Noise in Spatially Extended Systems

Jordi García-Ojalvo and José M. Sancho
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Noise is not a new concept in science and engineering. Much research has been devoted to understanding its origins, discovering ways to present it mathematically, and finding techniques for its reduction. Over the past two decades, however, a notable change in emphasis has occurred in this area. Researchers in several disciplines have begun to study what has been coined "the active role of noise" in dynamic systems and devices. This term denotes phenomena that are due solely to random fluctuations and would not occur in their absence. Thermally activated processes are one common example of such phenomena, but there are more unusual phenomena of this kind. These include noise-induced rectified motion, stochastic resonance, and noise-induced interface dynamics. Many examples can be found in the life sciences, which increasingly include mathematical and computational tools in their studies of such systems as biochemical processes in the cell, molecular motors, signaling in cellular assemblies, and neuronal networks. All of these can be characterized as spatially distributed systems in which noise is important.

Noise in Spatially Extended Systems, by Jordi García-Ojalvo and José M. Sancho, targets researchers and graduate students interested exactly in these phenomena, or more precisely, those who want to learn the mathematical tools used to analyze models describing these phenomena. The book is accessible to readers with a solid background in stochastic processes and basic knowledge in statistical physics and critical phenomena. But the reader still requires some assistance. The introductory sections on Langevin equations, Fokker–Planck equations and noise-induced transitions in systems with parametric noise, statistical physics of phase transitions, scaling laws, critical phenomena, and nonequilibrium critical phenomena are not self-contained; some supplementary knowledge is presumed. The same applies to the description of the basic analytical techniques, such as mean-field theory and perturbation theory for small stochastic forces. The treatment of dynamic renormalization group technique is also somewhat sketchy. If this book were supplemented by additional texts on stochastic processes and critical phenomena, however, it would be useful for beginning graduate students attempting to become acquainted with mathematical modeling of noise-induced phenomena.

García-Ojalvo and Sancho's book combines some materials that have not been published in book form before. For example, noise-induced nonequilibrium phase transitions and phase separation due to parametric fluctuations are quite novel topics, which cannot be found in traditional books on critical phenomena and phase transitions. Similarly, the authors introduce the computational tools that are commonly used to study stochastic differential equations and partial differential equations. Numerical techniques to generate spatiotemporal noise of any given characteristics, and methods of subsequent solution of the stochastic differential equations, previously scattered through a large body of literature, are now easily accessible in compact form.

The book is written by specialists who have made significant contributions to their fields of study. The selection of material, including noise-induced phase transitions, dynamics of nonequilibrium phase transitions, pattern formation in the presence of multiplicative noise, and noise effects on the motion of interfaces (fronts) reflects the authors' research. Overall, the book masterfully describes the technical aspects and the numerical and computational analysis of models. But it falls short in motivating the numerous models and comparing the results of their analyses to actual observations. Although some experiments are mentioned in the first chapter (chemical kinetics, turbulent jets, noise-sustained convective structures in nematic liquid crystals and Taylor–Couette flows, and spatial stochastic resonance), they appear disconnected from the rest of the book.

In conclusion, this book is a valuable contribution, focused on mathematical and computational techniques to solve stochastic partial differential equations. It is certainly timely, since models of this type are abundant in the life sciences. Links between numerical results and experimental observations would have been desirable, but this field is still young, and we will probably see more books on the subject in the years to come.

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