

# Preface

This is a textbook about the relation between nonlinear dynamics, classical statistical physics and stochastic theory of systems out of thermodynamic equilibrium. The central concepts are instability, entropy, nonequilibrium and Brownian motion. Instability stands here as a central point of modern dynamics, it means the local (or global) divergence of trajectories, which are near one to another at the initial time. It will be shown that this property, which seems to be a characteristic feature of all many-particle (macroscopic) systems, is responsible for a statistical (stochastic) behaviour connected with the existence of probabilities and effects like ergodicity and mixing of microscopic trajectories. On the other hand entropy is the central statistical concept: entropy is a measure of uncertainty of the microscopic state. The idea that the instability of the microscopic trajectories generates uncertainty of the state, what means entropy and macroscopic properties, is the central point of this course. We believe, that this is the natural way to look at statistical physics now. In this respect we feel encouraged by other modern courses in statistical physics, say e.g. the books of R. Balescu (1975, 1997), L. Reichl (1980, 1992), P. Gaspard (1998), L. R. Dorfman (1999) etc. In explaining the main ideas of statistical physics, we prefer the inductive and sometimes the historical view. Telling about the history of the relations between thermodynamics, statistical physics and nonlinear science, we must apologize for some bias to historical events connected with Berlin, a town closely connected with the roots of thermodynamics and statistical physics, and with our own professional activities. However we do not claim for accuracy of the historical details; the historical research in this important field is still at the beginning. We are interested more in the origin and in the flow of ideas which became essential for the development of our science. In connection with the important anniversaries of fundamental papers on Brownian motion in the upcoming years 1905-1906, we give some more details on the development of this field, which is near to our own interests.

This work is based on lecture notes on general courses on “Thermodynamics” and “Statistical Physics” and special topics courses on “Stochastic Theory”, “Brownian Motion”, “Nonlinear Dynamics”, “Self-Organization”, “Entropy and

Information”, “Physics of Evolutionary processes”, “Physics of Macromolecules”, “Kinetics” and related subjects given by the authors in close cooperation with Lutz Schimansky–Geier at the Humboldt University Berlin between 1980 and 2004, as well as at the University of Freiburg between 1995 and 2000. This way, basically this book it is to be considered as a textbook. However, the book contains also some original results of the research work of the authors (especially in Chapters 6–12). We thank the former and the present members of the Berlin group: Andreas Engel, Harald Engel, Udo Erdmann, Rainer Feistel, Ulrike Feudel, Jan Freund, Horst Malchow, Alexander Neiman, Thorsten Pöschel, Andrea Scharnhorst, Frank Schweitzer and others, who had a great impact on the ideas and results developed in this book. A great impact had also the discussions with friends and frequent visitors as Vadim Anishchenko, Michael Conrad, Hermann Haken, Peter Hänggi, Yuri Klimontovich, Frank Moss, Gregoire Nicolis, Ilya Prigogine, Yuri Romanovsky, Manuel Velarde, Michael Volkenstein, as well as Alex Blumen, Aleksei Chechkin, Katja Lindenberg, Ralf Metzler, Ramon Reigada, Francesc Sagues, Jose Maria Sancho, Len Sander, Manuel G. Velarde and others. Further we reflected the results of several conferences and workshops hold in or near Berlin, as e.g. “Selforganization by Nonlinear Irreversible Processes” (1979, 1984, 1986), “Stochastic Processes” (1990), “Models of Self-Organization in Complex Systems” (1991), “Statistical Physics and Thermodynamics of Nonlinear Systems” (1992), “Stochastic Processes and Granular Media” (1995), “Complexity and Self-Organization” (1995). Essentially, this is a textbook for physics students of the higher semesters and for graduate students in physics and related sciences which try to pave their way through the dschungel of modern research. The orientation is more on understanding than on details. In other words our aim is in the first line to contribute to the education of students and young scientists, to show them what holds physics and natural sciences together and not so much to fill their brains with thousands of equations.

The manuscript of this book was written in Berlin under conditions reminding of a “*far from equilibrium phase transition*”. The great political and social transitions which were taking place at the end of the 20th century especially in the eastern part of Europe were shaking also the scientific and university structures. In this way the present book about far from equilibrium (chaotic) states may profit from an intimate personal experience about instability and mixing processes in chaotic transitory states and the take-over by new order parameters. As we have learned by experience the most effective stabilizing factors which guarantee survival in turbulent human systems are good friends, enthusiastic students and last but not least the solidarity in the scientific community. We are very grateful that the solidarity between scientists, which was so self-understood for Helmholtz, Planck and Einstein is not completely forgotten in the hectic and competitive science business of our days.

This book is dedicated to our friends, coworkers and students, who helped to transform the chaos of ideas into the order of a book. In particular we have to thank our colleague Lutz Schimansky–Geier, who was involved in the early stage of this book, before he was forced to concentrate on important research projects. We are indebted to Yossi Klafter who carefully read the whole manuscript and made important suggestions which lead to a considerable improvement of the book.

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