Introduction to Part II: Beyond fluctuation relations

Part II of the book embeds the topics of Part I into the wider remit of statistical mechanics and nonequilibrium dynamics. It discusses in particular anomalous transport processes, large fluctuations and dissipation on small scales, and the role of entropy and currents. The final five chapters thus establish cross-links to other fundamental theoretical concepts of small systems science by including further experimental applications to selected problems in the bio- and nanosciences.

The initial chapter by Gradenigo, Puglisi, Sarracino, Villamaina, and Vulpiani takes up the main thread of the previous part by embedding fluctuation relations into the more general context of fluctuations in statistical physics. By focusing on fluctuation-dissipation relations the authors present an overview about how to relate entropy production and generalised response functions to fluctuation properties of systems far from equilibrium. These concepts are illustrated by applications to anomalous dynamics and to granular media.

The following contribution by Zhang, Liu, and Li widens the scope towards the study of anomalous energy fluctuations on the nanoscale. The authors summarise recent studies about heat transport in nanomaterials, such as nanotubes and nanowires, from both the theoretical and the experimental perspective. Heat transport in these structures is crucially determined by anomalous fluctuations resulting in superdiffusive behaviour.

The third chapter by Touchette and Harris focuses again on fundamental aspects of statistical mechanics. The authors review how large deviation theory, a prominent topic within mathematical physics with applications to the study of extreme events, can be exploited for the investigation of fundamental problems in nonequilibrium statistical physics, such as the notion of macroscopic hydrodynamic limits or generalised nonequilibrium statistical ensembles. These concepts are illustrated by applications to nonequilibrium processes such as, for example, the analysis of current fluctuations in interacting particle systems.

The contribution by Yang and Radons adds a new facet to the previous discussion by reviewing a very recent direction of research in dynamical systems theory applied to nonequilibrium statistical mechanics. The authors use Lyapunov stability analysis in order to study the implications of microscopic chaos in liquids and glasses for macroscopic statistical behavior. They derive relevant structure functions assessing these dynamical features, which provide a more profound understanding of the emergence of hydrodynamic modes in complex and disordered dynamical systems.

The book concludes with a review by Mackowiak and Bräuchle about the state of the art of experimental investigations using single molecule microscopy. By experimentally investigating the diffusion of individual molecules in meso- and naonstructures they explore a particularly interesting case of fluctuations in small systems physics. Their contribution demonstrates how to link experimental research to topics of theoretical relevance by suggesting a wide range of applications in biology, medicine, and bio-nano-technology.