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Universal approach to overcoming nonstationarity, unsteadiness and non-Markovity of stochastic processes in complex systems

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Abstract

In the present paper, we suggest a new universal approach to study complex systems by microscopic, mesoscopic and macroscopic methods. We discuss new possibilities of extracting information on nonstationarity, unsteadiness and non-Markovity of discrete stochastic processes in complex systems. We consider statistical properties of the fast, intermediate and slow components of the investigated processes in complex systems within the framework of microscopic, mesoscopic and macroscopic approaches separately. Among them theoretical analysis is carried out by means of local noisy time-dependent parameters and the conception of a quasi-Brownian particle (QBP) (mesoscopic approach) as well as the use of wavelet transformation of the initial row time series. As a concrete example we examine the seismic time series data for strong and weak earthquakes in Turkey (1998, 1999) in detail, as well as technogenic explosions. We propose a new possible solution to the problem of forecasting strong earthquakes. Besides we have found out that an unexpected restoration of the first two local noisy parameters in weak earthquakes and technogenic explosions is determined by exponential law. In this paper we have also carried out the comparison and

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have discussed the received time dependence of the local parameters for various seismic phenomena.

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1. Introduction

Nonstationarity, unsteadiness and non-Markovity are the most common essential peculiarities of stochastic processes in nature. The existence of similar properties creates significant difficulties for the theoretical analysis of real complex systems [1]. At present, methods connected with localization of the registered or calculated parameters for the quantitative account of the dramatic changes caused by the fast alternation of the behavior modes and intermittency came into use. For example, the time behavior of the local (scale) Hurst exponents was found in the recent work of Stanley et al. to study multifractal cascades in heartbeat dynamics [1] and to analyze and forecast earthquakes and technogenic explosions in Ref. [2]. The application of the local characteristics allows to avoid difficulties connected with nonergodicity of the investigated system and gives a possibility to extract additional valuable information on the hidden properties of real complex systems. From the physical point of view this approach resembles the use of nonlinear equations of generalized hydrodynamics with the local time behavior of hydrodynamical and thermodynamical parameters and characteristics.

It is well known that one of the major problems of seismology is to predict the beginning of the main shock. Although science still seems to be far from the guaranteed decision of this problem there exist some interesting approaches based on the peculiar properties of precursory phenomena [3–9]. Another important problem is recognition and differentiation of weak earthquakes and technogenic underground explosion signals. One of the useful means of solving this problem is by defining their local characteristics [1,2].

In the present work we suggest a new universal description of real complex systems by means of the microscopic, mesoscopic and macroscopic methods. We start with a macroscopic approach based on the kinetic theory of discrete stochastic processes and the hierarchy of the chain of finite-difference kinetic equations for the discrete time correlation function (TCF) and memory functions [2,10,11].

The mesoscopic phenomena of the so-called "soft matter" physics, embracing a diverse range of system including liquid crystals, colloids, and biomembranes, generally involve some form of coupling of different characteristic time- and length-scales. Computational modelling of such multi-scale effects requires a new methodology applicable beyond the realm of traditional techniques such as ab initio and classical molecular dynamics (the methods of choice in the microscopic