§23. Stochastic Transition of an Inhomogeneous Plasma Turbulence

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There have been observed various kinds of formation and destruction of transport barriers. Both in edge and internal regions of high temperature plasmas, the dynamical change often occurs on the short time scale, sometimes triggered by subcritical excitation. These features naturally lead to the concept of transition.

The transition takes place as a statistical process in the presence of statistical noise source induced by turbulence interactions. As a generic feature the transition occurs with a finite probability when a control parameter approaches the critical value.

Statistical theory for plasma turbulence has been developed and the framework to calculate the probability density function (PDF), the transition probability etc. has been made[1].

We firstly apply the theoretical algorithm to a realistic high temperature plasma. Micro turbulence of current diffusive interchange mode (CDIM) is known to be subcritically excited from the thermal noise state. Hence, the transition between the thermal noise state and the turbulent (noise) state occurs, when the pressure-gradient is changed.

In order to capture the characteristics of the transition, we concentrate on the time-development of the energy of fluctuation of the electric field, $\epsilon(t)$. The quantity obeys a stochastic equation of motion, so called the Langevin equation:

$$\frac{d}{dt}\epsilon(t) = -\lambda(\epsilon)\epsilon(t) + \eta(\epsilon)R(t). \qquad (1)$$

Here, $R(t)$ is assumed to be the Gaussian noise whose variance is unity. The coefficients $\lambda(\epsilon)$ and $\eta(\epsilon)$ depend on the pressure-gradient and the temperature. The essential point is that the function $\lambda(\epsilon)$ takes both a positive and a negative value in the bi-stable regime.

By numerically solving the Langevin equation Eq. 1, the typical time-development of the fluctuation is obtained (Fig.1). It tells that the transition occurs intermittently.

The PDF for various parameter regimes is analyzed. In addition, the transition rates are calculated as a function of the control parameter, i.e. the pressure-gradient (Fig.2). It is shown that the transition from the turbulent state to the thermal noise state occurs with almost equal frequency in almost entire bi-stable region. In other words, the transition from the turbulence state occurs in a "region" instead of a "point" of the parameter space. The results explained above have been published[2].

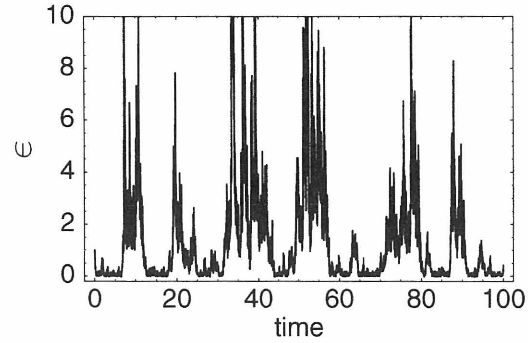

Fig. 1: A sample of a time-series of $\epsilon(t)$ in the bi-stable regime. After the laminar continues for a certain period, bursts are observed intermittently. The laminar and the burst corresponds to the thermal noise state and the turbulent state respectively. It means that the transition between the two states occurs stochastically.

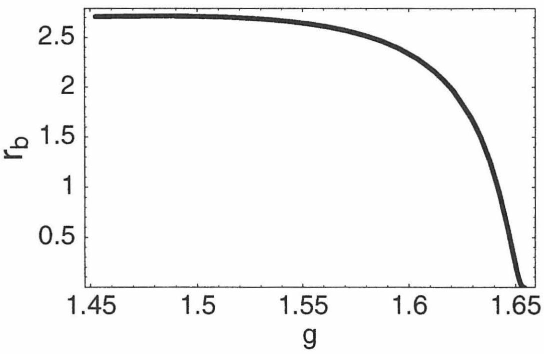

Fig. 2: The normalized pressure-gradient g dependence of the transition rate r_b from the turbulent state to the thermal noise state. The dependence is shown in the bi-stable regime; the edges of the horizontal axis correnspond to the stability boundaries. It is seen that the transition occurs in the almost entire bi-stable regime.

References
1) S.-I. Itoh, K. Itoh, M. Yagi, M. Kawasaki and A. Kitazawa, Phys. Plasmas **9**, (2002) 1947 and references therein.
2) M. Kawasaki, S.-I. Itoh, M. Yagi and K. Itoh, J. Phys. Soc. Jpn. **71**, (2002) 1268.