

Final Report

Fluctuations and Noise in Out of Equilibrium Physical Systems FNOEPS 2007

a ESF-STOCHDYN Conference

September 3-7, 2007, Beaulieu sur Mer, France

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Summary

After the success of the first FNOEPS meeting, that was held in Beaulieu sur Mer in 2005, this second workshop FNOEPS 2007 has been organized with the aim of mainly focusing on the following objectives: 1) making the point on the recent advancements in the field of stochastic dynamics, 2) attract young scientists to the field and open the subjects to the interaction with other disciplines, 3) create novel collaborations between scientists. The multidisciplinary character of the workshop, that was peculiar to the first meeting, has been preserved and enhanced, with invited speakers from many different fields, such as statistical mechanics, turbulence, microfluidics, granular matter, optics, hydrodynamics, chemistry, geophysics, where all these topics have been addresses in the context of stochastic phenomena and complex systems.

The meeting was held at La Berlugane, a center located in Beaulieu sur Mer, equipped with a conference room and housing facilities. The meeting has been attended by 36 scientists from 8 European countries (Germany, France, UK, Belgium, Italy, Switzerland, Greece, Spain) and 4 scientists from USA. All participants have been hosted at la Berlugane (single room accommodation) and have enjoyed the charm of the location, as well as the facilities for common meals and activities, stimulating exchanges and discussions even outside the dedicated time scheduled for the conference presentations.

The format of the conference has been of three full-days and one half-day, from Tuesday 4th to Friday 7th, with invited (45 or 35 minutes) and contributed talks (20 minutes). Monday 3rd has been free for arrivals and a reception has been organization in the evening to welcome all the participants. The workshop has been closed on Friday 7th after lunch.

All participants were pleased with the scientific program, which provided overviews of ongoing research topics and updates on topics of interest related to stochasticity and nonlinearity. The program was also organized by taking care of leaving enough free time for spontaneous discussions to take place between the participants. The scheduled presentations were talks on statistical physics, Gallavotti-Cohen theorem, Brownian motors, wave turbulence, optics, granular media, chaotic dynamo, chemical media, microfluidics, biophysical research, nonequilibrium phase transitions, excitable systems, quantum fluctuations and collective phenomena. All participants appeared to highly appreciate the workshop and several of them expressed the wish that it will be held again in the future.

Scientific content

The invited and contributed talks were presented during three and half days of work and touched upon several aspects of the field, from the foundation of statistical mechanics in out of equilibrium systems to the applications on biophysics, granular systems, microfluidics, dynamo effect and turbulence.

We briefly mention the different contributions discussed during the meeting:

- 1) **STATISTICAL PHYSICS:** Stochastic thermodynamics of non equilibrium systems have been reviewed and general approach have been proposed for extended fluctuation-dissipation theorems and generalized Einstein relations with applications for colloidal systems (Seifert) and driven granular gases (Vulpiani, Petri, Aumaitre); quasi-stationary states have been presented and discussed for Hamiltonian systems and their relevance for plasmas and self-gravitating systems has been outlined (Ruffo); dissipation and time arrow has been discussed and on the basis of the Jarzynski equality and general inequalities have been illustrated for the case where the full information of phase densities is not available (Kawai); fluctuation theorem for black-body radiation has been proven to be verified provided photon bunching is taken into account (Cleuren); fluctuations in quantum systems have been discussed and an extension of the Gallavotti-Cohen theorem has been proposed which will be valid for quantum thermostats (Gallavotti); derivation of various transient and steady state fluctuation relations have been illustrated for deterministic reversible systems, and the physical mechanisms underlying the validity of these relations have been discussed (Rondoni).
- 2) **WAVE TURBULENCE AND COMPLEX FLOWS:** Wave turbulence theory has been reviewed and illustrated on the basis of the closed kinetic equation that leads to statistically stationary solutions corresponding to equipartition and finite flux Komogorov-Zakharov states, then the breakdown of the theory has been discussed in relation with condensates and collapse in optical media and Phillip's spectrum in water waves (Newell); finite size effects on the wave turbulence theory have been presented and discussed (Nazarenko); experimental techniques have been presented for characterizing the Lagrangian trajectories of an intensely turbulent water flow (Bodenschatz); the dynamics of a visco-elastic fluid subjected to an oscillatory pressure gradient have been presented, showing complex oscillatory behaviors and instabilities that have been characterized experimentally through particle-image-velocimetry (Ortin); experimental realization of the dynamo effect by a turbulent von Karman flow in liquid sodium has been presented and discussed (Fauve).
- 3) **BROWNIAN MOTORS AND MICROFLUIDICS:** Brownian motors have been illustrated in the general case, when the nonequilibrium is produced by heat flow from a hot to a cold reservoir and then generalized to the case of a Brownian refrigerator (Van den Broeck); experiments in microfluidics have been presented, showing small-scale phenomena where thermal fluctuations become important and can be rectified, such as self-propelled droplets placed in contact with hot surfaces with asymmetric (ratchet-like) grooves structured into the surface (Linke); a theory accounting the spreading of viscous drops assisted by thermal fluctuations has been illustrated (Moro).

- 4) **BIOPHYSICS:** it has been shown that Brownian motion can be exploited to analyze the mechanics of individual molecules or to image the three-dimensional architecture of polymer networks by a technique called “thermal noise imaging” (Florin); the single photon response of invertebrate photoreceptors has been presented and analyzed on the basis of a quantitative model describing the stochastic dynamics of the signaling cascade (Pumir).
- 5) **NOISE-INDUCED PHENOMENA AND COLLECTIVE BEHAVIORS:** the similar effects of noise and diversity have been discussed and a general scenario has been proposed for the emergence of collective behaviors (Toral); collective phenomena have been presented for excitable units and explained on the basis of Non Markovian models (Schimansky-Geier); experiments of dynamical patterns in photosensitive chemical media have been presented and discussed in relation with noise-assisted propagating waves (Sagues); models of self-propelled particles describing the collective behaviors of many living systems, such as for example bird flocks or swarms of insect, have been presented and generalized to the case when particles move in open space (Gallos).
- 6) **OPTICS:** large amplitude fluctuations leading to the formation of spatiotemporal pulses have been presented for an optical cavity employing a liquid crystal gain medium (Residori).
- 7) **NONEQUILIBRIUM PHASE TRANSITIONS:** a Langevin description of a class of out of equilibrium phase transitions has been presented and numerical scheme for the integration of stochastic equations with multiplicative noise have been illustrated (Munoz); numerical methods for an efficient sampling of stochastic equations with multiplicative noise have been presented and employed for a detailed description of absorbing phase transitions (Chaté).
- 8) **TIME SERIES:** distributed hydrological models have been illustrated and discussed in relation with numerical experiments for extreme flood event forecasting (Baroncini); the return time statistics of the extreme values in time series presenting intermediate-term correlations has been presented and shown to display a stretched-exponential behavior (Pennetta).

Perspectives

From the lectures presented at the meeting it appears that fluctuations and noise are playing a major role in out of equilibrium systems, and this especially when small scales are concerned. Understanding the role of fluctuations and noise in these systems and modeling the stochastic contribution with respect to the deterministic part of the problem, are the challenges to be addressed in future works. Several advancements have been already made with the establishment of extended fluctuation-dissipation theorems and generalized Einstein relations, however the debate is still open on the foundations and the limit of validity of these relations and the experimental verifications are still not conclusive. From the front of Brownian motors, there has been a great advancement in the theoretical understanding, which has been accompanied by several experimental demonstrations. The possibility of exploiting Brownian motion for applications, for example in biophysical research, is very attractive and opens a

new field of investigation. The role of noise has also been underlined as essential for the emergence of collective behaviors, which implies potential applications of noise that still are to be investigated in many different systems, and not only physical. From the presentations, it results also that fluctuations and noise often lead to extreme events, these events appearing for example in turbulence, in optics, in dynamo effect, which claims for a general theoretical framework of description. Finally, the development of appropriate numerical methods for the treatment of stochastic problems is still an active and open area of investigation, which is essential in accompanying the advancements of theoretical understandings.

Final Program

	Tuesday 4 th	Wednesday 5 th	Thursday 6 th	Friday 7 th
9h30-10h20	U. Seifert <i>Stochastic Thermodynamics: Theory and experiments</i>	G. Gallavotti <i>Fluctuations in quantum systems</i>	C. Van den Broeck <i>Brownian Motors</i>	F. Sagues <i>Noise-Based Selection Mech. of Turing vs. Hopf Bif. in a Photosensitive Chemical Medium</i>
10h20-10h55	S. Ruffo <i>Quasi-stationary states in mean-field dynamics</i>	L. Rondoni <i>Transient and Steady State Relations for Deterministically Thermostated Systems</i>	E.L. Florin <i>Exploiting Brownian motion and thermal fluctuations for biophysical research</i>	S. Residori <i>Spatiotemporal pulses in a liquid crystal optical oscillator</i>

COFFEE BREAK

11h25-12h00	E. Bodenschatz <i>Lagrangian Turbulence</i>	L. Schimansky-Geier <i>Non-Markovian Models of Collective Phenomena</i>	H. Chaté <i>Multiplicative Noise and Absorbing Phase Transitions</i>	E. Moro <i>Spreading of Viscous Fluid Drops on a Solid Substrate Assisted by Thermal Fluctuations</i>
12h00-12h35	J. Ortin <i>Oscillatory Flow of Newtonian and Complex Fluids</i>	R. Kawai <i>Dissipation and Time's Arrow</i>	M.A. Munoz <i>Non-perturbative nature of a broad class of non-equilibrium phase transitions</i>	S. Aumaitre <i>PDF of the power injected by a random forcing</i>
12h35-12h55	F. Baroncini <i>Retrieval of soil moisture time series (both gravitational and capillary)</i>	B. Cleuren <i>Fluctuation theorem for black-body radiation</i>	L. Gallos <i>Self-propelled particles in open space</i>	

LUNCH

16h00-16h50	A.C. Newell <i>Wave Turbulence: a Story Far from Over</i>	H. Linke <i>Self Propelled Leidenfrost Droplets</i>	A. Vulpiani <i>Violation of the Einstein relation in Granular Fluids: the role of correlations</i>
16h50-17h25	S. Nazarenko <i>Discrete Effects in Wave Turbulence</i>	R. Toral <i>Similar Effects of Noise and Diversity in the Dynamics of Nonlinear Systems</i>	A. Petri <i>A stochastic equation for sheared granular medium</i>

COFFEE BREAK

17h55-18h30	A. Pumir <i>Nonlinear Dynamics and Stochastic Effects in Invertebrate Phototransduction</i>	C. Pennetta <i>Statistics of Extreme Values in Time series with Intermediate-Term Correlations</i>	S. Fauve <i>Chaotic Dynamos Generated by a Strongly Turbulent Flow of Liquid Sodium</i>
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Beaulieu sur mer- 3th - 7th September 2007

Timetable

Monday 3 September

16:00-19:30	<i>Registration</i>
19:30	<i>Welcome cocktail at La Berlugane</i>
20:00-21:00	<i>Dinner at La Berlugane</i>

Tuesday 4 September

9:15-9:30	<i>Welcome</i>
9:30-10:20	U. Seifert Stochastic Thermodynamics: Theory and experiments
10:20-10:55	S. Ruffo Quasi-stationary states in mean-field dynamics
10:55-11:25	<i>Coffee</i>
11:25-12:00	E. Bodenschatz Lagrangian Turbulence
12:00-12:35	J. Ortin Oscillatory Flow of Newtonian and Complex Fluids
12:35-12:55	F. Baroncini Retrieval of soil moisture time series (both gravitational and capillary)
12:55-14:00	<i>Lunch at La Berlugane</i>
16:00-16:50	A.C. Newell Wave Turbulence: a Story Far from Over
16:50-17:25	S. Nazarenko Discrete Effects in Wave Turbulence
17:25-17:55	<i>Coffee</i>
17:55-18:30	A. Pumir Nonlinear Dynamics and Stochastic Effects in Invertebrate Phototransduction

Wednesday 5 September

9:30-10:20	G. Gallavotti Fluctuations in quantum systems
10:20-10:55	L. Rondoni Transient and Steady State Relations for Deterministically Thermostated Systems
10:55-11:25	<i>Coffee</i>
11:25-12:00	L. Schimanky-Geier Non-Markovian Models of Collective Phenomena
12:00-12:35	R. Kawai Dissipation and Time's Arrow

- 12:35-12:55 **B. Cleuren**
Fluctuation theorem for black-body radiation
- 12:55-14:00 *Lunch at La Berlugane*
- 16:00-16:50 **H. Linke**
Self Propelled Leidenfrost Droplets
- 16:50-17:25 **R. Toral**
Similar Effects of Noise and Diversity in the Dynamics of Nonlinear Systems
- 17:25-17:55 *Coffee*
- 17:55-18:30 **C. Pennetta**
Statistics of Extreme Values in Time series with Intermediate-Term Correlations
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Thursday 6 September

- 9:30-10:20 **C. Van den Broeck**
Brownian Motors
- 10:20-10:55 **E. L. Florin**
Exploiting Brownian motion and thermal fluctuations for biophysical research
- 10:55-11:25 *Coffee*
- 11:25-12:00 **H. Chaté**
Multiplicative Noise and Absorbing Phase Transitions
- 12:00-12:35 **M.A. Munoz**
Non-perturbative nature of a broad class of non-equilibrium phase transitions
- 12:35-12:55 **L. Gallos**
Self-propelled particles in open space
- 12:55-14:00 *Lunch at La Berlugane*
- 16:00-16:50 **A. Vulpiani**
Violation of the Einstein relation in Granular Fluids: the role of correlations
- 16:50-17:25 **A. Petri**
A stochastic equation for sheared granular medium
- 17:25-17:55 *Coffee*
- 17:55-18:30 **S. Fauve**
Chaotic Dynamos Generated by a Strongly Turbulent Flow of Liquid Sodium
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Friday 7 September

- 9:30-10:20 **F. Sagues**
Noise-Based Selection Mech. of Turing vs. Hopf Bif. in a Photosensitive Chemical Medium
- 10:20-10:55 **S. Residori**
Spatiotemporal pulses in a liquid crystal optical oscillator
- 10:55-11:25 *Coffee*
- 12:00-12:35 **E. Moro**
Spreading of Viscous Fluid Drops on a Solid Substrate Assisted by Thermal Fluctuations
- 12:35-12:55 **S. Aumaître**
PDF of the power injected by a random forcing
- 12:55-14:00 *Lunch at La Berlugane*

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