ON THE MECHANISM OF TYPE I INTERMITTENCY IN NONLINEAR CURRENT DRIVEN DOUBLE LAYERS DYNAMICS

S. CHIRIAC, D. G. DIMITRIU

Faculty of Physics, "Al. I. Cuza" University, 11 Carol I Blvd., RO- 700506 Iasi, Romania

Chaotic evolution in filament type discharge plasma occurs frequently related to sheath instabilities [1-3]. Plasma, as a typical nonlinear dynamic system with many degrees of freedom, is subjected to a wide variety of transitions from ordered to low and high dimensional chaotic states trough different type of scenarios such as period doubling [1, 3], intermittencies [2], quasi-periodicity [4], torus breakdown [5], etc. These chaotic evolutions are known to be *driven* [1] and respectively *undriven* [3], being put in evidence by performing time series analysis of A.C. components arising from: discharge currents [1,4], floating potential [3], electrode currents [2,5], etc.

Here we investigate type I intermittency related to double layer dynamics in a geometry with a positively biased electrode immersed into diffusion plasma. Double layers (DLs) are localized nonlinear potential structures consisting of two adjacent positive and respectively, negative space charge sheaths sustaining a net potential difference equal or higher, depending on the gas pressure, than the ionization potential of the background gas. Their appearance in low temperature diffusion plasmas is related to a symmetry breaking phenomenon of excitation and ionization cross-sections functions [6], whose dependency on the kinetic energy of electrons accelerated locally in the electric field created by the positively biased electrode immersed in plasma, creates the premises for the accumulation of adjacent space charges. In this way, a quasi-spherical DL which confines a region of higher plasma density and potential develops in front of the electrode.

DLs are known to be at the origin of generation of nonlinear periodical oscillations, related to current limiting phenomena, during of which they appear, propagate and disrupt periodically sustaining ion-acoustic like oscillations (in the order of kHz). Our results indicate that, due to the local variation of ion plasma density where the double layer disrupts, a chaotic evolution by means of type I intermittency develops. We perform time series analysis of A.C. components of the current extracted by the electrode (I_E) from the diffusion plasma in order to emphasize a typical scenario of transition to chaos, by type I intermittency, as varying gradually only the potential of the electrode (V_E).

The transition indicated in the Fig. 1 from the frequency f_1 to f_2 proves that when a double layer disrupts, it sustains ion-acoustic like oscillations in the background plasma. The fundamental frequency of these oscillations (approximately 7 kHz) is small compared to the ion plasma frequency, so the dispersion relation is linear. The evolution of ion-acoustic oscillation is very sensitive to background plasma parameters. Any small variation of the localized (where the double layer disrupts) ion density modifies the frequency and amplitude of this oscillation, and also can cause its suppression (Fig. 2).

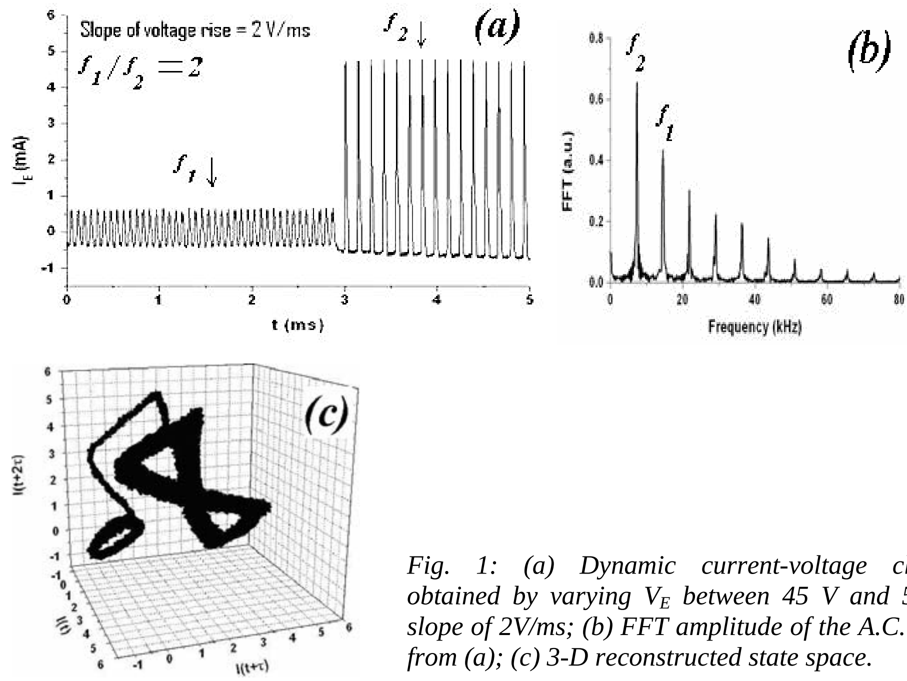

Fig. 1: (a) Dynamic current-voltage characteristic obtained by varying V_E between 45 V and 55 V with a slope of 2V/ms; (b) FFT amplitude of the A.C. components from (a); (c) 3-D reconstructed state space.

Type I intermittency is associated with a saddle-node bifurcation (tangent bifurcation in one dimensional maps). On type I intermittency, the theory is developed on quadratic map, based on which one can derive numerically or theoretically other characteristic features such as: probability distribution of laminar length, the scaling law of the average laminar length, *1/f* power spectrum, etc. The duration of the periodic state (so called laminar length) is seemingly at random due to the stochastic occurrence of burst which leads to intermittent states. The 3-D reconstructed state spaces indicate the loss of the stability of a periodic attractor through a succession of bursts. During their appearance, the ion-acoustic oscillation is suppressed. The mechanism of reinsertion of trajectories in the closed loop of the attractor is relevant for emphasizing the type I intermittency route to chaos [7]. By performing log-log plot representation of the power spectral density vs. frequency we obtained a slope which confirms a f^{-1} power law associated to the chaotic development state; by reconstructing the return map from the minima and maxima of time series, the orbits generated by the map are trapped in the narrow channel formed between the fitting curve and the identifying map.

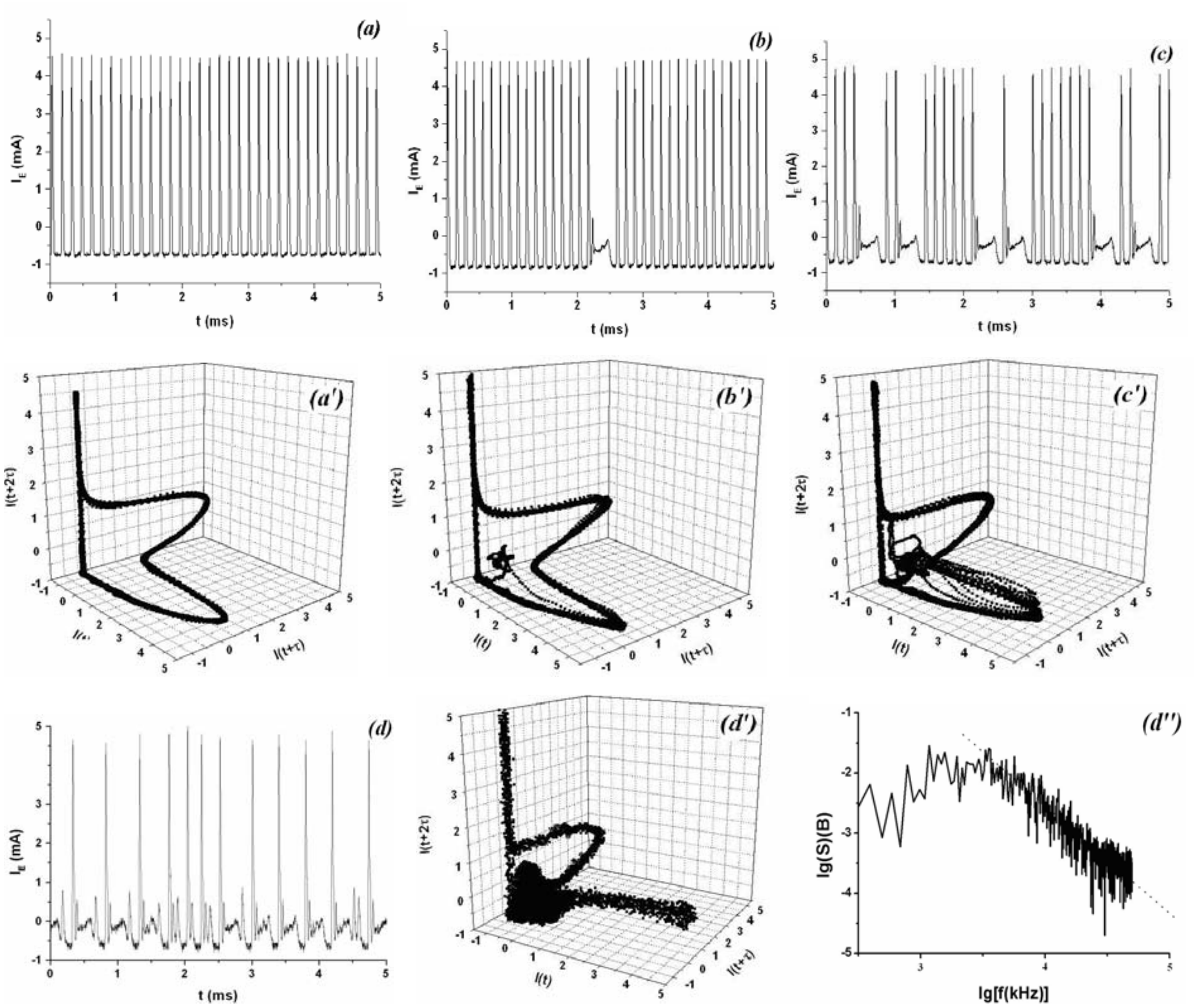

Fig. 2: (a-d) A.C. components of I_E for different values of V_E: (a) 55 V; (b) 57 V; (c) 60 V; (d) 64 V. (a'-d') 3-D reconstructed state spaces for the same values of V_E (d'') Log-log plot of the power spectral density vs. frequency for V_E = 64 V.

Reference:

[1] P. Y. Cheung and A. Y. Wong, *Phys. Rev. Lett.* **59** (1987) 551;

[2] P. Y. Cheung, S. Donovan and A. Y. Wong, *Phys. Rev. Lett.* **61** (1988) 1360;

[3] J. Qin, L. Wang, D. P. Yuan, P. Gao and B. Z. Zhang, *Phys. Rev. Lett.* **63** (1989) 163;

[4] W. Ding, W. Huang, X. Wang and C. X. Yu, *Phys. Rev. Lett.* **70** (1993) 2;

[5] S. Chiriac, M. Aflori and D. G. Dimitriu, *J. Optoelectron. Adv. Mater.* **8** (2006) 135;

[6] M. Sanduloviciu and E. Lozneanu, *Plasma Phys. Control. Fusion* **28** (1986) 585;

[7] Y. Pomeau and P. Maneville, *Commun. Math. Phys.* **74** (1980) 189.