V Summer School on Statistical Physics of Complex and Small Systems

Centre de Recerca Matemàtica

July 6 to 17, 2015

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Contents

1. Practical Information

Lecture room: The activity will take place in the CRM Auditorium. The CRM is located in building C (Edifici Ciències) on the "Eix central" of the UAB campus and our timetable is from 8 am to 5 pm (Monday to Friday, and 8 to 1:30 on Friday).

CRM entrance code number: sent by email

Registration and badge pick up: Will take place from 09:00 to 09:30 on **Monday, July 6**.

Computer facilities: The computer space of the CRM will be available for the participants of the course.

The timetable is Monday through Friday from 8:30 am to 6:00 pm. The CRM premises as well as most of the UAB campus have wireless access.

Wifi password: sent by email

Library: The library of the Science Building of the UAB will be open from 8:30 am to 7:30 pm on working days.

Breaks: Coffee and cookies will be served during the morning breaks.

Picture: A group picture will be taken on **Thursday, July 9**, before the coffee break. The picture will be posted on the activity's webpage.

Questionnaire: Following the directions of the CRM Governing Board, we send a questionnaire to all the people participating in activities at the CRM in order to assess their level of satisfaction. The questionnaire is anonymous and not mandatory, but we would greatly appreciate it if you could answer the questions. Thank you for your cooperation.

Local emergency numbers: General emergency (police, ambulance, fire-fighters) **call 112**.

2. Timetable

Monday, July 6	
08:30 – 09:00	Registration
09:00 – 11:00	Aurora Hernández-Machado *Biological membranes and biofluids at the microscale*
11:00 – 11:30	Poster session + Coffee break
11:30 – 13:30	Ignacio Pagonabarraga *Coarse grained dynamics and mesoscopic computational methods*
13:30 – 15:00	Lunch
15:00 – 17:00	Attendant's oral presentations
Tuesday, July 7	
09:00 – 11:00	Aurora Hernández-Machado *Biological membranes and biofluids at the microscale*
11:00 – 11:30	Poster session + Coffee break
11:30 – 13:30	Lourdes F. Vega. Invited talk *Challenges and opportunities using Statistical Mechanics modeling in the industrial world*
13:30 – 15:00	Lunch
15:00 – 17:00	Stefan Thurner *Information theory for complex systems*
Wednesday, July 8	
09:00 – 11:00	Ignacio Pagonabarraga *Coarse grained dynamics and mesoscopic computational methods*
11:00 – 11:30	Poster session + Coffee break
11:30 – 13:30	Stefan Thurner *Information theory for complex systems*
13:30 – 15:00	Lunch
15:00 – 17:00	Stefan Thurner (hands on) *Information theory for complex systems*

Thursday, July 9	
09:00 – 11:00	Stefan Thurner *Information theory for complex systems*
11:00 – 11:30	Poster session + Coffee break
11:30 – 13:30	Aurora Hernández-Machado *Biological membranes and biofluids at the microscale*
13:30 – 15:00	Lunch
15:00 – 17:00	Aurora Hernández-Machado (hands on) *Biological membranes and biofluids at the microscale*
Friday, July 10, 2015	
09:00 –11:00	Ignacio Pagonabarraga *Coarse grained dynamics and mesoscopic computational methods*
11:00 – 11:30	Poster session + Coffee break
11:30 – 13:30	Ignacio Pagonabarraga (hands on) *Coarse grained dynamics and mesoscopic computational methods*
13:30 – 15:00	Lunch
15:00 – 17:00	TBA

Monday, July 13	
09:00 – 11:00	Gunnar Pruessner *Field theory of reaction diffusion processes*
11:00 – 11:30	Poster session + Coffee break
11:30 – 13:30	Albert Díaz-Guilera *Dynamics on and of complex networks*
13:30 – 5:00	Lunch
15:00 – 16:00	David Jou. Invited talk *Entropy, temperature and second law of thermodynamics beyond local equilibrium*
16:00 – 17:00	Attendant's oral presentations
Tuesday, July 14	
09:00 – 11:00	Gunnar Pruessner *Field theory of reaction diffusion processes*
11:00 – 11:30	Poster session + Coffee break
11:30 – 13:30	Ton Coolen *Statistical physics of tailored random graphs: entropies, processes, and generation*
13:30 – 15:00	Lunch
15:00 – 17:00	Gunnar Pruessner (hands on) *Field theory of reaction diffusion processes*
Wednesday, July 15	
09:00 – 11:00	Ton Coolen *Statistical physics of tailored random graphs: entropies, processes, and generation*
11:00 – 11:30	Poster session + Coffee break
11:30 – 13:30	Gunnar Pruessner *Field theory of reaction diffusion processes*
13:30 – 15:00	Lunch
15:00 – 17:00	Ton Coolen (hands on) *Statistical physics of tailored random graphs: entropies, processes, and generation*

Thursday, July 16	
09:00 – 11:00	Ton Coole *Statistical physics of tailored random graphs*
11:00 – 11:30	Poster session + Coffee break
11:30 – 13:30	Albert Díaz-Guilera *Dynamics on and of complex networks*
13:30 – 15:00	Lunch
15:00 – 17:00	Albert Díaz-Guilera (hands on) *Dynamics on and of complex networks*
Friday, July 17	
09:00 – 11:00	Albert Díaz-Guilera *Dynamics on and of complex networks*
11:00 – 11:30	Poster session + Coffee break
11:30 – 13:30	Alex Roxin. Invited talk *Kinetic theory for neuronal networks*
13:30 – 15:00	Lunch
15:00 – 17:00	TBA

3. Abstracts

3.1. **Courses first week.**

Aurora Hernández-Machado

Biological membranes and biofluids at the microscale.

Abstract: Biological membranes are fundamental ingredients of cells. They are the boundaries which separates the intracellular components from the extracellular medium. In this course I will present theoretical and experimental results regarding physical properties of membranes and its relation with rheological properties of biofluids like blood. Mechanical properties of blood cell membranes, like the elasticity of the membrane, will be related to the elastic properties of the viscous blood flow. I will discuss rheological properties of biofluids at the microscale, such as the viscosity of blood in microfluidic devices. The effects of the walls of the device will be discussed. Different purposes of these studies are the design of lab-on-a-chip micro-devices for bio-medical analysis of diseases such sickle cell anemia, malaria and cancer.

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Ignacio Pagonabarraga

Coarse grained dynamics and mesoscopic computational methods.

Abstract: In this set of lectures I will focus on the basics of coarse grained dynamics and the use of mesoscopic computational methods to study the physical properties of complex systems.

I will discuss the theoretical foundations of some of these approaches and will describe how the knowledge of kinetic theory can be used to implement them. I will also analyze the flexibility of these approaches to address a variety of complex fluids. I will show how coarse grained models can be used and the information that can provide.

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Stefan Thurner

Information theory for complex systems.

Abstract:

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3.2. **Courses second week.**

Albert Diaz-Guilera
Dynamics on and of complex networks.

Abstract: In this set of lectures I will focus on two particular dynamical aspects of complex networks.

First, about properties of dynamical process on static networks, including networks that are hierarchically organized.

Second, about generation of networks based on some local constraints, as can be the case of origin-destination networks with applications to human mobility data, by using techniques derived from statistical physics.

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Ton Coolen
Statistical physics of tailored random graphs: entropies, processes, and generation.

Abstract: These lectures are devoted to the statistical mechanical analysis of various problems related to large but sparse complex graphs and networks, and stochastic processes that take place on such systems. Although we will solve models in the asymptotic regime, they are 'locally small' in the sense that (in contrast to simple mean field models) each component in a sparse graph feels only a finite (small) environment. The analytical tools to be used tend to be built on various flavours of the replica method and on path integrals, but they will be explained as we go along for those who are not familiar with them. The envisaged structure is roughly as follows (but I am happy to adapt plans and content to the needs of the audience):

Lecture 1: Ensembles of sparse random graphs. Loops, clustering, tree-like versus loopy graphs. Ensemble entropies. Numerical generation of tailored random graphs.

Lecture 2: The replica method. Replica analysis of processes on tailored sparse random graphs with discrete variables. Order parameters, replica symmetry, and phase transitions.

Lecture 3: Replica analysis of processes on tailored sparse random graphs with continuous variables. Order parameters, replica symmetry, and Guzai expansion.

Lecture 4: Advanced topics. Replica analysis of loopy complex graphs.

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Gunnar Pruessner
Field theory of reaction diffusion processes.

Abstract: The language of reaction diffusion processes can be used to describe many complex systems very elegantly. Powerful field theoretic tools, in particular diagrams and field theoretic renormalisation, exist to analyse the resulting theories, to determine the underlying physics and to make predictions about the asymptotic behaviour on the large spatio-temporal scale. This approach can be applied to a very wide range of phenomena in complex systems, including those with excluded volumes constraints or those "living" on networks. In the lectures, I will introduce and discuss the theory with the aim that the audience will be able to apply the techniques successfully to their problems. I will provide further discussions and exercises in the classes to get our hands dirty.

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3.3. **Keynotes.**

David Jou
Entropy, temperature and second law of thermodynamics beyond local equilibrium.

Abstract: The basic ideas of local-equilibrium thermodynamics for heat transfer in the framework of classical Fourier's law will be presented. The Fourier equation will be generalized with relaxation tems and non-local terms, and we will show how the thermodynamical consistency of the generalized transport laws requires an extension of the entropy and of the entropy flux beyond local equilibrium. Eventually, the consequences of the extended non-equilibrium entropy on the concept of temperature beyond local equilibrium will be discussed.

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Alex Roxin
Kinetic theory for neuronal networks.

Abstract:

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Lourdes F. Vega
Challenges and opportunities using Statistical Mechanics modeling in the industrial world.

Abstract: Mathematical and computer skills, an inquisitive mind, imagination, intuition and the ability to work independently are important traits developed and exercised in Physical Sciences (and Mathematics) studies. Physicist and

mathematicians are trained to deal with various physical challenges that they will find in the professional world, even though they may not be conscious of this. Indeed, in most industries and many companies, there are activities firmly based in scientific knowledge, and, therefore, there is a need for physicists and mathematician with the right skills. However, it is also important to be prepared to deal with these problems in an environment very different than the academic where one it is usually trained.

After a general introduction I will use, as an illustration, the application of a Statistical Mechanical based equation of state (Statistical Associating Fluid Theory - SAFT) to problems found in the chemical and oil industries. The equation was developed in an academic institution (Cornell University), in an industrial-supported project (with ExxonMobile) and it is well suited as an example of the need for accurate models, and the physics behind it, in the industrial world. In fact, it is the adequate coarse grain level behind SAFT what has made it a successful modeling tool in both, academia and industry.

It is well known that most industrial processes require a detailed knowledge of the thermodynamic properties, including phase and interfacial behavior and transport properties of their working fluids. Although the preferred method for obtaining these data would be the experimental one, there are several difficulties associated to it, mainly due to the great amount of data required to have a reliable database for multicomponent mixtures over a wide range of thermodynamic conditions. Theoretical approaches can be used as an alternative in this case; however, the intrinsic non-ideal behavior of these mixtures and the limited range of available experimental data pose a challenge to any theoretical method aimed at quantitative predictions of thermodynamic properties for these complex fluids, especially when the process works near the critical region, or for multicomponent systems. Due to their classical formulation most equations of state are unable to accurately describe the density (and concentration) fluctuations appearing as the critical region is approached. This problem has been tackled in recent years with great success thanks to the combination of renormalization group theories, such as the phase cell-space approximation, with accurate theoretical based equations of state, including different versions of SAFT. An additional advantage of these methods is that, as they are built from Statistical Mechanics, they can systematically been extended to other regions of the phase diagram or for other properties, with the same degree of accuracy.

We will first provide an overview on how having the right physics with the adequate level of approximations can lead to an accurate modeling tool for engineering purposes. However, and in spite of its great success, there are still challenges for SAFT being used as a standard modeling method in industry. This applies to SAFT and several other thermodynamic models. Some of these challenges and the opportunities coming with them will also be addressed here.

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3.4. **Contributions Talks.**

Daniel Østergaard

Large deviation function of an out-of-equilibrium system, bounded versus unbounded phase space.

Abstract: We investigate the properties of the large deviation function (LDF) for heat currents in systems in contact with two heat baths, and discrete energy levels. In particular, we are interested in the difference of the LDF for systems whose energy is bounded or unbounded.

In the case of continuous systems with unbounded energy, it is know that the LDF exhibits tails which decrease exponentially [1, 2, 3, 4, 5]. Interestingly, the rates of the exponential decay is given by the inverse temperatures of the two reservoirs. However, our preliminary results show that the LDF of bounded systems does not exhibit this properties. In particular we want to investigate how the finiteness of the system phase space affects the properties of the LDF, and how such properties change as the number of energy levels tends to infinity.

This is work in progress as it has proven a challenge to determine the LDF for a simple system with equispaced energy levels.

Our work is possibly also of technological interest, since it outlines a scheme to probe the temperature of microscopic heat baths. By coupling a probe system to two heat baths, one with unknown temperature, one can measure the heat current. The temperature of the other reservoir can then be determined from the statistics of the rare events, given that the temperature of first reservoir is known. In particular, the knowledge of the theoretical expression for the LDF can provide a measurement for the unknown temperature.

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Francesco Avanzini

Statistical properties of a single Bohm's trajectory.

Abstract: Quantum Mechanics represents the fundamental language for the description of material systems. Recent studies about the statistical properties of quantum pure states (wave functions) proved that the expectation values of a subsystem are nearly time independent that means the absence of fluctuations [1, 2, 3]. The Bohm theory (or pilot wave theory) is a different formulations of Quantum Mechanics and it has the advantage to represent a quantum system according to the spatial configuration of its constituents evolving in time as a fluctuating trajectory under the action of the wave-function [4, 5]. Its standard formulation invokes the statistical ensemble of all the possible trajectories in to establish the exact correspondence with the Copenhagen interpretation (Born's rule).

The Bohm theory has found many applications in Physics and Chemistry. For example, it can be employed to describe complex dynamics as the ionization of molecules [6]. Moreover the pilot wave theory has a computational role in order to reconstruct the time dependent wavefunction from a collection of evolving system's configurations or to address the semi-classical approximation of quantum mechanics [7, 8].

The pilot wave theory allows a formally self-consistent representation of quantum systems as a single Bohm's trajectory, but in this case there is no room for the Born's rule at least in its standard form. In our work, we explore the possibility of using the pilot wave theory at the level of a single Bohm's trajectory, that is a single realization of the time dependent configuration which should be representative of a single realization of the quantum system. We will show that a correspondence exists between the statistical distribution of configurations along the single Bohm's trajectory and the equilibrium quantum distribution for a subsystem interacting with the environment in a model multicomponent system [9].

This is a joint work with Barbara Fresch, Giorgio J. Moro.

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Daniel M. Busiello

Reaction-diffusion system on multiplex networks.

Abstract: Patterns are widespread in nature: regular forms and geometries, like spirals, trees and stripes, recur in different contexts. In a seminal paper Alan Turing set forth a theory by which patterns formation might arise from the dynamical interplay between reaction and diffusion in a system. Under specific conditions, diffusion drives an instability by perturbing an homogeneous stable fixed point, via an activator-inhibitor mechanism. As the perturbation grows, nonlinear reactions balance the diffusion terms, yielding the asymptotic, spatially inhomogeneous, steady state. However, the conventional approach to network theory is not general enough to ascertain the complexity that hides behind real world applications. Self-organization may proceed across multiple, inter-linked networks. For this reason, multiplex, networks in layers whose mutual connections are between twin nodes, have been introduced as a necessary leap forward in the modelling effort. Here we aim at developing the theory of patterns formation for a reaction-diffusion system defined on this latter kind of complex networks by means of a perturbative approach. The interlayer diffusion constants act as a small parameter in the expansion and the unperturbed state coincides with the limiting setting where the multiplex layers are decoupled. The interaction between adjacent layers can seed the instability of a homogeneous fixed point, yielding self-organized patterns which are instead impeded in the limit of decoupled layers. Patterns on individual layers can also fade away due to cross-talking between layers. Analytical results are compared to direct simulations.

This is a joint work with Malbor Asllani, Timoteo Carletti, Duccio Fanelli, Gwendoline Planchon.

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Maurizio Coden

Quantum statistical ensemble resilient to thermalization.

Abstract: The new possibilities to investigate single-molecule properties [1, 2] as well as the better control of the nanoscale devices suitable for quantum computing tasks [3, 4], have led to a renaissance about fundamental issues on quantum statistical mechanics. A new perspective is gaining interest in the last years [5, 6, 7], with a shift on the focus from the average of the observables to the predictability of a single realization of a system described as pure state and characterized by a wave function.

Rather than assuming a statistical density matrix, previous studies have demonstrated the possibility to obtain the thermodynamic properties of the isolated system by a statistical analysis on its pure state [8]. This corresponds to the definition of a probability distribution on the wave function. Different probability distributions have been proposed on the ground of reasonable assumptions. In particular, for the *Random Pure State Ensemble* (RPSE) [9], one can demonstrate the agreement with thermodynamic behavior when the macroscopic limit is considered [10]. However, it shows also a relevant drawback: it does not survive to the process of thermalization. When two systems, initially described by the RPSE, are brought into contact and allowed to exchange energy, the resulting equilibrium state does not follow the RPSE statistics.

To overcome this fundamental limitation, we have developed the Thermalization Resilient Ensemble (TRE), by imposing the condition of invariance of the average properties of the system in the thermalization experiment. Contrary to the RPSE ensemble, the Hilbert space directions are no more equally probable since lower energy directions results to be privileged.

The statistical anisotropy of the wave function is recovered by constraining the state vector to an anisotropic surface embedded in the Hilbert space. In particular, we show how ellipsoidal geometry can be used to generate a sampling

of the wave function for pure states unambiguously related with thermodynamic properties.

This is a joint work with Barbara Fresch, Giorgio J. Moro.

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Dániel Czégel

How to quantify hierarchy?

Abstract: Signs of hierarchy are prevalent in a wide range of systems in nature and society. One of the key problems is quantifying the importance of hierarchical organization in the structure of the network representing the interactions or connections between the fundamental units of the studied system. Although a number of notable methods are already available, their vast majority is treating all directed acyclic graphs as already maximally hierarchical. Here we propose a hierarchy measure based on random walks on the network. The novelty of our approach is that directed trees corresponding to multilevel pyramidal structures obtain higher hierarchy scores compared to directed chains and directed stars. Furthermore, in the thermodynamic limit the hierarchy measure of regular trees is converging to a well defined limit depending only on the branching number. When applied to real networks, our method is computationally effective, as the result can be evaluated with arbitrary precision by subsequent multiplications of the transition matrix describing the random walk process. In addition, the tests on real world networks provided very intuitive results, e.g., the trophic levels obtained from our approach on a food web were highly consistent with former results from ecology.

This is a joint work with Gergely Palla.

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Stefano Duca

Heterogeneous players in voluntary contribution games with contribution-based group matching.

Abstract: We study how competitive group formation in a voluntary contribution game is affected by unequal rates of return for players.

We find that, depending on the functional form of the payoff function, a high-contributing Nash equilibrium (the socially preferable outcome) might or might not exist. We also examine the effect of different ranking criteria for the group matching. Different rankings result in consequences for trade-offs between global efficiency and inquality.

This is a joint work with Heinrich Nax.

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Núria Folguera

Mathematical modelling of oncometabolic reprogramming of somatic cells.

Abstract: In our work, we aim to model the minimal gene regulatory netwok which allows differentiated cells to reprogram into pluripotent cells. This network consists of three pluripotency genes- the three Yamanaka factors: Oct4, Sox2 and Klf4- and two generic lineage-specific genes (LSGs). The main difference between our model and models previously built is the introduction of epigenetic regulation (ER) of the LSGs, which will enable to account for the effects of metabolism in the reprogramming process [1]. More precisely, ER will be expressed by the

acetylation and methylation levels of the LSGs. Acetylation and methylation, as well as deacetylation and demethylation, are assumed to be mediated by some enzymes such as the hystone demethylases (HDMs) [2]. These enzymes are the responsible for the coupling of the differentiation/reprogramming system and the metabolism.

Both asymptotic and numerical methods have been used to study our model for metabolic reprogramming. In the numerical case, Gillespie's stochastic simulation algorithm [3] has been used, whilst for studying the deterministic system, a separation of time-scales together with a quasi-steady state approximation (QSSA) have been applied. We conclude that metabolic transformations normally associated to cancer interfere with the epigenetic regulation of lineage-specific genes, thus enhancing the efficiency of the reprogramming of somatic cells by induction of the Yamanaka factors.

This is a joint work with Javier Menéndez and Tomás Alarcón.

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Joseph Hickey

Physics of legal decision making.

Abstract: Physicists have investigated legal decision making in recent years through modeling of the voting patterns of U.S. Supreme Court judges (Lee *et al.*, 2015; Guimerà and Sales-Pardo, 2011), and by analyzing the structure of the network of citations between decisions of the U.S. Supreme Court (Leicht *et al.*, 2007).

In this short presentation, I will discuss how quantitative data regarding monetary awards (damage awards) in Canadian defamation lawsuits may be analyzed using the methods of factor analysis (Dell Inc., 2013) and extreme value theory (Viscusi and McMichael, 2014; Schmittmann and Zia, 1999).

My goal in this presentation is to make my research interests known to participants at the summer school in order to get feedback and participate in discussion at this early stage in my research.

I also propose to do a poster presentation regarding preliminary ideas for mechanistic models of judicial decision making (see poster outline, below).

Poster: Modeling judicial decision making as a random Boolean network.

Abstract: Freedom of expression is guaranteed by national constitutions and by the International Covenant on Civil and Political Rights. Consequently, defamation is protected by law where a common law or statutory defence applies. This poster presents some preliminary work on the quantitative modeling of judicial decision making as a Boolean network, with particular application to the defence of fair comment in the common law of defamation. Each node in the network represents an element of evidence or an element of the fair comment defence test. The test is conjunctive and requires all yes answers for the defence to apply. Our approach considers judicial decision making as a cooperative phenomenon in which a set of evidence is represented as a set of individual components that interact according to rules in the judge's mind. Such a statistical physics-oriented approach can be used to verify or challenge ongoing qualitative and quantitative efforts in the social sciences to model judicial decision making (McCormick and Greene, 1990; Klein and Mitchell, 2010; Epstein *et al.*, 2013; Bordalo *et al.*, 2013).

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Sarah Klein

Motility states in bidirectional cargo transport.

Abstract: Intracellular cargos which are transported by molecular motors move stochastically along cytoskeleton filaments in a bidirectional manner. In particular for bidirectionally transported cargos it is an open question whether the characteristics of their motion can result from pure stochastic fluctuations or whether some coordination of the motors is needed. The results of a mean-field model of cargo-motors dynamics, which was proposed by Müller *et al.* [1] suggest

the existence of states which show bimodal distribution in the cargo velocity and number of attached motors. In their model those states would result from a stochastic tug-of-war. Here we analyse a non-mean field extension of their model, that takes explicitly the position of each motor into account. We find that those states with bimodal distributions then disappear. We show by introducing an effective synchronisation via an artificial mutual motor-motor activation, that the results of the mean-field model are recovered only in case of a strong activation in the limit of a high number of motors.

This is a joint work with Cécile Appert-Rolland, Ludger Santen.

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Daniel Molina

Stochastic processes for anomalous diffusion with biological applications.

Abstract: The progress in techniques for analysing biological cells has provided very rich in- formation on the motion of their internal individual particles. Some molecules, such as the mRNA inside living E. Coli cells, often reveals stochastic trajectories that can not be explained by means of the classical Brownian motion [1, 2]. In particular, the observed mean square displacement fits a power-law with an exponent different than 1, such that it is referred to anomalous diffusion. This particular behaviour motivates the development of new stochastic models. Working in this direction, we have analysed several variants of the so-called generalised grey Brownian motion [3]. An interesting property of this approach is the possibility to reproduce statistical behaviours belonging to two alternative approaches: the ergodic fractional Brownian motion (fBm) and the non-ergodic continuous time random walk (CTRW). In particular, the observed p-variation is similar to that which characterises the fBm while also ergodicity breaking occurs, which indeed characterises the CTRW. In addition, we were able to set the model in order to reproduce ageing, an important property that is present in several experiments with biological cells [4].

This is a joint work with Gianni Pagnini.

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Isabel Moreno

Quantifying Zipf's law in human communication systems.

Abstract: In Zipf-like systems, individual entities, here called tokens, can be classiffied into types. Zipf's law is verified when the number of tokens corresponding to any type is a power-law function of the type rank, with exponent close to one. A second formulation consists in performing the statistics of the number of types with the same number of counts, for which Zipf's law states a power-law distribution of type counts, with exponent around two. A continuum approximation yields the equivalence between the two descriptions; however, a more careful analysis unveils different count distributions in each case, as first derived by Mandelbrot in 1961. We study the suitability of these and related distributions for describing the statistics of both written texts and musical pieces.

Fitting methodology is reviewed, noting the drawbacks of using the rank representation. A procedure based on maximum likelihood estimation and Kolmogorov-Smirnov test is applied to large databases.

In this way, we find the distribution that best describes each system, which, remarkably, turns out to be the same for both texts and music.

This is a joint work with Francesc Font Clos, Joan Serrà and Álvaro Corral.

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Enrico Nale

Wigner random modeling of a quantum system.

Abstract: Chemists' interest typically involves the investigation of condensed matter systems which have a complex and random structure without any particular symmetry elements. Energy spectra of this category of systems has been analyzed theoretically since the '60s by Wigner and the idea behind these studies is the characterization of their statistical properties by ignoring the precise

physical details [1, 2]. In such theories the system's hamiltonian is modeled by a so-called Random Matrix whose elements have well defined statistical properties.

Starting from the these results we aim to develop a theoretical framework and a computational protocol in order to model quantum systems which are defined only by their density of states. Since the density of states considered as a function of the energy determines completely the thermodynamic properties of a system, our method allow us to design a system with the desired equilibrium properties [3].

The main points of the developed theoretical framework are presented and an application is shown in order to demonstrate the capability of our protocol and to highlight its potentialities. The main feature of our strategy is the complete control of the thermodynamic properties of a microscopic temperature.

This is a joint work with Giorgio J. Moro.

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Daniel Ruiz

Continuous model for clonal growth plants.

Abstract: The dynamics of growth of clonal plants is well understood in terms of the development of a single plant. The growth of the meadows can be modeled accurately taking into account the main processes of growth.

Starting from previous results of growth models of clonal plants [Sintes2005] we develop continuous models of vegetation patterns (from the microscopic relations towards a macroscopic description) that could serve to identify the relevant physical and biological mechanisms leading to the observed population structures in Posidonia oceanica meadows. Although it is clear that the interaction between plants and nonlinearity play a crucial role, the mechanisms behind the emergence of these spatial structures are still not well understood.

This is a joint work with Damià Gomila, Tomàs Sintes, Emilio Hernández-García

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Bálint Jenö Tóth

Picturask: An experiment on the emergence of hierarchy between humans.

Abstract: Flow hierarchy is best described as an acyclic, treelike graph of asymmetric relationships between the actors of a system [1]. In nature, social structures of animals or humans often exhibit this property. Although the phenomena has been wellobserved in multiple systems [25], it is still unclear what the necessary conditions are for its emergence, and what its consequences are on the overall efficiency of a given community. We argue that imitation combined with subjective knowledge about the performance of the other actors is one sufficient condition of the emergence of hierarchy. This is supported by our experiments conducted with an online dot guessing game with approximately 140 volunteers.

In my short presentation I will describe the most important aspects of the game, and also give a preliminary overview of our findings. On my poster I will give a more detailed explanation of the methodology used for the data analysis.

This is a joint work with Enys Mones, Nóra Páll, Péter Pollner, Gergely Palla and Tamás Vicsek.

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Mapping irreversible thermodynamics into quantum mechanics.

Abstract: To elaborate on the problem of irreversibility VS unitarity, we present a thermodynamical theory that is dual to quantum mechanics, motivated by the Chapman-Kolmogorov equation. We interpret the analytic properties of the functional spaces involved (non-existence of scalar product, absence of a denumerable basis, non-reflexivity) as being a source of irreversibility. As an example, we study the point spectrum of the harmonic oscillator in the irreversible thermodynamics representation.

This is a joint work with P. Fernández de Córdoba, J.M. Isidro, Milton H. Perea.

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