50 years of Stochastic processes at UCSD: a symposium in honor of Katja Lindenberg

TENTATIVE SCHEDULE

DAY 1: Thursday, August 15, 2019				**LOCATION**
8:30 – 9 AM	BREAKFAST			NSB atrium
	SESSION 1: Solitons and transport			NSB auditorium
9:00-9:30 AM	David Campbell	Boston University	The Subtle Road to Equilibrium in the FPUT Model	NSB auditorium
9:30-10:00 AM	Yang Zhao	Nanyang Technological University	The multiple Davydov trial states: formulation and applications	NSB auditorium
10-10:30 AM	Jose Ma. Sancho	Universitat de Barcelona	The thermophoresis effect: theoretical analysis of experimental data	NSB auditorium
10:30-11:00 AM	COFFEE BREAK			NSB atrium
	SESSION 2: Historical remarks			NSB auditorium
11:00 AM -12:30 PM	Isabelle Vanschoonbeek, Raul Toral, J. M. Parrondo	University of Hasselt, Universidad de las Islas Baleares, Universidad Complutense de Madrid	Round table	NSB auditorium
12:30-2 PM	LUNCH			NSB atrium
	SESSION 3: Stochastic thermodynamics			NSB auditorium
2-2:30 PM	Ryoichi Kawai	University of Alabama at Birmingham	Thermodynamics of small quantum systems strongly interacting with environments	NSB auditorium
2:30-3 PM	Massimiliano Esposito	University of Luxembourg	Thermodynamics of nonequilibrium phase transitions in driven Potts models	NSB auditorium

3-3:30 PM	Juan M. Parrondo	Universidad Complutense de Madrid	Micro-reversibility and thermalization in classical and quantum systems	NSB auditorium
3:30-4:00 PM	COFFEE BREAK			NSB atrium
	SESSION 4: Biological systems			NSB auditorium
4:00-4:30 PM	Olga Dudko	University of California San Diego	On the Border of Order: Chromosomal Organization in Space and Time	NSB auditorium
4:30-5 PM	Javier Buceta	Lehigh University	From Patterning to Scutoids: Stochasticity in Development	NSB auditorium
5-5:30 PM	Kevin Wood	University of Michigan	Statistical physics and the evolution of drug resistance in bacteria	NSB auditorium

DAY 2: Friday, August 16, 2019				**LOCATION**
8:30 – 9 AM	Breakfast			NSB atrium
	SESSION 5: Long tail distributions			NSB auditorium
9:00-9:30 AM	Ewa Gudowska-Nowak	Jagiellonian University	Lévy fluctuations and dynamic response - from thermodynamics to search strategies	NSB auditorium
9:30-10:00 AM	Ralph Metzler	Universität Postdam	Superstatistics and non-Gaussian diffusion	NSB auditorium
10-10:30 AM	Igor M. Sokolov	Humboldt Universität zu Berlin	Brownian yet non-Gaussian diffusion in heterogeneous systems	NSB auditorium
10:30-11 AM	COFFEE BREAK			NSB atrium
	SESSION 6: Pattern formation			NSB auditorium
11-11:30 AM	Eli Ben-Naim	Los Alamos National Laboratory	Jamming and Tiling of Rectangles	NSB auditorium

11:30 AM-12 PM	Raúl Toral	Universidad de las Islas Baleares	A phase transition in persistent random walks.	NSB auditorium
12-12:30 PM	Sidney Redner	Santa Fe Institute	First-Passage Fixation	NSB auditorium
12:30-2 PM	LUNCH			NSB atrium
	SESSION 7: Dynamics and synchronization			NSB auditorium
2-2:30 PM	Bruce West	Army Research Office	42 years of agreeable disagreements	NSB auditorium
2:30-3 PM	Daniel Escaff	Universidad de los Andres	Topics in synchronization of discrete states stochastic oscillators	NSB auditorium
3:30-4 PM	Alexandre Rosas	Universidade Federal da Paraíba	Effect of fluctuations due to finite numbers in the synchronization of discrete state units	NSB auditorium
4-5:30 PM	FREE TIME			
5:30-9 PM	Reception and dinner			Faculty club

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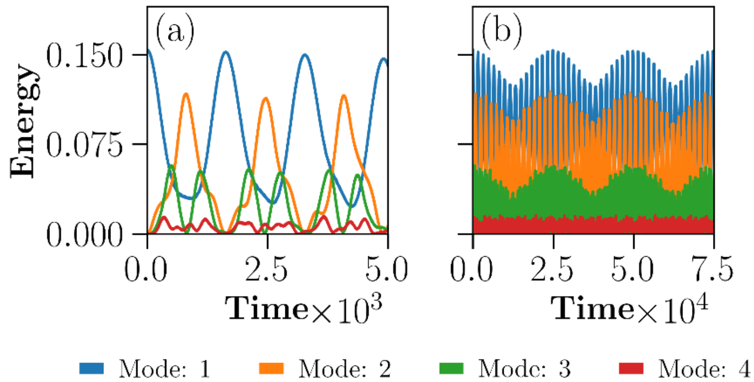
ABSTRACTS

The Subtle Road to Equilibrium in the FPUT Model

David K Campbell *
Boston University

ABSTRACT: The interpretation and consequences of the celebrated Fermi, Pasta, Ulam, Tsingou (FPUT) numerical experiment have challenged scientists for more than six decades. The history of how the original FPUT discovery led to the theory of "solitons," was key in the understanding of Hamiltonian chaos, and led to the birth of "nonlinear science" is well documented, but there are many fascinating details which are only now being explored and understood. In this presentation, I will discuss two recently studied examples: namely, the details of the existence and breakdown of recurrences and super-recurrences in both the alpha- and beta- versions of the FPUT system, and the remarkable intermittent dynamics, involving long-time, large deviations, that occur once the systems has nominally reached equilibrium.



In the first study[1], we find higher-order recurrences (HoR)s—which amount to "super-super-recurrences" in both the alpha and beta models. The periods of these HoR scale non-trivially with energy due to apparent singularities caused by nonlinear resonances, which differ in the two emodels. Further, the mechanisms by which the HoR breakdown differ strikingly in the two models.

In the second study[2], we find that the dynamics at equilibrium is characterized by a power-law distribution of excursion times far off equilibrium, with diverging variance. Long excursions arise from sticky dynamics close to localized excitations in normal mode space (q-breathers). Measuring the exponent allows to predict the transition into nonergodic dynamics.

*Work in collaboration with Carlo Danielli, Sergej Flach, and Salvatore Pace.

[1] Salvatore D. Pace and David K. Campbell, "Behavior and Breakdown of Higher-Order-Fermi-Pasta-Ulam-Tsignou Recurrences," arXiv:181100663 (*Chaos*, to appear)
[2] C. Danieli, D. K. Campbell, and S. Flach, "Intermittent many-body dynamics at equilibrium," *Phys. Rev. E* **95** 060202(R) (2017).

The multiple Davydov trial states: formulation and applications

Yang Zhao
Nanyang Technological University

ABSTRACT: Numerically exact in the limit of large multiplicity, the multiple Davydov trial states grew out of the Davydov solitons in the 1980s. In particular, the multi-D2 ansatz is especially versatile, capable to handle various forms of particle-boson interactions. A highly competitive alternative to methods such as NRG, HEOM, and QUAPI, time-dependent variation with the multi-D2 ansatz has found applications in a variety of problems ranging from one- and two-impurity spin-boson models, dissipative Landau-Zener transitions, driven Rabi dimers, to singlet fission dynamics, super bloch oscillations, multidimensional spectroscopy of molecular aggregates, and dissipative dynamics at conical intersections.

The thermophoresis effect: theoretical analysis of experimental data

José M. Sancho
University of Barcelona

ABSTRACT: Electrophoresis is a transport phenomenon induced by a temperature gradient. Small particles in a fluidic medium present a biased motion either to the hotter side (thermophilic) or to the colder side (thermophobic). This behavior is characterized by a transport quantity, ST (Soret coefficient). There is a lot of experimental information about the behaviors of this coefficient under very different set-ups. Here a review of the experiments is presented and analyzed under a recent theoretical approach based in the Fokker-Planck equation for brownian motion (Journal of Statistical Physics 172, 1609 (2018)).

Thermodynamics of small quantum systems strongly interacting with environments

Ryoichi Kawai
University of Alabama at Birmingham

ABSTRACT: TBA

Thermodynamics of nonequilibrium phase transitions in driven Potts models

Massimiliano Esposito
University of Luxembourg

ABSTRACT: We propose a thermodynamically consistent minimal model to study synchronization which is made of driven and globally interacting three-state units. This system exhibits at the mean-field level two bifurcations separating three dynamical phases: a single stable fixed point, a stable limit cycle indicative of synchronization, and multiple stable fixed points. These complex emergent dynamical behaviors are understood at the level of the underlying linear Markovian dynamics in terms of metastability, i.e. the appearance of gaps in the upper real part of the spectrum of the Markov generator. Stochastic thermodynamics is used to study the dissipated work across dynamical phases as well as across scales. This dissipated work is found to be reduced by the attractive interactions between the units and to nontrivially depend on the system size. When operating as a work-to-work converter, we find that the maximum power output is achieved far-

from-equilibrium in the synchronization regime and that the efficiency at maximum power is surprisingly close to the linear regime prediction.

We furthermore find that the phenomenology of the three-state-model can also be observed for a whole class of driven Potts models with spin states q. It follows from thermodynamic consistency that the low- and high-temperature phase are universal for any q. We furthermore derive the critical point that destabilizes the symmetric fixed point and generically show that the system exhibits a Hopf bifurcation. Supported by numerical studies, we claim that there are two classes of universal (thermo)dynamical properties exhibited by the Potts model depending on q: If q is even the Hopf bifurcation occurs subcritical and there are only the two high- and low-temperature phases. Conversely, if q is odd, the Hopf bifurcation occurs supercritical, meaning that there is an intermediate phase characterized by stable oscillations.

[1] T. Herpich, J. Thingna and M. Esposito, "Collective Power: Minimal Model for Thermodynamics of Nonequilibrium Phase Transitions", Phys. Rev. X 8, 031056 (2018)
[2] T. Herpich and M. Esposito, "Universality in driven Potts models", Phys. Rev. E 99, 022135 (2019)

Micro-reversibility and thermalization in classical and quantum systems

Juan M. Parrondo
Universidad Complutense de Madrid

ABSTRACT: Micro-reversibility, that is, the time reversal symmetry exhibited by microscopic dynamics, plays a central role in thermodynamics and statistical mechanics. From micro-reversibility one can prove that isolated systems and systems in contact with a thermal bath relax to micro-canonical and canonical ensembles, respectively. However, some problems arise when trying to reproduce this proof for classical and quantum collisional baths, i.e. particles at equilibrium interacting with a localized system via collisions. First, the velocity distribution of particles hitting a fixed target which is not Maxwellian, but the so-called effusion. Second, micro-reversibility may appear to be broken and some models do not thermalize in contact with a bath of Maxwellian particles. Here, we clarify these issues by showing that Liouville's theorem is a sufficient condition for micro-reversibility in classical and semi-classical scenarios. As a consequence, all canonical coordinates and momenta must be taken into account. This includes the position of the incident particles which maps the Maxwellian distribution of the bath particles into the effusion distribution. We finally show by an example that seemingly plausible collision rules that break conservation of phase-space volume may give rise to violations of the second law of thermodynamics.

On the Border of Order: Chromosomal Organization in Space and Time

Olga Dudko
University of California San Diego

ABSTRACT: Many processes in biology, from antibody production to tissue differentiation, share a common fundamental step — establishing a physical contact between distant

genomic segments. How do the distant segments find each other on a remarkably short timescale despite being strung out over millions of base pairs along the DNA? What is the mechanism of the high degree of orchestration of the remote genomic interactions? We address these questions in the context of adaptive immunity – the system that enables the individual to respond to a great variety of pathogens through a diverse repertoire of antibodies. The antibodies are generated by the genes that are themselves assembled from gene segments through a precisely orchestrated process of somatic recombination. Experimental data from live-cell imaging in B-lymphocytes reveal the signatures of anomalous diffusion that help us identify the dominant mechanism of genomic motion. Comparison of experimental and simulated data, along with insights from polymer physics, suggest that an interphase chromosome behaves as a network of cross-linked chains characteristic of a gel phase, yet it is poised near the sol phase, a solution of independent chains. Chromosome organization near the phase boundary provides the genome with a tradeoff between stability and responsiveness and orchestrates the timing of genomic interactions.

From Patterning to Scutoids: Stochasticity in Development

Javier Buceta
Lehigh University

ABSTRACT: In this talk I will review some of our contributions on the field of stochastic pattern formation that reveal how fluctuations, rather than a nuisance, can be considered as a source of order. These studies were the result of my collaboration with Katja Lindenberg (and with Christian van den Broeck too!) and largely shaped my research career, that currently focused on developmental biological problems. From that perspective I will introduce our recent discovery of a novel geometrical shape, the scutoid, its role in morphogenesis and will discuss further stochastic principles underlying development.

Statistical physics and the evolution of drug resistance in bacteria

Kevin Wood
University of Michigan

ABSTRACT: Antibiotic resistance is a growing public health threat. The emergence of resistance far outpaces the development of new drugs, underscoring the need for new strategies aimed at slowing the resistance threat. In this talk, I'll discuss our group's ongoing work to understand the evolution of drug resistance in *E. faecalis*, an opportunistic bacterial pathogen, using quantitative experiments and theoretical tools from statistical physics and dynamical systems. By combining laboratory evolution with simple mathematical models, we show that unconventional strategies--including aperiodic drug dosing, spatially distributed selection pressures, or adaptive containment protocols--can significantly slow resistance under a surprisingly wide range of conditions. These approaches exploit common (but sometimes neglected) features of microbial evolution--ranging from drug-drug correlations in resistance profiles to spatial heterogeneity and resource competition--to steer adaptation through potentially high-dimensional phenotype spaces. At the same time, the results paint an increasingly nuanced picture of the spatiotemporal dynamics of microbial populations across multiple length and time scales.

ABSTRACT: In this talk I will review some of our contributions on the field of stochastic pattern formation that reveal how fluctuations, rather than a nuisance, can be considered as a source of order. These studies were the result of my collaboration with Katja Lindenberg (and with Christian van den Broeck too!) and largely shaped my research career, that currently focused on developmental biological problems. From that perspective I will introduce our recent discovery of a novel geometrical shape, the scutoid, its role in morphogenesis and will discuss further stochastic principles underlying development.

Lévy fluctuations and dynamic response - from thermodynamics to search strategies

Ewa Gudowska-Nowak
Jagiellonian University

ABSTRACT: A generalization of Gaussian white noise to its non-Gaussian, Lévy stable counterpart serves as a model of impulsive, large scale variations observed e.g. in turbulent heat flow, solar flare fluctuations, hole transport in semiconductors or transmission of light in inhomogeneous materials. There is also an accumulating evidence from biological experiments showing that production of mRNA and proteins occurs in a pulsatile manner and creates non-Gaussian noise in individual cells [1–3]. Those bursty events result in high transcriptional activity followed by long periods of inactivity and are characterized by heavy tailed distributions and Lévy-like statistics. Moreover, the cytoplasmatic mechanical activity has been documented to be far from equilibrium [4] and the total intensity of cytoskeletal noise has been estimated to exceed the level of thermal noise $k_B T$. Since the intrinsic stochastic excitations may play a crucial role in transcriptional regulatory systems [3], it can well be that non-Gaussian Lévy noise should be a proper model of choice for underlying fluctuations in biological systems [5–7]. The evidence for bursty, Lévy flight-like behavior have been also recently documented in human cognition retrieval from semantic memory and mental searches. In the talk we will briefly overview nonequilibrium properties of Lévy flights [8, 9] and delineate some properties of Lévy noise in search strategies with random relocation (resetting) [10, 11].

[1] Gallet F.; Arcizet D.; Boheca P.; Richerta A. Power spectrum of out-of-equilibrium forces in living cells: amplitude and frequency dependence Soft Matter 2009 5 2947.
[2] Xu, Y.; Li, Y.; Zhang, H. Li, X.; Kurths, J. The switch in a genetic toggle system with L_evy noise Scientific Rep. 2016 631505.
[3] Zheng, Y,; Serdukova, S.; Duan, J.; Kurths, J. Transitions in a genetic transcriptional regulatory system under Lévy motion Scientfic Rep. 2016 6 29274.
[4] Soares e Silva M.; Stuhrmann B.; Betz T.; Koenderink G. H.; Time-resolved microrheology of actively remodeling acto-myosin networks New J. Phys. 2014 16 075010.
[5] Lisowski, B.; Valenti, D.; Spagnolo, B.; Bier, M.; Gudowska-Nowak, E. Stepping molecular motor amid Lévy white noise Phys. Rev. E 2015 91 042713.
[6] Ku_smierz, L.; Chechkin, A.V.; Gudowska-Nowak, E.; Bier, M. Breaking microscopic reversibility with Lévy flights EPL 2016, 114, 60009.
[7] Gudowska-Nowak, E.; Ochab, J.K.; Ole_s, K.; Beldzik, E.; Chialvo, D.R.; Domagalik, A.; Fafrowicz, M.; Marek, T.; Nowak, M.A.; Oginska, H.; Szwed, J.; Tyburczyk, J.; Seeking a

fingerprint: analysis of point processes in actigraphy recording, Journal of Statistical Mechanics: Theory and Experiment 2016, 5, 054034.
[8] Dybiec, B.; Gudowska-Nowak, E.; Sokolov I.M. Underdamped stochastic harmonic oscillator driven by Lévy noise Phys. Rev. E 2017 96, 042118.
[9] Kusmierz, L.; Dybiec, B.; Gudowska-Nowak, E.; Thermodynamics of superdiffusion generated by L_evy-Wiener uctuating
forces Entropy 2018 20, 658.
[10] Kusmierz, L.; Gudowska-Nowak, E.; Optimal first arrival times in Lévy ights with resetting Phys. Rev. E 2015 92, 052127.
[11] Kusmierz, L.; Gudowska-Nowak, E.; Subdiffusive continuous time random walks with stochastic resetting Phys. Rev. E 2019 95 052116.

Superstatistics and non-Gaussian diffusion

Ralph Metzler
Universität Postdam

ABSTRACT: In a growing number of complex systems non-Gaussian displacement distributions of diffusive processes are observed, while the mean squared displacement shows the linear time dependence of normal diffusion. At short times this behaviour can be explained with classical superstatistical approaches. Often, however, a crossover behaviour is observed: at longer times the displacement distribution assumes a Gaussian shape, with an effective diffusivity. The talk will present a minimal diffusing diffusivity model to explain such dynamic crossover behaviours for different initial conditions of the system [1]. Moreover, the associated first passage behaviour relevant for random search processes will be addressed [2]. In the range of viscoelastic anomalous diffusion, typically described in terms of fractional Brownian motion, similar non-Gaussianity is observed, and theoretical approaches will be introduced [3].

[1] A. V. Chechkin, F. Seno, R. Metzler, and I. M. Sokolov, Phys. Rev. X 7, 021002 (2017); V. Sposini, A. V. Chechkin, F. Seno, G. Pagnini, and R. Metzler, New J. Phys. 20, 043044 (2018).

[2] V. Sposini, A. V. Chechkin, and R. Metzler, J. Phys. A 52, 04LT01 (2019)

[3] J.-H. Jeon, M. Javanainen, H. Martinez-Seara, R. Metzler, and I. Vattulainen, Phys. Rev. X 6, 021006 (2016); J. Slezak, R. Metzler, and M. Magdziarz, New J. Phys. 20, 023026 (2018).

Brownian yet non-Gaussian diffusion in heterogeneous systems

Igor Sokolov
Humboldt Universität zu Berlin

ABSTRACT: Many experiments in different complex systems point onto a wide-spread behavior of displacements of tracer particles in complex systems termed Brownian yet non-Gaussian diffusion. The mean squared displacement of the tracers grows linearly in time, like in the normal, Fickian diffusion; the probability density function (PDF) of the displacements is, however, strongly non-Gaussian. At short times the PDF often approximately follows the two-sided

exponential (Laplace) pattern. We discuss the situations under which such behavior can be observed in the model of a particle's motion in a system with a diffusion coefficient slowly varying in time or in space. While in the case of the diffusion coefficient varying in time (a "diffusing diffusivity" model) this behavior is quite typical, its appearance in the spatially disordered case ("diffusivity landscape") is only possible under specific conditions, which will be discussed in detail. Thus, the corresponding behavior may only arise in the case when the diffusion (as described in Ito interpretation) is observed under equilibrated conditions, e.g. in an equilibrated trap model. We also discuss how this paradigmatic situation can be translated into the model of "diffusing diffusivity".

Jamming and Tiling of Rectangles

Eli Ben-Naim
Los Alamos National Laboratory

ABSTRACT: In this talk, I will describe aggregation and fragmentation of rectangles. In planar fragmentation, a large rectangles breaks into smaller rectangles through a series of horizontal and vertical
cuts. In the jammed state, the system consists of sticks, rectangles of minimal width and variable length which can not be broken further. Statistical properties of the jammed state including the are obtained analytically. Planar aggregation is the opposite process in which small rectangles rectangles are embedded in a plane and can only merge with nearest neighbors. In the jammed state, neighboring rectangles are incompatible, and these frozen rectangles form a tiling of the two-dimensional domain. Statistical properties of the jammed state including the area distribution are obtained numerically.

A phase transition in persistent random walks

Raúl Toral
Universidad de las Islas Baleares

ABSTRACT: Persistent random walks have been used to model self-propelled particles that are able to move with almost constant speed while randomly changing their direction of motion. Under the effect of interactions these self-propelled particles might exhibit self-organized motion where the
majority of the particles move in the same direction, a behavior known as flocking. In this talk I will analyze a simple model of continuous-time persistent random walkers from the point of view of the large deviation theory, and I will show that it displays a phase transition that bears many similarities with the Bose-Einstein condensation. I will also present a mathematical model (taking ingredients from some well-known models of collective behavior in social systems) for self-propelled particles that under appropriate conditions are capable of collective motions.

First-Passage Fixation

Sidney Redner

Santa Fe Institute

ABSTRACT: We apply first-passage ideas to determine fixation dynamics for the fluctuating voter model (FVM), in which the population size fluctuates while opinions are changing, and for a neutral model for the microbiome. In the FVM, population fluctuations lead to power distribution of fixation times with a non-universal exponent. For a neutral model of the microbiome, we determine the time needed for a closed population to reach a state that consists of only a single species. We also discuss the distribution of species abundances when migration of new species can also occur.

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42 years of agreeable disagreements

Bruce West
Army Research Office

ABSTRACT: Where else but in science can a person forge a life-long friendship based on disagreements? The focus of my remarks will be on what Katja has contribution to how I have done science since we first met and began collaborating in the 1970s. From *The non-equilibrium statistical physics of open and closed systems* by Lindenberg and West, that summarized our decade of work together, to our independent research into network science, done independently a quarter century later. I will attempt to relate the lessons learned during our collaborations, both regarding the science and the sociology of doing and recording the science. My memory is that we rarely, if ever, had to revise a paper to get it accepted for publication and how we accomplished that was one of her gifts to me. Resolve all the disagreements before sending it to the publisher.

Topics in synchronization of discrete states stochastic oscillators

Daniel Escaff
Universidad de los Andes

ABSTRACT: In this talk I will briefly review one of the research lines that we have developed with Professor Katja Lindenberg, and many other collaborators, during our collaboration in San Diego, since 2011. Starting from previous works of Katja, we addressed the question of how memory (non-markovian stochastic oscillators) affects synchronization. In this talk, I will briefly summarize our findings: namely, state dependent delays (fixed or distributed delays) may induce a first order transition to synchrony. Then, we switch our attention to non-local interaction, finding that, even when the coupling strength precludes global synchronization, the system may form a waving pattern that can be interpreted as a spatially heterogonous synchronization. Finally, I will comment on the link between these discrete state oscillators and continuous phase Kuramoto-type noisy oscillators.

Effect of fluctuations due to finite numbers in the synchronization of discrete state units

Alexandre Rosas

Universidade Federal da Paraíba

ABSTRACT: Ensembles of a finite number of interacting discrete-state units are studied and compared to the mean field (infinite population) version of the same models. It is shown that ensembles with a finite number of units and mean field ensembles (infinite number of units) may behave differently due to fluctuations in the former but not in the latter. The differences between the finite and infinite population models become increasingly prominent as the number of units increases, in contradiction with naively expected behavior. The reason for this behavior lies in the breaking of ergodicity.