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Glassy dynamics: effective temperatures and intermittencies from a two-state model

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Abstract

We show the existence of intermittent dynamics in one of the simplest model of a glassy system: the two-state model, which has been used [Physica A 329 (2003) 357] to explain the origin of the violation of the fluctuation–dissipation theorem. The dynamics is analyzed through a Langevin equation for the evolution of the state of the system through its energy landscape. The results obtained concerning the violation factor and the non-Gaussian nature of the fluctuations are in good qualitative agreement with experiments measuring the effective temperature and the voltage fluctuations in gels and in polymer glasses. The method proposed can be useful to study the dynamics of other slow relaxation systems in which non-Gaussian fluctuations have been observed.

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1. Introduction

Complex systems are often distinguished by the existence of a very intricate free energy landscape consisting of many barriers which the system has to overcome to evolve. It is precisely the presence of these barriers responsible for the slow

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relaxation dynamics that manifests in the appearance of peculiar phenomena as aging, lack of a fluctuation–dissipation theorem and intermittencies caused by the presence of large fluctuations. These features, predicted and observed in systems of different nature as glasses, granular flows, foams, crumpled materials and in the dynamics of the disordered systems [2–7], have attracted the interest of many researchers during the last years with the purpose of describing the main features of slow relaxation dynamics [8].

In a previous paper [1], we have proposed a minimal relaxation model aimed at characterizing the dynamics of a system relaxing in two very different time scales, which are related to inter-well and intra-well relaxation processes. Two scenarios were analyzed for this purpose. In the first of them, the system may explore the whole reaction coordinate space undergoing a diffusion process described by a Fokker–Planck equation [9], which accounts for the intra-well and inter-well relaxations. In the other, obtained from the first one by eliminating the fast variable, the system undergoes an activated process. In spite of its simplicity the model shows some of the peculiar features of the dynamics of slow relaxation systems and proposes an explanation of why and how the fluctuation–dissipation is violated. It was found that the violation factor or effective temperature depends on the observable and on the initial populations in the wells. This result shows that the effective temperature does not univocally characterize the thermal state of a glassy system undergoing activated dynamics [10].

Our purpose, in this paper, is to use that model to explain the presence of intermittencies in the dynamics of a system in a glassy phase and the non-Gaussian nature of the probability distribution function, which have recently been observed in measurements of the dielectric properties of gels and polymer glasses [11,12], and in some theoretical studies of spin-glass models [13,14].

The paper is organized as follows. In Section 2, we analyze some of the main traits of glassy dynamics from a two-state model. Section 3 is devoted to present the results concerning the intermittent behavior and the non-Gaussian nature of the fluctuations. Some conclusions and perspectives are presented in the final section.

2. Glassy dynamics from a two-state model

In a two-state model, the minimal relaxation model for glassy systems [15–17], one assumes that the process consists of two main steps: a slow relaxation, in which the coordinate characterizing the state of the system jumps from a potential well to the next one, and a fast equilibration process in the well. It has been shown [1] that the dynamics of the system can be analyzed in terms of a Fokker–Planck equation describing a diffusion process through the free energy landscape $\Phi(\gamma)$ [18],

$$\frac{\partial \rho(\gamma,t)}{\partial t} = \frac{\partial}{\partial \gamma} D\left[\frac{\partial \rho(\gamma,t)}{\partial \gamma} + \frac{\rho(\gamma,t)}{k_B T}\frac{\partial \Phi(\gamma)}{\partial \gamma}\right]. \tag{1}$$

In the simplest case, $\Phi(\gamma)$ would be just a bistable potential. In the previous equation, $\rho(\gamma,t)$ is the probability distribution function that depends on the order parameter or