XXIV National Conference on Statistical Physics and Complex Systems

in collaboration with the **Department of Physics and Astronomy** of the **University of Florence**, the **IMT School for Advanced Studies Lucca** and the **Italian National Institute for Nuclear Physics**

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Conference Center - Aule delle Scienze, University of Parma - Campus

List of Oral Presentations

Salvatore Miccichè - *Università degli Studi di Palermo*
Anagraphical relationships in Cosa Nostra network communities
The aim of the present work is to investigate the role of anagraphical relationships amongst mafia members by making use of unconventional network-based techniques. A distinctive feature of our investigation is that it is based on the analysis of the crime records (*Certificati Penali*) of a set of 632 affiliates to Cosa Nostra selected from a set of 135 judgements emitted by the *Tribunale di Palermo* from 2000 to 2014. Such set represents 10% of the whole population recognized to be affiliated to Cosa Nostra, according to the records of the Palermo Prosecutor Office. Moreover, the Registry Office of the Palermo municipality provided us in an anonymized form the information about the anagraphical relationships amongst 235 subjects condemned for mafia crimes. With this additional information the number of subjects considered in the study raised to 3989. We thus constructed the network of the anagraphical relationships amongst these subjects. Such anagraphical-based network contains about 3400 nodes and about 5000 links. We modified the anagraphical-based network by grouping together all nodes representing subjects belonging to the same mafia clan. We therefore have two types of nodes in the modified anagraphical-based network: nodes representing individuals, and nodes representing mafia clans. We can observe that 98.8% of affiliates to mafia clans are males. When considering the network nodes outside the mafia clans we observe that about 45% of the nodes are representing male subjects and about 50% of the nodes are representing female subjects. Despite these facts, the striking result is that in the large majority of cases the nodes that allow the connection between two given mafia clans, according to the shortest path, are representing female subjects. Moreover the total number of female subjects involved is 19, which is an incredibly small number. This clearly shows that the role of anagraphical relationships becomes extremely important when the links between different communities are considered. In particular, the role of female subjects emerges as crucial in setting up relationships amongst different social groups and determine alliances and splittings.

Cecilia Vernia - *Università di Modena e Reggio Emilia*
Inverse Problem in Mean-Field Models
We consider the inverse problem for a class of mean-field models: the Curie-Weiss model together with its multi-species version and the monomer-dimer model with attractive interaction. The inversion is obtained by analytically identifying the model parameters in terms of the correlation functions. We discuss the numerical robustness of the inversion procedure that strongly depends on the phase in which the system is. As a test problem we use a data set coming from a health screening campaign conducted in the district of Parma to derive a quantitative estimate of the mutual influence between participating groups.

Simona Olmi - *Inria Sophia Antipolis Méditerranée Research Centre*
Controlling seizure propagation in large-scale brain networks
Information transmission in the human brain is a fundamentally dynamic network process. In partial epilepsy, this process is perturbed and highly synchronous seizures originate in a local network, the so-called epileptogenic zone (EZ), before recruiting other close or distant brain regions. We studied patient-specific brain network models of 15 drug-resistant epilepsy patients with implanted stereotactic electroencephalography (SEEG) electrodes. Each personalized brain model was derived from structural data of magnetic resonance

imaging (MRI) and diffusion tensor weighted imaging (DTI), comprising 88 nodes equipped with region specific neural mass models capable of demonstrating a range of epileptiform discharges. Each patient's virtual brain was further personalized through the integration of the clinically hypothesized EZ. Subsequent simulations and connectivity modulations were performed and uncovered a finite repertoire of seizure propagation patterns. Across patients, we found that (i) patient-specific network connectivity is predictive for the subsequent seizure propagation pattern; (ii) seizure propagation is characterized by a systematic sequence of brain states; (iii) propagation can be controlled by an optimal intervention on the connectivity matrix; (iv) the degree of invasiveness can be significantly reduced via the proposed seizure control as compared to traditional resective surgery. To stop seizures, neurosurgeons typically resect the EZ completely. We showed that stability analysis of the network dynamics, employing structural and dynamical information, estimates reliably the spatiotemporal properties of seizure propagation [1]. This suggests novel less invasive paradigms of surgical interventions to treat and manage partial epilepsy.

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Miguel A. Muñoz - *Universidad de Granada & Università di Parma*

Jensen's force and the statistical mechanics of cortical asynchronous states

Cortical networks are shaped by the combined action of excitatory and inhibitory interactions. Among other important functions, inhibition solves the problem of the all-or-none type of response that comes about in purely excitatory networks, allowing the network to operate in regimes of moderate or low activity, between quiescent and saturated regimes. Here, we elucidate a noise-induced effect that we call "Jensen's force" –stemming from the combined effect of excitation/inhibition balance and network sparsity– which is responsible for generating a phase of self-sustained low activity in excitation-inhibition networks. The uncovered phase reproduces all key empirically-observed features of cortical networks in the so-called asynchronous state, characterized by low, un-correlated and highly-irregular activity. The parsimonious model analyzed here allows us to resolve a number of long-standing issues, such as proving that activity can be arbitrarily low, but self-sustained even in the complete absence of external stimuli or driving. The simplicity of our approach allows for a deep understanding of asynchronous states and of the phase transitions to other standard phases it exhibits, opening the door to reconcile, asynchronous-state and critical-state hypotheses, putting them within a unified framework. We argue that Jensen's forces are measurable experimentally and might be relevant in contexts beyond neuroscience.

Mario Nicodemi - *Università di Napoli "Federico II"*

Models of Polymer Physics for the 3D Structure of Chromosomes

Principled approaches from polymer physics are important to make sense of the complexity of experimental data on chromosome 3D architecture and to explain their underlying molecular mechanisms. I discuss first the current picture of the spatial organisation of our DNA across genomic scales at the single cell level, as emerging from recent technologies such as GAM [1]. Next, I discuss how different models of polymer physics can help understanding the origin of the patterns in the data and the underlying folding mechanisms [2,3]. Finally, I show that polymer physics can be used to predict the impact of large mutations (Structural Variants) on chromosome structure, in particular on how the network of contacts between genes and regulators is rewired, hence enabling the identification of their pathogenic potential [3,4].

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[2] M. Barbieri, ..., M. Nicodemi*, A. Pombo*, Active and poised promoter states drive folding of the extended HoxB locus in mouse embryonic stem cells. Nature Struct. Mol. Bio, 24, 515 (2017).
[3] S. Bianco, ..., S. Mundlos*, M. Nicodemi*, Polymer physics predicts the effects of structural variants on chromatin architecture, Nature Genetics 50, 662 (2018).
[4] B.K. Kragesteen, ..., M. Nicodemi*, S. Mundlos* and G. Andrey*, Dynamic 3D Chromatin Architecture Determines Enhancer Specificity and Morphogenetic Identity in Limb Development, Nature Genetics 50, 1463 (2018).

Federico Corberi - *Università di Salerno*

Geometrical properties of phase-ordering systems

The geometrical properties of aggregates which form and grow after a quench of a binary ferromagnetic system across its critical temperature are reviewed. Such properties are rather different, depending on the observation scale. On lengthscales much larger than the typical size L of the growing ordered domains the morphology is that of critical random percolation and is therefore fractal. On lengthscales much smaller than L, instead, growing domains are compact objects. The boundary of such domains, is flat or rough and fractal depending on on the absence/presence of quenched disorder. We discuss how this complex structure informs the scaling properties of observable quantities.

Luca Leuzzi - *CNR-NANOTEC Roma*

Statistical mechanics of light amplification in random media: an awesome mixture of nonlinearity, ergodicity-breaking, glassiness, mode-locking and energy condensation

A unified theory of multimode light amplification in systems ranging from ordered cavities to random media is presented. The leading model, derived from fundamental light-matter interaction, is a phasor spin-glass model with multi-mode coupling, undergoing gain saturation, i. e., a spherical complex multi-p-spin model. Through analityc theoretical approaches, numerical simulations and experimental measurements we have been investigating the phenomenon called "random laser", displaying many interesting properties: a lasing phase transition, ergodicity breaking, glassiness at high power pumping, energy condensation, and nonlinear mode-locking. Replica Symmetry Breaking theory allows to identify a laser critical point at a certain pumping power and different kinds of randomness in the high pumping regime, including the most complex and intriguing glassy randomness. At the same critical point a breakdown of energy equipartition occurs among light modes, a signature of broken ergodicity typical of non-linear systems. Unlike in systems with intrinsic localized variables like, e.g., the Ising, XY or Heisenberg spins, the overall intensity shared by all modes eventually condenses in a few of them as the coupling network is diluted enough. A particularly relevant connectivity regime is the case of coexistence of partial energy equipartition and energy consensation. An intensity fluctuation overlap parameter is introduced, measuring the correlation between intensity fluctuations of waves. It allows to identify the laser transition in random media and its possible high pumping glassy nature in terms of emission spectra data, the only data so far accessible in random laser experimental measurements. Investigating pulse-to-pulse fluctuations in real organic random lasers, the distribution of intensity fluctuation overlaps, indeed, yields evidence of a transition to a glassy light phase compatible with a replica symmetry breaking. In ultra-fast multi-mode lasers, mode-locking is implemented by means of ad hoc devices, like saturable absorbers or modulators, allowing for very short pulses. Our theory predicts that the same nonlinear locking of modes would occur in random lasers, though in absence of any device. This is confirmed through detailed analysis of experimentally measured multi-mode space correlations in cavity-less powder random lasers. Last, but not least, complicated properties of the material composing the random laser, like the so far inaccessible nonlinear optical response, can be learned as an inverse problem.

Vittorio Loreto -*SONY Computer Science Laboratories & Sapienza Università di Roma & Complexity Science Hub Vienna*

Exploring the adjacent possible: play, anticipation, surprise

Novelties frequently occur in our individual daily lives. We meet new people, learn and use new words, listen to new songs, watch a new movie, adopt new technology. Such unique experiences sometimes happen by chance. Often they are triggered by earlier new experiences, thus providing a compelling correlation between their appearances. Historically the notion of the "new" has always offered challenges to humankind. What is new often defies the natural tendency of humans to predict and control future events. Still, we base most of our decisions on our expectations about the future. From this perspective, a deep understanding of the underlying mechanisms through which novelties emerge and humans anticipate their occurrence is key to progress in all sectors of human activities. The common intuition that one new thing often leads to another is captured, mathematically, by the notion of "adjacent possible", i.e., the set of all those things (ideas, linguistic structures, concepts, molecules, genomes, technological artifacts, etc.) that are one step away from what actually exists, and hence can arise from incremental modifications and recombination of existing material. In this talk, I'll present a mathematical framework, describing the expansion of the adjacent possible, whose predictions are borne out in several data sets drawn from social and technological systems.

Andrea Di Gioacchino - *Università di Milano & INFN*

Exact value for the average optimal cost of bipartite traveling salesman problem in two dimensions

Standard analytical statistical physics techniques, such as the replica and cavity methods, allow to compute typical properties of combinatorial optimization problems in infinite dimensions, as long as the random variables that describe the specific instance of the problem are uncorrelated. However, in finite dimension correlations between random variables are not negligible anymore, and new techniques are needed. In this contribution we address this issue for the bipartite version of the paradigmatic traveling salesman problem in two dimensions. We propose a novel scaling argument, which allows us to obtain the average optimal tour length in the thermodynamic limit. This provides one of the few cases where this observable can be computed for combinatorial optimization problems in two dimensions, despite the difficulty introduced by Euclidean correlations.

Tiziano Squartini - *Scuola IMT Alti Studi Lucca*

Detecting Mesoscale Network Structures

Detecting the presence of mesoscale structures in complex networks is of primary importance: this is especially true for financial networks, whose structural organization deeply affects their resilience to events like default cascades, shocks propagation, etc. The definition of a set of techniques aimed at revealing the many ways a networked system can self-organize itself would be, thus, desirable. So far, several methods have been proposed to detect communities, i.e. groups of nodes whose internal connectivity is significantly large. Communities, however do not represent the only kind of mesoscale structures characterizing real-world networks: other examples are provided by bow-tie structures, core-periphery structures and bipartite structures. Here we propose a unifying framework to detect statistically-significant mesoscale structures, based on the family of the surprise-like score functions. Briefly speaking, the actual network topology is compared with a null model retaining only some features of the former and acting as a benchmark against which the significance of the observed patterns is assessed: remarkably, such a recipe can be implemented to reveal mesoscale structures in both binary and weighted networks. To illustrate the performance of our methods, we employ our framework to study the temporal evolution of economic and financial systems across 2008: signals of the crisis are clearly visible as the topological structure of the considered networks evolve from core-periphery to bipartite. As our results suggest, these techniques may be employed to carry out a sort of high-frequency monitoring of economic and financial systems, in order to reveal significant deviations from some expected pattern in real time.

Massimo Palma - *Università degli Studi di Palermo*

Large deviation theory of quantum jump statistics in a chiral waveguide

Resonance fluorescence, consisting of light emission from an atom driven by a classical oscillating field, is well-known to yield a sub-Poissonian photon counting statistics. This occurs when only emitted light is detected, which corresponds to a master equation (ME) unraveling in terms of the canonical jump operator describing spontaneous decay. Formally, an alternative ME unraveling is possible in terms of a shifted jump operator. We show that this shift can result in sub-Poissonian, Poissonian or super-Poissonian quantum jump statistics. This is shown in terms of the Mandel Q parameter in the limit of long counting times, which is computed through large deviation theory. We present a waveguide-QED setup, comprising a chiral waveguide coupled to a driven atom, where photon counting is described by the considered class of shifted jump operators.

Pasquale Calabrese - *SISSA-Trieste*

Entanglement and thermodynamics in non-equilibrium quantum systems

Entanglement and entropy are key concepts standing at the foundations of quantum and statistical mechanics. In the last decade the study of the non-equilibrium dynamics of isolated quantum systems revealed that these two concepts are intricately intertwined. Although the unitary time evolution ensuing from a pure initial state maintains the system globally at zero entropy, at long time after the quench local properties are captured by an appropriate statistical ensemble with non zero thermodynamic entropy, which can be interpreted as the entanglement accumulated during the dynamics. Therefore, understanding the post-quench entanglement evolution unveils how thermodynamics emerges in isolated quantum systems.

Amos Maritan - *Università di Padova*
Optimality and Scaling in Living Systems and Ecological Communities

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Michele Caselle - *Università di Torino*
Statistical Physics and Systems Biology
Since the completion of the Genome project at the beginning of this century, several interesting results have been obtained in Molecular Biology using tools and ideas borrowed from Statistical Physics. This talk will present two exemplary applications of this approach. In the first example we use a combination of stochastic analysis and network theory to identify and characterize the regulatory strategies adopted by eukaryotic cells to guarantee fine tuning of gene expression within the cell and mantain an optimal control of stochastic fluctuations in the amount of produced proteins. In the second example, data mining tools inspired by statistical physics are used to identify cancer driver genes and to optimize disease subtype annotations from gene expression data. In this case the final goal is to refine therapeutic strategies in the so-called "precision medicine" framework.

Filippo Colomo - *INFN Firenze*
Arctic curves and limit shapes
We shall review the state of the art in the field, and, time permitting, illustrate some of its numerous connections with other branches of mathematics and physics, ranging from algebraic combinatorics to Quantum Quenches.

Andrea Puglisi - *ISC-CNR Roma*
Similarities between granular and active matter
Agitated grains of sand and living bacteria share an important physical property: they are not in thermal equilibrium with their surroundings. In fact a current of energy flows from the high energy reservoir (shaker or nutrients) to the low energy one (environment). In this talk I will try to sketch some analogies in the statistical behavior of the two classes of systems. First I will consider a recent granular experiment with vibrofluidized steel spheres (also reproduced by detailed numerical simulations) where collective motion spontaneously emerges as the "temperature" is reduced or the density is increased. Then I will consider a recent simple model for self-propelled particles on a lattice, with aligning interactions, where polar order is also observed at low temperature/high density. A discussion of "hydrodynamic" theories will support this analogy.

Edgar Roldan - *ICTP Trieste*
Martingale theory of stochastic thermodynamics
We describe fluctuations of thermodynamic quantities in mesoscopic systems using martingale theory a key tool used to describe fair financial markets and gambling stategies. Identifying martingales in stochastic thermodynamics, we derive equalities and inequalities for the extreme-value, stopping-time and passage statistics of the entropy production and heat in both classical and quantum mesoscopic systems driven away from equilibrium. These results include fluctuation theorems at random times, second laws at first-passage times, and the so-called "infimum law" for extreme reductions of entropy production. In this talk, I will discuss recent work within the framework of the "martingale theory" for stochastic thermodynamics, both in the theoretical and experimental context. Furthermore, I will briefly discuss applications of this refreshing framework to extreme-value statistics of molecular motors and nanoelectronic systems.

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[2] S. Pigolotti, I. Neri, E Roldan, F Fulicher, PRL 119 (14), 140604
[3] G Manzano, R Fazio, E Roldan, arXiv 1903.02925 (PRL, in press)
[4] R Chetrite, S Gupta, I Neri, E Roldan, EPL 124, 60006 (2018) - Editor's choice

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Livio Nicola Carenza- *Università di Bari*
Mesoscopic Active Turbulence and Multi-Scale Control of Active Emulsion
Constituents of active matter inject energy in their surroundings, on scales much smaller than the system size, thus keeping the system far from thermodynamics equilibrium. Many examples of active matter evolve in the low Reynolds number regime, such as suspensions of bacteria or microtubules. It is somehow surprising that this kind of systems exhibit a behavior reminescent of inertial turbulence [1]. Here a fluid, comprising a mixture of a polar active material and a passive solvent, is considered [2] in presence of a surfactant favouring emulsification of the two species; this allows for the confinment of the turbulent behavior in one of the two phases, by triggering the typical size of active domains, i.e. the characteristic lengthscales of energy injection. Quantitative analysis of kinetic energy spectra and fluxes shows that the system develops a multi-scale dynamics due to the existence of a flux induced by the active stress only, without the presence of a turbulent cascade. An increase in the intensity of active doping induces drag reduction due to the competition of elastic and dissipative stresses against active forces. Furthermore a non-homogeneous pattern of activity in the bulk induces a localized response opening the way toward the control of active flows by external doping.

Carlo Baldassi - *Università Bocconi - Milano*
The statistical physics of wide flat minima in neural network landscapes
Learning in Deep Neural Networks takes place by minimizing a non-convex high-dimensional loss function. In current practice, the learning process is often observed to somehow avoid getting stuck in local critical points, and to get to good minima that avoid overfitting. How these two features can be kept under control in nonlinear devices composed of millions of tunable connections is a profound and far reaching open question. In recent years, we have developed a framework based on a large-deviation statistical physics analysis of simplified models (and corroborated by numerical simulations on more realistic ones) that suggests some answers in terms of the geometrical properties of the optimization landscape. We have found that, in a surprisingly wide variety of models, "bad" minima coexist with rare "wide flat minima" regions (or "high local entropy" regions) with good generalization properties. We have developed a series of algorithmic schemes that make such regions accessible (ranging from MCMC, to message-passing, to local search algorithms, to quantum annealing). We have also found that some of the heuristic techniques used in current neural network practice bias the search towards such wide flat minima. Finally, we have observed that targeting such regions can significantly boost automatic feature extraction in unsupervised models (autoencoders).

Vito Latora - *Queen Mary University of London & Università di Catania*
Simplicial models of social contagion
Complex networks have been successfully used to describe the spread of diseases in populations of interacting individuals. Conversely, pairwise interactions are often not enough to characterize social contagion processes such as opinion formation or the adoption of novelties, where complex mechanisms of influence and reinforcement are at work. Here we introduce a higher-order model of social contagion in which a social system is represented by a simplicial complex and contagion can occur through interactions in groups of different sizes. Numerical simulations of the model on both empirical and synthetic simplicial complexes highlight the emergence of novel phenomena such as a discontinuous transition induced by higher-order interactions. We show analytically that the transition is discontinuous and that a bistable region appears where healthy and endemic states co-exist. Our results help explain why critical masses are required to initiate social changes and contribute to the understanding of higher-order interactions in complex systems.

Giulia Cencetti - *Università di Firenze*

Turing patterns on complex networks in absence of diffusion

In this talk, I will review the theory of pattern formation for a reaction-diffusion system defined on a complex network. I will then extend the analysis to a general multi-species model, assuming that local interactions can be scaled by the node degree, following a mean field working ansatz. In this case, the species are not relocating in space but they mutually interfere via long-ranged couplings. The onset of the instability, which anticipates the emergence of self-organized patterns, is traced back to a linear dispersion relation that is shaped by the spectrum of an unconventional Laplacian operator. This latter stems from the purely reactive couplings between immobile species, thus permanently anchored to the nodes they are bound to. The effect of short and long-range interaction will also be explored. As an example, I will discuss the emergence of a generalized Benjamin-Feir instability for a collection of Stuart-Landau oscillators coupled through their linear terms. Applications to systems of coupled Lotka Volterra equations will be also discussed.

Giacomo Gradenigo - *Sapienza Università di Roma*

Many-body Localization in the Discrete Non-Linear Schrödinger Equation: mechanism of a First-Order Transition in the Microcanonical Ensemble

When constrained to high energies, the wave function of the non-linear Schrödinger equation on a lattice becomes localized. We demonstrate here that localization occours as a first-order transition in the microcanonical ensemble, in a region of phase space where canonical and microcanonical ensembles are not equivalent. Quite remarkably, the transition to the localized non-ergodic phase takes place in a region where the entropy of the system grows sub-extensively with the size of the system, $S_N\ N^{1/3}$, signalling a shrinking of phase space quite typical of broken ergodicity phases. The detailed study of $S_N(E)$ reveals that the first-order derivative of the entropy has a jump at the critical energy E_c, hence the transition is first order. The negative temperature of the localized phase emerges naturally in the microcanonical ensemble, without invoking any kind of "effective" long-range interactions. The first-order nature of the transition is further assessed by the study of participation ratios.

List of Ignite Talks

Guido Caldarelli - *Scuola IMT Alti Studi Lucca*
Statistical Physics of Real World Networks

Andrea Cavagna - *ISC-CNR Roma*
Renormalization group approach to the collective behaviour of strongly correlated biological systems

Giuseppe Gonnella - *Università di Bari*
A journey in equilibrium and nonequilibrium statistical mechanics: from hard disks, melting and percolation transitions to active brownian particles and singular rate functions

Enzo Marinari - *Sapienza Università di Roma*
Statistical Mechanics of Disordered and Complex Systems

Giuseppe Mussardo - *SISSA - Trieste*
Statistical Field Theory

Angelo Vulpiani - *Sapienza Università di Roma*
What I would like to understand in the next decade

List of Poster Presentations

Ihusan Adam - *Università di Firenze*

Unravelling the topological arrangements and selected reaction parameters from global measurements of an extended neural model

Living brains show immensely complex dynamics that are often modelled by ensembles of simple neuron models connected through a network of intricate structure. The complexity displayed by these systems stem from the topology of the network support. To gain an insight into this problem, we propose and test a procedure that is aimed at reconstructing the a priori unknown architecture of the embedding network. To this end we consider and extended model of Leaky-Integrate and Fire (LIF) neurons with short-term plasticity. The neurons are coupled to directed network and display a level of heterogeneity in the associated current a, which dictates the firing regime in which a neuron is operating in. The aim of the method is to recover the distribution of connectivity $\tilde{k}$ of the underlying networks as well as the distribution of the assigned a. Our approach to the inverse problem makes use of the celebrated Heterogenous Mean-Field (HMF) approximation to rewrite the dynamics of the system by splitting the types of neurons into classes which reflect the associated a and in-degree $\tilde{k}$. The HMF reduction scheme allows us to in essence, create a mesh on the space defined by the variables a and $\tilde{k}$ in such a way that all possible neurons fall within this space. he two sought distributions of $P(a)$ and $P(\tilde{k})$ are then the correct solutions that sum the classes of neurons to reproduce the global field that was obtained by simulating the original model. We have tested this on synthetic data, where the global field was generated by a random network and a bell-shaped distribution of currents, and here the method captures the two distributions remarkably well and manages to almost exactly reproduce the global field.

Irene Adroher-Benítez - *SISSA Trieste*

Modelling branching polymers in different solvent conditions

Branching polymers are very versatile systems, which can be found in industrial processes as well as in biological ones. In particular, we are interested in the considerable analogy that their behaviour exhibits with the crumpling of topologically constrained ring polymers and chromosomes. Our final goal in this direction is to understand the spatial architecture and dynamics of the genomic material inside the nucleus of eukaryotic cells, since it may play an determinant role in many processes. With this aim, a combination of computer simulations, Flory theory and scaling relations were employed to study the connectivity and conformational statistics of different configurations of 3-dimensional branched polymers in good solvent conditions. However, in these cases to model the short-range interactions only the excluded volume repulsion was considered. But we are aware that to model chromosomes specific interactions between monomers should be taken into account. Therefore, in our last work we have studied the behaviour of randomly branched polymers in θ-solvent in 2 and 3 dimensions by means of Monte Carlo simulations to construct a model that considers the three-body interactions. This study itself provides valuable information about randomly branching polymers, but also it is the first step to develop a model for branching copolymers, which will help us to understand the physics of chromatin fibers.

Federico Battiston - *Central European University - Budapest*
Reactive Random Walkers on Complex Networks
We introduce and study a metapopulation model of random walkers interacting at the nodes of a complex network. The model integrates random relocation moves over the links of the network with local interactions depending on the node occupation probabilities. The model is highly versatile, as the motion of the walkers can be fed on topological properties of the nodes, such as their degree, while any general nonlinear function of the occupation probability of a node can be considered as local reaction term. In addition to this, the relative strength of reaction and relocation can be tuned at will, depending on the specific application being examined. We derive an analytical expression for the occupation probability of the walkers at equilibrium in the most general case. We show that it depends on different order derivatives of the local reaction functions and not only on the degree of a node, but also on the average degree of its neighbours at various distances. For such a reason, reactive random walkers are very sensitive to the structure of a network and are a powerful way to detect network properties such as symmetries or degree-degree correlations. As possible applications, we first discuss how the occupation probability of reactive random walkers can be used to define novel measures of functional centrality for the nodes of a network. We then illustrate how network components with the same symmetries can be revealed by tracking the evolution of reactive walkers. Finally, we show that the dynamics of our model is influenced by the presence of degree-degree correlations, so that assortative and disassortative networks can be classified by quantitative indicators based on reactive walkers.

Physical Review E 98 (5), 052302 (2018) by Giulia Cencetti, Federico Battiston, Duccio Fanelli, Vito Latora

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Miguel Ibáñez Berganza - *Sapienza Università di Roma*
Optimal accuracy/complexity trade-off in Maximum Entropy inference: an application to brain science
In the under-sampling regime, statistical inference algorithms suffer from overfitting, or the excessive dependence of the inference results on the spurious or non-significant details of the dataset. We will compare various strategies of overfitting mitigation in the framework of Maximum Entropy (MaxEnt) inference. According to such methods, the MaxEnt inferred parameters are not set by likelihood maximisation. Rather than reproducing the raw experimental correlations, the model is required to reproduce only the correlations resulting statistically significant within an optimal significance soil. We will present an illustration of such techniques in the inference of human resting-state brain activity retrieved by functional Magnetic Resonance Imaging (fMRI).

Marco Bianucci - *ISMAR-CNR*
Optimal Fokker Planck Equation for a large class of stochastic and chaotic dynamical systems
We present the optimal Fokker Planck Equation (FPE) for the probability density function (PDF) of a general class of stochastic and chaotic dynamical systems. Using a clear and sound framework, that consists of a revisited and corrected version [1] of the Kubo's theory of Generalized Cumulants [2-3] and exploit the recent Lie approach to the evolution of differential operators [4], we generalize some "sparse" classical results we can find in literature (e.g.[5] and references therein). A crucial assumption of t he present work is the finite time scale of the dynamics of the variables that we do not observe directly. This is the very classical hypothesis that underlies the emergence, for large time scales, of effective Markovian processes for the system of interest, hypothesis that in the physics literature of the last fifty years has been largely discussed and questioned. The results hold true in general for weak interactions between the system of interest and the hidden variables, and, in some cases, far beyond the limit of weak interaction.

References
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approach". Submitted
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Davide Botto - *Politecnico di Torino*
Unbalanced Langmuir kinetics affects TASEP dynamical transitions: mean-field theory
Within a mean-field approximation, we study the dynamical transition in the Totally Asymmetric Simple Exclusion Process with open boundaries and Langmuir kinetics (TASEP-LK). The dynamical transition corresponds to a singularity in the slowest relaxation rate of the system which is not accompanied by any change in the steady state properties and, for the TASEP, it was located exactly on the phase diagram. In the high-density phase, this transition separates a region (which can be called fast) in which the relaxation rate is higher and depends only on the extraction parameter, that determines the steady state bulk density, from a slow region in which the rate is smaller and depends also on the injection parameter. Extending a previous work [1], where the analysis was restricted to the case with equal binding and unbinding rates, we study the smallest eigenvalue of the mean-field relaxation matrix in the more general case of unbalanced rates. We observe a new kind of dynamical transition, whose behaviour shows some analogies with ordinary equilibrium first-order transitions.

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Giovanni Catania - *Politecnico di Torino*
Density Consistency on discrete graphical models
Computing marginal distributions of discrete graphical models is a fundamental problem with a vast number of applications in many fields of science. However, the problem is typically intractable as it scales exponentially with the system size and therefore approximation schemes are needed to estimate marginal distributions. We present a new family of approximation schemes called Density Consistency. The scheme computes exact marginals on acyclic graphs as Belief Propagation: in addition, it includes some loop corrections, i.e. it takes into account correlations coming from long cycles in the factor graph. The method is also similar to Adaptive TAP but with a different consistency condition. Results on random connectivity and finite dimensional Ising and Edward-Anderson models show a significant improvement with respect to the Bethe (tree) approximation in all cases, and significant improvement with respect to Cluster Variational Methods and other loop correction schemes in many cases. We also estimate the phase diagram of homogeneous Ising Models on hypercubic lattices. In particular, for the critical inverse temperature β_c the $1/d$ expansion of $(d\beta_c)^{-1}$ of the proposed scheme turns out to be exact up to the d^{-4} order.

Gloria Cecchini - *Università di Firenze*
Tracking propagation patterns in mice before and after stroke
The ability to find propagation patterns is a useful tool that can have various applications in many disciplines, such

as climatology and neuroscience. Here we investigate neuronal activity propagation patterns in mice brain during motor tasks. Namely, using wide-field calcium imaging, the cortical activity has been recorded during forelimb movements. Analysing the pixels of the recorded image, we construct a raster plot of the occurrence of discrete events. Applying multivariate techniques, global events, i.e., events that occur quasi-simultaneously in the majority of the pixels, are selected for the analysis, and propagation patterns are found for each one of them. Using the singular value decomposition, we are able to detect the direction of the propagation and thus identify two main classes of propagation patterns. In addition, we investigate whether a stroke, induced in the motor cortex, affects such patterns, and in particular we focus on the angle of the direction of the propagation. We evaluate if this could be used as an indicator of recovering after the stroke.

(authors and co-authors in alphabetic order: Ihusan Adam, Gloria Cecchini, Emilia Conti, Duccio Fanelli, Thomas Kreuz, Roberto Livi, Anna Letizia Allegra Mascaro, Francesco Saverio Pavone, Alessandro Scaglione)

Giulio Cimini - *ISC-CNR Roma*

Fragility and anomalous susceptibility of weakly interacting networks

Percolation is a fundamental concept that brought new understanding on the robustness properties of complex systems. Here we consider percolation on weakly interacting networks, that is, network layers coupled together by much less interlinks than the connections within each layer. For these kinds of structures, both continuous and abrupt phase transition are observed in the size of the giant component. The continuous (second-order) transition corresponds to the formation of a giant cluster inside one layer, and has a well defined percolation threshold. The abrupt transition instead corresponds to the merger of coexisting giant clusters among different layers, and is characterised by a remarkable uncertainty in the percolation threshold, which in turns causes an anomalous trend in the observed susceptibility. We develop a simple mathematical model able to describe this phenomenon and to estimate the critical threshold for which the abrupt transition is more likely to occur. Remarkably, finite-size scaling analysis in the abrupt region supports the hypothesis of a genuine first-order phase transition.

Mattia Conte - *Università di Napoli "Federico II"*

Polymer Physics captures key principles of genome folding at both population and single-cell level

Understanding the molecular mechanisms underlying the three-dimensional architecture of the genome is one of the most challenging problems in biology, currently open and debated. Models from Polymer Physics have been employed to investigate the structure of the cell nucleus, even though a unified quantitative framework describing the complex spatial chromosome organization is still lacking. In the last few years, the Strings and Binders Switch (SBS) model, a phase-separation-based polymer approach, has been shown to recapitulate average behaviour of entire chromosomes [1] as well as to predict, with a very high accuracy, the impact of structural mutations on chromosome architecture [2]. Here, we present some preliminary results concerning the SBS modeling of a DNA region cohesin-depleted, recently investigated by high resolution imaging experiments [3]. We show that the SBS polymer model can reproduce with high precision the experimental data at both the population and single-cell level. Moreover, our model provides also a possible explanation of the role of the cohesin in driving genome folding.

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Antonio De Candia - *Università di Napoli*

Information capacity of a network of spiking neurons

We study a model of spiking neurons, with recurrent connections that result from learning a set of spatio-temporal patterns with a spike-timing dependent plasticity rule. We investigate the ability of the network to store and selectively replay multiple patterns of spikes, with a combination of spatial population and phase-of-spike code. Each neuron in a pattern is characterized by a binary variable determining if the neuron is active in the pattern, and a phase-lag variable representing the spike-timing order among the active units. After the learning stage, we study the dynamics of the network induced by a brief cue stimulation, and verify that the network is able to selectively replay the pattern correctly and persistently. We calculate the information capacity of the network, defined as the maximum number of patterns that can be encoded in the network times the number of bits carried by each pattern, normalized by the number of synapses, and find that it reaches a value $\alpha_{max} \sim 0.27$, similar to the one of sequence processing neural networks, and almost double of the capacity of the static Hopfield model. We study the dependence of the capacity on the global inhibition, connection strength (or neuron threshold) and fraction of neurons participating to the patterns. The results show that a dual population and temporal coding can be optimal for the capacity of an associative memory.

Pierfrancesco Di Cintio - *CNR-IFAC & INFN Firenze*

Noise, N-body chaos and the onset of radial-orbit instability

We study the stability of a family of γ-models with Osipkov- Merritt velocity anisotropy by means of N-body simulations. In particular, we analize the effect of self-consistent N-body chaos and external noise on the onset of radial-orbit instability (ROI). We find that degree of chaoticity of the system associated to its largest Lyapunov exponent Λ_{max} has no appreciable relation with the stability of the model for fixed density profile and different values of radial velocity anisotropy. Moreover, we find that the addition of an external isotropic source of noise has a stabilizing effect against ROI, at least when the degree of anisotropy is close to its limit for stabilty. Vice-versa, models where a noise-plus-friction disturbance, modelled with a Ornstein-Uhlenbeck process is included are always unstable.

Ivan Di Terlizzi - *Università di Padova*

Kinetic Uncertainty Relation

We start from a recent theorem of microscopic thermodynamics, pictorially called thermodynamic uncertainty relation (TUR), which forms part of the more general framework of thermodynamic inequalities that arise from the handling of microscopic processes in a non-equilibrium state. More specifically, the above-mentioned theorem puts a bound on the ratio between the average rate of the an out of equilibrium current and the generalized diffusivity (proportional to the variance of the current) times the entropy production rate. However, it was showed that this thermodynamic relation can be obtained in a very general way, namely using a mathematical object called the Kullback-Leibler divergence that, for some particular cases, can be linked to entropy production. We will hence use the latter to obtain a new non-equilibrium inequality for systems modelled by continuous time Markov chains: in fact, performing a simple perturbation on the system's dynamic (namely a linear rescaling of the transition rates) we calculate the Kullback-Leibler divergence that arises from this procedure and show that it is proportional to the dynamical activity of the system, namely the average total number of jumps that the system performs in a given time interval. This final result has been called kinetic uncertainty relation (KUR). Finally we investigate the differences between the TUR and the KUR and analyse the regimes in which they give tighter constraints.

See: https://iopscience.iop.org/article/10.1088/1751-8121/aaee34

Gianfranco Durin - *Istituto Nazionale di Ricerca Metrologica*

Earthquake-like dynamics of weakly-driven domain walls in ultrathin magnetic film

The vast majority of studies of magnetic domain wall (DW) dynamics in the so-called creep regime has focused on investigating mean properties, most notably the dependence of average DW velocity on applied field [1-3]. Only recently a theoretical work unveiled the existence of spatio-temporal correlations between weakly-driven creep events, in a similar fashion to earthquake dynamics [4]. In this work we demonstrate experimentally these predictions by investigating DW creep dynamics in an ultrathin Ta/CoFeB/MgO film with perpendicular magnetic anisotropy. We use magneto-optical Kerr effect (MOKE) microscopy to detect the expansion of a magnetic bubble under a small perpendicular field H, by acquiring images every 200 ms. We are able to confirm that creep events (portions of bubble growth between two consecutive images) aggregate into larger independent clusters using a technique successful applied to earthquake dynamics [5]. The cluster area distribution exhibits a power law behavior with an exponent which is consistent with both qEW and qKPZ universality classes. To resolve this issue, we also evaluate the structure factor S(q). Following the procedure in [6], we estimate that the critical lengthscale L_{opt} separating creep regime at short scales from depinning regime at large scales is comparable to the image pixel size (0.3 μm). Thus, we conclude the S(q) contains information about depinning only. Best fit provides a depinning roughness exponent χ_{dep} consistent with the qKPZ class ($\chi_{dep} = 0.63$) but not the qEW one ($\chi_{dep} = 1.25$). These unprecedented and unexpected results shed new light on our understanding of DW dynamics in the ultra-slow creep regime.

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Vittorio Erba - *Università di Milano*

Full correlation integral estimator for Intrinsic Dimension: robustness and multiscalability

High-dimensional data are ubiquitous in contemporary science and finding methods and tools to analyze them is one of the primary goal of Machine Learning. Given a dataset lying in a high-dimensional space (in principle hundreds to several thousands of dimensions), identifying the minimal dimension for representing it without losing information is a challenging problem known in the literature as intrinsic dimension estimation (IDE). Traditionally, most IDE algorithms are either based on principal component analysis (PCA) or on the notion of correlation dimension (and more in general on k-nearest neighbors distances and are affected, in different ways, by a severe curse of dimensionality that often puts limitations on the reliability of such methods. Here we introduce a new ID estimator based on the full correlation integral that exploits information away from the limit of small radius used for the estimation of the correlation dimension. We argue that our estimator fixes the well known underestimation problem of local geometric methods on linearly embedded manifolds. More surprisingly, it provides a reliable estimate of the ID even in the extreme undersampled limit N d log d number of samples to work. Based on this insight, we introduce a multiscale generalization of the algorithm that satisfactorily deals with the IDE of twisted and extremely curved manifolds and identifies multiple dimensionalities in the same dataset, considered a challenge for state-of-the-art ID estimators.

Andrea Esposito - *Università di Napoli "Federico II"*

Chromatin architecture code inferred by machine learning and polymer physics

The genome has a complex 3D organization, serving key functional purposes, yet the nature of the factors shaping its architecture and their mode of action remain largely unknown. New technologies, such as Hi-C, and developments in microscopy have revealed the complexity of the genome 3D architecture and its deep connections with gene regulation. By combining machine learning methods and polymer physics we infer, starting from experimental data, the specific genomic location of the distinct binding sites whereby DNA contacts are spontaneously established by the action of their cognate binding factors through only physics (1,2). In this talk, I will discuss the key aspects behind our model, showing how it can be used to accurately describe real genomic loci and the effects of disease-linked genetic mutation on the DNA spatial organization (3).

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Gianmaria Falasco - *University of Luxembourg*

Dynamics and Thermodynamics of chemical reaction networks

Living cells sustain themselves through a wealth of complex chemical processes—from ATP synthesis to DNA replication. Most of them are naturally noise and take place under large chemical potential differences. A thorough characterization thus requires deep understanding of the stochastic dynamics and nonequilibrium thermodynamics of chemical reaction networks. I will review recent advances in the field, in particular focusing on: I) large deviation methods to study the complex behavior (multistability, limit cycles) emerging in the thermodynamic limit, II) the stability of chemical pathways to internal and environmental noise and its relation to energy dissipation.

Roberto Franzosi - *Istituto Nazionale di Ottica - CNR - Firenze*

A microcanonical entropy correcting finite-size effects in small systems

In a recent paper [Franzosi, Physica A **494**, 302 (2018)], we have suggested to use of the surface entropy, namely the logarithm of the area of a hypersurface of constant energy in the phase space, as an expression for the thermodynamic microcanonical entropy, in place of the standard definition usually known as Boltzmann entropy. In the present manuscript, we have tested the surface entropy on the Fermi-Pasta-Ulam model for which we have computed the caloric equations that derive from both the Boltzmann entropy and the surface entropy. The results achieved clearly show that in the case of the Boltzmann entropy there is a strong dependence of the caloric equation from the system size, whereas in the case of the surface entropy there is no such dependence. We infer that the issues that one encounters when the Boltzmann entropy is used in the statistical description of small systems could be a clue of a deeper defect of this entropy that derives from its basic definition. Furthermore, we show that the surface entropy is well founded from a mathematical point of view, and we show that it is the only admissible entropy definition, for an isolated and finite system with a given energy, which is consistent with the postulate of equal a-priori probability.

Andrea Gabrielli - *ISC-CNR Roma*

Statistical Physics for Heterogeneous Random Networks

In the last years the formulation of statistical ensembles of binary and weighted random graphs satisfying some arbitrary constraints has attracted much attention in phys/math communities for its two-fold potential application [1, 2]: (i) The construction of appropriate null models for the statistical validation of high order properties of real networks; (ii) the reconstruction of the statistical properties of real network starting for partial accessible information. The cornerstone of the statistical physics of complex networks is the idea that the links, and not the nodes, are the effective particles of the system. Here we formulate a mapping between weighted networks and lattice gasses, making the conceptual step forward of interpreting weighted links as particles with a generalised coordinate [3]. This leads to the definition of the grand canonical ensemble of weighted complex networks. We derive exact expressions for the partition function and thermodynamic quantities, both in the cases of global and local (i.e., node-specific) constraints on density and mean energy of particles. We further show that, when modeling real cases of networks, the binary and weighted statistics of the ensemble can be disentangled, leading to a simplified framework for a range of practical applications.

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Marco Gherardi - *Università di Milano*
Machine learning of geometrically structured data
Understanding and predicting the performance of neural networks is a crucial pursuit of contemporary science. Cover's function counting theorem was a milestone of learning theory. It counts how many binary classifications (dichotomies) can be realized by a given architecture, a meaningful quantity related to capacity, expressiveness, and generalization capability. Yet, while classic results such as this are formulated for inputs with unspecified relations, there is now raising consensus that the organization of data into significant geometrical structures, such as clusters or perceptual manifolds, is a paramount factor affecting the effectiveness of machine learning tools. With the aim of predicting and measuring how such geometrical structure in the data affects classification algorithms, we extended Cover's result to generically correlated sets of inputs. As an application, we obtained a closed formula for the capacity of a binary classifier trained to distinguish polytopes of any dimension. I will discuss the relevance of these results and how they open up opportunities for useful applications.

Jacopo Grilli - *ICTP Trieste*
A physics approach to macroecological laws across microbial communities
Microbes are everywhere. For every human cell of our body, there is at least one bacterial cell living inside us. Due to the advancement of sequencing techniques, there has been an explosion of data that track the composition of microbial communities. In a traditionally data-poor discipline as ecology, this novel richness of data represents a unique opportunity to understand quantitatively how different ecological forces shape diversity. In this talk, I will present three independent, "physics-like", emergent statistical patterns of distribution of abundances across species and communities, which are conserved across different ecosystems. I will then discuss how these "laws" can inform us about the fundamental mechanisms that are shaping the composition of these communities.

Stefano Iubini - *Università di Padova*
Topological sieving of rings according to their rigidity

I will present a novel mechanism for resolving the mechanical rigidity of nanoscopic circular polymers that flow in a complex environment. The emergence of a regime of negative differential mobility induced by topological interactions between the rings and the substrate is the key mechanism for selective sieving of circular polymers with distinct flexibilities. A simple model accurately describes the sieving process observed in molecular dynamics simulations and yields experimentally verifiable analytical predictions, which can be used as a reference guide for improving filtration procedures of circular filaments. The topological sieving mechanism we propose ought to be relevant also in probing the microscopic details of complex substrates.

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Antonio Lamura - *IAC-CNR Bari*
Anchored semiflexible polymer under oscillatory shear flow
The properties of a semiflexible polymer with fixed ends under oscillatory shear flow are investigated by numerical simulations. The polymer is confined in two dimensions and is modeled as a worm-like chain. The interaction with the fluid is taken into account by the Brownian multiparticle collision dynamics approach. For small shear rates, a linear oscillatory response appears. However, at high shear rates, we find a strongly nonlinear behavior with the polymer wrapping around the fixation points and shrinking. The polymer center of mass is distributed on a spatial curve resembling a limaçon with an inhomogeneous distribution. Normal-mode correlation functions are changed by shear and a frequency doubling is observed at high shear rates. An even-odd asymmetry for the Cartesian components of the correlation functions is found with rather similar spectra for odd x- and even y-modes and vice versa. Our study yields an interesting nonlinear behavior of anchored semiflexible polymers under oscillatory shear flow. Preliminary results for the case of a semiflexible polymer with one fixed end exposed to oscillatory shear will be also provided.

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Elena Magnanini - *Università di Bologna*
Approximating the scaled cumulant generating function of triangles in the dense Erdos-Rényi model
The computation of the probability of rare events is the main purpose of Large Deviation Theory. For instance, in a simple case, one can consider the rare event in which a sum of i.i.d. Bernoulli variables attains a value which is larger than its average. A completely different, and much more difficult problem, is the computation of large deviations probability of nonlinear functionals of the Bernoulli variables, e.g. cubic polynomials. A case in which such nonlinear problems arise is, for instance, the study of Complex Networks. In this poster I will present the behaviour of the so-called scaled cumulant generating function of the triangle observable in the context of the dense Erdos-Rényi random graph. The scaled cumulant generating function is strictly related to large deviations since, when it is possible to apply the Gärtner-Ellis theorem, it turns out to be the Legendre transform of the large deviations rate function. The goal of this poster presentation is twofold: on one hand to describe the extension of a known Monte Carlo method, called Cloning algorithm, devised for approximating the scaled cumulant generating function of an additive observable in the framework of random graphs. On the other hand, keeping the focus on the triangle observable, to present the numerical investigation performed in the region of parameters where the analytical expression of such function is not known, thus revealing a phase transition.

Marco Mancastroppa - *Università di Parma*

Epidemic spreading on temporal networks with burstiness

The heterogeneous distribution of times between two consecutive actions – often denoted as *burstiness*– is a typical signature of time-resolved records of human activities [1]. In bursty processes the probability distribution for the inter-event time between two successive events is not an exponential as in Poisson processes but, typically, it features a fat tail, easily measured from large datasets [1]. Heterogenous temporal patterns in the evolution of time-varying networks can affect in a non-trivial way dynamical processes, such as epidemics, unfolding on top of them: interestingly, when comparing bursty with Poisson dynamics in epidemics, conflicting observations have been reported [1]. To understand such conflicting observations and keep track at the same time of the temporal evolution of interactions, in this work we focus on the Susceptible-Infected-Susceptible (SIS) process on activity-driven temporal networks [2] in the presence of burstiness [3,4]. By using an activity-based mean-field (ABMF) approach we find a closed analytical form for the epidemic threshold for general activity and inter-event time distributions including, as a particular case, bursty dynamics. The ABMF approach is exact here due to the fully mean-field nature of the model and the analytical results are in excellent agreement with extensive numerical simulations. We show that burstiness lowers the epidemic threshold, while surprisingly its effect on epidemic prevalence is twofold: burstiness tends to raise the average stationary infection probability in low infective systems, therefore strengthening the epidemic, while it weakens the epidemic in high infective systems, lowering the prevalence. This result can help to clarify the conflicting effects of burstiness reported in the literature [1]. We also discuss the scaling properties at the transition, showing that they are not affected by burstiness.

(see Mancastroppa M., Vezzani A., Munoz M.A. and Burioni R., "Burstiness in activity-driven networks and the epidemic threshold", J. Stat. Mech. (2019) 053502)

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Rossana Mastrandrea - *Scuola IMT Alti Studi Lucca*

Functional brain network topology maps the dysfunctional substrate of cognitive processes in Schizophrenia

Current understanding of schizophrenia associates this disorder with alterations in the functional organization of the brain. Resting-state functional connectivity failed to models symptoms expression in the attempt to characterize global and local changes induced by this mental illness, Network neuroscience sheds some light on the functional and structural modifications of the brain. Comparing forty-four medicated patients and forty healthy subjects, we detected significant differences in the robustness of these functional networks. This work, comparing forty-four medicated patients and forty healthy subjects, shows that the distribution of connectivity strength among brain regions is spatially more homogeneous in schizophrenic patients than in healthy ones, with a larger resistance to edge removal for the schizophrenic functional graphs. As a consequence, the precise hierarchical modularity of healthy brains is crumbled in schizophrenic ones, making possible a peculiar arrangement of region-to-region interaction. The altered hierarchical modularity and the manifold nature of the basal scheme in the functional organisation of brain could contribute to positive symptoms of schizophrenia. Our work also fits the disconnection hypothesis that describes schizophrenia as a brain disorder, characterized by abnormal functional integration among brain region.

Piero Olla - *ISAC-CNR*
Stochastic dynamics with mixed boundary conditions in time
Rare events in a nonequilibrium system not necessarily involve all the variables that describe the dynamics. We may have for instance situations in which only part of the system is of interest for the rare events, and the rest only provides the nonequilibrium forcing. The dynamics of such a system could be described by means of an incomplete Schroedinger bridge, in which boundary conditions are imposed in the future only on part of the variables (the forced system), while the remaining variables are conditioned in the past. The case of an ensemble of small systems that exchange work among themselves and heat among themselves and a set of thermostats is discussed explicitly.

Matteo Paoluzzi - *Sapienza Università di Roma*
The non-Debye spectrum in structural glasses and supercooled liquids
At small enough frequencies glasses and disordered solids follow Debye's law. This is because at large length scales they are continuum media and thus phonons, i.e., Goldstone bosons, dominate the low-frequency spectrum. However, the mechanical and thermodynamic properties of glasses, even though universal, deviate from those in crystalline solids. These anomalies imply peculiar and universal deviations from Debye's law at low frequencies. Theoretical models predict a population of soft and quasi-localized non-Goldstone modes following a power law that is subdominant with respect to the Goldstone sector. We show that the non-Goldstone sector can be efficiently probed at any system size by employing a random pinning protocol that destroys spatial translational invariance symmetries and thus removes phonons from the spectrum[1]. Moreover, we show that non-Debye modes dominate the low-frequency spectrum in supercooled liquids equilibrated at parental temperatures close to the dynamical transition temperature. Finally, we make in contact the emerging of non-Goldstone modes with the growing of dynamical heterogeneous regions[2].

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Mauro Pastore - *Università di Milano & INFN*
Large deviations of the free energy in the p-spin glass spherical model
The theory of large deviations is the natural framework to study the rare fluctuations of physical observables, including thermodynamic variables in disordered systems, where, however, the attention has been mostly focused on typical values. The Gärtner-Ellis theorem provides a powerful tool to evaluate the rate functions describing the exponential decay of the probability of these variables around their typical values, via a Legendre transformation of the corresponding cumulant generating functions, which can be obtained in Replica Theory. In this contribution I will show how to apply these ideas to find the rate function of the free energy in the p-spin glass spherical model. As in many other disordered systems, the probability of the rare fluctuations above or below the typical value has a very different behaviour. While in one case the decay is exponential with the number of degrees of freedom, as simple arguments of extensivity suggest, in the other is super-exponential, with an infinite rate function. I will show how the switching of a magnetic field cures this infinity, suggesting that this might represent a useful regularisation to obtain the unknown super-exponential scaling.

Francesco Petiziol - *Università di Parma*
Creation of entanglement by superadiabatic quantum state transfer
Quantum adiabatic driving is one of the pillars of time-dependent quantum control. However, the limitations imposed by the coherence times are typically in sharp contrast with the necessity of slow evolutions imposed by

the adiabatic theorem. A method will be presented for accelerating adiabatic state transfer for few-level quantum systems. This works by introducing suitably tailored fast oscillations in the intrinsic parameters of the original Hamiltonian: the oscillations mediate an effective Hamiltonian dynamically compensating for undesired transitions. It will be shown how the protocol can be exploited for producing entanglement between two qubits in a circuit QED setting.

Mirko Pieropan - *Politecnico di Torino*

Compressed Sensing Reconstruction using Expectation Propagation

Linear estimation problems are ubiquitous in many fields of science. One of the most studied ones is Compressed Sensing (CS), which consists in finding the sparsest solution x̲ of a system of linear equations $\mathbf{F}\underline{x} = \underline{y}$ given a set of M measurements y̲, where N¿M is the number of unknowns and the sensing matrix $\mathbf{F}$ is assumed to be given. We have addressed the problem within a bayesian setting, by considering a Bernoulli-Gauss prior distribution for the solution to be retrieved and a computational message passing scheme called Expectation Propagation (EP), which was originally developed in Statistical Physics. The method provides a natural framework to learn the parameters of the prior distribution, which are in general unknown as well. We have studied the reconstruction by EP in the presence of dense correlated measurement matrices by means of large scale simulations and found that the method is able to outperform current state-of-the-art methods such as belief propagation and matching pursuit algorithms. We show that the same scheme can be used in order to infer the weights of a diluted perceptron and to compute the associated generalisation error as a function of the number of presented patterns.

Lorenzo Piroli - *Max-Planck Institute for Quantum Optics*

Nonequilibrium quantum states of matter and generalized hydrodynamics

I will give an overview of recent developments in the field of nonequilibrium dynamics of isolated 1D quantum systems, discussing in particular the special role played by integrable models. In the first part of the talk, I will discuss the main motivations, questions and technical challenges which were faced in the past years and mention the main theoretical techniques which were developed, especially those with a strong connection with problems in 2D classical statistical mechanics. In the second part of the talk, I will focus on a novel generalized hydrodynamic approach which allowed us to tackle many open questions in the field, providing an exact description of the many-body dynamics at large space and time scales.

Marco Pretti - *ISC-CNR*

Dynamical transitions in driven-diffusive lattice-gas models

We discuss a generalized mean-field approach to driven-diffusive lattice-gas models such as the totally-asymmetric simple-exclusion process (TASEP), in order to investigate the so-called dynamical transition. In the pure TASEP with open boundaries, such a phenomenon has been studied exactly and appears as a singularity in the relaxation rate of the system toward its non-equilibrium steady state. In the presence of adsorption/desorption (Langmuir) kinetics (TASEP-LK), we point out an unexpectedly richer dynamical phase diagram, including unusual first-order-like dynamical transitions. Taking inspiration from our mean-field theory, earlier exact results and the so-called (approximate) domain-wall theory, we put forward a conjecture about the exact analytical expression of the relaxation rate for the TASEP-LK, and consequently about its full dynamical phase diagram. We find a striking agreement of our conjecture with finite-size numerical results processed by extrapolation techniques.

Fabio Saracco - *Scuola IMT Alti Studi Lucca*

The role of bot squads in the political debate on Twitter

Among different platforms, Twitter is one of the most studied, due to the availability of data about the traffic and for being strongly used for the political debate. Indeed, one of the problems for the analysis is the reliability of the users in the game: in such sense a stream of research was devoted to find the right features for detecting automated accounts [1, 2].

Anyway, in the previous analyses the effect of random noise was rarely tackled. In recent years an entropy-based approach for the analysis of complex networks was developed in order to pro- vide an unbiased benchmark for the analysis and filtering out random noise [3, 4]. In the present study we merge the bot detection with the use of an entropy-based null-model for the analysis of the content exchange on Twitter in the Italian debate about the migration flux from North Africa.

First, in order to get the political affiliations of users, we focused on the bipartite network in which the two layers are represented by verified and unverified users, respectively, and (undirected) links label the interactions among these two classes of users. The main idea is to infer the membership to a certain political idea from (a proxy of) the contacts of an account, similarly to [5]. Verified users cluster in 3 main groups: one including government representatives, the right wing and the Movimento 5 Stelle party; one including the Italian Democratic party; and eventually one including NGOs, the official accounts of online and offline media and journalists and different kind of VIPs. Confirming results presented in several studies [6], the polarization of unverified users is particularly strong: in almost all the cases the unverified users interact at $\sim$90% only with accounts belonging to a single community. We use the previous memberships in order to label the users involved in the non trivial exchange of contents. We use the validated projection developed in [5]: this permits to extract the significant flow of messages among users, discounting at the same time the virality of messages, the retweetting activity of users and their productivity in writing messages. Such an approach provides the backbone of the content exchange among users on Twitter: indeed, we found that all the most effective accounts in delivering their messages (i.e. the Hubs [7]) refers to the right wing area, the first account referring to a different community being the official account of a newscast, ranking 176th in the hub score. The top 20 hubs list contains a relatively small amount of verified users, the strongest being the one of the Minister of Internal Affairs Matteo Salvini. The striking result, as far as we know never detected in other systems, is the presence of a group of common bots for some of those hubs, uncovering a strategy in order to increase the visibility of the previous accounts. Let us underline that these shared bots are particularly effective since their activity was validated by the entropy-based projection. Such a framework resulted to be extremely helpful, since it hits one feature of an automated user that cannot be avoided by programmers. Indeed, the sense of a bot is to increase the visibility of a user by retweetting her/his messages and that is exactly what is revealed by the entropy-based filtering.

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Vittore Ferdinando Scolari - *Institut Pasteur*

Kinetic signature of cooperativity in the irreversible collapse of a polymer

We investigate the kinetics of a polymer collapse due to the formation of irreversible cross-links between its monomers. Using the contact probability P(s) as a scale-dependent order parameter depending on the chemical distance s, our simulations show the emergence of a cooperative pearling instability. Namely, the polymer undergoes a sharp conformational transition to a set of absorbing states characterized by a length scale ξ corresponding to the mean pearl size. This length and the transition time depend on the polymer equilibrium dynamics and the cross-linking rate.

Samir Suweis - *Università di Padova*

Adaptive Metabolic Strategies in Consumer-Resource Models

Competitive eco-systems are widespread and most commonly they are described mathematically using MacArthur's consumer-resource model [1], leading to so called the "Competitive Exclusion Principle", which limits the number of coexisting competing species to the number of available resources. Nevertheless, several empirical evidences – for example bacterial community culture experiments – show that this principle is violated in real ecosystems. Another experimental evidence involving microbial populations that cannot be explained in this framework is the existence of diauxic (or polyauxic) shifts in microbial growth curves: microbes can adapt their metabolic strategies to the availability of different resources in the environment: when exposed to different sugars they often consume them sequentially resulting in population growth curves with distinct phases of growth rates. In this talk I will share ideas from our recent work [2], where we show that by introducing adaptive metabolic strategies to consumer-resource models we can reproduce diauxic shifts in agreement with experimental observations and it allows consumer-resource models to violate the "Competitive Exclusion Principle".

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Pablo Villegas Góngora - *ISC-CNR Roma*

Landau–Ginzburg theory of cortex dynamics: Scale-free avalanches emerge at the edge of synchronization

The human cortex operates in a state of restless activity, the meaning and functionality of which are still not understood. A fascinating, though controversial, hypothesis, partially backed by empirical evidence, suggests that the cortex might work at the edge of a phase transition, from which important functional advantages stem. However, the nature of such a transition remains elusive. Here, we adopt ideas from the physics of phase transitions to construct a general (Landau–Ginzburg) theory of cortical networks, allowing us to analyze their possible collective phases and phase transitions. We conclude that the empirically reported scale-invariant avalanches can possibly come about if the cortex operated at the edge of a synchronization phase transition, at which neuronal avalanches and incipient oscillations coexist.