

## §2. Probability Density Functions of Intermittent Local Electron Flux in an ECR Plasma

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Understanding intermittent behaviors of particle flux in the edge region of magnetically confined plasmas is of great importance in the field of fusion research. An edge localized mode (ELM) and bursty transport of blobs in the scrape-off layer are crucial for evaluating plasma-wall interactions. To characterize such intermittent phenomena, statistical analysis is a powerful tool. Study of probability density functions (PDFs) of Type III ELMs in JET tokamak, for example, implied that fundamentally different statistical processes may be at work under various plasma conditions.<sup>1)</sup> It should be noted that, among the ELM time-series analyzed in Ref. 1, some waiting-time PDFs exhibit inverse exponential dependence, which may reflect an underlying Poisson process. On the other hand, a new intermittent behavior of the local electron flux has been observed recently in a linear electron cyclotron resonance (ECR) plasma.<sup>2)</sup> These flux changes are attributable to spontaneous transitions of the electron energy. Since the floating potential on a Langmuir probe is very sensitive to electron energy, we utilized it to investigate statistical properties of this phenomenon.

The experiments were performed in the HYPER-I device at the National Institute for Fusion Science. The plasma was produced by an ECR discharge of a helium gas of which pressure was 1.5 mTorr with the microwave power of 20 kW. A part of typical floating potential time-series analyzed in this study is shown in Fig. 1. Sporadic large amplitude fluctuations seen in this figure correspond to the intermittent influx of the high-energy electrons. Figure 2 shows the PDF of the whole 10-second time-series. The horizontal axis is the fluctuating component of the floating potential signal normalized to the standard deviation  $\sigma$  of the time-series. In the positive-value side, the PDF is well fitted by a Gaussian curve, implying that the potential fluctuation is randomly distributed about the mean value. In the negative-value side, however, the PDF exhibits a fat tail which reflects the intermittent behavior seen in the time-series. In what follows, we shall consider only negative spikes, and each negative spike of which amplitude is larger than triple the standard deviation  $\sigma$  is taken as an intermittent event. The 10-second time-series contains about 50,000 intermittent events.

The statistics of the *waiting time*, which is defined by the time interval between two consecutive events, contains important information about the mean occurrence rate and the randomness of the events.<sup>3)</sup> Figure 3 shows the waiting-time PDF in a semi-logarithmic scale. The PDF is found to be an exponential distribution,  $f(\tau) = \lambda \exp(-\lambda\tau)$ , where  $\lambda$  is the rate parameter. This distribution describes the waiting

time of a stationary Poisson process in which events occur independently at a constant average rate. The same type of exponential distributions has been found in the waiting times of ELMs and blobs<sup>4)</sup>. Consequently, we have found a similarity behind the intermittent time-series of different phenomena observed in different plasma configurations.

- 1) Greenhough, J. et al.: PPCF **45** (2003) 747.
- 2) Yoshimura, S. et al.: Proceedings of 39th EPS & 16th ICPP, P2.181 (2012).
- 3) Aschwanden, M.: *Self-Organized Criticality in Astrophysics* (Springer, Heidelberg, 2011), Chap. 5.
- 4) Banerjee, S et al.: Nucl. Fusion **52** (2012) 123016.

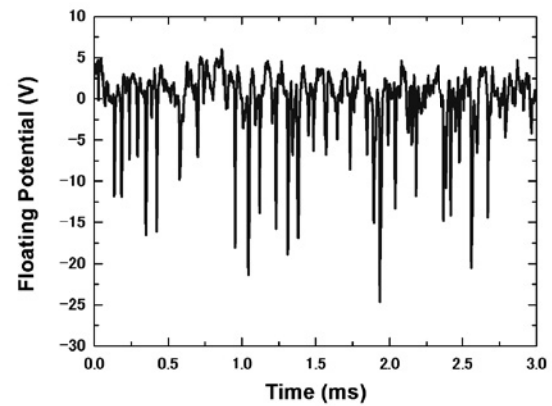


Fig. 1 A part of typical floating potential time-series.

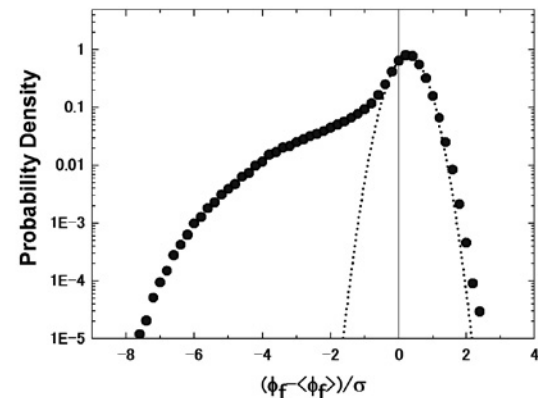


Fig.2 The PDF of the floating potential time-series.

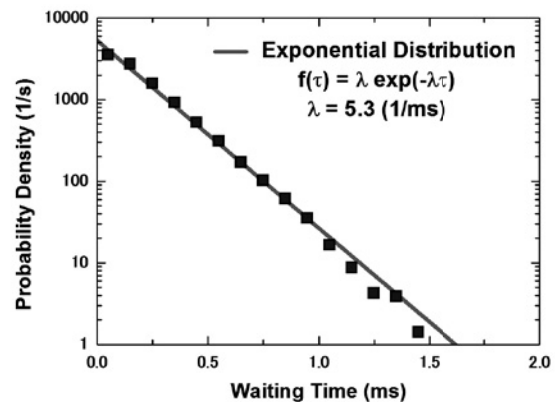


Fig. 3 The waiting-time PDF of the intermittent events.