Eur. Phys. J. Special Topics **222**, 2387–2389 (2013)

DOI: 10.1140/epjst/e2013-02022-y

THE EUROPEAN PHYSICAL JOURNAL
SPECIAL TOPICS

Editorial

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From the dynamics of the solar system to the functioning of the nerve cell of a snail, nonlinear phenomena are related to some of the most intriguing features of the world around us. In the form of self-sustained oscillations, synchronization, bifurcations, pattern formation, and chaos, nonlinear dynamic phenomena are manifest in physical, chemical, ecological and biological systems. Life itself is characterized by the large number of mutually interacting rhythmic processes it sustains. Nonlinear dynamic phenomena are also important for many types of engineering systems, and the same type of phenomena may be involved in the generation of complex forms of economic and managerial dynamics. It is also interesting to note that nonlinear systems can display non-trivial forms of response to random forces, i.e. forms of response that cannot be observed in purely deterministic systems. Investigation of the complex dynamic phenomena that can arise in all of these different circumstances help us to get a deeper understanding of the mechanisms underlying a broad range of important problems that, for lack of a proper theoretical framework, were inaccessible for many years and, hence, considered as irrelevant or poorly posed. At the same time the study of nonlinear dynamic phenomena has proved to challenge several classical concepts in physics and mathematics.

This *European Physical Journal Special Topics* issue is a collection of papers illustrating diverse aspects of nonlinear dynamics of deterministic and stochastic systems as well as its application in natural sciences. The issue is divided into 4 sections. We start with the "classical" field of nonlinear dynamics and synchronization represented by studies performed with simple generic models of nonlinear oscillators. Quasiperiodic oscillations are often studied in the framework of periodically driven nonlinear oscillators. However, Kuznetsov et al. describe a family of three dimensional autonomous oscillators and study distinct mechanisms of torus formation in these low-dimensional systems. Dynamics of phase-locked loops, classical models in electrical engineering, is a subject of study by Matrosov et al. The authors demonstrate that with an additional high-frequency filter these simple systems demonstrate a plethora of dynamical regimes, including those similar to dynamics of neurons. Several papers are devoted to ensembles of oscillators. Using the Hindmarsh-Rose neuronal model Ehrich et al. reveal a new scenario of synchrony breaking and demonstrate that even for identical neurons and simple coupling the dynamics can be more complicated than mere tendency to synchronize with an increase of coupling strength. Levanova et al. analyze the dynamics of an ensemble of inhibitorily coupled Van der Pol oscillators and demonstrate the existence of a stable heteroclinic contour or a stable heteroclinic channel between saddle cycles, the dynamics often observed in generators of biological rhythms. A rich variety of dynamical regimes in unidirectionally coupled Toda oscillators is described by Dvorak et al. Finally, Smirnov et al. propose a method for detection of coupling between oscillators from multivariate time series and provide analytical results for tests of statistical significance.

The second section is devoted to nonlinear dynamics of stochastic systems such as Brownian particles and motors as well as randomly perturbed oscillators. Martens et al. study transport of Brownian particles suspended in viscous fluid through two-dimensional periodic channel with broken spatial symmetry. They show that in

addition to entropic rectification of particles, hydrodynamic flow can reduce particles diffusivity resulting, e.g. in more efficient separation for particles of different sizes. Dynamics of active Brownian motors with internal oscillatory modes is studied by Romanovsky et al. Zaharova et al. present their results on coherence resonance and stochastic synchronization in Duffing – Van der Pol oscillator operating near a subcritical Hopf bifurcation. Belykh et al. consider the effect of random switching of oscillators parameters and discuss the appearance of the so-called ghost attractor in the averaged system which is absent in the phase space of the switching system. Pankratova and Belykh study synchronization of self-sustained oscillators coupled via common linear load which is subjected to external stochastic force. They show that noise applied to the common load may induce in-phase synchronization, the phenomenon which cannot be observed in the corresponding deterministic system. Sonnenschein et al. study the collective dynamics of complex networks of excitable stochastic elements and show how the network structure and noise in individual elements control dynamical regime of the network's global dynamics.

Various applications of nonlinear dynamics in chemistry, physics and engineering are presented in the third section. An example of condensed matter application is given by Chetverikov et al. who study fast charge transport via soliton-like excitations in two-dimensional atomic lattices. Shabunin and Provata use the kinetic Monte Carlo simulations to study nonlinear dynamics of chemical reactions on a two-dimensional lattice. Two papers are devoted to nonlinear dynamics of coupled high-frequency semiconductor and electronic generators. Matharu et al. show that semiconductor superlattices coupled with a common load can be used as generators of sub-THz and THz oscillations. Synchronization in networks of chaotic microwave oscillators is studied by Moskalenko et al. Nonlinear dynamical systems can be used as sensors of weak signals. Nikitin et al. study a bistable sensor for detection of weak dc signal and introduce a new effective method for the power spectrum estimation. Cosseddu et al. use molecular dynamics simulations to analyze statistical and dynamical properties of cations in the selectivity filter of a potassium ion channel.

The fourth section is devoted to applications of nonlinear dynamics in biology and medicine. Toronov et al. review mathematical models and non-invasive experimental methods related to dynamics of the brain activity. Computational modeling of chemotactic signaling and aggregation of microglia around the implantation site during deep brain stimulation is a subject of paper presented by Silchenko and Tass. Janson et al. report on experimental study of responses of breathing patterns in humans to delayed auditory and visual stimuli generated from breathing. Spontaneous oscillation in diameter an tone of blood vessels, called vasomotion, is studied by Postnov et al. using a functional modeling approach. Several contributions are devoted to neuronal dynamics. Dmitrichev et al. discuss anti-phase wave patterns in a ring of electrically coupled oscillatory neurons. Schwalger et al. provide an analytical study of statistics of neuronal discharges in a popular model in neurodynamics, the so-called leaky integrate and fire neuron, in the limit of weak leak current. Freund et al. study the dynamics of a Hodgkin-Huxley type model using a phase description. Assanov et al. use a computational model to predict responses of biological cellular oscillators to brief heat pulses generated by the light-actuated gold nanoparticles. Methods of nonlinear dynamics are widely used in modern time series analysis. Ponomarenko et al. study interactions between low-frequency oscillation of the heart rate and the blood pressure employing the synchronization theory for experimental time series. Pavlov et al. perform a wavelet-analysis of gastric microcirculation in rats with bleeding ulcer. The work by Nazimov et al. is devoted to a new approach of serial identification of EEG patterns with adaptive wavelet-based analysis.

This *European Physical Journal Special Topics* issue is dedicated to Prof. Dr. Vadim Anishchenko, who celebrates his 70th birthday this year. Vadim has made

significant contributions to many fields of deterministic and stochastic dynamics of nonlinear systems and initiated studies in several subjects presented in this volume. Besides his research accomplishments Vadim is an outstanding teacher. Professor Anishchenko has graduated many doctoral students who continued their carriers in academia. In fact, all guest editors of this *Special Topics* issue were lucky to be Vadim's doctoral students. We wish Vadim a good health and continuation of his excellent scientific research for years to come. We would like to thank all the authors of this issue for their contributions and many other scholars for rigorous and prompt peer reviews. We thank Sabine Lehr for her guidance in preparing this issue.

Warwick, Athens Ohio, Saratov, and Copenhagen in July 2013

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