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Intermittent Electron Flux in an ECR Plasma (II): Statistical Analysis
ECRプラズマ中の間欠的電子流束(II)：統計解析

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Statistical analysis is applied to a time series of the floating potential (V_f) fluctuation associated with the intermittent electron flux generation in an electron-cyclotron-resonance (ECR) plasma. The probability density function (PDF) of V_f exhibits a non-Gaussian distribution with a long tail in the negative amplitude side, indicating that the signal is dominated by large amplitude negative spikes. The waiting-time defined by time interval between two consecutive spikes shows an exponentially decaying distribution. The Hurst exponent determined with the rescaled range (R/S) method is H = 0.5, which suggests the randomness of the events.

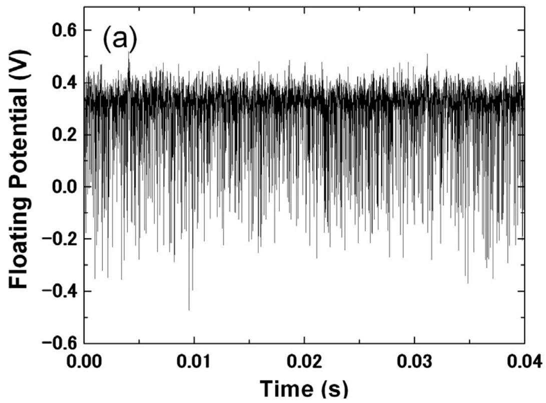
1. Introduction

In recent decades, much attention has been paid to statistical analysis of intermittent phenomena in plasmas. Universality of turbulence and intermittent particle transport in the boundary plasmas of many magnetic confinement devices for fusion research is deemed to the main impetus for such activities [1-3]. Various useful tools for time-series analysis have been developed to characterize the properties of intermittent events, such as the probability density (distribution) function (PDF) [4-5], the waiting-time statistics [6-7] and the Hurst exponent [8-10].

Here we present the initial results of statistical analysis on the intermittent high-energy electron flux generation observed in an ECR plasma produced in the HYPER-I device (Two-dimensional measurement of the electron flux is reported in this conference, poster number 24P-157B). The time series analyzed in this study is a floating potential (V_f) signal measured with a single Langmuir probe, which is sensitive to the influx of high-energy electrons.

2. The Probability Density Function

Figure 1(a) shows a part of the time series of V_f fluctuations, where the sampling rate and the full sampling time are 1 MHz and 20 s, respectively (20,000,000 data points are used in this analysis). The corresponding PDF is shown in Fig. 1(b) in a



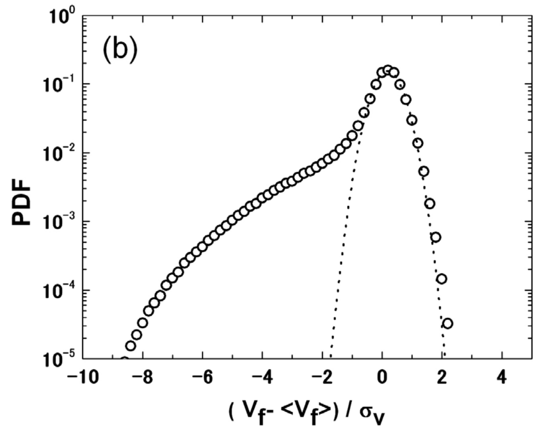


Fig.1 (a) A part of the time-series of V_f fluctuations. (b) A semilogarithmic plot of the PDF of V_f time series with a Gaussian fit (dotted line). The fluctuating amplitude is normalized to the standard deviation σ_v.

semilogarithmic scale with a Gaussian fit within the small-amplitude region. The PDF exhibits a non-Gaussian distribution with a pronounced long tail in the negative-amplitude side, indicating that the signal is dominated by intermittent bursts of the large-amplitude negative spike; however, those spikes seem to impose no influence to the Gaussianity of the positive-amplitude side.

3. The Waiting-Time Statistics

The statistics of waiting-time contains important information on the mean rate of event occurrence and the randomness of the events. The definition of waiting-time in this study is time interval between two minima of consecutive negative spikes. The threshold value for negative spike detection is $3\sigma_v$, where σ_v is the standard deviation.

Figure 2 shows the waiting-time distribution in a semilogarithmic scale (136,807 events are included). The obvious linear dependence seen in probability reflects an exponential-type distribution, implying a probable connection to a stationary *Poisson process*, i.e., a sequence of events which occur randomly and independently of one another.

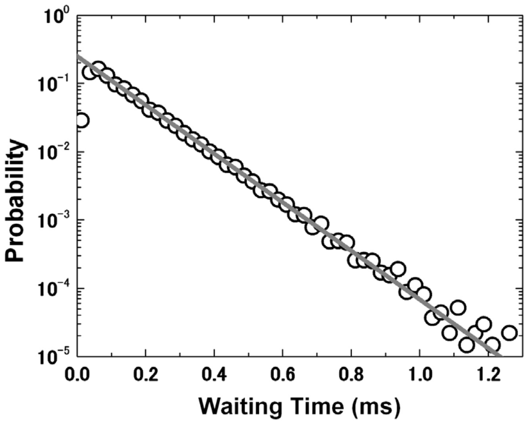


Fig. 2 The waiting-time distributions of the V_f signal.

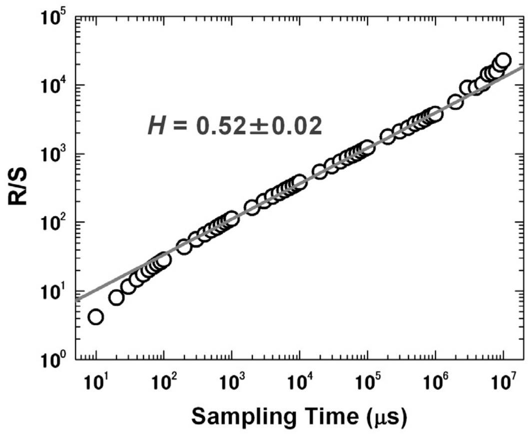


Fig. 3 R/S as a function of sampling time.

4. The Hurst Exponent

The rescaled range (R/S) method is applied to the time series of V_f fluctuations for estimating the Hurst exponent. The R/S is defined as the ratio of the maximal range of the integrated signal normalized to the standard deviation. Detailed calculation procedure of the R/S can be found in Ref. 8. The Hurst exponent H is determined by fitting the empirical power law $R/S = Cn^H$ to the data, i.e., the R/S exhibits linear increase in a double logarithmic plot. The values $0.5 < H < 1.0$ are often found in various phenomena in nature, suggesting that the self-organized criticality (SOC) [11] is the underlying mechanism behind the phenomena. Whereas the values $H > 0.5$ indicate persistence or long term memory in the data, $H = 0.5$ is expected for classical *Brownian* random motion.

The calculated R/S as a function of sampling time is shown in Fig. 3, where the power-law dependence of R/S is clearly seen. The estimated value of the Hurst exponent is $H = 0.52 \pm 0.02$, indicating randomness of the intermittent electron flux generation in an ECR plasma.

5. Conclusions

From the statistical analysis applied to a time series of the intermittent electron flux generation in an ECR plasma, we have obtain the following characteristics as an initial result. (i) The PDF represents the intermittency of the events as a pronounced deviation from a Gaussian. (ii) The waiting-time statistics shows an exponential-type distribution similar to a stationary Poisson process. (iii) The Hurst exponent estimated from the R/S method is $H = 0.5$ that is expected for Brownian random motion. These results suggest the strong randomness of the intermittent electron flux generation events under study.

References

[1] G. Y. Antar *et al.*: Phys. Plasmas **8** (2001) 1612.
[2] C. Hidalgo *et al.*: Plasmas Phys. Control. Fusion **44** (2002) 1557.
[3] G. Y. Antar *et al.*: Phys. Plasmas **10** (2003) 419.
[4] B. A. Carreras *et al.*: Phys. Rev. Lett. **83** (1999) 3653.
[5] T. A. Carter: Phys. Plasmas **13** (2006) 010701.
[6] V. E. Lynch *et al.*: Phys. Plasmas **12** (2005) 052304.
[7] M. Aschwanden: *Self-Organized Criticality in Astrophysics* (Springer, Berlin, 2011), Chap. 5.
[8] J. Feder: *Fractals* (Plenum Press, New York, 1988), Chap. 8, pp.149-183.
[9] G. Wang *et al.*: Phys. Plasmas **7** (2000) 1181.
[10] A. Scipioni *et al.*: Phys. Plasmas **15** (2008) 112303.
[11] P. Bak *et al.*: Phys. Rev. Lett. **59** (1987) 381.