Preface

Stochastic processes in physics and chemistry (in honor of Peter Hänggi)

The mathematical discipline of stochastic processes has always been inspired by problems from natural sciences, in particular from physics, chemistry, and biology. This special issue presents a collection of state of the art papers by leading scientists demonstrating the vitality and breadth of this field. In these papers a broad variety of topics, from both quantum and classical physics with applications to statistical mechanics of equilibrium and non-equilibrium systems, properties of materials, and biological problems is covered.

Whenever the interaction with an environment influences the dynamics of a system on the time scale on which an experiment takes place or on which the state of a system is monitored, elements of randomness will affect the dynamics of the system giving rise to a stochastic time evolution [1]. For an environment in thermal equilibrium, the randomness goes hand in hand with dissipation of energy. This mechanism of environmentally induced dissipation and fluctuation applies to both classical and quantum systems. The effects of noise are surprisingly multifaceted and by no means restricted to blurring the unperturbed evolution of the ideal closed system. Activation processes destabilize locally stable states and lead to rare events such as transitions between these states. They are well known in the context of chemical reaction rate theory and phase transitions and can be found in almost all areas of natural sciences [2,3]. Stochastic resonance, for example, taught us the lesson that noise may improve rather than deteriorate the detection of a weak signal. This effect has found an enormous range of applications [4,5]. Various startling phenomena caused by the presence of noise can be observed for particle transport in systems with periodic potentials such as rectification of noise in Brownian motors [6,7] and negative mobility [8]. The influence of confined geometries and the resulting entropic effects on the transport properties of Brownian particles represent another emerging field of research where noise plays a relevant role [9]. In the theory of special relativity, the lack of an absolute time gives rise to various delicate problems in the formulation of relativistic stochastic processes [10].

In quantum systems the coupling to an environment not only produces noise and dissipation but also leads to decoherence, i.e. to a suppression of specific quantum mechanical phase relations and to the emergence of classical behavior [2,11]. In the presence of several environments at different temperatures or chemical potentials, charge, particles, and heat can be transported through the system. In addition, time-dependent fields can be employed to control these transport processes [12].

This special issue is dedicated to Professor Peter Hänggi on occasion of his 60th birthday. Peter has always been an extraordinary scientist with an exceptionally broad expertise and a good taste for timely and interesting problems. He has strongly influenced the development of non-equilibrium statistical physics during the past thirty years and has guided a large number of graduate students and postdoctoral associates to become successful scientists in academia and industry. The topics covered in this special issue reflect a part of his wide spectrum of scientific interests and accomplishments.

In a series of his early papers [13] a microscopic foundation of stochastic phenomenological time-evolution laws in terms of generalized Langevin and generalized Fokker–Planck equations was investigated. These studies established a solid base on which he together with Irwin Oppenheim and collaborators formulated a stochastic description for the gross variables of a mesoscopic equilibrium system once the relaxation of mean values and the equilibrium distribution of the gross variables are known.

The escape from a metastable state by means of classical noise-activated processes, by means of quantum tunneling, and also by the combination of tunneling and thermal activation are topics that have been thoroughly investigated in various of Peter's publications. Another central aspect of Peter's research has been the investigation of systems that are driven out of thermal equilibrium. Examples include stochastic systems driven by colored noise or periodic forcing. His investigations of periodically driven classical and quantum processes by means of Floquet theory have played a seminal role for the understanding of stochastic resonance, and of other periodically driven systems such as rocking ratchets. These also led to the discovery of the remarkable effect of coherent destruction of tunneling. The study of open quantum systems and its peculiarities compared to classical systems has always attracted Peter's scrutiny, sparking off pioneering research on the thermodynamics of small quantum systems strongly coupled to their environment as well as on quantum fluctuation theorems.

As guest editors we express our thanks to the authors of this special issue as well as to the Editor Prof. Hofacker for his guidance, and last but not least to Peter Hänggi. We hope that he will enjoy his special issue.

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[13] A complete list of Peter Hänggi's publication can be found on <http://www.physik.uni-augsburg.de/theo1/hanggi>.

Igor Goychuk
Institut für Physik, Universität Augsburg,
Universitätsstrasse 1, 86135 Augsburg,
Germany
E-mail address: igor.goychuk@physik.uni-augsburg.de

Peter Jung
Department of Physics and Astronomy,
Ohio University, Athens,
USA
E-mail address: jungp@ohio.edu

Sigmund Kohler
Instituto de Ciencia de Materiales de Madrid (CSIC),
C/Sor Juana Inés de la Cruz 3,
Cantoblanco, 28049 Madrid,
Spain
E-mail address: sigmund.kohler@icmm.csic.es

Gerhard Schmid
Institut für Physik, Universität Augsburg,
Universitätsstrasse 1, 86135 Augsburg,
Germany
E-mail address: gerhard.schmid@physik.uni-augsburg.de

Peter Talkner
Institut für Physik, Universität Augsburg,
Universitätsstrasse 1, 86135 Augsburg,
Germany
E-mail address: peter.talkner@physik.uni-augsburg.de