Diversity of Extinction Process in Virtual Experiments of Cultivation of Bacteria

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1.Introduction

Study on the process to biospecies extinction is very important for conservation biology. In this paper, we carry out virtual experiments of cultivation of bacteria on agar medium. We apply the contact process (CP) which has been extensively studied from mathematical and physical aspects. So far, considerable date on CP have been accumulated, but they are mainly related to stationary state. Here, we study the dynamic process of CP.

2.The Model

The rule of CP can be dened as follows:

$$X + O \to 2X \tag{1a}$$

$$X \xrightarrow{a} O, \tag{1b}$$

where X denotes an individual of biospecies (particle) and O is the vacant site. The reactions (1a) and (1b) mean reproduction and annihilation processes of X, respectively. Namely, $(1a)$ corresponds to the growth process of bacteria; on the other hand, $(1b)$ is the death process X. The parameter a represents the annihilation rate of X. Now we consider the extinction process caused by sudden increase of the value of a. It is known that CP exhibits a nonequilibrium phase transition at a critical point $a = a_c$. The value of a_c is $a_c \sim 1.213$ on square lattice. We perform perturbation experiment as follows. Before the perturbation ($t < 0$), our system stays in a stationary state at $a = a_1$ (existing phase: $a_1 < a_c$). At $t = 0$, the annihilation rate a of particle is suddenly increased from a_1 to a_2 ($a_2 > a_c$). We prepare N kinds of initial patterns (*ensembles*) which are in stationary state at $a = a_1$; each of them has the density $x_i(0)$ ($i = 1, 2 \ldots N$). The value of $x_i(0)$ is almost equivalent to the steady-state density. We obtain the dynamics $x_i(t)$ for $t > 0$ in order to calculate the ensemble average $A(t)$ and the variance $V(t)$ which are dened

$$A(t) = \frac{1}{N} \sum_i x_i(t), \tag{2}$$

$$V(t) = \frac{1}{N} \sum_i [x_i(t) - A(t)]^2. \tag{3}$$

3.Results of Simulation

In Fig.1, the time dependencies of both average density $A(t)$ and the variance $V(t)$ are plotted. It is found from Fig.1(a) that the uctuation enhancement takes place. Even though the average density $A(t)$ decreases, the variance $V(t)$ increases at intermediate stage of phase transiation. Note that such a phenomenon is not always observed for all experiments. Fig.1 (b) illustrates the time dependencies of both $A(t)$ and $V(t)$ for the case of $a_2 = 2.0$. As the value of a_2 increases, the enhancement of uctuation disappears.

- The uctuation enhancement ecologically means that there are variety of process to extinction of a species. It is not easy to predict the extinction process of species.

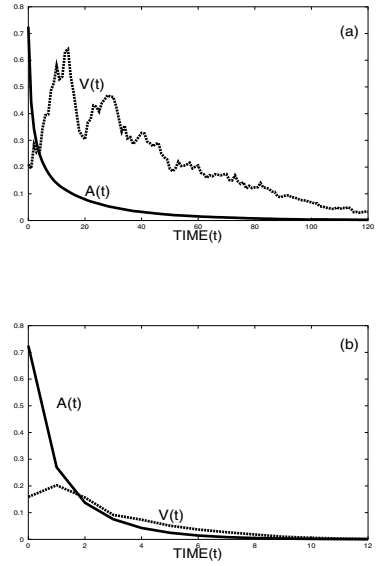

Fig. 1: Perturbation experiment for two-dimensional CP (100×100). The value of a is jumped from 0.5 to a_2 ;(a)=1.3 (b)=2.0 ($N = 100$). Both average $A(t)$ and variance $V(t)$ are depicted against time, where the value of $V(t)$ is multiplied by 7000