6^{th} Giovanni Paladin Memorial

Large deviations and rare events in physics and biology

Dipartimento di Fisica, Università "Sapienza" Roma,
September 23-25, 2013

Invited Speakers

E.G. Altmann (MPIPKS Dresden, Germany)

J. Bec (CNRS Nice, France)

G. Benettin (University of Padova, Italy)

R. Burioni (University of Parma, Italy)

A. Crisanti (University "Sapienza" of Rome, Italy)

L. Gammaitoni (University of Perugia, Italy)

K. Gawedzki (ENS Lyon, France)

J. Kurchan (ESPCI Paris, France)

A. S. Lanotte (CNR-ISAC Lecce, Italy)

S. Lepri (CNR-ISC Florence, Italy)

P. Muratore-Ginanneschi (University of Helsinki, Finland)

I. Pagonabarraga Mora (University of Barcelona, Spain)

S. Pigolotti (Univesity of Catalugna, Barcelona, Spain)

F. Ritort (University of Barcelona, Spain)

K. Sekimoto (Université Paris Diderot, France)

K. Sneppen (Niels Bohr Institute, Copenhagen, Denmark)

I. Sokolov (Humboldt University Berlin, Germany)

Organizers

F. Cecconi (CNR-ISC Rome, Italy)

M. Cencini (CNR-ISC Rome, Italy)

A. Puglisi (CNR-ISC Rome, Italy)

A. Vulpiani (University "Sapienza" of Rome, Italy)

Scientific Program

MONDAY 23	
08.00 - 09.15	*Registration*
09:15 - 09.30	*Welcome*
09.30 - 10.40	**K. Gawedzki**
10.40 - 11.10	*Coffee Break*
11.10 - 12.00	**P. Muratore-Ginanneschi**
12.00 - 12.50	**K. Sekimoto**
12.50 - 14.10	*Lunch*
14.10 - 15.00	**F. Ritort**
15.00 - 15.50	**A. Crisanti**
15.50 - 16.20	*Coffee break*
16.20 - 17.10	**I. Pagonabarraga Mora**
17.10 - 18.00	**L. Gammaitoni**

TUESDAY 24	
09.00 - 09.50	**J. Kurchan**
09.50 - 10.40	**E.G. Altmann**
10.40 - 11.10	*Coffee break*
11.10 - 12.00	**K. Sneppen**
12.00 - 12.50	**S. Pigolotti**
12.50 - 14.10	*Lunch*
14.10 - 15.00	**R. Burioni**
15.00 - 15.50	**G. Benettin**
15.50 - 16.20	*Coffee break*
16.20 - 18.00	POSTER SESSION

WEDNESDAY 25	
09.00 - 09.50	**I. Sokolov**
09.50 - 10.40	**J. Bec**
10.40 - 11.10	*Coffee break*
11.10 - 12.00	**A. Lanotte**
12.00 - 12.50	**S. Lepri**
12.50 - 13.00	*Closing*

Monday, September 23

08.00 *Registration*

Chair: *A. Vulpiani*

09.15 *Welcome*

09.30 **K. Gawedzki**
Macroscopic fluctuation theory for non-equilibrium systems with mean-field interactions

10.40 *Coffee break*

Chair: *L. Biferale*

11.10 **P. Muratore-Ginanneschi**
On extremals of the entropy production by Kramers-type stochastic dynamics

12.00 **K. Sekimoto**
Interplay between energy and momentum in stochastic phenomena beyond description Langevin Momentum transfer deficit due to dissipation

12.50 *Lunch*

Chair: *M. Zannetti*

14.10 **F. Ritort**
Statistical mechanics in the nanoscale: from physics to biology

15.00 **A. Crisanti**
Fluctuation relation for weakly ergodic aging systems

15.50 *Coffee break*

Chair: *E. Caglioti*

16.20 **I. Pagonabarraga Mora** *Emergent structures in suspensions of molecular motors*

17.10 **L. Gammaitoni**
Operating basic switches in the presence of large fluctuations: minimal energy consideration

Tuesday, September 24

Chair: *S. Ruffo*

09.00 **J. Kurchan**
Stochastic perturbation of integrable systems: a window to weakly chaotic systems

09.50 **E.G. Altmann**
Rare words and scaling laws in language

10.40 *Coffee break*

Chair: *A. Giansanti*

11.10 **K. Sneppen**
Biological competition and diversity

12.00 **S. Pigolotti**
Thermodynamics of biological copying

12.50 *Lunch*

Chair: *R. Livi*

14.10 **R. Burioni**
Rare events and scaling in superdiffusive materials and in field-induced anomalous dynamics

15.00 **G. Benettin**
The Fermi-Pasta-Ulam problem: old ideas, recent results

15.50 *Coffee break*

16.20 **POSTER SESSION**

Wenesday, September 25

Chair: *L. Rondoni*

09.00 **I. Sokolov**
Normal and anomalous diffusion in random potential landscapes

09.50 **J. Bec**
Effective rates in dilute advection-reaction systems

10.40 *Coffee break*

Chair: *A. Petri*

11.10 **A. Lanotte**
Extreme Deviations in Turbulent Pair Dispersion

12.00 **S. Lepri**
Fluctuations in a diffusive medium with gain

12.50 *Closing*

INVITED SPEAKERS

abstracts

Rare words and scaling laws in language

EDUARDO G. ALTMANN

Max Planck Institute for the Physics of Complex Systems, Noethnitzer Str. 38, 01187 Dresden, Germany

The availability of large databases of written texts allow for improved quantitative investigations of dynamical aspects of language usage. Language shows remarkable statistical properties such as the presence of long-range correlation in long literary texts and the sub-linear growth of the vocabulary size (number of distinct words) with database size. This talk will show how simple models explain these observations and allow for an improved understanding of dynamical aspects of language usage both on the scale of individual texts and on historical time scales.

M. Gerlach and E. G. Altmann, "Stochastic model for the vocabulary growth in natural languages", Phys. Rev. X 3, 021006 (2013)

E. G. Altmann, G. Cristadoro, and M. Degli Esposti, "On the origin of long-range correlations in texts", Proc. Natl. Acad. Sci. USA 109, 11582 (2012)

Large Effective rates in dilute advection-reaction systems

JÉRÉMIE BEC

Laboratoire Lagrange, UMR7293, Université de Nice Sophia-Antipolis, CNRS, Observatoire de la Côte d'Azur, BP 4229, 06304 Nice Cedex 4, France

Many natural and industrial settings involve dilute systems of reacting particles transported by an unsteady fluid flow. We consider the simple case of an annihilation process $A+A \to \varnothing$ with a given rate when two particles are within a finite radius of interaction. The system is described in terms of the joint n-point number spatial density that it is shown to obey a hierarchy of transport equations. An analytic solution is obtained in either the dilute or the long-time limit by using a Lagrangian approach where statistical averages are performed along non-reacting trajectories. In this limit, we show that the moments of the number of particles have an exponential decay rather than the algebraic prediction of standard mean-field approaches. The effective reaction rate is then related to Lagrangian pair statistics by a large-deviation principle. A phenomenological model is introduced to study the qualitative behavior of the effective rate as a function of the interaction length, the degree of chaoticity of the dynamics and the compressibility of the carrier flow. Exact computations, obtained via a Feynman-Kac approach, in a smooth, compressible, random delta-correlated-in-time Gaussian velocity field support the proposed heuristic approach.

Rare events and scaling in superdiffusive materials and in field-induced anomalous dynamics

RAFFAELLA BURIONI

Dipartimento di Fisica Università di Parma. Viale G.P.Usberti 7/A. 43100 - Parma - Italy

Large fluctuations and rare events play an important role in many physical processes, where heterogeneous spatial structures or temporal inhomogeneities can give rise to anomalous transport. We consider here two effects, driven by rare events, in transport processes. On a class of random Lévy structures, modeled on recent experimental settings, we characterize the superdiffusive behavior by a "single-long-jump approximation", that takes into account the effects of rare events. Then, on Lv́y walks and Continuous Time Random Walks with broad trapping distributions, we study the effects of an arbitrary small external field and we show that this can induce an anomalous growth of fluctuations, even when the unperturbed system features standard diffusion.

The Fermi-Pasta-Ulam problem: old ideas, recent results

GIANCARLO BENETTIN

Dipartimento di Matematica Pura e Applicata, Università di Padova, Via Trieste, 63 35121 Padova, Italy

The aim of the talk is to revisit, in the light of some recent numerical results, some old ideas concerning the FPU problem, namely (i) The presence, in the so called "alpha-model" (dominant cubic nonlinearity), of at least two well separated time scales: a short one, where only a few normal modes share energy, and a larger one, where energy equipartition among all normal modes occurs and the behavior of the model, in view of Statistical Mechanics, is regular. (ii) The fact that in the short time scale the dynamics of FPU, in spite of the partial energy sharing, is essentially integrable and practically coincides with the dynamics of the Toda model, while in the large time scale nonintegrability becomes manifest. The role of the constants of motion of the Toda model in the FPU dynamics will be also discussed.

Fluctuation relation for weakly ergodic aging systems

ANDREA CRISANTI

Dipartimento di Fisica, Università di Roma La Sapienza, P.le Aldo Moro 5, 00185 Roma, Italy

A fluctuation relation for aging systems is introduced and verified by extensive numerical simulations. It is based on the hypothesis of partial equilibration over phase-space regions in a scenario of entropy driven relaxation. The relation provides a simple alternative method, amenable of experimental implementation, to measure replica symmetry breaking parameters in aging systems. The connection with the effective temperatures obtained from the fluctuation-dissipation theorem is discussed.

Operating basic switches in the presence of large fluctuations: minimal energy consideration

LUCA GAMMAITONI

Dipartimento di Fisica, Università di Perugia, via A. Pascoli, 1, I-06100 Perugia

According to the International Technology Roadmap for Semiconductors in the next 10-15 years the limits imposed by the physics of switch operation will be the major roadblock for future scaling of the ICT devices. Among these limits the most fundamental is represented by the heat dissipated during operation and the presence of large fluctuations. Here we discuss a simple switch conceptual model that shows that the fundamental lower limit in energy dissipation can be beaten by trading the dissipated energy with the uncertainty in the distinguishability of switch logic states. We establish a general relation between the minimum required energy and the maximum error rate in the switch operation and briefly discuss the potential applications in the design of future switches.

Macroscopic fluctuation theory for non-equilibrium systems with mean-field interactions

KRZYSZTOF GAWEDZKI

C.N.R.S., ENS Lyon, Laboratoire de Physique, 46 Alée d'Italie, F69007 Lyon, France

I shall discuss a joint work with F. Bouchet and C. Nardini applying the macroscopic fluctuation theory of Bertini et al. to non-equilibrium systems with mean field interactions, in particular, to a model of active rotators that exhibits 2nd order phase transitions between stationary and periodic phases.

Stochastic perturbation of integrable systems: a window to weakly chaotic systems

JORGE KURCHAN

Laboratoire de Physique et Mécanique des Milieux Hétérogénes - UMR CNRS 7636 École Supérieure de Physique et de Chimie Industrielles 10, rue Vauquelin 75231 Paris Cedex 05

Lyapunov exponents may be defined for noisy systems, as Giovanni proposed years ago. I will show that integrable non-linear Hamiltonian systems perturbed by additive noise develop a Lyapunov instability, and are hence chaotic, for any amplitude of the perturbation. The situation described here being 'multi-resonance' – by nature well beyond the Kolmogorov-Arnold-Moser regime, it offers an analytic glimpse on the regime in which many near-integrable systems, such as some planetary systems, find themselves in practice.

Extreme Deviations in Turbulent Pair Dispersion

ALESSANDRA SABINA LANOTTE

Istituto di scienze dell'atmosfera e del clima, CNR, Str. Prov. Lecce Monteroni I-73100 Lecce, Italy

I will discuss the problem of turbulent pair dispersion of neutrally buoyant (tracer) and heavy particles, i.e. the way two particles separate in a turbulent flow. In the case of tracers only, there is a classical theory, which is due to L. F. Richardson (1926): it is in terms of a diffusion equation for the relative separation distribution, with a scale dependent diffusion coefficient. As a result, relative dispersion of pairs of tracer particles in a turbulent flow is a globally self-similar in time process. Experimental and numerical evidences show the existence of large and intermittent fluctuations, pointing to a limited applicability of such an approach. To illustrate the key questions in the topic, I will present recent results from high resolution direct numerical simulations, and then discuss research directions in the problem. This work is done in collaboration with L. Biferale, R. Scatamacchia and F. Toschi.

Fluctuations in a diffusive medium with gain

STEFANO LEPRI

Istituto dei Sistemi Complessi, CNR Via Madonna del Piano 10 I-50019 Sesto Fiorentino, Italy

We present a stochastic model for amplifying, diffusive media like, for instance, random lasers. Starting from a simple random-walk model, we derive a stochastic partial differential equation for the energy field with contains a multiplicative random-advection term yielding intermittency and power-law distributions of the field itself. Dimensional analysis indicate that such features are more likely to be observed for small enough samples and in lower spatial dimensions. The model prediction are compared with experimental data.

S. Lepri Fluctuations in a diffusive medium with gain Phys. Rev. Lett. 110, 230603 (2013).
E. Ignesti et al Experimental and theoretical investigation of statistical regimes in random laser emission to appear in Phys. Rev. A

On extremals of the entropy production by Kramers-type stochastic dynamics

PAOLO MURATORE-GINANNESCHI

Department of Mathematics and Statistics PL 68 FIN-00014 University of Helsinki Finland

We refer as "Kramers-type" dynamics to a class of stochastic differential systems exhibiting a degenerate "metriplectic" structure. Systems in this class are often encountered in applications as elementary models of Hamiltonian dynamics in an heat bath eventually relaxing to a Boltzmann steady state.

The control of entropy production by systems in this class differs from the now well-understood case of Langevin dynamics for two reasons. First, the entropy production as defined from fluctuation theorems specifies a cost functional which does not act *coercively* on all degrees of freedom of control protocols. Second, the presence of a symplectic structure imposes a *non-local* constraint on the class of admissible controls in the form of a condition on the divergence. Using Pontryagin and Bismut control methods and restricting the attention to additive noise, we show that *smooth* control protocols attaining extremal values of the entropy production appear generically in continuos parametric families as a consequence of a trade-off between smoothness of the admissible protocols and non-coercivity of the cost functional. Uniqueness is, however, always recovered in the over-damped limit as extremals equations reduce at leading order to the Monge-Ampère-Kantorovich optimal mass transport equations.

Emergent structures in suspensions of molecular motors

IGNACIO PAGONABARRAGA MORA

Departament de Fsica Fonamental, Universitat de Barcelona, 08028 Barcelona, Spain

Active systems generate motion due to energy consumption, usually associated to their internal metabolism or to appropriate, localized chemical reactivity. As a result, these systems are intrinsically out of equilibrium and their collective properties result as a balance between their direct interactions and the indirect coupling to the medium in which they displace. Therefore, a dynamical approach is required to analyze their evolution and quantify their self-assembly and ability to generate intermediate and large scale stable structures.
I will analyze the peculiarities of collective transport of molecular motors along biofilaments, and the patterns they give rise to due to their coupling to the embedding fluid medium in which they displace. I will also analyze the impact that confinement has in the effective motion of molecular motors and the possibility that confinement modifies the intrinsic molecular motor rectification.

Thermodynamics of biological copying

SIMONE PIGOLOTTI

Dept. de Fisica i Eng. Nuclear, Universitat Politecnica de Catalunya Edif. GAIA, Rambla Sant Nebridi 22, 08222 Terrassa, Barcelona, Spain

Biological systems are able to copy information at a finite temperature with outstanding fidelity. In biochemical reactions, discrimination of copies with respect to a template can either occur in the binding rates (forward discrimination) or in the unbinding rates (backward discrimination), or both. I will show how, in simple copying schemes, these two discrimination modes lead to opposite tradeoffs between error, dissipation and reaction velocity. I will also discuss examples of how different schemes can be combined in multi-step reactions, and compare the results with experimental studies of DNA duplication and protein synthesis.

Statistical mechanics in the nanoscale: from physics to biology

FELIX RITORT

Departament de Fsica Fonamental, Universitat de Barcelona, Avda. Diagonal 647, 08028 Barcelona, Spain

The possibility to manipulate and apply forces on individual biomolecules offers to the physicist a new viewpoint to investigate the thermodynamics of small systems. A detailed understanding of the general principles governing energy exchange processes in the nanoscale is relevant to understand the astonishing high efficiency of molecular machines and the emergence of biological order in living systems. Biomolecular systems operate out of equilibrium in aqueous environments in a regime where free energy transduction occurs at the edge of Brownian motion where energy fluctuations are on the scale of kT (where k is the Boltzmann constant and T the absolute temperature). In this talk I will review the most relevant single molecule experiments probing energy fluctuations in the nanoscale, the theories describing them and outline future open problems in this exciting field.

Interplay between energy and momentum in stochastic phenomena beyond description Langevin Momentum transfer deficit due to dissipation

KEN SEKIMOTO

Matiéres et Systémes Complexes, CNRS-UMR7057, Université Paris-Diderot, 75205 Paris, France,

Since the last 15 years, the thermodynamic structure has been introduced in the Langevin level description. One reason that it was possible is that the energy is a scalar quantity. The linear frictional force and Gaussian random force were sufficient to describe the energy (heat) exchange between the system and environment. When, however, the momentum is involved in the system-environment interface, the Langevin description is no more satisfactory. It is because of the vectorial nature of the momentum. For example, in the analysis of the so-called "adiabatic piston," the rare but important collisions of hot gas particles from one side of the piston and the frequent but inefficient collisions of cold gas particles from the other side must be distinguished. To explain the physics behind the phenomena this system exhibits, correct understanding of the interplay between energy transport and momentum transport is crucial. In my talk I will describe the "momentum transfer deficit due to dissipation" (MDD), the concept we introduced recently. I will show how this concept helps to understand many stochastic phenomena like adiabatic piston, hitherto having been analyzed separately, from a universal physical point of view. I will also discuss an implication of MDD in the thermo-hydrodynamics of interacting gas having energy absorbing boundaries.
[References. Phys. Rev. Lett. 108, 160601 (2012); Phys. Scr. 86, 058508 (2012);in press, Acta Physica Polonica B (2013)]

Biological competition and diversity

KIM SNEPPEN

Center for Models of Life Niels Bohr Institute University of Copenhagen Blegdamsvej 17 2100 Copenhagen, Denmark

The talk will consider biological diversity is systems of immobile species, which spreding is locally confined to growth. As models systems we prmarely consider cmmunities of lichen on rock surfaces, and demonstrate that a state of high diversity is sustaniable by a dynamics of creation and annihilation of ecological patches.

Normal and anomalous diffusion in random potential landscapes

IGOR SOKOLOV

Institute for Physics, Humboldt-University of Berlin, Newtonstr. 15, 12489 Berlin, Germany

The talk reports on attempts to give a classification of anomalous diffusion regimes based on physical reasons in search for the order in the large Zoo of pertinent mathematical models. We confine ourselves to systems possessing thermodynamical equilibrium and consider the particle's diffusion in a generic lattice model with sites representing potential wells separated by barriers associated with the bonds. We discuss under what conditions the diffusion in such a system can get anomalous and how this anomalous diffusion can be mimicked by probabilistic models. We moreover discuss how the two generic types of disorder, the structural one (typical for percolation) and the energetic one (typical for trap models) appear within the general picture, and how the corresponding situations can be distinguished. We discuss practical methods for disentangling the influences of structural and energetic disorder in pure cases and for anomalous diffusion of the mixed origins.

POSTERS

abstracts

Friction dynamical weakening in a randomly sheared granular bed

MARIO ALBERTO ANNUNZIATA*, FERGAL DALTON and ALBERTO PETRI

Istituto dei Sistemi Complessi CNR, Roma, Italy
* *presently at Institut für Theoretische Physik II, Heinrich-Heine-Universität Dsseldorf, Germany*

We investigate experimentally and numerically the response of a granular bed to a shearing stress under both stationary and irregular, that is stick-slip, dynamics. We observe that the granular friction law in the stick-slip regime changes drastically with respect to the stationary state, exhibiting a local minimum that is not present when the plate is driven at constant speed. By means of molecular dynamics simulations we also analyze the behaviour of microscopic granular state variables, like coordination number, packing fraction, and shear velocity profile.

Large deviations and optimization of dynamical processes on graphs

FABRIZIO ALTARELLI

Politecnico di Torino, Italy

Cascade processes are responsible for many important phenomena in natural and social sciences. Simple models of irreversible dynamics on graphs, in which nodes activate depending on the state of their neighbors, have been successfully applied to describe cascades in a large variety of contexts. Over the last decades, many efforts have been devoted to understand the typical behavior of the cascades arising from initial conditions extracted at random from some given ensemble. However, the problem of optimizing the trajectory of the system, i.e. of identifying appropriate initial conditions to maximize (or minimize) the final number of active nodes, is still considered to be practically intractable. Here we introduce an efficient algorithm based on statistical physics for the optimization of trajectories in cascade processes on graphs. We show that for a wide class of irreversible dynamics the spread optimization problem can be solved efficiently on large networks. Analytic and algorithmic results on random graphs are complemented by the solution of the spread maximization problem on a real-world network (the Epinions consumer reviews network).

A large deviation principle for a disordered neutral competition model

CLAUDIO BORILE

Politecnico di Torino, Italy

Stochastic models of interacting degrees of freedom are nowadays widely spread in different scientific disciplines, from Physics to Biology, Ecology and social sciences. Among these models, a famous example is the voter model (VM) [1] , which is an analytically tractable mathematical equivalent of the neutral theory in ecology [2] and genetics, known among geneticists under the name of Moran model. This model has been deeply studied and has gradually become due to its conceptual simplicity that nevertheless ends up in a very rich phenomenology and its possible applications in many different scientific areas [35] a paradigmatic example of non-equilibrium lattice models. Despite the fact that the original formulation of the VM can be exactly solved in any spatial dimension [2] fact that contributed greatly in its rise , any slight modification made in order to improve the realism of the model complicates drastically its mathematical formulation. In the last few years there has been a growing interest in studying the behavior of the VM in presence of a quenched random-field-like disorder, whose motivations span from Ecology [6, 7] to Social modeling [8, 9] through models of chemical reactants [10], but yet a rigorous analysis of the stochastic dynamics of this model is still missing, as present results rely on simulations and/or analytical approximations. Here we present a finite-size large deviation analysis for the mean time to absorption of a disordered VM, proving that, in accord with previous findings, in any spatial dimension the typical time to absorption scales exponentially in the system?s size instead of power-law as in the original VM. We furthermore characterize the stochastic dynamics around the deterministic stable fixed point, showing that the disorder does not self-average. Possible implications in conservation ecology will be discussed.

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[3] R. Durrett and S. A. Levin. Stochastic spatial models: A users guide to ecological applications. Phil. Trans. Royal Soc. London. Ser B: Biol. Sci., 343(1305):329350, 1994.

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[10] P.L. Krapivsky, S. Redner, and E. Ben-Naim. A Kinetic View of Statistical Physics. Cambridge University Press, 2010.

Metastable wetting on superhydrophobic surfaces: Continuum and atomistic views of the Cassie-Baxter–Wenzel transition

MAURO CHINAPPI

CLNS@Sapienza, Istituto Italiano di Tecnologia, Roma, Italy

Wetting on rough surfaces is a conundrum that challenges both the scientific and the technological communities. A rough surface with an hydrophobic coating promotes the entrapment of air or vapour within asperities - Cassie-Baxter state - resulting in remarkable macroscopic properties that are collectively known as superhydrophobicity; among them, we mention the large apparent contact angle and low hysteresis of the contact angle that promotes the easy roll-off of the rain droplets on superhydrophobic surfaces (self-cleaning). In addition, under flow conditions, superhydrophobic surfaces induce an apparent liquid slippage at the solid walls (drag reduction). Superhydrophobicity, however, may be fragile since it is strictly related to the Cassie-Baxter state. Most superhydrophobic properties are lost if the liquid completely wets the surface (Wenzel state) [1]. In spite of the recent technological advancements that allow to control many microscopic features of artificial superhydrophobic surfaces, the stability of the entrained bubbles and the mechanism of wetting remains largely elusive, making it difficult to predict how long a superhydrophobic state will last and to design effectively synthetic surfaces. Therefore, understanding the mechanism, the influence of thermodynamic conditions, and the kinetics of the transition from Cassie-Baxter to the Wenzel state is of crucial importance for all applications of superhydrophobic surfaces. In this contribution, we present results for the wetting a model superhydrophobic surface decorated with a nanogroove. On the one hand we employed rare events atomistic techniques aimed at computing the free energy of the stable and metastable states of the system, as well as the intermediate states separating them. The measured free energy barrier separating the CassieBaxter from the Wenzel state (and vice versa) largely exceeds the thermal energy, attesting the existence of CassieBaxter/Wenzel metastabilities. MD simulations also suggest that, even for very simple geometries, the transition mechanism is non-trivial [2]. On the other hand, inspired by the restrained atomistic technique, a continuum method for rare events is devised. This approach extends the theory for the Cassie-Baxter/Wenzel transition to the length scales of typical applications, which are best described in terms of continuum mechanics. The method relies on the minimization of the free energy functional of a liquid-vapour-solid system constrained to a given advancement of the phase transition. The resulting transition path is the collection of the most probable configurations (specifically of the liquid-vapour meniscus) encountered along the Cassie-Wenzel transition. The minimization problem is solved analytically for the wetting of a rectangular groove, shedding light on the stability of the superhydrophobic Cassie state, the influence of thermodynamic conditions, the free energy barriers, and the transition mechanism [3]. A very good agreement is found between MD simulation and continuum results up to nanoscale.

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Sample dependence of mobility in models for quantum transport in organics

SERGIO CIUCHI

Dipartimento di Scienze Fisiche e Chimiche Università dell'Aquila, Italy

In organic field effects transistors - that are electronic devices made by organic molecules - fluctuations from sample to sample of mobility can achieve values of order of magnitudes. This can affect severely the reproducibility of measurements and makes difficult to produce a standard high quality devices. We theoretically approach the problem using quantum random energy model, appropriate to describe strongly disordered polymers, and a decoration of the Anderson model which is appropriate to describe molecular crystals. In both case large fluctuations of mobility are found due power-law or log-normal distributions depending on the distribution of the disorder, the density of the carriers, the relevance of electron-phonon interaction. Increasing the carrier density seems to prevent such a large fluctuation regime in both studies cases.

Large-deviations and condensation of fluctuations in equilibrium and off-equilibrium systems

FEDERICO CORBERI

Università di Salerno, Italy

We present the exact calculation of the large deviation function of the spontaneous fluctuations of macroscopic observables (such as energy, exchanged heat etc. ..) in the equilibrium or non-equilibrium regime of classical magnet described by solvable models of Statistical Mechanics, as the spherical model. We show the existence of a singularity in the distributions which must be attributed to a phenomenon of condensation of fluctuations resembling the Bose-Einstein condensation: Large fluctuations can only be developed when a macroscopic fraction is provided by a single mode (usually the one with $k = 0$). We discuss the relevance and generality of such a behavior and its implications.

Some exact results for generalized Malthus-Verhulst model with random carrying capacity having stable probability distribution

ALEXANDER DUBKOV

Lobachevsky State University of Nizhni Novgorod, Russia

The generalized stochastic Malthus-Verhulst equation for the population density with random carrying capacity is analyzed. Based on the exact solution of the equation the probability density of transitions is calculated for the excitation in the form of Levy white noise with one-sided stable distribution. The exact analytical results can be obtained for the case of noise with Levy-Smirnov distribution. The transient bimodality in the system under consideration are discussed. The steady-state probability density function and some first moments are also found.

Anergy in self-directed B-cells from a statistical mechanics perspective

ANDREA GALLUZZI

Dipartimento di Matematica, Università Sapienza, Roma Italy

The ability of the adaptive immune system to discriminate between self and non-self mainly stems from the ontogenic clonal-deletion of lymphocytes expressing strong binding affinity with self-peptides. However, some self-directed lymphocytes may evade selection and still be harmless due to a mechanism called "clonal anergy". As for B lymphocytes, two major explanations for anergy developed over three decades: according to "Varela theory", it stems from a proper orchestration of the whole B-repertoire, in such a way that self-reactive clones, due to intensive interactions and feed-back from other clones, display more inertia to mount a response. On the other hand, according to the 'two-signal model", which has prevailed nowadays, self-reacting cells are not stimulated by helper lymphocytes and the absence of such signaling yields anergy. The result we present, achieved through disordered statistical mechanics, shows that helper cells do not prompt the activation and proliferation of a certain sub-group of B cells, which turn out to be just those broadly interacting, hence it merges the two approaches as a whole (in particular, Varela theory is then contained into the two-signal model).

Brownian Ratchet in a Thermal Bath Driven by Coulomb Friction

ANDREA GNOLI

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We study an experimental setup where a rotating probe is suspended in a shaken and dilute granular uid. The stochastic dynamics of the probe results from the subtle interplay of dry friction (due to the ball bearings where the probe is mounted) and inelastic collisions with the granular particles. For a geometrically symmetric probe, an unbiased Brownian-like motion with non-linear friction is detected, with interesting features which can be accounted for through kinetic theory. For an asymmetric probe, a Brownian motor (a ratchet) is realized. Changing the intensity of the shaking, it is possible to tune the relative importance of friction with respect to collisions, obtaining very different dynamical regimes. The friction-dominated regime reveals an unanticipated phenomenon, i.e., a ratchet effect which does not depend on granular inelasticity, but only on dry friction. This implies the possibility of realizing a collisional ratchet in micro-nano systems, where collisions are elastic but friction is still present

Heat fluctuations in a quenched ferromagnet

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The off-equilibrium probability distribution of the heat exchanged by a ferromagnet in a time interval after a quench below the critical point is calculated analytically in the large-N limit. Here N is the number of components of the vectorial order parameter. The distribution shows a singular behavior with a critical threshold below which a macroscopic fraction of heat is released by the $k = 0$ Fourier mode of the order parameter. The mathematical structure producing this phenomenon is the same responsible of the order parameter condensation in the equilibrium low temperature phase. The heat exchanged by the individual Fourier modes follows a non trivial pattern, with the unstable modes at small wave vectors warming up the modes around a characteristic finite wave vector k_M. Two internal temperatures, associated to the $k = 0$ and $k = k_M$ modes, rule the heat currents through a fluctuation relation similar to the one for stationary systems in contact with two thermal reservoirs.

Rare events and scaling properties in field-induced anomalous dynamics

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I will show that, in a broad class of continuous time random walks, a small external field can turn diffusion from standard into anomalous. These findings are illustrated in a continuous time random walk (CTRW) and in the Levy walk process. For both models, in the presence of an external field, rare events induce a singular behavior in the originally Gaussian displacements distribution, giving rise to power-law tails. Remarkably, in the subdiffusive CTRW, the combined effect of highly fluctuating waiting times and of a drift yields a non-Gaussian distribution characterized by long spatial tails and strong anomalous super diffusion.

A coarse-grained model of facilitated diffusion

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Transcription Factors (TF) play a key biological role acting as gene expression activators and inhibitors. The mechanism used by TFs to reach their target site, "facilitated diffusion", resulting in a reduction of the dimensionality of the search space, allows association rates two orders of magnitude higher than those predicted by Smoluchowski equation for diffusion-limited association reactions. The mechanism comprises a cycle of events of 3D-diffusion, attachement to DNA, 1D-diffusion along the polynucleotide (sliding) and further detachements leading to a reassociation to a neighbouring site (hopping) or to an uncorrelated position (jumping). Our work aims at a characterization of the influence of aspecific interactions on the motion of a TF. In our model, while DNA is represented as a single chain of beads, the TF mirroring the features of prokaryotic homodimeric TF, is portrayed as a triangular object with the first and last bead representing the binding regions of the two subunits and the central bead simulating the scaffold of the protein that enforces the correct orientation of the binding domains. The behaviour of the TF is studied as a function of the equilibrium distance sigma of the DNA-TF Lennard-Jones potential. Our MD simulations show that as sigma is increased, three different phenomenological regimes can be identified. For small sigma the energy landscape is characterized by several metastable minima separated by high energy barriers preventing sliding and depressing the D1 diffusion constant. For intermediate sigma, the minima coalesce yielding a tube-like attractive region that acts as a barrierless avenue for sliding so that the D1 constant can reach its maximum. For even larger sigmas the tube-like attractive region moves away from the DNA axis imposing a long winding route to the TF which results in a drop of the diffusion constant. Despite the crude approximations our model turns out to be capable of reproducing a number of known experimental patterns such as the coupling of translation and rotation in the TF motion and the parallel orientation of the TF with respect to DNA axis.

Elastic-turbulence-induced melting of a nonequilibrium vortex crystal in a fluid film with polymer additives

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We perform a direct numerical simulation (DNS) of the forced, incompressible two-dimensional Navier-Stokes equation coupled with the FENE-P equations for the polymer-conformation tensor. The forcing is such that, without polymers and at low Reynolds numbers Re, the film attains a steady state that is a square lattice of vortices and anti-vortices. We find that, as we increase the Weissenberg number (Wi), this lattice undergoes a series of nonequilibrium phase transitions, first to spatially distorted, but temporally steady, crystals and then to a sequence of crystals that oscillate in time, periodically, at low Wi, and quasiperiodically, for slightly larger Wi. Finally, the system becomes disordered and displays spatiotepmoral chaos and elastic turbulence. We then obtain the nonequilibrium phase diagram for this system, in the $Wi--Re$ plane, and show that (a) the boundary between the crystalline and turbulenct phases has a complicated, fractal-type character and (b) the Okubo-Weiss parameter Λ provides us with a natural measure for characterizing the phases and transitions in this diagram.

Monte Carlo Sampling in Fractal Landscapes

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We design a random walk to explore fractal landscapes such as those describing chaotic transients in dynamical systems. We show that the random walk moves efficiently only when its step length depends on the height of the landscape via the largest Lyapunov exponent of the chaotic system. We propose a generalization of the Wang-Landau algorithm which constructs not only the density of states (transient time distribution) but also the correct step length. As a result, we obtain a flat-histogram Monte Carlo method which samples fractal landscapes in polynomial time, a dramatic improvement over the exponential scaling of traditional uniform-sampling methods. Our results are not limited by the dimensionality of the landscape and are confirmed numerically in chaotic systems with up to 30 dimensions.

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Critical connectivity for emergence of collective oscillations in strongly diluted neural networks

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In this work we study the dynamics of random networks models focusing on the role played by the connectivity K on the onset of collective oscillations. In modeling networks two classes of systems are generally considered: massive networks, where K is proportional to the network size N; sparse (or strongly diluted) networks, where $K \ll N$, and specifically K is independent on N as $N \to \infty$. While it is not surprising to observe the onset of a collective motion in massive networks, it is less obvious to predict whether and when this can happen in sparse ones. Here we show that a finite critical connectivity K_c is able to sustain the emergence of collective oscillations and that this is a general and robust property of sparse networks. Since K_c turns out to be surprisingly of the order of a few tens in all models we investigate, macroscopic motion appears to be rather ubiquitous and relevant in the context of neural dynamics. Moreover, we show that the microscopic evolution of sparse networks is extensive (i.e. the number of active degrees of freedom is proportional to the number of network elements). This property is highly nontrivial, as the dynamics of a sparse network is intrinsically non additive (it cannot be approximated with the juxtaposition of almost indepedent sub-structures). We find all the above striking results to hold for networks of pulse-coupled leaky-integrate-and-fire neurons, among the most popular and yet simple models used in computational neuroscience, and more generally also for networks of chaotic maps and Stuart-Landau oscillators.

Critical signatures in the stick-slip dynamics of a sheared granular medium

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We study the transition between a stick-slip response and a continuous slide behavior of a 3-D granular sample in spring-driven shear tests, by mean of Acoustic Emission (AE) signals. We find that the AE from the frictional sliding depends non-linearly on the applied shear rate in any case, but the AE signals are clearly different for the two regimes. On long time-scales, AE signals of stick-slip motion (characteristic of low shear rate) is easy to distinguish from that of continuous sliding (higher rates) because of its intermittency, but we observe that in addition they present different statistical signatures for each regime, both in the frequency domain and in the distribution of AE intensities. These differences show that the system approaches a critical state at the transition and allow to discriminate between slips and continuous sliding also on the short time-scales.

Large Deviations of Correlation Functions in Random Magnets

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Quenched randomness in ferromagnetic models (e.g. random fields) leads to physical observables that strongly depend on the local environment and consequently show huge fluctuations. An example is the spin-spin connected correlation function, whose probability distribution remains non-trivial even in the thermodynamical limit. It turns out that the average correlation function is dominated by few atypical correlations. Rare events of atypically correlated variables are particular important at the critical point: the phase transition is driven by few pairs of strongly correlated spins, while the majority remains basically uncorrelated. In order to give a quantitative description of the phenomenon we develop the large deviations theory of the spin-spin correlation functions in the Random Field Ising Model on the Bethe lattice, both at finite and zero temperature.

Kinetic theory for non-equilibrium long-range interacting systems: from plasma to geophysical flows

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Long-range interacting systems include neutral plasma, gravitational systems, two-dimensional and geophysical fluid models. A tool of paramount importance in their study is kinetic theory (Vlasov equation, Lenard-Balescu equation, Landau equation...). In particular, many problems in nature deal with long-range interacting systems driven out of equilibrium by external forces. This situation is very common for geophysical flows, which are characterised by their self-organisation into large scale coherent structures (such as jet-streams,

cyclones, anti-cyclones) resulting from the balance between the energy injected by turbulent fluctuations and the energy dissipated. I will discuss how we can describe the formation, the evolution and phase transitions between non-equilibrium stationary states by generalising the classical tools of kinetic theory and large deviations techniques. Rare events in which the system goes from a given state to a macroscopically different one will also be illustrated by means of numerical simulations.

Genome-wide analysis of promoters: clustering by alignment and analysis of regular patterns

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We investigate the relation between structural and functional properties of promoters in H. sapiens. For this purpose we have developed and combined two mathematical procedures, that allow to (i) cluster promoters into structurally similar groups and (ii) identify the features at the origin of this classification. Such features emerge as global properties of the promoters and are related to patterns of regular sequences. One of the main findings of this analysis is that H. sapiens promoters can be classified into three main groups. Two of them are distinguished by the prevalence of weak or strong nucleotides and are characterized by short compositionally biased sequences, while the most frequent regular sequences in the third group are strongly correlated with transposons. Taking advantage of the generality of these mathematical procedures, we have compared the promoter database of H. sapiens with those of other species. We have found that the above mentioned patterns characterize also the evolutionary content appearing in mammalian promoters, at variance with ancestral species in the phylogenetic tree, that exhibit a definitely lower level of differentiation among promoters.

Notes on the large deviations of the cycle currents

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Invoking tools from graph theory, we provide a representation for the transition probability of discrete-state-space, continuous-time Markov processes in terms of cycle currents and traffic variables. As an application, we extend the fluctuation theorem for the currents of Andrieux and Gaspard [J . Stat. Phys. 127, 107 (2007)] to the transient regime. With the aid of simple examples, we address a conjectural relationship between the asymptotes of the current's rate function and physically meaningful affinities.

Crack propagation as a realization of Manna Self Organized Criticality

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By putting in correspondence the dynamics of fracture with that of classical sand-piles, we show that the slow propagation of a crack in a heterogeneous medium is a realization of Self Organized Criticality, and report very strong numerical evidences that it belongs to the Manna class. In fact we find that the scaling properties of the crack dynamics can be quantitatively reproduced also by the Manna model when complemented with the suitable conditions. This establishes, pherhaps for first time, a quantitative correspondence of SOC models with real systems.

Universality and Deviations in Disordered Systems

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We compute the probability of positive large deviations of the free energy per spin in mean-field Spin-Glass models. The probability vanishes in the thermodynamic limit as $P(\Delta f) \propto \exp[-N^2 L_2(\Delta f)]$. For the Sherrington-Kirkpatrick model we find $L_2(\Delta f) = O(\Delta f)^{12/5}$ in good agreement with numerical data and with the assumption that typical small deviations of the free energy scale as $N^{1/6}$. For the spherical model we find $L_2(\Delta f) = O(\Delta f)^3$ in agreement with recent findings on the fluctuations of the largest eigenvalue of random Gaussian matrices. The computation is based on a loop expansion in replica space and the non-gaussian behaviour follows in both cases from the fact that the expansion is divergent at all orders. The factors of the leading order terms are obtained resumming appropriately the loop expansion and display universality, pointing to the existence of a single universal distribution describing the small deviations

of any model in the full-Replica-Symmetry-Breaking class.

G. Parisi and T. Rizzo, Phys. Rev. B 81, 094201 (2010)

Non-equilibrium stochastic long-range systems

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Long-range interacting systems include plasmas, gravitational systems, two-dimensional and geophysical fluid models. We consider long-range interacting systems perturbed by external stochastic forces. Unlike the case of short-range systems, where stochastic forces usually act locally on each particle, here we consider perturbations by external stochastic fields. These systems reach stationary states where the external forces balance the dissipation on average. These states do not respect detailed balance and support non-vanishing fluxes of conserved quantities. Classical tools of kinetic theory can be extended to describe their evolution [1,2]. Comparisons with numerical simulations in a case of a particularly simple system, show an excellent agreement between the theory and simulations. Results on non-equilibrium phase transitions and bistable behavior nu- merically observed in these systems [2] are also discussed as well as applications of our work to two-dimensional and geophysical turbulence models.

[1] C. Nardini, S. Gupta, S. Ruffo, T. Dauxois, and F. Bouchet, JSTAT, L01002, 2012.
[2] C. Nardini, S. Gupta, S. Ruffo, T. Dauxois, and F. Bouchet, JSTAT, P12010, 2012.

Stokes Drift for inertial particles trasported by water waves

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We study the effect of surface gravity waves on the motion of inertial particles in an incompressible fluid. We perform analytical calculations based on perturbation expansions which allow us to predict the dynamics of inertial particles in the deep-water regime. We find that the presence of inertia leads to a non-negligible correction to the well-known horizontal Stokes drift velocity. Moreover, we find that the vertical sedimentation velocity is also affected by a drift induced by waves. The latter result may have some relevant consequences on the rate of sedimentation of particles of finite size. We underline that the vertical drift would also be observed in the (hypothetical) absence of the gravitational force. Kinematic numerical simulations are performed and the results are found to be in excellent agreement with the analytical predictions, even for values of the parameters beyond the perturbative limit.

Ratchet models with nonlinear friction

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We discuss the relevance of nonlinear friction, in particular in the form of Coulomb (or dry) friction, in the framework of ratchet models. We show that such a source of dissipation can be sufficient to drive a unidirectional motion in systems where a spatial asymmetry is present and where fluctuations are induced by the coupling with an equilibrium thermal bath. In particular, we study by numerical simulations and analytical methods two theoretical models in the presence of Coulomb friction: the asymmetric Rayleigh piston and the Langevin equation in a ratchet potential. Our theoretical analysis also allows us to elaborate on equilibrium and detailed balance conditions in this kind of systems.

Large scale flucutuations and correlations in the distribution of the galaxies

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We studied the conditional galaxy density in the newest samples of several galaxy surveys. Over a large range of scales, both the average conditional density and its variance show a nontrivial scaling behavior, which resembles to criticality. The density show a power law behavior of the type $1/r$ up to $\sim 20 Mpc$. For $20 < r < 150$ Mpc, it depends only weakly on scale, decaying as $1/r^{0.3}$. Correspondingly, we find that the density fluctuations follow the Gumbel distribution of extreme value statistics. This distribution is clearly distinguishable from a Gaussian distribution, which would arise for a homogeneous spatial galaxy configuration. We also point out similarities between the galaxy distribution and critical systems of statistical physics.

Multitasking Associative Networks

DANIELE TANTARI

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We introduce a bipartite, diluted and frustrated, network as a sparse restricted Boltzmann machine and we show its thermodynamical equivalence to an associative working memory able to retrieve several patterns in parallel without falling into spurious states typical of classical neural networks. We focus on systems processing in parallel a finite (up to logarithmic growth in the volume) amount of patterns, mirroring the low-level storage of standard Amit-Gutfreund-Sompolinsky theory. Results obtained through statistical mechanics, and Monte Carlo simulations are overall in perfect agreement and carry interesting biological insights. Indeed, these associative networks pave new perspectives in the understanding of multitasking features expressed by complex systems, e.g., neural and immune networks.

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6^{th} Giovanni Paladin Memorial

Mountain Castor May 1994 (photo by Guido)

This conference aims at commemorating and honoring our dear friend and colleague **Giovanni Paladin** by bringing together scientists working in statistical mechanics and dynamical systems, scientific disciplines which were close to his interests and very dear to him.

Giovanni (1958-1996) had a distinguished career in education and research in statistical physics, turbulence and chaotic systems. In 1992 he became associate professor at the University of L'Aquila. His enchanting enthusiasm inspired and introduced many young researchers to his passions: chaos, turbulence, disordered systems, climbing and skiing. Giovanni left us while climbing on Gran Sasso.

Large Deviations Theory, whose applications to turbulence and disordered systems are among the main contributions by Giovanni, is nowadays a well established theoretical framework allowing systematic treatments of rare events and fluctuations going beyond the Gaussian approximation in several subjects. This conference aims at offering to scientists, coping with rare events and large deviations in different contexts from physics to biology, the occasion to exchange ideas, tools and techniques.