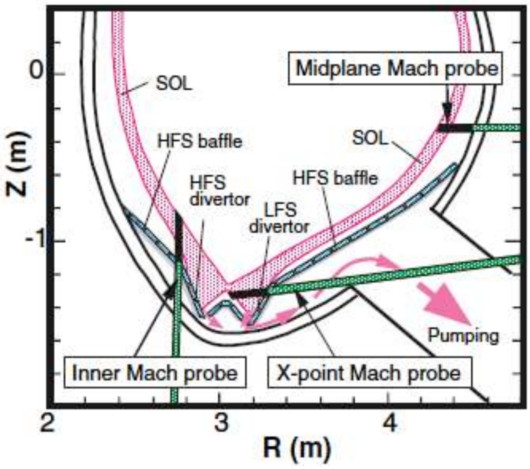

Fig. 1. Plasma cross-section and location of reciprocating probe in the JT-60U.

2. Analysis of edge fluctuation in L-mode discharge

Figure 2(b) shows typical time evolution of I_{sat} measured with the Mach probe in the mid-plane at the low-field side. The sampling time of I_{sat} is 2 μ s. The position of the Mach probe changes in time as shown in Fig. 2(a). Figures 2(c) and (d) show I_{sat} obtained at different positions from separatrix, d_{sep} of 60 mm and 20 mm, respectively. It is clearly found that there are many intermittent bursty fluctuations in Fig. 2(c) in comparison with Fig. 2 (d).

Fluctuation property has been analyzed with a probability distribution function (p.d.f.) to obtain a basic property of the intermittent plasma transport. For fully random signal, the p.d.f. has a Gaussian profile. When large positive fluctuations are much greater than expected values from Gaussian distribution, the p.d.f. is positively skewed. The p.d.f. can give important statistical quantities for turbulence research. The deviation from Gaussian distribution function can be characterized by skewness and flatness. The skewness is defined as $S=\langle x^3\rangle/\langle x^2\rangle^{3/2}$ to describe asymmetry of the p.d.f. and the flatness $F=\langle x^4\rangle/\langle x^2\rangle^2$ measures the tail's weight with respect to core of the

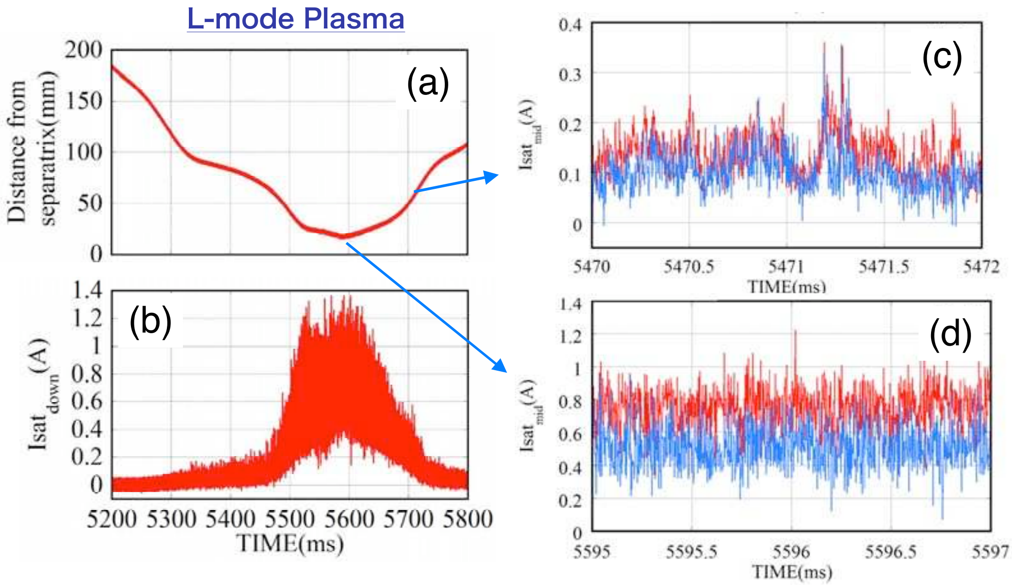

Fig. 2 (a) position of Mach probe, (b) time evolution of ion saturation current, ion saturation currents (c): at d_{sep} of 60 mm and (d): at d_{sep} of 20 mm.

distribution, where x is the deviation from averaged value. In Gaussian distribution function, the skewness and flatness are 0 and 3, respectively.

Closed circles in Fig. 3(a) shows profile of mean values of I_{sat} measured with one of the double probes in the mid-plane Mach probe facing to LFS divertor plate. It is found that the profile of averaged I_{sat} has three different e-folding lengths depending on d_{sep}. The e-folding length of the averaged I_{sat} is about 28mm at d_{sep} below 60 mm and 46 mm at d_{sep} from 60 mm to 120 mm, respectively. Above d_{sep} of 120 mm, the e-folding length becomes shorter again. Open squares in Fig. 3(b) represent Mach numbers of parallel SOL plasma flow along the magnetic field. The Mach number becomes zero around d_{sep} of 75 mm, then the direction of the parallel SOL plasma flow changes from upward to downward at this position. The small Mach number around d_{sep} of 75 mm could be

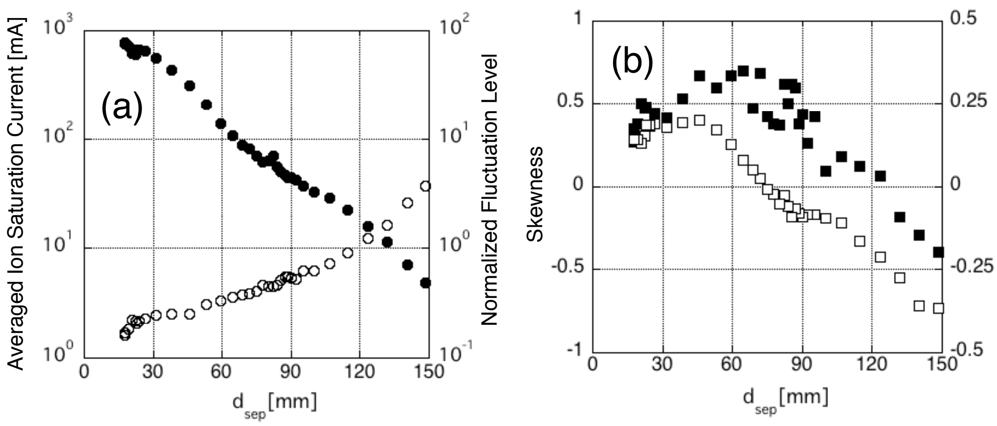

Fig. 3 Profiles of (a) mean value of ion saturation current (closed circles) and fluctuation amplitude normalized by the averaged value (open circles), (b) skewness (closed squres) and Mach number of plasma flow along magnetic field (open squares).

related to larger e-folding length of the averaged I_{sat} at the d_{sep} between 60 mm and 120mm.

Open circles in Fig. 3(a) show normalized fluctuation amplitude, which monotonically increases with d_{sep}. On the other hand, the skewness shown in Fig. 3(b) peaks around d_{sep} = 75 mm, where the SOL plasma flow velocity is zero. Large skewness indicates that positive bursty signals are dominating in the time evolution of I_{sat}, which could be associated with the convective blobby plasma transport.

Figure 4 shows interrelationship between skewness S and flatness F. In fluid dynamics, turbulence states were categorized by interrelationship between higher order moments of the p.d.f. such as skewness and flatness. For example, in turbulence of wall bounded flow, the universal interrelationship between skewness and flatness: F=3.13+2.48S^2 was reported [7]. From SOL plasma electrostatic fluctuation, we can also obtain F=2.96+2.58S^2 shown as solid line in Fig. 4. These two interrelationships are quite similar, although it is not understood yet what underlying physics is behind them. The characterization of plasma turbulence based on the interrelationship between the high order moments will be interesting future work.

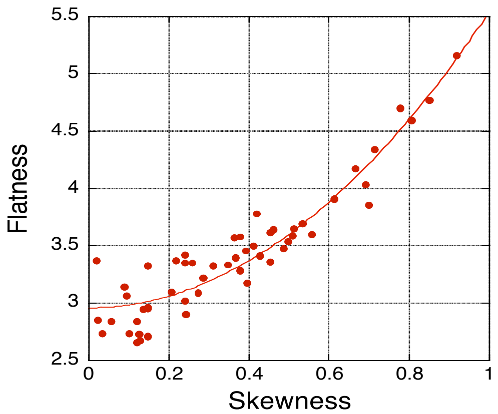

Fig. 4 Flatness as a function of skewness.

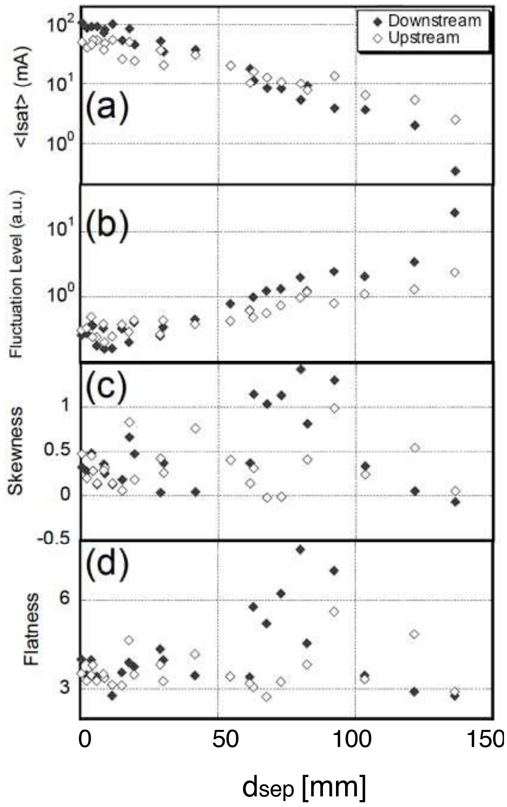

Fig. 5 Profiles of (a) mean value of I_{sat}, (b) normalized fluctuation amplitude, (c) skewenss, (d) flatness between ELMs.

3. Analysis of edge fluctuation in ELMy H-mode discharge

We also analyze I_{sat} measured with mid-plane Mach probe in ELMy H-mode discharge. Figure 5 shows profiles of mean value, normalized fluctuation level, skewness, flatness of I_{sat} between ELMs. The fluctuation level is found to be increased with d_{sep}. It seems that skewness of I_{sat} increases with d_{sep} and it peaks around d_{sep} = 70-80mm where the direction of the parallel SOL flow changes from upward to downward as same as that in the L-mode discharge, although the data in Fig. 5 scatter so much in comparison with those in Fig. 3 because the dynamic range of A-D converter was set to measure I_{sat} during ELMs. These results shown in Figs. 3 and 5 indicate that SOL fluctuation properties in L-mode and between ELMs of ELMy H-mode are quite similar.

Figure 6 shows typical time evolution of I_{sat} during ELM event. Measurement of I_{sat} with a high time resolution reveals that one ELM is composed of many positive spikes.

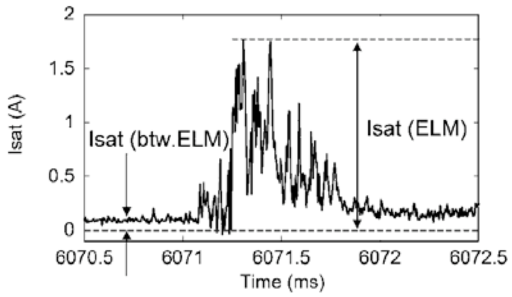

Fig. 6 Typical time evolution of I_{sat} to show ELMs.

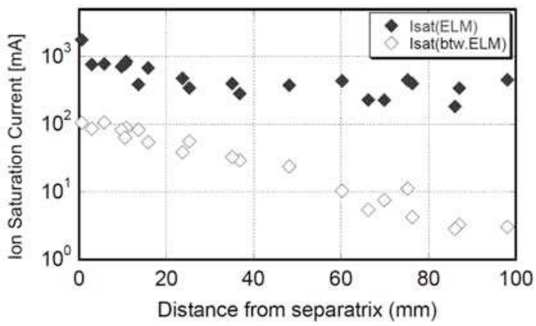

Fig. 7. Radial profiles of I_{sat} during ELM (Isat ELM) and between ELMs (Isat btw. ELM).

Figure 7 shows radial profiles of I_{sat} during ELM defined as I_{sat} (ELM) in Fig. 6 and I_{sat} between ELMs (I_{sat} (btw. ELM)). It is found that the I_{sat} during ELM decreases much slower than the averaged I_{sat} between ELMs. The effective radial decay length of I_{sat} (ELM) is estimated to 87 mm, which is about three times larger than 28 mm for I_{sat} (btw. ELM). This experimental result indicates that ELM could be convectively transported across the magnetic field much easier in comparison with bulk plasmas.

4. Summary

The properties of the intermittent bursty fluctuation observed in peripheral region of the JT-60U have been investigated by p.d.f. analysis. At the LFS mid-plane, the skewness of I_{sat} increases with a distance from separatrix d_{sep}. It peaks around d_{sep}=60-80mm, where direction of the parallel SOL flow changes upward to downward, in both L-mode and between ELMs of ELMy H-mode. It could indicate that there is strong relation between the process of cross-field transport like blobs and parallel SOL flow. From analysis SOL profiles of I_{sat} in ELMy H-mode discharge, decay length of I_{sat} during ELM is about three times as long as one of I_{sat} between ELMs. Thus the plasma during ELM is convectively transported in the radial direction much easier in comparison with the one between ELMs, which corresponds to bulk plasma.

Reference

[1] G. Y. Antar *et al.* Phys. Rev. Lett. **87**, 065001-1 (2001).
[2] J. A. Boedo, D. Rudakov *et al.* Phys. Plasmas, **8,** 4826 (2001).
[3] S. I. Krasheninnikov, Phys. Lett. A, **283**, 368 (2001).
[4] N. Asakura *et al.* Nucl. Fusion **44** (2004) 503-512.
[5] N. Asakura, *et al.*, Journal of Nucl. Mater. **337-339** (2005) 712-716.
[6] H. Miyoshi *et al.* Proc. of 31st EPS Conference on Plasma Phys. London, 2004 ECA Vol.**28G**, P-5.101 (2004).
[7] J. Jovanovic *et al.* Phys. Fluids **A5**(1993)2887.