Microscopic Chaos and Transport in Many-Particle Systems: Introductory comments

October 9, 2003

This special issue of Physica D is based on papers from the International Workshop and Seminar on **Microscopic Chaos and Transport in many Particle Systems** held at the Max-Planck-Institut für Physik komplexer Systeme, Dresden, Germany, August 5-25, 2002. The workshop and seminar were attended by about 80 scientists, from graduate students through senior scientists, working in the fields of classical and quantum transport theory, non-linear dynamics, quantum chaos, molecular dynamics, and experimental studies of trapped atoms.

The papers in this issue are grouped in three categories, reflecting general themes of the talks. They are (A) *Anomalous Transport: Stochastic and Deterministic Dynamics*; (B) *Chaos and Transport: Billiards, Low-dimensional Maps and Related Models*; and (C) *Dissipative Dynamical Systems: Thermostats, Lyapunov Instability, Entropy Production*. Collectively, these papers reflect the "state of the art" as of 2002. Each section starts with at least one paper that in part reviews a key aspect of the work in that area. In Section 1, it is the paper by Radons, and in Section 2 the papers by Balint and Toth, and Vollmer, Tel and Breymann. In Section 3 it is the papers by Hoover et al. and by Ebeling and Röpke. Each of these papers will be of pedagogical value to non-specialists as well as to those with a primary interest in the research they present. As one can see from a perusal of the papers included, the topics range from rigorous mathematical analyses over computer simulation physics to recent experimental work. This broad range of topics and approaches, the long history and substantial accomplishments of previous workers in classical and quantum transport theory, and non-linear dynamics, and the challenging problems still to be solved, account, in large part, for the appeal of the area to the many young scientists attracted to it.

Many interesting questions are addressed in these papers, including such lively ones as:

- What is the role of chaotic dynamics for generating hydrodynamic behavior in a classical mechanical system? What kind of randomness is essential for normal transport to take place in a given system? Clearly chaos is not essential since non-chaotic models exist that have well behaved transport properties, but differ from chaotic systems in other ways. What is essential? How do quantum systems differ from their classical counterparts?

- How do stochastic and deterministic systems differ in their transport properties? In what ways does deterministic, chaotic dynamics mimic, replace, or render unnecessary, externally imposed randomness in a system? What kind of systems exhibit anomalous transport, with sub-diffusive or super-diffusive behavior, for example?

- In what way is a Gaussian thermostat a representative of a laboratory thermostat? Are the results obtained from studies of systems with Gaussian thermostats applicable to more general thermostated systems? A good example of results with wide applicability, discussed in this issue, is the class of results called *fluctuation theorems*, which have been proven for a wide variety of physical systems, but which had their origins in a study of viscous flow in a system with a Gaussian thermostat.

- Is the correct spelling 'thermostated' or 'thermostatted'?

- Can fractal structures that form in the phase spaces of chaotic systems for our understanding of hydrodynamic phenomena, such as irreversible entropy production? Such structures include fractal SRB measures, fractal microscopic hydrodynamic modes, and related quantities. Are there structures, fractal or not, that play a similar role for non-chaotic systems? Further, are transport coefficients which are fractal functions of a control parameter in low-dimensional, chaotic systems typical, in some sense, of more general chaotic systems, and, in any case, is there some physical importance one can attach to fractal properties of such transport coefficients.

- How can one understand and explain the hydrodynamic-like structures that appear in the tangent space of hard sphere systems associated with the lowest non-zero Lyapunov exponents? How can one understand and calculate the full Lyapunov spectrum of a many-particle system?

- What are the experimental consequences of non-linear dynamics and chaotic behavior in the motion of atomic particles? Can experimental observations distinguish between chaotic and non-chaotic behaviors? How can we observe and measure, in nonequilibrium systems, the large fluctuations of dynamical origin and test their symmetry properties? What are the types and the sizes of the systems where such effects become observable and which experimental techniques allow the study of the dynamics of particles at the microscopic level?

The conference logo that can be found on the cover page of this special issue, a fractal Takagi function, was chosen to illustrate chaotic transport in a very simple model, a deterministic version of the familiar random walk on a line.

In addition to the talks devoted to recent progress in research in this general area, there were also tutorial seminars designed to introduce broad research areas to students and recent Ph.D.'s. The topics and speakers for these tutorial sessions included: A. Ozorio de Almeida, *Quantum Mechanics in Phase Space*; P. Cvitanović, *Chaos and What To Do About It*; C. Maes, *Time-reversal and Entropy for Non-equilibrium Fluctuations*; D.J. Evans, *Experiments, Simulation, and Theory on Microscopic Chaos and Macroscopic Transport*, and P. Gaspard, *From Hydrodynamic Modes to Entropy production*. Much of the detailed information on the program can be found at the conference web-site: http://www.mpipks-dresden.mpg.de/∼chaotran.

No description of the workshop and seminar program would be complete without mentioning the Dresden Flood that took place at the same time. The flood caused a great deal of damage to the center of Dresden, close to the Elbe River, while more distant locations were also affected, through loss of electricity, transportation problems, and so on. Through the creativity and vigor of the attendees, and with the help of the institute staff, the conference continued in spite of the flood, and attendees tried to be of help to the Dresden community whenever possible. Certainly the high level of the conference, figuratively not literally, is due to the considerable help and support we received from our hosts at the Max-Planck Institut für Physik komplexer Systeme. On behalf of the attendees, we express our appreciation to the institute, on behalf of the attendees, and, personal thanks to Dr. Sergej Flach and Ms. Mandy Stiegler for their daily help as we planned, organized, and conferred.

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