SWEDISH—UKRAINIAN on-line SEMINAR
in THEORETICAL PHYSICS

February 6, 2024

Program*

10.00–10.05 – Opening

10.05–10.45 – Bernhard Mehlig (University of Goteborg, Sweden) **“Turbulent aerosols”**

10.45–11.25 – Yuriy Holovatch (Institute of Condensed Matter Physics, NAS of Ukraine, Lviv, Ukraine) “**The fate of Ernst Ising and the fate of his model: a hundred years on”**

11.25–11.40 – Coffee break

11.40–12.20 – Peter Samuelsson (Lund University, Sweden) “**Stochastic thermodynamics of a quantum dot coupled to a finite-size reservoir”**

12.20–13.00 – Bohdan Lev (BITP, NAS of Ukraine, Kyiv, Ukraine) “**Fluctuations in open systems and power law distribution function”**

***EE Time, CE Time is one hour earlier**

Turbulent aerosols

Bernhard Mehlig

University of Goteborg, Sweden

Turbulent aerosols are suspensions of droplets or solid particles in a turbulent gas, such as water droplets in the turbulent air of a cumulus cloud. The analysis of such highly non-linear and multi-scale problems poses formidable challenges. Laboratory experiments resolving the particle dynamics have only recently become possible, and direct numerical simulations of such systems are still immensely difficult.

In this talk I describe recent progress in understanding the dynamics of turbulent aerosols. We formulated and analysed statistical models that capture the relevant physics, that account for the statistical properties of the turbulent flow, and that allow systematic mathematical analysis using dynamical-systems theory. I summarise how this helps to understand fundamental mechanisms determining particle dynamics in incompressible turbulence: small-scale fractal clustering, caustic singularities, and anomalously large relative particle velocities. I highlight successes and failures of this approach, as well as the most important open questions.

Reference: Bec, Gustavsson & Mehlig, Ann. Rev. Fluid Mech. (2024)
https://www.annualreviews.org/doi/10.1146/annurev-fluid-032822-014140
https://arxiv.org/abs/2304.01312

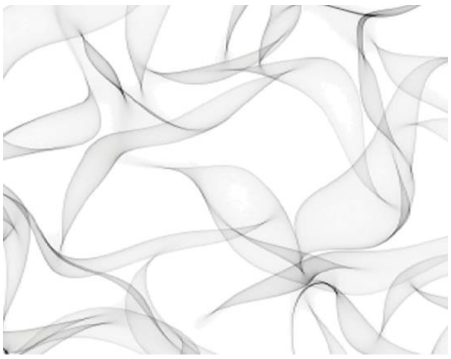

Illustration: Model calculation. Spatial distribution of heavy particles in a two-dimensional incompressible flow. The image looks like light patterns seen at the bottom of a swimming pool on a sunny day.

The fate of Ernst Ising and the fate of his model: a hundred years on

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The talk is based on an ongoing project that aims to prepare a bilingual, commented edition of the doctoral thesis of Ernst Ising [1]. This project emerged through collaborations enabled by the Ising lectures [2], a workshop that started in Lviv (Ukraine) in 1997 with ’traditional’ statistical physics and has recently broadened its scope to encompass a more general context of complex systems. Gradually the workshop gave rise to various research projects centered around the Ising model and its history [3-5], and some collected historical documents and memoirs are displayed publicly with permission of Ernst Ising’s family at http://www.icmp.lviv.ua/ising .

Another goal of the talk is to present a personal story of Ernst Ising who had to struggle to survive during the years of the Nazi regime. The story of his fate stirs special feelings today, when its background is repeated by an (academic) community supporting a dictator, and supporting aggression - in this case Russian aggression in Ukraine.

[1]. B. Berche, R. Folk, Yu. Holovatch, R. Kenna, in preparation
[2]. ISING LECTURES IN LVIV (1997 - 2017). Ed. by M. Krasnytska, R. de Regt, P. Sarkanych. Lviv, ICMP, 2017, 218 p.
[2]. T. Ising, R. Folk, R. Kenna, B. Berche, Yu. Holovatch. The fate of Ernst Ising and the fate of his model. *Journ. Phys. Stud.* **21** (2017) 4001
[4]. R. Folk, Yu.. Holovatch. Schottky's forgotten step to the Ising model. *Eur. J. Phys. H* **47** (2022) 9
[5]. R. Folk. The survival of Ernst Ising and the struggle to solve his model. In *Order, Disorder and Criticality. Advanced Problems of Phase Transition Theory.* Yu. Holovatch (editor). vol. 7, World Scientific, Singapore, 2023, pp. 1-77.

Stochastic thermodynamics of a quantum dot coupled to a finite-size reservoir

Peter Samuelsson

Lund University, Sweden

In nano-scale systems coupled to finite-size reservoirs, the reservoir temperature may fluctuate due to heat exchange between the system and the reservoirs. To date, a stochastic thermodynamic analysis of heat, work and entropy production in such systems is however missing. Here we fill this gap by analyzing a single-level quantum dot tunnel coupled to a finite-size electronic reservoir. The system dynamics is described by a Markovian master equation, depending on the fluctuating temperature of the reservoir. Based on a fluctuation theorem, we identify the appropriate entropy production that results in a thermodynamically consistent statistical description. We illustrate our results by analyzing the work production for a finite-size reservoir Szilard engine.

Ref. Saulo V. Moreira, Peter Samuelsson, Patrick P. Potts, Phys. Rev. Lett. 131, 220405 (2023).

Fluctuations in open systems and power law distribution function

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According to the basic principles of thermodynamics, a macroscopic system in contact with the environment, reaches a state of equilibrium during the relaxation time. Establishing equilibrium in an isolated system leads both to the establishment of the thermodynamic parameters, equivalent to the parameters of the thermostat, and to the absence of flows in the system under consideration. In the case of non-equilibrium open systems flows are present, but steady states may exist. Such states can be interpreted as "quasi-equilibrium" in the sense that they do not change with time, but the thermodynamic parameters of the system and the environment will be different. The distribution function of such systems usually are different from the known equilibrium distributions.

An example of such a stationary distribution can be, in particular, a distribution with "heavy tails" for the large value of variable (power law distribution), which is extremely important from both a theoretical and a practical point of view. Many power law distributions was have been found in physics, biology, and social sciences. The Fokker-Planck equation is formulated for the distribution functions of macroscopic open systems in the space of slowly changing physical variables (energy, adiabatic invariants, etc.). The stationary solution of such equations determines a quasi-equilibrium distribution function in the corresponding space. The proposed approach takes into account the evolution of systems under the action of dissipation and diffusion in the space of the control variables. It is shown that the well-known power law distribution can be obtained by taking into account internal and external fluctuations in systems where slowly parameter are present.