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Intermittent Fluctuation Property of Edge Plasmas in JT-60U and LHD

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1. Introduction

From experiment on fusion devices there is a lot of evidences that plasma turbulence is highly intermittent[1]. Intermittent events are well-known to play a crucial role in transport dynamics. Intermittent transport resulted from rare, large events is due to coherent structures, leading to losses above one predicted by neo-classical heat diffusive scaling. The cross-field transport in the scrape-off layer is directly related to the heat deposition width on the divertor target plate and the first wall, which is crucial to determine the averaged heat flux on it. Recently, intermittent convective plasma transport, so-called "blobs" has been observed in the edge plasmas of several fusion devices, which is thought to play a key role for cross-field plasma transport. Intermittent bursty fluctuations of ion saturation currents (I_{sat}) and/or floating potentials measured with probes are analyzed to obtain a basic property of the blobs[2]. Detailed comparison of the fluctuation properties in the edge plasmas of tokamak and helical fusion devices is expected to give an understanding of the blobby plasma transport, because the blobby plasma transport is thought to be strongly influenced by the magnetic configuration.

In this presentation, we will report the statistical analysis of the intermittent edge plasma fluctuations in the JT-60U tokamak and the Large Helical Device (LHD). The fluctuation property has been analyzed with probability distribution function (p.d.f.).

2. Analysis of edge fluctuation in ELMy H-mode plasma in JT-60U

Fig. 1 shows the plasma cross-section and locations of the reciprocating Mach probes installed at the high field side (HFS) baffle, low field side (LFS) mid-plane and just below the X-point in JT-60U. We have mainly analyzed the time evolution of the ion saturation current I_{sat} with the Mach probe installed in the mid-plane at the low-field side and divertor probe array. The sampling time of I_{sat} is 5μs. Cross- and parallel- transports of the intermittent density bursts including ELM events are also discussed by comparing the spatiotemporal behaviour of the fluctuations in I_{sat}. Fig. 2 shows the typical time evolution of I_{sat} measured near the separatrix with the mid-plane reciprocating probe. Fluctuations of I_{sat} with intermittent bursts including ELM are observed. The measurement of I_{sat} with high time resolution reveals that one ELM is composed of many spikes. Fig. 3(a) shows radial profile of the peak amplitude of ELM defined as I_{sat} (ELM) in Fig. 2 as well as averaged I_{sat} between ELMs (I_{sat} (btw. ELM)). It is found that the peak amplitude of ELM decreases much slower than the averaged I_{sat} between ELMs. The effective radial decay length of I_{sat} (ELM) is estimated to 87mm which is about three times larger than 28 mm for I_{sat} (btw. ELM). This experimental result indicates that ELM can be convectively transported across the magnetic field much easier in comparison with bulk plasmas.

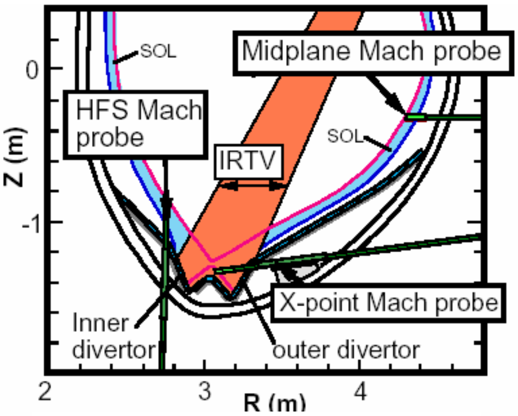

Fig 1. Plasma cross-section and location of reciprocating probe in JT-60U.

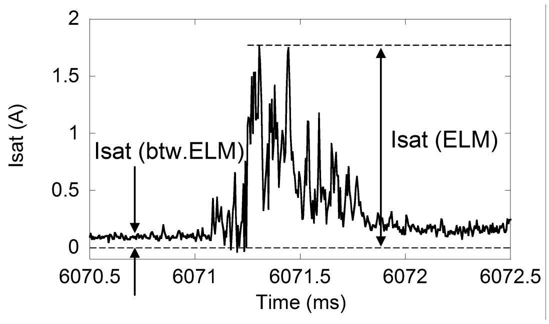

Fig 2. Typical time evolution of ion saturation currents measured with the mid-plane probe.

Next, we analyze fluctuation property of the time evolution of I_{sat} between ELMs based on probability distribution function (p.d.f.). The p.d.f. is an important statistical quantity for turbulence research. In order to obtain the p.d.f. function, we construct a histogram of the fluctuation signal. For fully random signal, the p.d.f. has a Gaussian profile. In edge plasmas of fusion devices, p.d.f.'s of density fluctuations are non-Gaussian and positively skewed, meaning that large positive fluctuations are much greater than expected values from fully random distributions. The fluctuations are sometimes negatively skewed. The deviation from the Gaussian distribution function can be characterized by flatness and skewness. The skewness $S=<x^3>/<x^2>^{3/2}$ describes the asymmetry of the p.d.f., and the flatness $F=<x^4>/<x^2>^2$ measures the tail's weight with respect to the core of the distribution, where

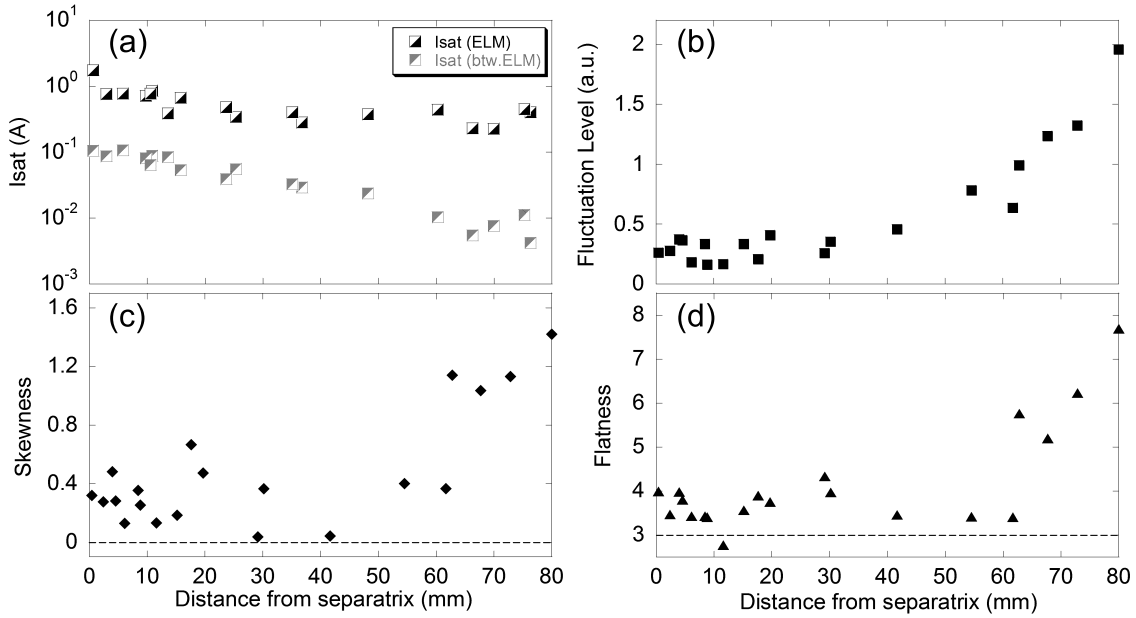

Fig 3. Radial profiles of (a):the peak amplitude of ELM and averaged ion saturation current of I_{sat} between ELMs, (b) normalized fluctuation level of I_{sat} between ELMs, (e)skewness and (f)flatness.

x is the deviation from averaged quality. In the Gaussian distribution function, the skewness and flatness are 0 and 3, respectively. Fig. 3(b) shows that the fluctuation level of I_{sat} between ELMs, corresponding to standard deviation of the p.d.f., is monotonically increasing with the distance from the separatrix d. On the other hand, the skewness and flatness also increase with d, deviating from 0 and 3 respectively. This means that the bursty positive spikes become dominant in the fluctuation of the I_{sat} at the positions near $d \sim 80$ mm, which could be related to the blobby plasma transport.

3. Fluctuation property in the edge plasma of LHD

Recent theory[3] predicts that the blobs propagate toward low field side in tokamaks because the blob motion is driven by charge separation in the scrape-off layer due to gradient B effect. On the other hand, in the LHD, the direction of the gradient in B is not uniform because the helical system has a complex magnetic configuration. Comparison between the intermittent bursty fluctuations in the edge plasma of tokamaks and helical devices makes it possible to understand the essential physics of the blob transport.

In the LHD, I_{sat} is measured by a Langmuir probe array (16 channels) embedded in the divertor plate, which is installed at inboard, outboard and bottom board. Fig. 4 shows the radial profiles of averaged I_{sat}, skewness and flatness. The averaged I_{sat} peaks near the probe

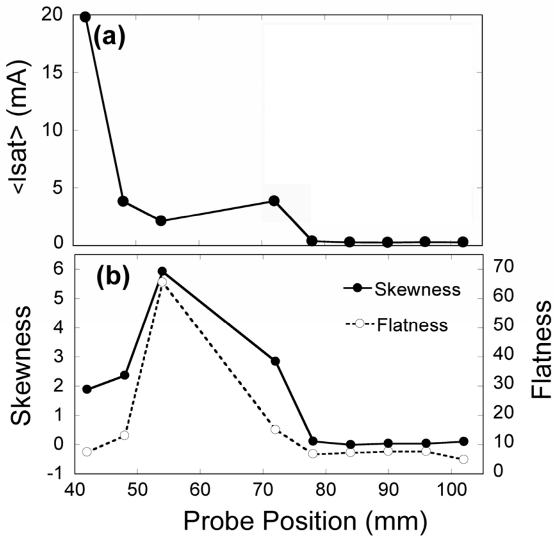

Fig 4. Radial Profiles of (a): averaged ion saturation current measured by the divertor probe array, (b): skewness and flatness.

position of 40 mm, which corresponds to the striking point where magnetic line of force with long connection length are concentrated. On the other hand, it is found that large positive spikes of I_{sat}, characterized by large skewness and flatness, are strongly localized near the striking point (~55mm) on the divertor plate. Away from the probe position of 55mm, the skewness and flatness decrease. This tendency is completely different from the observation in the JT-60U. Moreover, it should be noted that the absolute values of the skewness and flatness are much higher than those in Fig. 3, which means that the p.d.f. of the I_{sat} fluctuation in the LHD strongly deviate from the Gaussian distribution in comparison with that of JT-60U. Careful observation of the I_{sat} at the probe position of 55mm shows that time evolution of I_{sat} are mainly composed of the spiky signals without the dc level. These fluctuation properties could be related to the complex magnetic structure in the edge region of the LHD.

4. Summary

The properties of the intermittent bursty fluctuation observed in the tokamak device JT-60U and helical device LHD have been investigated by p.d.f. analysis. In JT-60U, intermittent density fluctuations including ELMs are transported in radial direction. The fluctuation level, skewness and flatness of I_{sat} increase away from separatrix. On the other hand, in LHD, intermittent bursty signals are localized and skewness and flatness of I_{sat} are much larger than that of JT-60U.

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