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MEC 45

45TH MIDDLE EUROPEAN COOPERATION IN STATISTICAL PHYSICS

14-16 SEPTEMBER 2020

This conference is the 45$^{\text{th}}$ in a series of meetings of scientists working in the domain of Statistical Mechanics and Condensed Matter Physics. The Conferences of the Middle European Cooperation in Statistical Physics (MECO) were initiated in 1974 with the aim of bridging the gap between the communities of scientists from the Eastern and Western blocks of Europe, separated by the iron curtain. Since then, MECO conferences have become the yearly itinerant reference meetings for the community of scientists who are active in the field of Statistical Physics in the broader sense, including modern interdisciplinary applications to biology, finance, information theory, and quantum computation.

Unfortunately, the onsite organization of this 45$^{\text{th}}$ edition in Cluj-Napoca (Romania) at the Babeș-Bolyai University was not possible due to the COVID-19 pandemics, and therefore it had to be organized as an online conference. The conference was oriented mainly in the direction of applications of statistical mechanics in complex systems. However, some invited talks and many contributed talks were selected also from other areas of statistical physics.

abstract book edited by: Katalin **Nagy-Póra** and Zsuzsa **Sárközi**
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Cluj-Napoca, 5 September 2020

MONDAY, September 14, 2020

(Romanian official time)

9:45	**Opening**	
	Session I Chairman: **C. Gros**	
10:00	**T.S. Biró** Dynamical LGGR model for income distributions	INV-01
10:40	**S. Burov** Packets of diffusing particles exhibit universal exponential tails	CON-01
11:00	**D. Kessler** Regularized Boltzman-Gibbs statistics for deep non-confining potentials	CON-02
11:20	**A. Ryabov** Nonequilibrium transport and phase transitions in driven diffusive systems with space-continuous dynamics	CON-03
11:40	**Y. Itto** Analogy of fluctuating diffusivity of RNA-protein particles to thermodynamics	CON-04
12:00	**Poster Discussion I**	PD-I
	Session II Chairman: **T.S. Biró**	
14:00	**F. Iglói** Reentrant random quantum Ising antiferromagnet	CON-05
14:20	**N. Schreiber** Unusual changeover in the transition nature of local-interaction Potts models	CON-06
14:40	**H.S. Wio** Variational approach to KPZ: Fluctuation theorems, large deviation function for entropy production, and probability distribution	CON-07
15:00	**H. Kori** Tackling Complex Dynamics in Biology and Chemistry with Phase Oscillator Models	KEY-01
16:00	**Break/ Cultural program**	
	Csaba T. Szabó: ***Transylvania: historical confluences and cultural heritage in Central-East Europe***	CLT-01
	Session III Chairman: **A. Motter**	
17:00	**G. Bianconi** Higher-order networks: simplicial complexes and their dynamics	INV-02
17:40	**M. Karsai** Reentrant phase transitions in complex contagion on multiplex networks	CON-08
18:00	**Break**	
18:20	**V. Blavatska** Shape of random polymer networks	CON-09
18.40	**Z. Toroczkai** Architectural principles of the mammalian connectome: a machine learning approach	INV-03

TUESDAY, September 15, 2020

(Romanian official time)

	Session IV Chairman: **F.Iglói**	
10:00	**C.P. Moca** Spin fluctuations after quantum quenches in the S = 1 Haldane chain	INV-04
10:40	**G. De Polsi** Conformal invariance in the nonperturbative renormalization group: A rationale for choosing the regulator	CON-10
11:00	**M. Weigel** Scaling of the random-field Ising model in two dimensions	CON-11
11:20	**H. Jeong** Quantitative analysis of painting arts	INV-05
12:00	**Break/ Cultural program**	
	Róbert Oláh-Gál and Zoltán Néda: ***The mathematical heritage of János Bolyai. Creating a new world out of nothing***	CLT-02
	Session V Chairman: **J. Cartwright**	
14:00	**M. Krasnytska** Critical behaviour of the Ising model with invisible states on a scale-free network	CON-12
14:20	**E. Bokányi** Patterns of social connections in urban space	CON-13
14:40	**C. Räth** Predicting chaotic time series by means of reservoir computing	CON-14
15:00	**Gy. Korniss** Using noise-correlated stochastic differential equations to model cryptocurrency rates and social media activities	INV-06
15:40	**Poster Discussion II**	PD-II
	Session VI Chairman: **Gy. Korniss**	
17:00	**A.E. Motter** Converse Symmetry Breaking in Network Dynamics	KEY-02
18:00	**Break**	
18:20	**K. Proesmans** Finite-time Landauer principle	CON-15
18:40	**Yu.Yu. Tarasevich** Transparent electrodes with rod- and ring-like fillers: Monte Carlo simulation and analytical evaluation	CON-16
19:00	**C. Gros** Statistical physics of envy	INV-07

WEDNESDAY, September 16, 2020

(Romanian official time)

	Session VII Chairman: **J. Kertész**	
10:00	**J. Cartwright** Chemobrionics and the origin of life	INV-08
10:40	**G. Gonella** Phase diagram of active disks and dumbbells in D=2	CON-17
11:00	**I. Santiago** Strategies for motile cell-like compartments	CON-18
11:20	**N. Lebovka** Elongated particles: From diluted two-dimensional systems to dense ones	CON-19
11:40	**S. Mathey** Activating new universality with the Kibble-Zurek mechanism	CON-20
12:00	**Poster Discussion III**	PD-III
	Session VIII Chairman: **G. Bianconi**	
14:00	**C. Gros** Autonomously adapting non-conserving sandpiles	CON-21
14:20	**B. Seoane** A scaling approach to estimate the COVID-19 infection fatality ratio by age	CON-22
14:40	**N. Fytas** Evidence for supersymmetry in the random-field Ising model at D = 5	CON-23
15:00	**J. Kertész** Sampling networks by nodal attributes	KEY-03
16:00	**Break/ Cultural program** **Viktória Adrienn Barazsuly:** ***Mesmerized by light and colour: the Nagybánya (Baia Mare) Artists' Colony***	CLT-03
	Session IX Chairman: **Y. Holovatch**	
17:00	**Á. Horvát** The science of sharing and the sharing of science: Diffusion of scientific articles across online platforms	INV-09
17:40	**A.J. Ramirez-Pastor** Adsorption statistics of structured molecules	CON-24
18:00	**Break**	
18:20	**H. Taitelbaum** Thin film spreading: bulk and precursor non-universal dynamics	CON-25
18.40	**R. Folk** Middle European Cooperation in Statistical Physics: a historical overview	INV-10
19:20	**Closing**	

P-01 **J. Berx**
Beyond linear use of equation superposition

P-02 **K. Dénes**
Stablizing phase locked patterns in systems of Kuramoto oscillators with delayed coupling

P-03 **B. Molnár**
Voronoi diagrams to detect communities in weighted directed graphs

P-04 **S.K. Mehdi**
Bosonics systems in the canonical ensemble

P-05 **G. Pál**
Phase transitions in low-velocity impact phenomena

P-06 **A. Rusu**
Complex fluctuations of a Lotka-Volterra type attention dynamics model

P-07 **R. Juhász**
Population boundary across an environmental gradient: Effects of quenched disorder

P-08 **K. Biswas**
Information theoretic comparison of transcriptional and post-transcriptional regulations

P-09 **H. Dashti-Naserabadi**
Competing universalities in Kardar-Parisi-Zhang growth models

P-10 **L. Varga**
Characterizing resting state brain networks based on probability distributions of network properties

P-11 **V. Kádár**
Record statistics of bursts signals the onset of acceleration towards failure

P-12 **O. Mryglod**
Over 40 years of statistical physics history: bibliometric analysis of MECO

P-13 **R. Szatmári**
Anisotropic crack patterns induced by shrinkage in thin layers

P-14 **Cs. Szuszik**
Debris flow generated by a collapsing granular column

P-15 **Z. Tahiri**
The investigation of the correlation created by single anisotropic node on two-lane roads

P-16 **M. Bakumenko**
Influence of solute polarity on diffusion in dimethylimidazolium chloride

P-17 **I. Gere**
Towards probabilistic forecasting of earthquakes

P-18 **M.O. Hase**
Weakening connections in heterogeneous mean-field theory

P-19 **R.P. Salazar Romero**
Monte Carlo simulations as an efficient method to calculate electric fields in gapped surface electrodes

P-20 **Yu.Yu. Tarasevich**
Random sequential adsorption of stiff linear k-mers onto a square lattice: Characterization of domain formation

P-21 **J.J. Riccardo**
Generalized exclusion statistics

P-22 **D. Ábel**
Modeling hierarchical and modular network of organizations

P-23 **A. Gergely**
Flickering candle flames: experiments and dynamical modelling

P-24 **R.-A. Inczefi**
Molecular dynamics simulation study of free and constrained Brownian motions

P-25 **M. Ercsey-Ravasz**
A max- SAT solver with high-performance analog dynamics

P-26 **B. Schneider**
Time-series analysis with state-transition networks

P-27 **A. Tunyagi**
Virtually coupled mechanical oscillators

P-28 **M. Józsa**
Reverse engineering complex systems from their network models

P-29 **B. Sándor**
Attractoring: a dynamical systems framework for self-organized robotic locomotion

P-30 **M. Dudka**
Phase transitions in three-dimensional random anisotropy Heisenberg model: two case studies

P-31 **M. Mancastroppa**
Active and inactive quarantine in epidemic spreading: a general formalism for adaptive activity-driven networks

P-32 **A. Matsuki**
Analysis of intervention threshold for epidemic control using metapopulation models

Tackling Complex Dynamics in Biology and Chemistry with Phase Oscillator Models

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Mathematical models are essential for understanding complex phenomena in a variety of systems, ranging from biology to engineering. In many cases, simpler models provide better understandings and deeper insights. For coupled oscillators, phase oscillator models provide a simple and useful platform not only to understand but also to predict and control complex dynamics in reality. In this talk, after illustrating the basics of phase oscillator models, I will introduce several studies on chemical and biological oscillations tackled with phase oscillator models. Topics include feedback control of synchronization dynamics [1, 2], precise oscillation out of noisy oscillators on networks [3], and jet lag [4, 5].

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Converse Symmetry Breaking in Network Dynamics

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Symmetry breaking—the phenomenon in which the symmetry of a system is not inherited by its stable states—underlies pattern formation, superconductivity, and numerous other effects. In this talk, I will present on the recently established possibility of *converse symmetry breaking* (CSB) [1, 2], an emergent phenomenon in which stable states are symmetric only when the system itself is not. In particular, I will discuss how CSB challenges the widely held assumption that identical entities are necessarily more likely to exhibit similar behavior than non-identical ones. I will show that CSB can, in fact, give rise to beneficial effects of heterogeneity in numerous complex systems in which interacting entities are required to exhibit coordinated behavior [3, 4]. I also plan to discuss experimental demonstrations of this phenomenon as well as concrete applications to network optimization and control [5, 6]. Finally, I hope to convey that our research in network dynamics is now not only benefiting from statistical and nonlinear physics, but also fostering fundamental discoveries in these areas.

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What do digital footprints tell about us? From the grandma effect to economic wrongdoing

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The new information communication technologies have changed our lives in fundamental ways: Creating and maintaining social relationships, learning and working, acquiring information and participating in relevant processes have all got radically new forms. In today's highly computerized world almost all of our activities leave records, digital footprints behind. While this system raises many ethical concerns, the data provide a gold mine for science. We analyze detailed call records from mobile phones, data from social media or the entire body of public procurement database to learn about human behavior.

Dynamical LGGR Model for Income Distributions

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Income distributions are being approximated by various formulas and a few have been supported by an underlying stochastic model. After reviewing a few earlier models, I put forward our simplified dynamical Local Growth Global Reset (LGGR) model. This model considers a local growth rate, increasing the income by small amounts in a short time, and a global entry and exit rate (reset) describing entering and leaving the set of people with income. Naturally the exit (retirement) is more typical at higher incomes, while the entry at lower incomes. Hence our reset rate is smart, it depends on the income level and interpolates between negative and positive values. A stationary solution to this process features a scaling with the average income; so disturbing factors, like inflation, are filtered out in the model. Amazing formal relations between the Gini index and entropy are outlined.

Higher-order networks: simplicial complexes and their dynamics

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Higher order networks which allow to go beyond the framework of pairwise interactions are attracting increasing attention. In fact in a large variety of complex systems including the brain, collaborations networks or face-to-face social interactions it is important to capture many-body interactions between two or more nodes. Simplicial complexes are the topological objects that can encode these high-order interactions as they are not only formed by nodes and links as networks but include also higher-order simplices such as triangles, tetrahedra and so on. In this talk I will present equilibrium [1] and non-equilibrium [2] models of simplicial complexes that extend the configuration model and the growing network models to the simplicial complex realm. I will then discuss non-linear dynamics on these networks including frustrated synchronization and higher-order simple and explosive synchronization [3, 4]. These results will allow to discuss the surprising effect of network topology and geometry on synchronization dynamics.

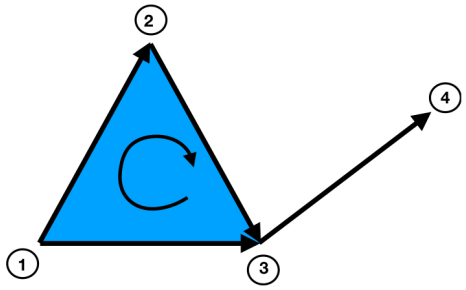

Figure 1: A small example of a simplicial complex

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Architectural Principles of the Mammalian Connectome: a Machine Learning Approach

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Although mammalian brains show a massive, 5 orders of magnitude variation in weight, they present common processing features, implying that cortical computing is built on a scalable architecture. We hypothesize the existence of network architectural organizational principles in the mammalian brain, critical for efficient and hierarchically modular information processing. By extending our empirical, consistent retrograde tract-tracing databases of the physical network of interareal cortical connections in the macaque [1], mouse and microcebus cortex [2], we confirmed the prevalence of the Exponential Distance Rule (EDR) in these species, showing that the EDR is an architectural network invariant. To predict the experimentally untested connections we developed and cross-validated machine learning based imputation algorithms, suitable for dense interareal networks, exploiting the weighted, directed and the spatially embedded nature of these networks. As we show, these algorithms can efficiently predict unknown connections (or lack thereof) and guide the tract-tracing experiments, for example by identifying potential injection targets that would generate the largest information gain, after every new injection.

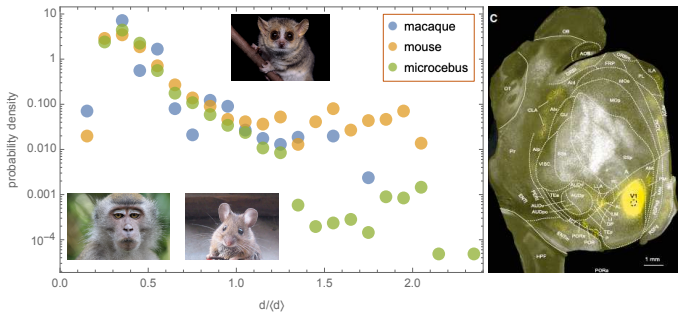

Figure 1: EDR as a possible architectural invariant of the mammalian connectome. a) Experimental data from three species. b) Labeled neurons from retrograde tracing in the mouse cortex.

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Spin fluctuations after quantum quenches in the S = 1 Haldane chain

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Understanding non-equilibrium dynamics in interacting quantum many-body systems is one of the major challenges in today's statistical physics [1]. The formation of current-carrying steady states [2, 3], the details of the thermalization process [4], entropy production [5] or the interplay with disorder [6] and topology [7] are just a few examples of the intriguing open questions which, due to recent breakthroughs in quantum simulation, can now be investigated experimentally. We study quantum quenches in the $S = 1$ Heisenberg spin chain and show that the dynamics can be described by the recently developed semi-semiclassical method [8, 9] based on particles propagating along classical trajectories but scattering quantum mechanically. We analyze the non-equilibrium time evolution of the distribution of the total spin in half of the system and compare the predictions of the semi-semiclassical theory with those of a non-Abelian time evolving block decimation (TEBD) algorithm [10]. We show that while the standard semiclassical approach using the universal low energy scattering matrix cannot describe the dynamics, the hybrid semiclassical method based on the full scattering matrix gives excellent agreement with the first principles TEBD simulation.

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Quantitative analysis of painting arts

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Painting is an art form that plays a major role in human expression and evolved under an interplay with philosophy, science, and social environments of the times. From the qualitative work of individual art historians emerges a meta-narrative, which remains difficult to evaluate in its validity with respect to its inherent dynamics and the historical evolution it depicts. Therefore, quantitative analysis on the creative process in painting could shed light on systematic ver- ification on the narratives. Yet, a quantitative understanding of spa- tial composition and geometric proportion by which painters com- pose paintings is still lacking. Here, we systematically analyze the compositional proportion in landscape paintings using a simple yet coherent information-theoretic dissection method that decomposes painting images into sub-elements. We apply the dissection algo- rithm on a dataset of paintings depicting landscapes collected from two major digital archives consisting of 15,092 paintings from 1,483 artists, covering a period from the Western Renaissance to Contem- porary art. We first analyze commonly preferred composition char- acterized by partition direction of paintings across nations. Next, we demonstrate that the frequency distributions of dissection ratio can serve as a meaningful signature for distinct time periods, artistic styles, and individuals capturing their unique compositional charac- teristics. The frequency distribution of dissection ratio was found to evolve smoothly and systematically over time. Lastly, network analyses based on family resemblance between the use of compo- sitional proportion uncover that artists and styles in art history are clearly clustered into three distinguished groups according to time with impressionism taking a bridge function. Contrary to the com- monly observed diverse stylistic expression in the modern era, the distributions of dissection ratio from various modern era styles were found to be similar. This is curiously different to simple visual fea- tures such as median hue, color contrast, and aspect ratio, which diverge.

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Using Noise-Correlated Stochastic Differential Equations to Model Cryptocurrency Rates and Social Media Activities

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Increasingly interconnected financial systems and online social networks present both critical challenges and opportunities. Volatility in the former (e.g., cryptocurrency rates) can give rise to increased volume of activities in online social networks on relevant topics, while sentiments and rumors in online social networks can also have a significant impact on the corresponding financial time series. Here, we analyze and exploit correlations between the price fluctuations of selected cryptocurrencies and social media activities, and develop a predictive framework using noisecorrelated stochastic differential equations. We employ the standard Geometric Brownian Motion to model cryptocurrency rates, while for social media activities and trading volume of cryptocurrencies we use the Geometric Ornstein-Uhlenbeck process. In our model, correlations between the different stochastic variables are introduced through the noise in the respective stochastic differential equation. Using a Maximum Likelihood Estimation on historical data of the corresponding cryptocurrencies and social media activities, we estimate parameters, and using the observed correlations, forecast selected time series.

This work was supported in part by DARPA/ARO, ARL NS-CTA, and ONR.

Statistical physics of envy

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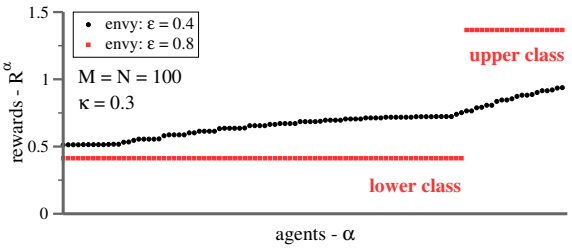
Game-theoretical modeling of human societies involves typically an extended group of agents able to select from a range of options q_i. Two features constitute the basis of both human societies and theoretical games: (i) Options, as for jobs, differ with respect to their bare utilities, e.g. as $v(q_i) = 1 - q_i^2$. (ii) Payoffs are reduced when several individuals compete for the same option, e.g. by an amount κ. In physics terms, agents correspond to classical particles, $-v(q_i)$ to the confining potential, and κ to the strength of the Coulomb blockade. Signs change, as the average payoff, the reward, is maximized in game theory, with energy being minimized in physics.



Reward spectrum. The spectrum of rewards is continuous when envy is small ($\varepsilon = 0.4$, black). For larger values of envy a gap opens ($\varepsilon = 0.8$, red). The two flat bands correspond to distinct social classes. Simulations for $M = 100$ agents, $N = 100$ options, and a competition strength $\kappa = 0.3$.

Is it possible that interactions split the reward spectrum, which would correspond to a self-organized transition to a class-stratified society? It is well established that people care how they are doing with respect to others, a trait denoted envy in game theory [1]. Envy contributes a term $\kappa p^\alpha(q_i)\log(R^\alpha/\bar{R})$, where R^α is the reward of agent α, $\bar{R}$ the mean reward of everybody, $p^\alpha(q_i)$ the probability that agent α selects q_i, and ε the strength of envy. Strategies $p^\alpha(q_i)$ corresponds in physics term to occupation factors in state space $\{q_i\}$.

It is shown that envy splits societies. In an ideal society agents are identical and by-birth privileges absent. In the reference model discussed, the shopping trouble model, random initial perturbances determine in which class an agent ends up. Increasing the strength of envy, the number of upper-class agents decreases, until a monarchy state with only one or two upper-class agents is reached. Communism, when everybody follows the same strategy, is never Nash stable.

Interactions between agents are mediated via state-dependent mean fields, in analogy to a generalized Hartree-Fock theory. This feature of the shopping-trouble model allows to derive explicit analytic expressions for the class-stratified state. One finds that the confining potential enters the gaped flat-band state only indirectly via the occupation factors of the lower- and respectively the upper class. External regulation and control of spontaneously stratified states of interacting agents is therefore difficult. A perspective of the field is given.

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Chemobrionics and the Origin of Life

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More than 3.5 billion years ago, something interesting happened on Earth. Somewhere matter self-organized so that it was able to reproduce its complex state. Life had begun. Where and how that happened are questions whose answers, after many centuries, seem at last within reach. About four decades ago there were discovered hydrothermal vents at the bottom of the oceans; thirty years ago it was proposed that cool, alkaline vents ought to exist; the first of these were found in 2000, and there is now increasing evidence that submarine alkaline hydrothermal vents may have been the cradle of life on Earth. Such vents are geological examples of chemical gardens, self-assembled complex structures of membranes, tubes and vesicles resembling plants that are, however, completely abiotic, being produced by simple chemical precipitation reactions involving metal salts and anions such as silicates, carbonates, phosphates, cyanoferrates, and many more. Chemical gardens have been known about for centuries, and their complex morphology has from the beginning marked them out as having a possible relation with the living world. Today we know that chemical gardens are not in and of themselves alive, but that they may have served as reactors within which complex (bio)chemistry could begin; as vesicles constituting the first protocells. In this talk I shall outline how the modern interdisciplinary field of chemobrionics, emerging from chemical gardens and similar phenomena, and combining chemical reaction, fluid mechanics and osmotic processes, arose, and how it contributes to the present drive towards understanding where and how life on Earth began.

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The Science of Sharing and the Sharing of Science: Diffusion of Scientific Articles across Online Platforms

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Most scholars now use online platforms such as social media sites, electronic news outlets, blogs, and wikis for sharing their findings. They have also become the primary source of information about scientific advances for the wider public. As the online dissemination of scientific content increasingly influences personal decision-making and government action, there is a growing interest in studying how people share research findings online. In this talk, I report results on analyses of the diffusion of scientific articles across major online platforms based on 63 million mentions of 7.2 million research articles over seven years. First, I show commonalities between people sharing science and other content such as news articles and memes. Second, I explore specifics of sharing science. We reconstruct the likely underlying structure of information diffusion and investigate the transfer of information about scientific articles within and across different platforms (Fig. 1 left). In particular, we study the role of different users in the dissemination of information to understand better who are the prime sharers of knowledge. Then, we explore the propagation of articles between platforms. Finally, we analyze the structural virality of individual information cascades to place science sharing on the spectrum between pure broadcasting and actual peer-to-peer diffusion (Fig. 1 right). This work provides the broadest study to date about the sharing of science online and builds the basis for an informed model of the dynamics of research coverage across platforms.

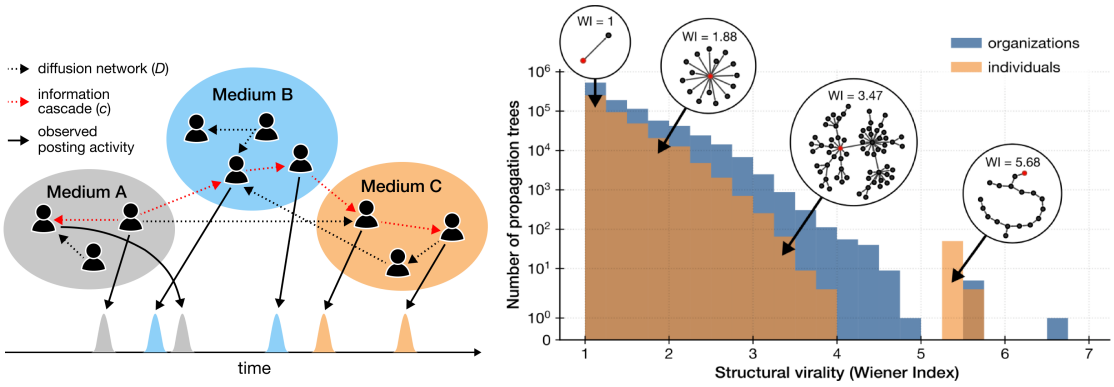

Figure 1: Left: Information cascades propagate along the edges of the unobserved diffusion network that includes users of different platforms. We infer the diffusion network from the time series of posts on various platforms. Right: Structural virality of individual propagation trees. Histogram colour denotes whether an organization or individual started the tree. Examples show example tree structures that correspond to the selected values of the Wiener index.

Middle European Cooperation in Statistical Physics: a historical overview

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The Middle European Cooperation in Statistical Physics (MECO) was created as an attempt to overcome the hurdles of the 'Iron Curtain' to establish and maintain exchanges between scientists from Eastern and Western countries in the fields of statistical and condensed matter physics [1]. It started at a period when important breakthroughs were being made in our understanding of phase transitions and critical phenomena. In addition to the merging of concepts from field theory and solid state physics, new numerical approaches were being added to exact solutions and experiments as ways to test theoretical models. In recent times the scientific emphasis has shifted from the traditional fields of the first MECO to include complexity science and interdisciplinary themes as well.

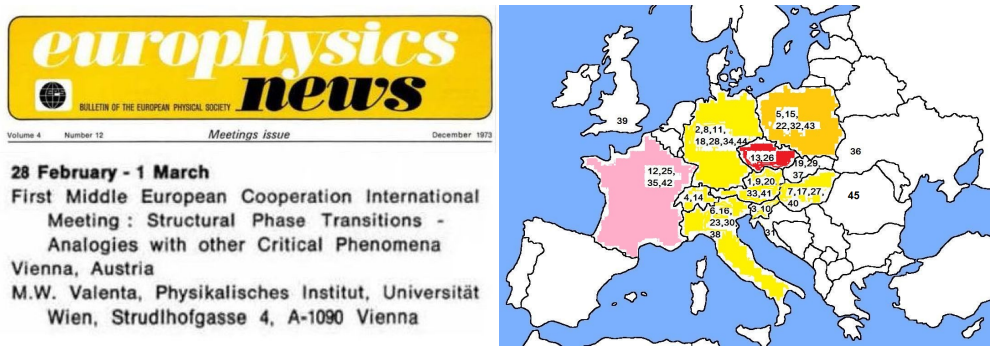

Figure 1: Announcement of the first MECO 1974 in the Bulletin of the European Physical Society 1973 and map of the present European countries showing the expansion of MECO in Europe (the numbers indicate the meeting).

Held every year since 1974, MECO was only interrupted by the Yugoslav War in 1991. But continued from 1993 and still endure today. Having navigated its way through the fall of the Iron Curtain and and evolving European Research programs, the ties created by MECO have enduring value today as it continues to nurture scientific exchanges. This talk, based on personal memories and historical resources, describes the birth and development of MECO [2]. A sister talk using scientometric methods to chart MECO's history is presented separately at this conference [3].

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Packets of Diffusing Particles Exhibit Universal Exponential Tails

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Brownian motion is a Gaussian process described by the central limit theorem. However, exponential decays of the positional probability density function $P(X,t)$ of packets of spreading random walkers, were observed in numerous situations that include glasses, live cells and bacteria suspensions. We show that such exponential behavior is generally valid in a large class of problems of transport in random media. By extending the Large Deviations approach for a continuous time random walk we uncover a general universal behavior for the decay of the density. It is found that fluctuations in the number of steps of the random walker, performed at finite time, lead to exponential decay (with logarithmic corrections) of $P(X,t)$. This universal behavior holds also for short times, a fact that makes experimental observations readily achievable.

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Regularized Boltzmann-Gibbs Statistics For Deep Non-confining Potentials

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We consider an overdamped Brownian particle subject to a deep potential minimum which is however asymptotically flat, and thus non-binding. When the temperature is small compared to the trap depth, $\xi \ll 1$, there exists a very wide range of timescales for which physical observables remain practically constant, or order the Arrhenius factor, $e^{1/\xi}$. For these quasi-equilibrium states, the usual Boltzmann-Gibbs recipe does not work, since the partition function is divergent due to the flatness of the potential at long distances. However, we show that the standard Boltzmann-Gibbs statistical framework can still be applied through proper regularization. This can be a valuable tool for the analysis of quasi-equilibrium in a non-confining. For longer times, the observables are time-dependent, as is the case for a nonconfining potential that is not deep [**?**].

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Nonequilibrium transport and phase transitions in driven diffusive systems with space-continuous dynamics

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Driven diffusive systems constitute a wide class of models for nonequilibrium transport phenomena. Among them, a driven lattice gas known as the asymmetric simple exclusion process (ASEP) is the most prominent example for which many intriguing exact results have been obtained. After a brief summary of key findings, we compare the ASEP with the recently introduced Brownian asymmetric simple exclusion process (BASEP) [1] as a related class of driven diffusive system with continuous space dynamics. In the BASEP, driven Brownian motion of hardcore-interacting particles through one-dimensional periodic potentials is considered [2, 3]. We discuss whether current-density relations of the BASEP can be considered as generic for arbitrary periodic potentials and whether repulsive particle interactions other than hardcore lead to similar results. Our findings [4] suggest that shapes of current-density relations are generic for single-well periodic potentials and can always be attributed to the interplay of a barrier reduction, blocking and exchange symmetry effect. This implies that in general up to five different phases of nonequilibrium steady states are possible for such potentials. The phases can occur in systems coupled to particle reservoirs, where the bulk density is the order parameter. For multiple-well periodic potentials, more complex current-density relations are possible and more phases can appear. The robustness of the collective dynamics in the BASEP with respect to variations of model details can be a key feature for a successful observation of the predicted current-density relations in actual physical systems.

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Analogy of fluctuating diffusivity of RNA-protein particles to thermodynamics

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Messenger RNA molecules fluorescently labeled with a protein in living cells have experimentally been found to exhibit exponential diffusivity fluctuations: the diffusivity, which spatiotemporally fluctuates over cytoplasm of the cell, obeys the exponential law [1]. This finding has turned out to lead to a nontrivial result [2] that a formal analogy with the thermodynamic relation concerning temperature exists for entropy associated with diffusivity fluctuations. Here, the analogy between fluctuating diffusivity of the RNA-protein particles and thermodynamics is discussed. Regarding the average value of the diffusivity as the analog of the internal energy, the analogs of the quantity of heat and work are identified. The Clausius-like inequality is also shown to hold for the entropy and the analog of the quantity of heat. Thus, the present discussion may contribute to a deeper understanding of diffusivity fluctuations of the RNA-protein particles in view of the laws of thermodynamics.

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Reentrant Random Quantum Ising Antiferromagnet

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We consider the quantum Ising chain with uniformly distributed random antiferromagnetic couplings $(1 \leq J_i \leq 2)$ and uniformly distributed random transverse fields ($\Gamma_0 \leq \Gamma_i \leq 2\Gamma_0$) in the presence of a homogeneous longitudinal field, h. Using different numerical techniques (DMRG, combinatorial optimisation and strong disorder RG methods) we explore the phase diagram, which consists of an ordered and a disordered phase. At one end of the transition line ($h = 0, \Gamma_0 = 1$) there is an infinite disorder quantum fixed point, while at the other end ($h = 2, \Gamma_0 = 0$) there is a conventional classical random fixed point. Close to this fixed point, for $h > 2$ and $\Gamma_0 > 0$ there is a reentrant ordered phase, which is the result of quantum fluctuations by means of an order through disorder phenomenon.

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Unusual changeover in the transition nature of local-interaction Potts models

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A combinatorial approach related to the asymptotic number of lattice animals with a fixed number of faces (lattice unit cells) is employed to study the critical behavior of a q-state Potts model with a *round-the-face* interaction [1, 2]. Using this approach it is shown that the model exhibits a first order transition for $q > 3$. A second order transition is numerically detected for $q = 2$. Based on these findings, it is deduced that for some two-dimensional ferromagnetic Potts models with *completely local* interaction, there is a changeover in the transition order at a critical integer $q_c \leq 3$. This stands in contrast to well known result for the standard pair-interaction Potts model where the maximal integer value for which the transition is continuous is $q_c = 4$ [3, 4, 5]. A lower bound on the first order critical temperature is additionally derived.

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Variational Approach to KPZ: Fluctuation Theorems, Large Deviation Function for Entropy Production, and Probability Distribution

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Motivated by the time behavior of the functional arising in the variational approach to the KPZ equation [1] [2], and in order to study fluctuation theorems in such a system, we have adapted a path-integral scheme that adequately fits to this kind of study dealing with unstable systems. As the KPZ system has no stationary probability distribution [3], we show how to proceed for obtaining detailed as well as integral fluctuation theorems. This path integral methodology, together with the variational approach, in addition to allowing analyze fluctuation theorems, can be exploited to determine a Large Deviation Function for entropy production [4]. As a final by-product, we show what could be an explicit expression for the probability distribution of the KPZ system.

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Reentrant phase transitions in complex contagion on multiplex networks

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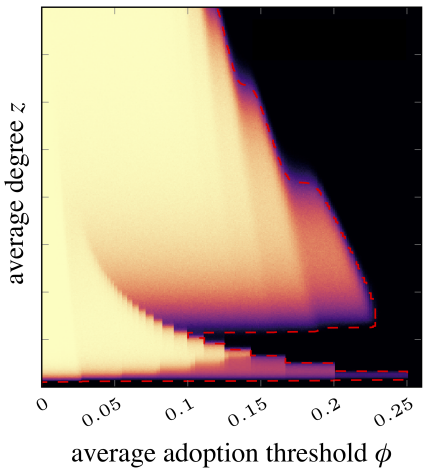

Figure 1: Expected final cascade size in weight heterogeneous multiplex networks with hierarchical layer density. Heat-maps come from numerical simulations, while dashed lines show solutions from linear stability analysis.

Information-communication technology provides an increasingly accurate picture of human interactions, allowing a detailed mapping of the underlying network structures that mediate contagion processes. In social contagion [1], characteristic for spreading of innovations, rumours or systemic risk, transmission is a collective phenomenon where all social ties of an individual may be involved. Consequently, degrees (number of links) of nodes are critical to the final dynamical outcome of the spreading process. This behaviour is well captured by threshold models of social contagion on single-layer networks [2], which predict large-scale cascades of adoption only for relatively sparse networks. Empirical social networks, however, indicate that individuals can maintain hundreds of ties with strength of interaction varying across a range of social contexts. These systems constitute dense and strongly heterogeneous networks that nonetheless exhibit frequent system-wide cascades of social contagion [3].

We address this issue by incorporating some of the most relevant features of empirical social networks into a conventional threshold model. First, we consider that network ties are heterogeneous and can be characterised by edge *"types"* modelled by multiplex structures. In social networks, due to finite cognitive and time resources, individuals actively maintain limited number of relationships, and organise them into hierarchical intimacy circles that increase in size as they decrease in importance, a phenomenon which can be arguably explained by an entropy maximisation process [4].

Here we study threshold driven contagion over such heterogeneous multiplex networks organised in weighted layers [5] with hierarchical density. By means of analytical and numerical tools [6], we show that multiplexity can lead to global cascades in networks with average degree in the hundreds or thousands, perturbed only by a single initial adoption. As a novel observation, we also show that in a multiplex network with increasing link density a sequence of phase transitions occur, resulting in alternating phases of stability and instability to global cascades as demonstrated in Figure 1.

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Shape of random polymer networks

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We propose the model of a random polymer network, formed on the base of the Erdös-Rényi random graph. In the language of mathematical graphs, the chemical bonds between monomers can be treated as vertices, and their chemical functionalities as degrees of these vertices. We consider graphs with fixed number of vertices $N = 5$ and variable parameter c (connectedness), defining the total number of links $L = cN(N-1)/2$ between vertices. Each link in such graphs is treated as a Gaussian polymer chain. The universal rotationally invariant size and shape characteristics, such as averaged asphericity $\langle A_3 \rangle$ and size ratio g of such structures are obtained both numerically by application of Wei's method [1] and analytically within the continuous chain model. In particular, our results quantitatively indicate an increase of asymmetry of polymer network structure when its connectedness c decreases [2].

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Conformal invariance in the nonperturbative renormalization group: A rationale for choosing the regulator

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Field-theoretical calculations performed in an approximation scheme often present a spurious dependence of physical quantities on some unphysical parameters associated with the details of the calculation setup (such as the renormalization scheme or, in perturbation theory, the resummation procedure). We propose to reduce this dependence by invoking conformal invariance. Using as a benchmark the three-dimensional Ising model, we show that, within the derivative expansion at order 4, performed in the nonperturbative renormalization group formalism, the identity associated with this symmetry is not exactly satisfied. The calculations which best satisfy this identity are shown to yield critical exponents which coincide to a high accuracy with those obtained by the conformal bootstrap. Additionally, this work gives a strong justification to the success of a widely used criterion for fixing the appropriate renormalization scheme, namely the principle of minimal sensitivity.

Scaling of the Random–Field Ising Model in Two Dimensions

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Being one of the simplest models of magnetic systems with quenched disorder, the random-field Ising model shows surprisingly rich critical behavior. Only recently has it been possible with the help of large-scale numerical simulations to shed some light on a range of fundamental questions in three and higher dimensions, such as universality, critical scaling and dimensional reduction. The two-dimensional model has received less attention, but is no less fascinating. We solve a long-standing puzzle by presenting compelling numerical evidence for the scaling behavior of the correlation length ξ. Results for two lattice geometries, square and triangular, consistently support the form $\xi \sim \exp[A/h^2]$, where h denotes the random-field strength, in line with early theoretical work [1], but at variance with some more recent numerical and analytical results [2, 3]. We also investigate the more widely used break-up length scale of the system, which we however find to be afflicted by much stronger scaling corrections and hence a rather less useful quantity.

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Critical behaviour of the Ising model with invisible states on a scale-free network

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The critical behavior of a generalized Ising model is investigated, in which each spin variable in addition to the usual states ± 1 can be in r invisible states. Such states do not contribute to the interaction energy, but change system entropy. Recently, models with invisible states are of great interest, in particular because they allow to analyse peculiarities of energy and entropy interplay on critical behaviour [1]. We consider such a model on an annealed scale-free network where the probability of a randomly chosen vertex having degree k is governed by the power law $P(k) \sim k^{-\lambda}$ [2]. Such problem has a number of interesting applications, ranging from nano- to socio-physics. A detailed analysis of the critical behavior of such a model is performed and a number of new effects are analysed.

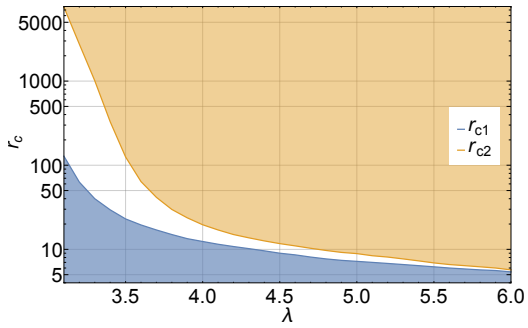

Figure 1: Phase diagram of the model in the λ–r plane. Three regions, presented here, differ in critical behaviour. In the lower (blue) region system possesses only second order phase transition; in the region in-between the lines there are both first and second order phase transitions at different temperatures; in upper region (yellow) only the first order phase transition occurs.

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Patterns of social connections in urban space

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Human interaction defines the structure and function of regions and cities. Online social media data provides researchers an unprecedented collection of digital human footprints that opens new possibilities to study these connections at a microscopic level. Recently, many studies tried to characterize different interplays between urban mobility patterns, socio-economic status and the social network of people from telecommunication or online social network data at the city level [1–4]. In this work, we follow individuals in the 25 largest metropolitan areas of the United States through their messages sent on the online social networking site, Twitter. Focusing on users with frequent messages containing exact coordinates, we identify their possible home and work location inside cities. Additionally, we construct the social network of users based on mutual followership on the site and analyze how social relationships are formed depending on home and work locations in urban space.

Our results suggest that the structure of individuals' social ties is sensitive to the income levels at their home and work locations. Residents of poor areas (bottom 30% income percentile) who commute to richer parts (top 30% income percentile) of a city travel more and tend to have a significantly lower degree in the social network than those who remain to work in the bottom 30% areas. Also, these users have a higher clustering of mutual followers in their ego network and a larger fraction of their friends concentrate geographically close to their home location. We thus discover fundamental patterns in social tie formation using only publicly available geolocated data combined with census information.

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Predicting chaotic time series by means of reservoir computing

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It has been demonstrated that in the realm of complex systems not only exact predictions of multivariate time series with large time horizons become possible but also the long term behavior of the underlying dynamical system (its climate) can well be reproduced using machine learning techniques (see e.g. [1]).
This is achieved by using reservoir computing (RC), which represents a special kind of recurrent neural networks (RNN). The core of the model is a network called reservoir, which is a complex network with loops. Input data are fed into the nodes of the reservoir, which are connected according to a predefined network topology (mostly random networks). Only the weights of the linear output layer transforming the reservoir response to output variables are subject to optimization via linear regression. This makes the learning extremely fast and omits the vanishing gradient problem of other RNNs.
Here, we investigate the question of statistical stability of short and long term predictions and find that the ability to exactly forecast the correct trajectory as well as the reconstruction of the long-term climate measured by the correlation dimension and largest Lyapunov exponent strongly varies among different realizations of the same reservoir setup [2]. Thus, special care must be taken in selecting the good predictions.
To improve upon the statistical robustness of the prediction results we tested different network topologies, namely (random) Erdös Renyi, small world and scale free networks for the reservoir. While the small world reservoir showed slightly better results for the Lorenz system than a random network, the scale-free network performed worse, where the difference to the other two network types is much pronounced for the Rössler system [2]. In-depth studies reveal that the nodes which contribute most to the output signal are not those, which have most connections in the network. Thus scale-free networks with some highly connected nodes do not represent the suitable topology for this kind of prediction task. Furthermore, we demonstrate that a controlled node removal and a suitable chosen weighting function significantly increase the prediction performance - even with a much smaller reservoir [3].
Studying and interpreting these results in detail will give new insights about the essential requirements for the emergence of complex behavior in nonlinear dynamical systems.

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Finite-time Landauer principle

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In this talk, I will discuss the finite-time erasure of a classical bit [1]. Using ideas from optimal transport theory, I will derive optimal protocols and a finite-time generalisation of Landauer's principle [1]. In particular, I will show that the minimum amount of dissipation needed to erase a bit is roughly one order of magnitude less then currrent state-of-art experiments.

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Transparent Electrodes with Rod- and Ring-Like Fillers: Monte Carlo Simulation and Analytical Evaluation

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Using both computer simulation and analytical consideration, we evaluated the electrical conductance of two-dimensional composites with both rod- [1, 2, 3, 4, 5] and ring-like [6, 7] fillers. For rod-like fillers, effect of tunneling [2], of filler length dispersity [3], and of alignment of fillers [5, 6] on the electrical conductivity has been evaluated. Anisotropy in electrical conductivity has been studied for both nonintersecting [4] and intersecting [5] aligned fillers. First, objects are randomly deposited onto a substrate with desired number density. Objects may obey a size distribution. In the case of rod-like objects, anisotropic deposition may also be produced. Then, the system transforms into a corresponding random graph which is treated as a random resistor network (RRN). Finally, the electrical conductivity of such the RRN is calculated.

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Phase behavior of passive and active disks in two dimensions

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We will show results for the phase diagram of active disks and dumbbells interacting by soft excluded volume potential [1, 2]. For disks, at small activity, we find that the 2D melting behavior of passive hard disks still holds with a continuous Halperin-Nelson transition between the solid and hexatic phases, and a first order transition between the hexatic and liquid phases, when density or packing fraction are decreased at constant temperature. By increasing activity, hexatic-liquid coexistence reduces to a critical line that reaches, at high activity, another coexistence region where clusters and a dilute phase are observed. We study the role of defects in the different transitions. We also show the differences with the phase diagram of active dumbbells where the coexistence region continuously extend from the passive limit to high activity [2].

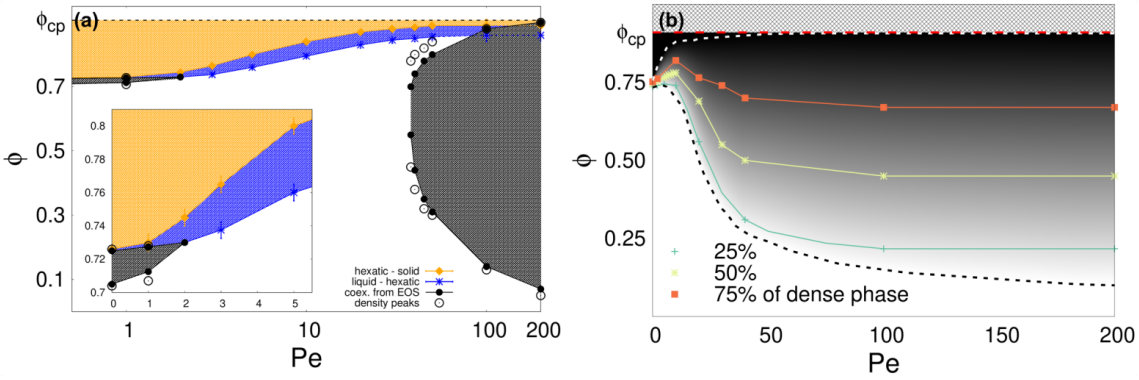

Figure 1: The (ϕ, Pe) phase diagram for disks (left) and dumbbells (right). In the panel (a), for disks, all the phases are highlighted with colors: white is used for disordered gas/liquid regions, grey for coexistence regions, blue for hexatic and orange for solid. See [1] for details about the symbols and the features of the phases. In panel (b) the shaded background and the three colored lines represent the increasing area fraction of the dense phase in coexistence. Figure adapted from [2].

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Strategies for motile cell-like compartments

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The reconstitution of life-like properties in artificial cells is a current research frontier in synthetic biology. Mimicking metabolism, growth, and sensing are active areas of investigation; however, achieving autonomous motility and directional taxis are also challenging in the context of artificial cells [1]. Merging the fields of active matter physics with synthetic biology provides a promising approach in this direction. Progress in nanotechnology has enabled the creation of active particles that convert energy into motion giving rise to motile behaviours that can be explained in the framework of non-equilibrium statistical physics [2].

In this talk I will present steps to create cell-like compartments with controlled geometry out of biomolecular components. Further, I will show multiple strategies to induce self-propulsion on these compartments across different length-scales with the assembly tools of DNA nanotechnology.

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Elongated particles: From diluted two-dimensional systems to dense ones

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During the past decades, the problems of particle packing have attracted growing both academic and practical interest. Systems composed of shape-anisotropic (elongated) particles are of special importance. The shape of the particles dictates the complex collective behavior, self-assembly and spontaneous orientational ordering. The phenomena including jamming, segregation, and pattern formation can be marked out in such systems.

This talk is devoted to the analysis of jamming and percolation behavior of two-dimensional systems of elongated particles. We consider the problems both in continuous space [1, 2] and in discrete one (with the special attention to the square lattice [3]), as well the systems with isotropically deposited and aligned particles. Overviews of different analytical and computational methods and main results are presented [4].

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Activating new universality with the Kibble-Zurek mechanism

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The Kibble-Zurek mechanism takes place when a system is slowly driven through a second order phase transition. This produces a diabatic freeze out of critical fluctuations and cuts off the divergence of the correlation length. Recasting this problem in a systematic RG formulation, we show that the slow drive can be used to activate not only the leading critical exponents of the underlying equilibrium problem, but the full critical exponent spectrum. We thus uncover an aspect of the Kibble-Zurek phenomenology, where the underlying equilibrium critical physics provides multiple universal scaling regimes [1].

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Autonomously adapting non-conserving sandpiles

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A autonomously adapting non conserving sandpile model is proposed and studied extensively [1]. The number of sandcorns distributed is independent of the state of the active site, which topples if at least two sandcorns are present, see Fig. 1. Either two or three sandcorns are distributed randomly to nearest neighbors, respectively with probability $1-p$ and p. An absorbing phase transition within the directed percolation class is observed. The model, which mimics the firing activity of neurons, is well suited to study critical phenomena in the brain.

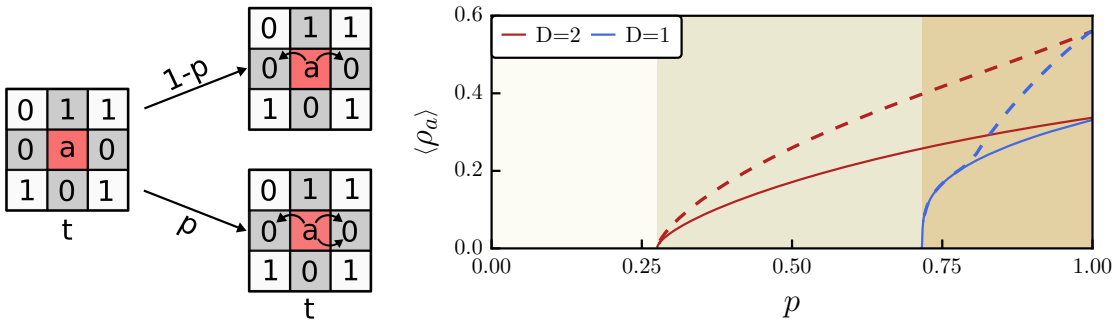

Figure 1: *Left*: A site with two or more sandcorns topples, distributing two or three sandcorns with probabilities $1-p$ and p. *Right*: The phase diagram as a function of p, in one and two dimensions, $D = 1/2$. Shown is the density ρ_a of active sites (full lines) and metastable solutions conserving the AB-sublattice symmetry (dashed lines). The transitions from absorbing to active phases take place at $p_c \approx 0.27453(1)$ and $p_c \approx 0.71692(2)$ in two and one dimensions.

Metastability. It is pointed out that nearest-neighbor toppling rules on bipartite lattices lead to states in which the AB-sublattice symmetry is broken spontaneously. This observation holds generally, including the Manna and the new AAS model. Synchronous dynamics leads to states in which all active sites are located either on the A or on the B sublattice, respectively for even/odd time steps. Critical exponents evaluated so far have been for sublattice symmetry braking states. In the here discussed AAS model long-lived metastable AB-sublattice symmetric states are observed.

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A scaling approach to estimate the COVID-19 infection fatality ratio by age

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SARS-CoV-2 has disrupted the life of billions of people around the world since the first outbreak was officially declared in China at the beginning of 2020. Yet, important questions such as how deadly it is or its degree of spread within different countries remain unanswered. In this work, we exploit the "universal" growth of the mortality rate with age observed in different countries since the beginning of their respective outbreaks, combined with the results of the antibody prevalence tests in the population of Spain, to unveil both unknowns. We validate these results with an analogous antibody rate survey in the canton of Geneva, Switzerland. We also argue that the official number of deaths over 70 years old is importantly underestimated in most of the countries, and we use the comparison between the official records with the number of deaths mentioning COVID-19 in the death certificates to quantify by how much. Using this information, we estimate the fatality infection ratio (IFR) for the different age segments and the fraction of the population infected in different countries assuming a uniform exposure to the virus in all age segments. We also give estimations for the non-uniform IFR using the sero-epidemiological results of Spain, showing a very similar growth of the fatality ratio with age. Only for Spain, we estimate the probability (if infected) of being identified as a case, being hospitalized or admitted in the intensive care units as function of age. In general, we observe a nearly exponential growth of the fatality ratio with age, which anticipates large differences in total IFR in countries with different demographic distributions, with numbers that range from 1.82% in Italy, to 0.62% in China or even 0.14% in middle Africa.

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Evidence for Supersymmetry in the Random-Field Ising Model at $D = 5$

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We provide a nontrivial test of supersymmetry in the random-field Ising model at five spatial dimensions, by means of extensive zero-temperature numerical simulations. Indeed, supersymmetry relates correlation functions in a D-dimensional disordered system with some other correlation functions in a $D-2$ clean system. We first show how to check these relationships in a finite-size scaling calculation and then perform a high-accuracy test. While the supersymmetric predictions are satisfied even to our high accuracy at $D = 5$, they fail to describe our results at $D = 4$.

Adsorption Statistics of Structured Molecules

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A major bottleneck in dealing with lattice gases of structured species (large molecules blocking more than one adsorption center on a lattice) within the framework of classical statistical mechanics is to properly calculate the entropic contribution to the adsorbate's free energy. In this work, multisite-occupancy adsorption is described as a fractional statistics problem [1]. Site exclusion is characterized by statistical exclusion parameter g which relates to the molecular size and lattice geometry. Under these conditions, the analytical expression of the adsorption isotherm is obtained,

$$\ln(Kc) = \ln\theta + (g-1)\ln[g-\theta(g-1)] - g\ln(g-\theta g), \tag{1}$$

where K is the adsorption constant, c is the concentration of the solute in the liquid and θ is the surface coverage. Adsorption isotherms for objects of different shape and size are obtained and compared with Monte Carlo (MC) simulations, and theoretical results from the Liu's model [see Eq. (16) in Ref. [2]]. An illustrative example for 2×2 squares and 2×4 rectangles adsorbed on square lattices is shown in Fig. 1. The reaches and limitations of the theoretical models are discussed, as well as its possible application to the problem of antifreeze protein-ice adsorption [2].

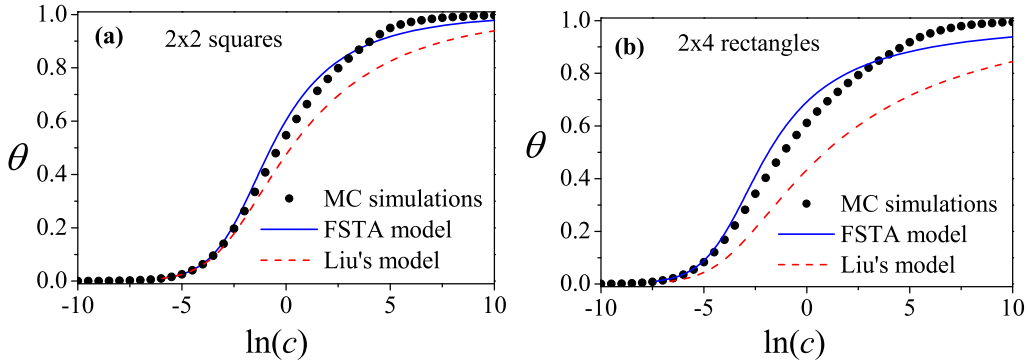

Figure 1: Adsorption isotherms obtained for 2×2 squares (a) and 2×4 rectangles (b) on square lattices with $K=1$. Symbols represent simulation results. Solid and dashed lines were calculated using FSTA [Eq. (1)] and Liu's model [see Eq. (16) in Ref. [2]], respectively.

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Thin film spreading: bulk and precursor non-universal dynamics

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One of the manifestations of thin film spreading is the phenomenon of a precursor spreading in front of an advancing droplet. The microscopic characteristics of the precursor dynamics is still not fully understood. We study top-view thin film spreading using a driven lattice-gas model of two layers, representing the bulk and the precursor film, first suggested by Abraham et al. By changing the relations between the Hamaker constant (van der Waals interaction), the nearest neighbor interaction (surface tension) and the temperature, we study the effects of these parameters on the scaling exponents describing the spreading of both layers. We find that the scaling exponents of both layers are not universal, and show that they strongly depend on these parameters. We also discuss the relation between our results and well-known laws for the bulk dynamics of spreading droplets, such as the Tanner and Lopez laws, as well as with recent results on precursor dynamics.

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Beyond Linear Use of Equation Superposition

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An iteration sequence based on the BLUES (Beyond Linear Use of Equation Superposition) function method [1] is presented for calculating analytic solutions to nonlinear differential equations. A recent work has shown that the use of the BLUES function method in ordinary differential equations (ODEs) is justified [2]. Two new case studies are now presented: a time-dependent viscous Burgers equation with chemical reaction and a fractional differential equation (FDE) arising in the study of nonlinear heating and cooling in a semi-infinite rod. A comparison with two established methods (VIM and ADM) is made. For the Burgers partial differential equation (PDE), it is shown that the BLUES function method converges globally to the exact solution, while the VIM or ADM converges for $t < 1$.

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Stablizing phase locked patterns in systems of Kuramoto oscillators with delayed coupling

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Stability of phase locked patterns is studied in a system of locally coupled identical Kuramoto rotators, interacting through a time delayed sinusoidal coupling. We generalize the results of [1] on the stability of in-phase synchrony in the case of Kuramoto oscillators to different synchronization modes. The presence of time delay causes bifurcations of phase locked states, meaning that states being unstable in the non-delayed case (see for example [2]) become stable and vice versa. Stability maps exhibit symmetric and periodic patterns after rescaling the relevant parameters. The size of the attraction basins, i.e. the probability of different modes, also changes periodically as a function of the parameters, resulting in a periodic shift of the most probable state from in-phase synchronization to anti-phase ordering (Figure 1).

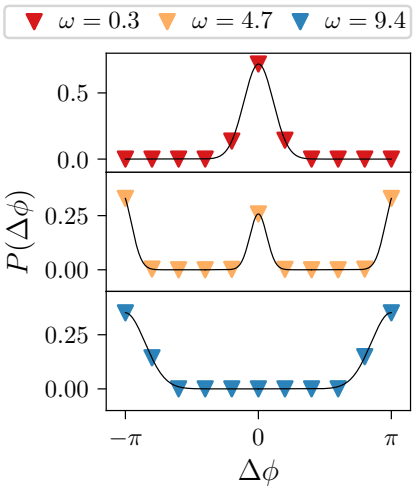

Figure 1: Shift from the most probable in-phase synchrony ($\Delta\phi = 0$) to anti-phase synchronization ($\Delta\phi = \pm\pi$) induced by varying the dimensionless natural frequency $\omega = \omega_0 \cdot \tau$, where τ is the time delay and ω_0 is the true natural frequency.

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Voronoi Diagrams to Detect Communities in Weighted Directed Graphs

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In the 21st century we are all surrounded by networks and their complexity can range from simple to highly complex ones. Many complex systems can be modelled with networks and this became a useful strategy in biology, neuroscience, social sciences, information technology, etc. [1, 2] One of the key challenges of this field is to accurately find optimal communities in these complex networks. Generally a simple unweighted and undirected network model is used, for which there are several good known algorithms to perform an optimal clustering [3, 4, 6, 7], however more and more complex systems use weighted and directed network models. One of the best algorithms is the Louvain algorithm [5], which can perform clustering on weighted networks, but it still does not take into account the direction of links. In a recent paper [8] a novel algorithm for community detection on unweighted and undirected graphs was introduced based on Voronoi diagrams. Based on [8] we present the generalized version of the method so it can be used on directed and weighted networks, and it also works on very dense networks, where communities are not determined by graph structure, but rather by the weights of links themselves. The approach presented here introduces two major modifications to the original algorithm: 1) the metric used to define distance between nodes must include the weights of links between nodes; 2) the selection of the Voronoi cell centers and the attribution of all nodes to the Voronoi regions must include the directions of links. We have tested the algorithm on randomly generated benchmark networks (the generating algorithm based on [9] also needed to be updated); and on real-life networks constructed from neuroscience data: inter-areal cortical network of the macaque monkey obtained by retrograde-tracing experiments [10].

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Bosonics systems in the Canonical Ensemble

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Quantum systems with infinite number of levels are difficult to treat with the canonical ensemble because of the difficulties in calculating the partition function of these systems[1]. We get to calculate the canonical partition function for these systems. We can then deduce the thermodynamic quantities such as the average energy. We have studied boson systems formed by N bosons distributed over a small number of energy levels. We have considered situations where the energy levels are arbitrary and then cases where the levels are equidistant [2]. We deduced the average energy in each case. Comparing with the classical case we have given an expression of the quantum correlation for the average energy for these systems. We have plotted this correlation as a function of temperature, for differents number of levels and differents number of particles. We found in particular that this correlation increases with the number of levels and also with the number of particles.

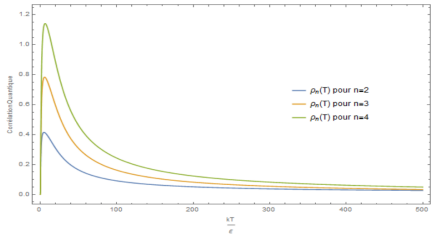

Figure 1: Correlation factor as a function of temperature (kT / ε)for different values of the number of particles, for a two-level system

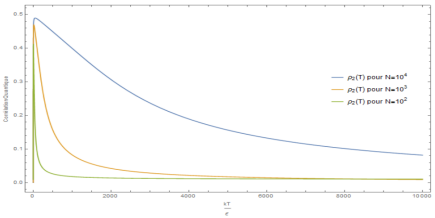

Figure 2: Correlation factor as a function of temperature (kT / ε)for different values of the number of levels, for fixed number of particles

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Phase transitions in low-velocity impact phenomena

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We investigate the impact induced breaking of heterogeneous materials in the range of low impact velocities far below the fragmentation threshold. Particle breakage is widely used by the industry in comminution processes of ores and minerals. In these industrial applications particles collide both with each other and with hard walls presented by the components of the process equipment (conveyors, transportation tubes, and containers). A specific area where particle-wall collisions are of utmost importance is the damaging of aircrafts, especially jet engines by impacting hail particles which can cause power reduction and even flame-out of the engine.

Over the past decades, a detailed knowledge has been accumulated in physics [1, 2], and engineering on single impact breakage phenomena, however, a comprehensive understanding of low velocity impact sequences responsible for the the gradual mass reduction and rounding of solid particles is still lacking. Here we present a theoretical study of the phase structure of impact induced attrition processes. Based on realistic discrete element simulations [3] of sequences of particle-wall collisions, we show that depending on the impact velocity, three distinct phases of breakage emerge: at sufficiently low velocities repeated impacts result in abrasion of the body and lead to a finite asymptotic residual mass, however, above a threshold velocity a complete destruction is achieved within a finite number of repetitions. Instantaneous fragmentation occurs above a second critical velocity where cracks span the entire body and the sample rapidly falls apart into a large number of small pieces. The transitions between the abrasion, cleavage, and fragmentation phases occur at well-defined critical velocities analogous to continuous phase transitions. Our computer simulations revealed that the evolution of the mass and shape of the solid is governed by scaling laws in terms of the impact velocity. Most notably, in the cleavage phase the sample lifetime decreases as a power law of the impact velocity analogous to the Basquin law of sub-critical fracture. In the abrasion phase the shape evolution of the sample is described by a universal scaling form with a power law dependence on the impact velocity. The precise phase structure and scaling laws of impact induced attrition are important to understand the evolution of landforms, and can be exploited in the design of comminution technologies.

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Complex fluctuations of a Lotka-Volterra type attention dynamics model

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There is an increasing amount of empirical evidence that cultural processes are accelerating [1]. Using a minimal model based on Lotka-Volterra dynamics for species (topics) which are competing for a common resource (collective attention), one can reproduce many statistical features of the empirical data collected from various sources (Twitter, Reddit, Wikipedia) [2]. Within this model the collective attention a topic receives is proportional to the occurrence counts of contents (e. g. hashtags) per day. Content volume growth is inhibited by the saturation due to existing content from the past, as well as by the competition with other topics. Furthermore, for the self-inhibiting saturation, contents from the distant past are discounted exponentially due to the finite memory of the public.

Here we study the fluctuating dynamics of this Lotka-Volterra type system (see Fig. 1). Although the number of fixpoints grows exponentially with the number of topics N, namely as 2^N, it is possible to perform linear stability analysis for general system sizes analytically. We find that during the time-like fluctuations of the distribution of collective attention the trajectory wanders among the exponentially large number of saddle points, visiting them eventually in a seemingly aperiodic order.

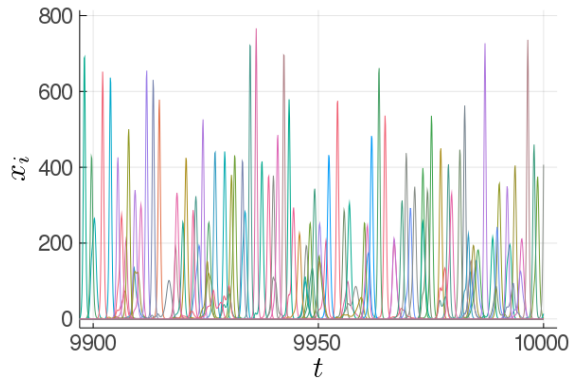

Figure 1: Fluctuating time series of content volumes for 300 topics. Note the sharp peaks with abrupt growing and decaying processes in the attention dynamics.

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Population boundary across an environmental gradient: Effects of quenched disorder

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Population boundary is a classic indicator of climatic response in ecology. In addition to known challenges, the spatial and dynamical characteristics of the boundary are not only affected by the spatial gradient in the environmental factors, but also by local heterogeneities in the regional characteristics. Here, we capture the effects of quenched heterogeneities on the ecological boundary with the disordered contact process in one and two dimensions with a linear spatial trend in the local control parameter. We apply the strong-disorder renormalization group method to calculate the sites occupied with an $O(1)$ probability in the stationary state, readily yielding the population front's position as the outermost site locally as well as globally for the entire boundary. We show that under a quasistatic change of the global environment, mimicking climate change, the front advances intermittently: long quiescent periods are interrupted by rare but long jumps. The characteristics of this intermittent dynamics are found to obey universal scaling laws in terms of the gradient, conjectured to be related to the correlation-length exponent of the model. Our results suggest that current observations might misleadingly show little to no climate response for an extended period of time, concealing the long-term effects of climate change.

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Information Theoretic Comparison of Transcriptional and Post-transcriptional Regulations

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Gene regulation in a cellular environment is a stochastic phenomenon leading to a large variability in mRNAs and protein numbers that are often produced in bursts. The regulation leading to varied protein dynamics can be ascribed to transcriptional or post-transcriptional mechanisms. In transcriptional regulation, the promoter dynamically switches between an active and an inactive state, while in the post-transcriptional regulation small RNAs tune the activity of mRNAs. The proteins produced from either regulatory networks may work as transcription factors which are the internal representative of both of internal and external environmental signal. Transcription factors are designed to transit rapidly between active and inactive molecular states, at a rate that is modulated by a specific environmental signal. Each active transcription factor can bind with the promoter to regulate the rate at which specific target genes are read. Hence, one may interpret a gene network as a communication network in which the information about the internal or external environment is carried by the transcription factor (message) to modulate the state of the promoter and expression levels of another gene (the receptor). Now one can frame the question that how much should we trust the message carried by the transcription factors and which gene regulatory network will provide more reliability. To address the question we can calculate the Shannon's entropy of the message and the mutual information between the message and the receptor which are quantifiers of the reliability of the gene network dynamics. Here we consider a stochastic models for transcriptional and post-transcriptional regulations and use exact steady state solutions to calculate the entropy and mutual information. We show that slow (fast) switching of promoter (mRNA) minimizes Shannon's entropy and maximizes mutual information. The larger value of Shannon's entropy and smaller value of mutual information provide less reliability of the information passed by the transcription factor, we can conjecture that slow (fast) switching of promoter (mRNA) gives more reliable information for comparable transcription factor yields.

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Competing Universalities in Kardar-Parisi-Zhang Growth Models

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We report on the universality of height fluctuations at the crossing point of two interacting $1+1$-dimensional Kardar-Parisi-Zhang interfaces with curved and flat initial conditions. We introduce a control parameter p as the probability for the initially flat geometry to be chosen and compute the phase diagram as a function of p. We find that the distribution of the fluctuations converges to the Gaussian orthogonal ensemble (GOE) Tracy-Widom (TW) distribution for $p < 0.5$, and to the Gaussian unitary ensemble (GUE) TW distribution for $p > 0.5$. For $p = 0.5$ where the two geometries are equally weighted, the behavior is governed by an emergent Gaussian statistics in the universality class of Brownian motion (Fig. 1). We propose a phenomenological theory to explain our findings and discuss possible applications in nonequilibrium transport and traffic flow [1].

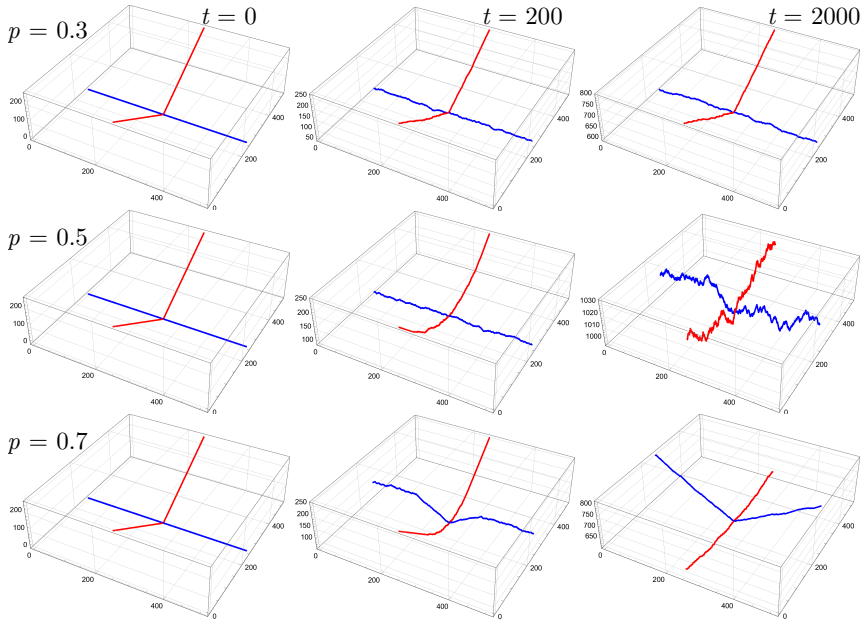

Figure 1:

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Characterizing resting state brain networks based on probability distributions of network properties

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Functional networks (FN) extracted from different trials (periods) even during the same experimental fMRI session can differ drastically. This remains true even if we take different parts of a longer session made in resting state. Even if there are studies discussing this dynamical nature, the common practice has been to build an average FN by taking the links one by one and averaging their weights along different experimental sessions. The problem with this averaging process is that it generates a network that is far from any real state of the FN, so any network analysis may lead to wrong conclusions. Here we argue, that the system is in a complex chaotic attractor not a fixed state, so the average of the samples most of the time falls outside of the attractor. The more correct approach is to study the probability distribution of network properties, which may be used as imaging fingerprints to characterize brain function in pathological conditions.

For comparing FNs between different groups we study two different measures: 1) The distance distribution between nodes (NDD), that was already mentioned to be a good description of a graph's global structure and has robust statistics such that even a small number of experimental trials is enough to see a stable pattern. In this case for each node we calculate its distance (shortest path) to all other nodes and calculate their distribution. 2) A more local measure will be called the node-edge weight distribution (N-EWD). In this case for each node we calculate separately the edge weight distributions of its own links. This network measure also shows a stable distribution that we can hypothesize to be a good characterization of the resting states attractor.

As a proof of concepts, we show an application in the study of early stages in alcohol pathology in a well-controlled rat model. We follow longitudinally the changes in the brain that are driven by chronic moderate levels of alcohol consumption during 1 month. With this new methodology developed we were able to identify key nodes that show significant differences between conditions. We saw that the main effect of alcohol is that it weakens the correlations between nodes (the edge weights).

Record statistics of bursts signals the onset of acceleration towards failure

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Forecasting the imminent catastrophic failure has a high importance for a large variety of systems from the collapse of engineering constructions, through the emergence of landslides and earthquakes, to volcanic eruptions. Failure forecast methods (FFM) predict the lifetime of the system based on the time-to-failure power law of observables describing the final acceleration towards failure [1]. We show that the statistics of records of the event series of breaking bursts, accompanying the failure process, provides a powerful tool to detect the onset of acceleration, as an early warning of the impending catastrophe. We generate fracture processes of heterogeneous materials using the fiber bundle model, which has the advantage that varying the amount of microscale disorder, it exhibits transitions between distinct phases of perfectly brittle, quasi-brittle, and ductile fracture [2]. To quantify how the degree of disorder determines the predictability of failure, we investigate the internal structure of the sequence of breaking bursts analyzing the record size events. We demonstrate that the waiting time between consecutive record breakings, i.e. the lifetime of records, is very sensitive to the details of the fracture process providing a clear signal of the acceleration of the dynamics towards ultimate failure [3]. In particular, we show the existence of a characteristic record rank k^* which marks the onset of acceleration of record breaking: below k^* record breaking slows down due to the dominance of disorder in the fracture process, while above it the stress redistribution gives rise to an enhanced triggering of bursts after breaking events. Detecting k^* can be exploited as an early signal of the imminent ultimate failure of the system, however, the significance of the accelerating regime strongly depends on the degree of disorder. Most notably, we show that the highly brittle fracture of low disorder materials and the ductile failure of strongly disordered ones are both unpredictable due to the absence of accelerated record breaking. Our results imply the existence of a lower and upper bound of the amount of materials' disorder beyond which no meaningful failure prediction is possible [3].

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Over 40 years of statistical physics history: bibliometric analysis of MECO

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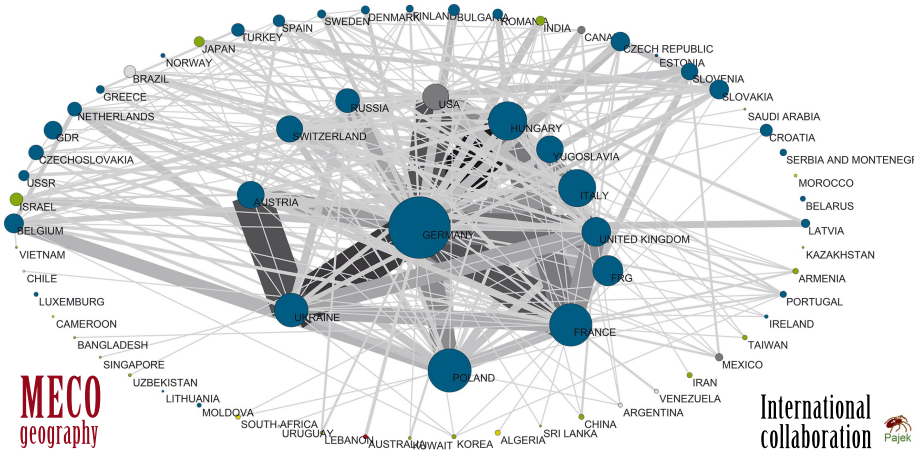
The history of European (and not only) statistical physics and the history of the Conferences of the Middle European Cooperation in Statistical Physics (MECO) are tightly intertwined. For over 40 years the latter brings together active researchers in the field. But while today this is simply one of possible ways to interact, in the time of its initiation it was rather a very special opportunity. MECO was born from the idea to bridge the gap between the Eastern and Western European scientific communities. In this report we present a scientometric part of a general overview of MECO activities [1]. The bibliographic data collected from MECO abstracts and programs [2] is used to quantitatively track the history of scientific contacts between separated nations. Over 3500 records about oral and poster contributions are used to construct coauthorship network on different levels (authors, countries) to study its peculiarities, evolution and maturing. Geographical spectrum, level of participation of individuals as well as countries, the strength of bonds between them are analyzed. This analysis can be considered as a general portrait of a big conference painted in numbers, but it can also serve as a piece in a mosaic depicting the history of European statistical physics.



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Anisotropic crack patterns induced by shrinkage in thin layers

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Layers of heterogeneous materials attached to a substrate often undergo sequential cracking due to shrinkage stresses caused by desiccation. From the spectacular crack patterns of dried out lake beds through the polygonal ground patterns of permafrost regions to the formation of columnar joints in cooling volcanic lava shrinkage induced cracking is responsible for a large variety of complex crack structures in nature [1]. Under laboratory conditions this phenomenon is usually investigated by desiccating thin layers of dense colloidal suspensions in a container, which typically leads to polygonal crack patterns with a high degree of isotropy.

It is a great challenge to control the structure of shrinkage induced two-dimensional crack patterns [2] also due to its high importance for technological applications [3]. Recently, it has been demonstrated experimentally for dense calcium carbonate and magnesium carbonate hydroxide pastes that applying mechanical excitation by means of vibration or flow of the paste the emerging desiccation crack pattern remembers the direction of excitation, i.e. main cracks get aligned and their orientation can be tuned by the direction of mechanical excitation.

In order to understand the mechanism of this memory effect, we studied the process of shrinkage induced cracking by means of realistic discrete element simulations. In the model a thin layer is discretized on a random lattice of Voronoi polygons attached to a substrate [4]. We assume that the initial mechanical vibration imprints plastic deformation into the paste, which is captured in the model by assuming that the local cohesive strength of the layer has a directional dependence: the layer is stronger along the direction of vibration. We demonstrate that based on this simple assumption, the model well reproduces the qualitative features of the anisotropic crack patterns observed in experiments. Gradually increasing the degree of anisotropy the system exhibits a crossover from an isotropic cellular structure to an anisotropic one where the spacing of aligned cracks is determined by the strength of adhesion to the substrate.

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Debris flow generated by a collapsing granular column

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Natural catastrophes like landslides and earthquakes are often caused by the nucleation and propagation of fractures in heterogeneous materials. Landslides are typically initiated by heavy raining events when water penetrates the pores and reduces the cohesion of soils leading to instability and cracking [1]. When it happens on a steep slope, the moving mass breaks up into pieces and the landslide gives rise to a debris flow composed of rapidly traveling fragments of soil and rocks. Such devastating catastrophes endanger the infrastructure and take thousands of lifes every years.

In order to understand the emergence of debris flows we investigated the collapse of a granular column under the action of gravity by means of discrete element simulations [2]. In the model, a cylindrical sample of soil is represented as a random packing of spherical particles. Cohesion is introduced by connecting the particles with spring elements along the edges of Delaunay triangles determined in the initial configuration of the particles. The constitutive law of springs captures the linearly elastic behavior of particle contacts at small deformations, the plasticity beyond a yield threshold, and the gradual softening and final breaking at large separation distances. A very important feature of the interaction is that particle contacts can be healed, i.e. if two particles approach each other within a capture distance, a new cohesive contact is established between them. Computer simulations were performed varying the strength of cohesion in a broad range.

Our calculations revealed that at high cohesion the granular column sinks in, i.e. its height gradually decreases while it undergoes restructuring and flattening, however, in the final state the system keeps its integrity. When the cohesion is sufficiently week, the process of collapse cannot stop: the system breaks up into a large number of fragments which run out at a high speed. The two phases of high and low cohesion represent the mass movement and the debris flow states of real landslides, respectively. We demonstrate that the transition occurs at a critical cohesion showing analogies to continuous phase transitions.

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The effect of anisotropy on the traffic flow behaviour: investigation of the correlation created by a single node on two-lane roads

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By the mean of a cellular automaton model, we studied the response of a quasi-one-dimensional system of two identical lanes with no lane changing to an anisotropic diverging node. Vehicles arrive into the node with an injection probability α and enter into one of the two lanes, while they leave it with a probability β . When the two first cells are available, the anisotropy at the node proceeds and pushes the vehicle to choose a lane over the other. Simulations highlighted a spontaneous symmetry breaking through the establishment of three phases: a symmetric high-density, an asymmetric low-density and an asymmetric phase of transition low-density/high-density. Indeed, by following the patterns of the injection of vehicles, we found that the entries of the two lanes are strongly correlated due to a self-organization process at the node. This correlation induces changes on the behaviors of both lanes. A cross correlation test proved that the flows of both lanes are interdependent especially in the symmetric phase. Accordingly, we suggested that this cross correlation can be considered as an order parameter that characterizes the transition of a quasi-one dimensional traffic system with a junction.

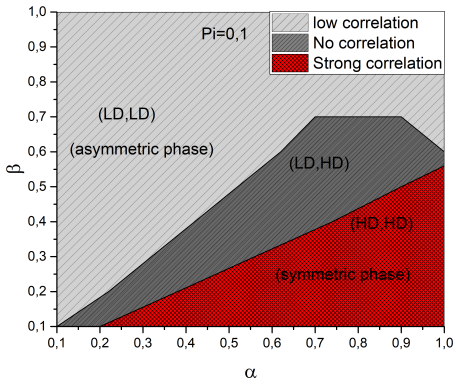

Figure 1: phase diagram exhibiting the different phases of the two lanes (L1-L2) for different values of α and β, Pi=0.1

Influence of solute polarity on diffusion in dimethylimidazolium chloride

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The dynamic features of infinitely diluted $dmim^+/Cl^-$ - monohydric alcohols and aromatic hydrocarbons liquid systems at T = 400K have been investigated using the molecular dynamics method. The study of infinitely dilute solutions allows to clearly determine the mechanisms of interaction between the molecule of solute (benzene, toluene, anisole, ethanol, propanol) and components of the ionic liquid, which allows to analyze the influence of physical and structural properties at the micro level. Analysis of the data allowed to establish:

- the nature of the motion of the solute and the mechanisms of diffusion in the studied systems are determined by the physical properties (mass and dipole moment) of the solute molecule
- mobility of aromatic hydrocarbons and monohydric alcohols dissolved in the ionic liquid correlates with the mass and value of the dipole moment of the solute molecule dissolved in the ionic liquid.
- based on the data obtained from RDF, MSD, VAF and FAF different diffusion mechanisms of solute molecules in IL were determined. At times less than 20 ps, the motion of aromatic hydrocarbon molecules (benzene, toluene and anisole) and monohydric alcohols (ethanol, propanol) in $dmim^+/Cl^-$ can be represented within the same model representations, namely, as a result of inelastic collisions with IL components. At times t> 40 ps there is there is a change in the nature of the IL components motion and a change in the nature of the diffusion processes in this system depending on the physical properties of the dissolved substance
- dynamic inhomogeneity in the motion of a solute molecule in the dmim+/Cl- system is associated with the transition from oscillatory processes in the motion of the molecule to translational, i.e. with a qualitative change in system dynamics and a change in the diffusion mechanism of solute molecules.

Towards probabilistic forecasting of earthquakes

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Similarly with financial indexes, for earthquakes there are also many carefully collected long-term databases, ideal for statistical studies. Due to the fact, that in recent years with better technology the earthquake detection accuracy increased, more uniform data sets are freely and electronically available. Another similarity with financial data is that earthquakes have also wide socio-economic impact and therefore researchers are keenly interested in revealing stylised facts in their statistics [1]. Examples in such sense are the widely known Guttenberg-Richter and Omori laws [2]. Statistical studies aim to reach a level where beside stylised facts probabilistic forecasting is also possible. In the present work we contribute in this sense. First we reconsider the Guttenberg-Richter law and show that the long-term statistics (for Japan, California, and Romania) in the released energy is compatible with a Tsallis-Pareto (or Lomax II) type distribution $\rho(x) = C(1+\frac{x}{b})^{-1-a}$, with the universal exponent $a = 0.6$ and $b = 10^{3.45}$(energy like units), see Figure 1. Inspired by recent studies on inverse statistics on stock indexes [3], we then study the relation between the waiting time for two consecutive earthquakes above a fixed magnitude and the total energy dissipated during this time by smaller earthquakes. Further universalities are found, and discussed in the view of forecasting earthquakes statistically. We successfully reproduced previous results in the literature [4], and describe other universalities observed.

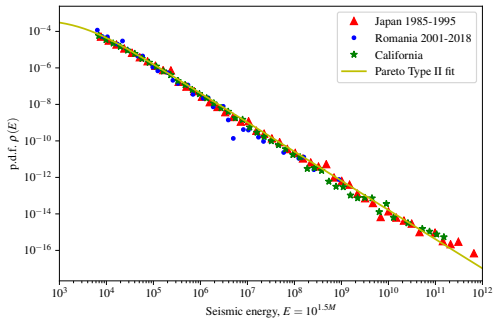

Figure 1: The probability density function for various earthquake datasets, with the same lower end magnitude cut-off, $M_{cl} = 2.5$. The yellow curve is a Lomax Type II distribution.

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Weakening connections in heterogeneous mean-field theory

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A model that introduces weakening effects in the connections of a network is introduced to investigate the propagation of an infection in the framework of a SIS (susceptible - infected - susceptible) compartment model. This modification may simulate the mitigation in contacts between individuals after an outbreak of a disease. The influence of this weakening parameter is examined through a heterogeneous mean-field theory, and two scale-free network models are considered. In the first one, the transmission occurs from an infected node to its neighbors; this is the well-known work of Pastor-Satorras and Vespignani [1, 2]. On the other hand, in the second model, the "active"node is a susceptible one, which changes its state when at least one of its neighbors is in infected state[3]. This work revisits the papers [1, 2], and extends the analytical results to the second model, where, except for the location of the infection threshold, numerical approaches prevail for the characterization of the order parameter.

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Monte Carlo Simulations as an Efficient Method To Calculate Electric Fields in Gapped Surface Electrodes

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In this work we study the Gapped Surface Electrode (GSE), a system composed by two conductor flat regions at different potentials with a gap $\mathscr{G}$ region between both planar sheets on the xy-plane. The computation of the Electric field and the surface charge density of the GSE requires to solve a Laplace's equation subjected to Direchlet conditions (on the electrodes) and Neumann Boundary Conditions (in the gap). This boundary conditions together with the electrodes geometry makes the problem difficult to be solved analytically and numerical methods are required. The current study models the GSE as a classical Coulomb gas where the surface charge density of the GSE can be obtained from the equilibrium states of an unmixed version of the bidimensional two-component plasma 2dTCP on the plane via Monte Carlo (MC) simulations (see Fig. 1). The system is globally neutral and point-like charges interact each other with an inverse power law $1/r$-potential. The study deals with both the circular GSE where $\mathscr{G}$ is an annular region, and the harmonically-deformed GSE. In general, the system can be studied in the Gran Canonical Ensemble since the number of charges on the electrodes and its distribution are unknowns depending on the electric potential difference between electrodes and the gap definition, specially the thickness of the gap. However, we show that MC simulations can be performed in the Canonical ensemble with a standard Metropolis algorithm if the results are properly rescaled using the potential difference. The GSE can also be studied by solving Biot-Savart Law like (BSL) integrals since the steady magnetic field generated by a ribbon displayed on $\mathscr{G}$ carrying a non-uniform but steady current is the magnetic analogue of the GSE in the region R^3 with $z > 0$. We present analytic approximated expressions of the electric field by using this approach. Numerical comparison are addressed against with analytical descriptions developed previously by the authors of the current study finding a good agreement between them.

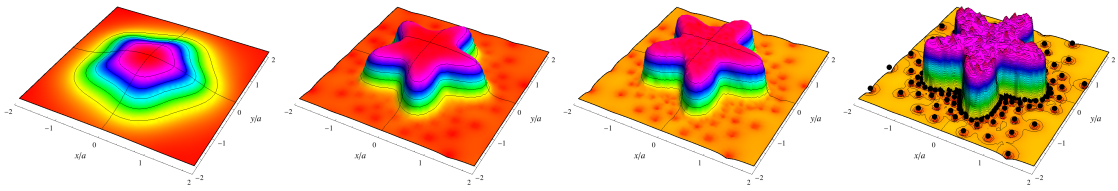

Figure 1: Electric potential due to a single MC configuration at vanishing temperature. Left to right. The electric potential is evaluated at a plane defined $z/R = 0.5, 0.1, 0.05$ and 0.01. These plots corresponds to SE with harmonically deformed boundaries.

Random sequential adsorption of stiff linear k-mers onto a square lattice: Characterization of domain formation

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Using computer simulation, we have studied an isotropic random sequential adsorption of stiff linear segments (k-mers) onto a square lattice with periodic boundary conditions along both directions. Each such particle occupies k adjacent lattice sites. During deposition, the two mutually perpendicular orientations of the particles are equiprobable, hence, a macroscopically isotropic monolayer is formed. However, this monolayer is locally anisotropic, since, due to the excluded area effect, the deposited particles tend to form domains of particles with the same orientation. Using the excluded area concept, we have classified lattice sites into several types. We have examined how the fraction of each type of lattice site varies with the number of deposited particles. The behaviors of these quantities provide for a classification of the stages of domain formation (Fig. 1): (i) the emergence of domain seeds; (ii) the filling of domains; (iii) densification of the domains. Our approach and results are closely related to that for RSA of needles [1] and rectangles [2] onto a plane. Since our computer simulation is restricted only to short particles, an additional study is needed for larger values of k ($k > 12$).

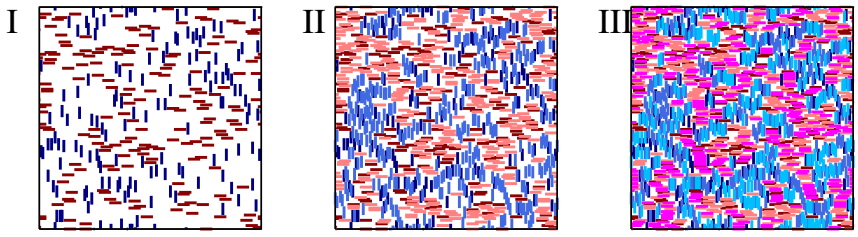

Figure 1: The patterns at the end of each stage are shown ($k = 8$, $L = 16k$).

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Generalized Exclusion Statistics

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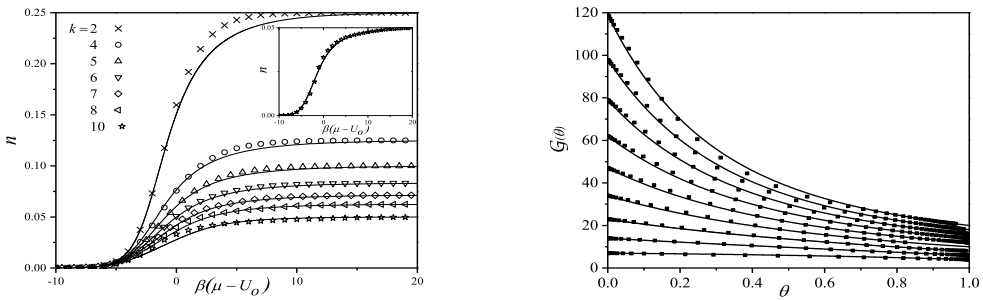
A new statistical distribution of particles and quasi particles in equilibrium observing exclusion of spatially correlated states in a confined region of the space is presented by extending the Haldane's state counting [2]. The approximation introduces an ansatz in order to account the multiple exclusion arising when the single particle states are constrained by spatial correlations [1]. By multiple exclusion we refer to correlated states that can be simultaneously excluded by more than one particle. The only parameter of new statistics for correlated states , g_c, characterizes the correlations in the state counting and can be fully determined within the statistics framework. Quantum statistics and fractional statistics are obtained as limits of the new distribution por non-correlated states. An Exclusion Spectrum Function $\mathscr{G}(n)$ was introduced, namely the average number of excluded states per particle as a function of occupation number n. Analitical thermodynamic functions, chemical potential ($\mu(n)$) and $\mathscr{G}(n)$ (see Fig. 1) compared with statistical simulations of linear particles (k-mers) on a square lattice show remarkable agreement for such a complex problem of state correlations. Application is extended to structured particle on lattices. Analytical predictions for thermodynamics of correlated anyons will be put forward as well.



(a) (b)

Figure 1: (a) State occupation number n versus $\beta\mu$ for $k = 2,4,5,6,7,8,10$. Lines represent the analytical predictions from the model; symbols come from simulations. and (b) Exclusion spectrum $\mathscr{G}(\theta)$, the lattice coverage $\theta = ng$, Being $g = \mathscr{G}(1)$, for $k = 2$ to $k = 10$ (k-mers on a square lattice). Solid lines represent the analytical results from the generalized statistics; symbols do for MC symulations.

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Modeling hierarchical and modular network of organizations

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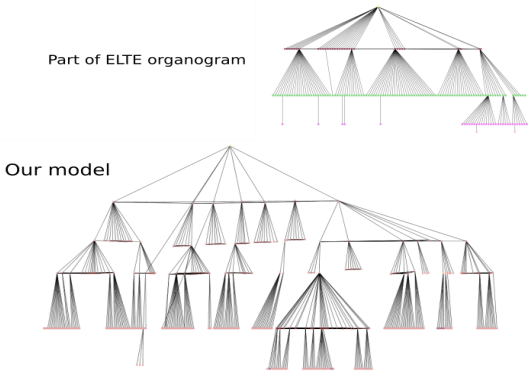

Figure 1: Modular Hierarchical structure

Hierarchies are a fundamental feature of many real-world systems. The concept of hierarchies in complex networks is an area of active research, based on mostly intuitive understanding, and with many open questions. Here we propose a new method for constructing modular and directed hierarchical networks based on a successive clustering method. Our approach is based on i) clustering the "agents" forming the subsequently generated directed network (so that similar agents become close to each other), ii) the clusters form "modules" and "elect" a leader, finally, iii) the levels of hierarchy are determined from the number of steps an agent/leader is "below" the top leaders. *Our study is motivated and supported by observations.* These observations can be based both on downloadable data about the structure of organizations and by our everyday personal considerations when we consider how large universities or companies are organized. First of all, in a network representation they are hierarchical (have "levels") and they have mostly two types of links: directed ones from an upper layer to the layer below and ones within a given layer without direction. Here direction stands for a leader-follower relation: the "bosses" can give instructions to the group of their subordinates.

Acknowledgement

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Flickering candle flames: experiments and dynamical modelling

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Contrary to the flame of single candles, the unified flame of candle bundles flicker with a frequency of 10-12 Hz [1, 2]. The oscillation period shows an increasing trend as a function of the bundle size and depends also on the topology of the arrangement of the candles in the bundle. Flickering bundles at close distances exhibit in-phase synchronization and anti-phase synchronization for larger distances. The collective behavior of the flames of bundles of different sizes can lead to the well-known beating phenomenon [2]. The above described intriguing phenomena can be modeled with a dynamical system approach [1], where the main variables are the temperature and oxygen concentration in the flame. The model is successful in reproducing both the stable and oscillating flame as a function of the bundle size, and explains the sync and ant-sync of interacting flames through a coupling via a radiation term. Here we point out some inconsistencies of this model and propose a modified version of it which is in good agreement with new and old experimental data. According to our approach we obtain a correct trend for the flickering frequency of the bundle as a function of its size and topology and the collective behavior of nearby flames appears as a result of a coupling in the oxygen flow rather than thermal radiation.

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Molecular Dynamics simulation study of free and constrained Brownian motions

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A molecular dynamics (MD) computer simulation approach of the Brownian motion [1] is presented. The simulations are realized by using the EspressoMD software, version 3.3.1 [2]. The simulation field is filled up by "medium particles" of diameter $d = 1$, and mass $m = 1$. These are considered to be the unit of our distance and mass measures. The particles are interacting by the repulisve part of the Lennard-Jones potential. In the middle of the simulation field one Brownian particle of diameter D and mass M is placed that interacts in the same way with the medium particles. The model is validated by the well-known scaling of the mean-squared displacement (MSD) with the motion time for different Brownian particle sizes. Moreover, the diffusion constant dependence on the particle radius is reproduced.

Then, the study is focusing on the Brownian motion in the presence of planar constraints in the system. Perpendicular to the z direction of the simulation field two planar surfaces are placed that are impenetrable by the particles. Figure 1 presents our simulated MSD results in case of free and constrained systems.

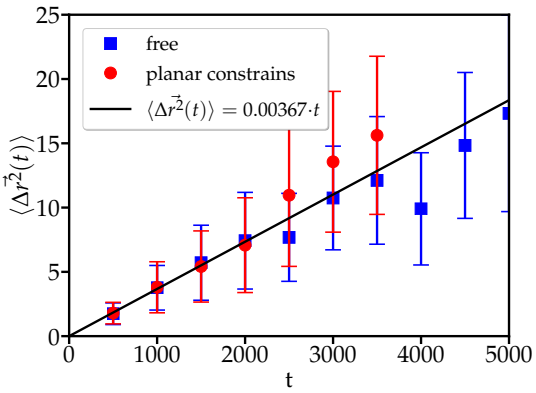

Figure 1: MSD as a function of the simulation time for free and constrained systems.

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A max-SAT solver with high-performance analog dynamics

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Many real-life optimization problem can be translated into Boolean logic as max-SAT. Starting from the ground-state problem of spin-glasses to protein folding, through Sudoku puzzles and various industrial applications, all have similar mathematical structures to max-SAT. This is a class of problems, where one has to find Boolean assignments to variables such that they satisfy the maximum number of logical constraints. Since max-SAT is NP-hard there is no known algorithm to efficiently solve these problems: exact solvers are extremely inefficient, on the other hand, heuristic solvers can never provide information on the correctness of the found optimum. In our previous work we mapped Boolean satisfiability to transiently chaotic continuous-time dynamical systems with one-to-one correspondence between the SAT solutions and the stable attractors of the system. To be able to apply this approach to the max-SAT problem one had to introduce modifications to the original algorithm. In this way we obtain a chaotic dynamical system, which has no stable attractors, but performs an efficient search for the global optimum. By generalizing a measure used in transient chaos theory we define an energy dependent escape rate, an invariant of the dynamic of the solver. The scaling behaviour of this measure can predict the global optimum energy well before the dynamics actually finds that state. A rough estimation of the time needed to find more optimal states also can be obtained. Simulating the solver, we illustrate its performance on max-SAT competition problems, finally we apply it to the two-color Ramsey number $R(m,m)$ problem. One of most the intriguing questions regarding the Ramsey-problem is the value of $R(5,5)$. Our dynamical system is able to find colorings without monochromatic 5-cliques of graphs sporting less or equal vertices to 42, however the best coloring for 43 vertices includes two monochromatic 5-cliques, this result also supporting the conjecture that $R(5,5) = 43$. This approach shows the potential of continuous-time analog dynamical systems as algorithms for discrete optimization.

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Time-series analysis with state-transition networks

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The combination of network sciences and nonlinear dynamics to time-series analysis provides novel insights and analogies between complex network structures and dynamical properties of the respective systems. Within these methods, state-transition networks (STNs) may be considered unique, since the causality of events, viz. the succession of dynamical states, is represented by directed and weighted graphs [1]. While a vast majority of the literature focuses on one-dimensional time series, here we introduce a novel sub-type of STNs for two or higher dimensional systems.

As a first step, the multivariate time series is reduced to a low (here two) dimensional map-like representation of the system, by considering an appropriately defined Poincaré section in the full phase space and recording the intersection points of the trajectory (see Fig. 1). The nodes of STNs correspond hence to mesh points in this 2D Poincaré section, while its weights are proportional to the transition probabilities [2]. As a second step, we define a network measure in analogy to Lyapunov exponents, by comparing pairs of Markov-chains started from the same initial state. The proposed measure is able to distinguish between periodic and chaotic time series, and detect furthermore internal-crisis-type bifurcations by presenting pronounced peaks in the vicinity of these parameters. The method is tested both on theoretical discrete- and continuous-time systems and also on multichannel EEG signals. Our preliminary study reveals that the state transition network approach to signal processing can offer substantial benefits over the traditional linear and nonlinear methods.

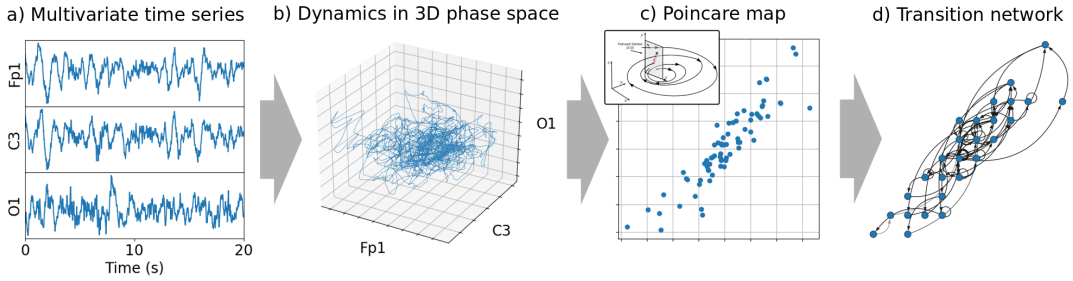

Figure 1: Steps of constructing state-transition networks. a) The multivariate time-series (here EEG) is considered in its b) three-dimensional phase space, then a c) Poincaré section is taken, after which the d) STN is constructed.

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Virtually coupled mechanical oscillators

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The work presents an experimental setup used to investigate collective behavior of electrically coupled mechanical metronomes. A small magnet is placed on the metronome's limb and a coil located on a fix place is used to both detect the limb's position and to interact with its motion. The voltage induced in the coil by the moving magnet is applied to an analog digital pin (ADC pin) of a microcontroller. The firmware in the microcontroller is able to measure the metronome's frequency and phase. The same microcontroller can generate voltage to the coil in order to interact with the magnet and alter the phase and frequency of the mechanical oscillator. Each such system has a reference signal input and the firmware is developed to synchronize the mechanical oscillator with the reference input in case the two frequencies are not too far apart. Several such metronome systems are connected to a central board with a different microcontroller with the role of collecting and controlling the metronome oscillators. In this way it is possible to adjust the reference applied to each individual metronome as a function of the other metronomes output, creating a coupling among the oscillators. The novelty of the setup is that the coupling is electronically controlled and can be altered by software.

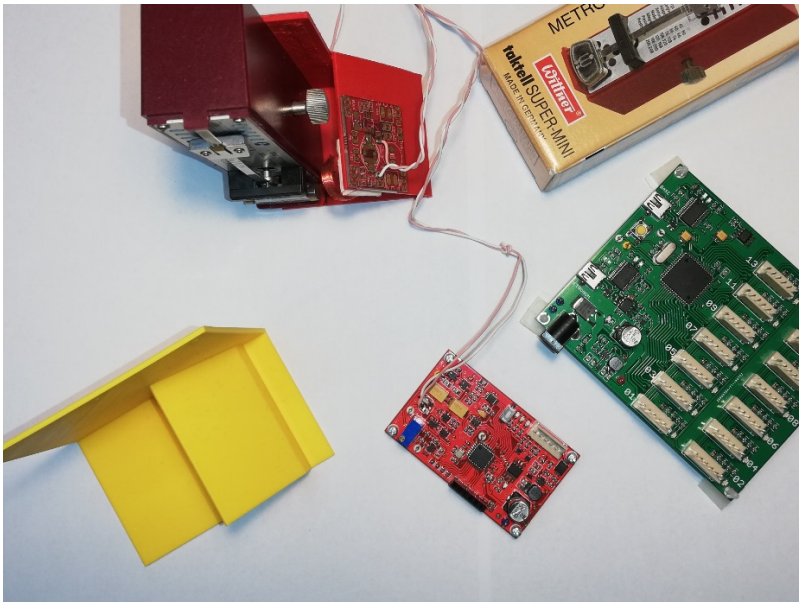

Figure 1: Virtually coupled mechanical oscillators. Experimental setup

Reverse engineering complex systems from their network models

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Network models have made possible the study of previously intractable complex systems. For a given phenomenon, the mathematical properties of its network model can be related to the relevant parameters of the phenomenon. The question arises to what extent a network carries the characteristics of the phenomenon it models, i.e. whether the phenomenon from which a network originates can be recognized from the topology of the network. The answer to this question can help identify the most important properties of different complex phenomena. Our study includes several types of real-world networks, obtained from the most popular databases available on the Internet. Based on our database of thousands of networks and using statistical and machine-learning methods we identify key features that may differentiate between network types. The origin of a real network can be determined with high certainty and the main characteristics of the underlying complex system can be estimated with relatively high accuracy. We also investigate the limits of these classifications caused by missing data and network transformations.

Attractoring: a dynamical systems framework for self-organized robotic locomotion

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From a complex systems point of view, robotic locomotion may either be generated by autonomous dynamical systems without sensory input from the environment or by non-autonomous systems with time-dependent signals. For the latter, sensory input may only be needed to modulate the actual behavior or, as for most of the time, it may be essential for generating self-organized attractors emerging within the local feedback-loop of the animal/robot [1].

Here, we review the recently introduced dynamical systems framework for generating self-organized attractors living in the combined phase space of the robot's controller, body, and environment [2]. As a novel application of attractoring, we present how hexapod-type motion patterns are stabilized using local proprioceptive feedback from the environment (see Fig. 1).

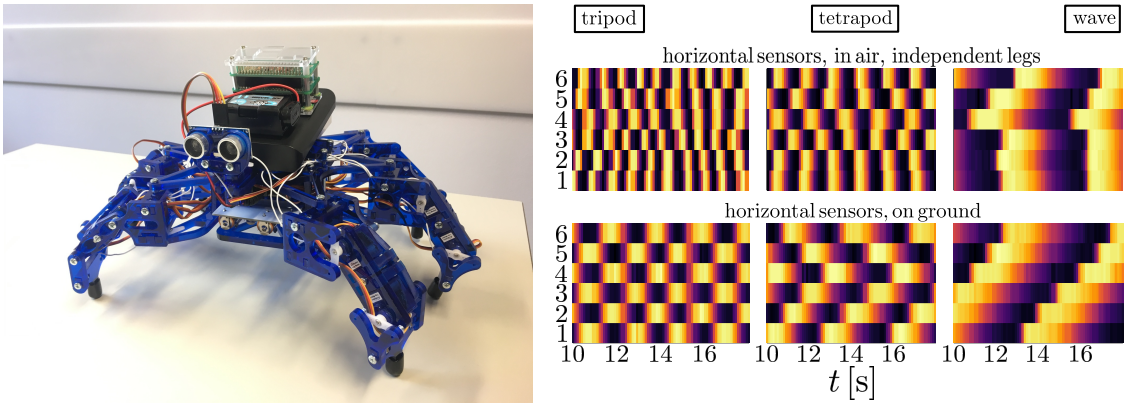

Figure 1: *Left:* Hexy six-legged robot with propriosensory feedback. *Right:* Self-organized gait patterns for the hexapod robot. The position of the actuators for the six legs $(1,\ldots,6)$ are indicated by the color-coded time-series, with light/dark colors denoting joint angles close to their maximal/minimal positions [3]. With independent legs, the robot being lifted in air, the walking gaits are unstable (*top row*). Self-organized phase-locking of actuators emerges when the robot is placed on the ground (*bottom row*).

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Phase transitions in three-dimensional random anisotropy Heisenberg model: two case studies

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We study phase transitions in the three-dimensional spin model with three-component order parameter and structural disorder in the random anisotropy form [1] by means of Monte Carlo simulations using the parallel tempering method. We simulate the model with two different random anisotropy axis distributions (cubic and isotropic ones) [2]. We consider two different values of random anisotropy strength for each disorder distribution case as well. We observe clear signatures of the second order phase transition (paramagnetic-ferromagnetic) for both distributions. We extracted critical exponents for each considered case. In contrast to study [3] obtained results support different collective behaviour for different random anisotropy axis distributions. Moreover while we find strong evidence of universality for the case of the anisotropic disorder distribution, results for isotropic case do not present universality showing dependence of the critical exponents on the disorder strength as well as on the lattice size therefore questioning the nature of low-temperature state in the thermodynamical limit.

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Active and inactive quarantine in epidemic spreading: a general formalism for adaptive activity-driven networks

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Human behaviour deeply affects the spread of infectious diseases: understanding the interplay between epidemic dynamics and adaptive behaviour is essential to improve response strategies to epidemics. We consider an adaptive activity-driven temporal network, coupled with an epidemic process occurring on top of it, taking into account both the temporal dynamics of the interactions network and the adaptive behaviours of populations exposed to epidemics. Each node of the network is assigned an activity parameter and an attractiveness parameter; the adaptive behaviour is implemented by considering a change in activity and attractiveness due to infection, described by a completely general distribution function for activity and attractiveness in infected and susceptible nodes. By using a mean-field approach, we derive an exact analytical estimate of the epidemic threshold for SIS and SIR epidemic models. The result holds for any adaptive strategies and it highlights the crucial role played by cross-correlations between activity and attractiveness, in the infected and susceptible states. We also obtain analytically the epidemic prevalence of the SIS process, while for the SIR active phase we perform numerical simulations.

Several adaptive behaviours can be implemented through our model, such as sick-leave, quarantine and targeted containment strategies. Here we focus on the effects of two types of quarantine, inspired by recent real case studies: an *active quarantine*, in which the population compensate the loss of links due to quarantine, rewiring the ineffective connections (link with quarantining nodes) towards non-quarantining nodes; an *inactive quarantine*, in which the links with quarantined nodes are not rewired, but they are simply not effective nor contagious. Both types of quarantine feature the same epidemic threshold but they differ in the dynamics of active phase (see Figure): we show that the active quarantine is extremely less effective in reducing the impact of the epidemic in the active phase compared to the inactive one, and that in SIR model a late adoption of measures requires inactive quarantine to reach containment.

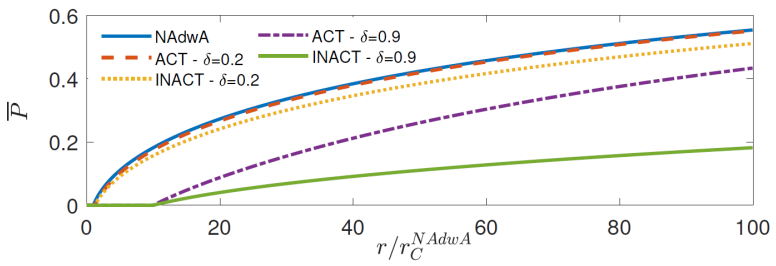

Figure 1: Effects of active (ACT) and inactive (INACT) quarantines on the epidemic prevalence $\overline{P}$ of the SIS epidemic model, for different fraction δ of quarantining nodes and for the case without containment measures (NAdwA - $\delta = 0$)

Analysis of intervention threshold for epidemic control using metapopulation models

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Epidemic control is an increasingly difficult task in the modern age of expanding globalization. Mathematical models of epidemic diseases are powerful tools for understanding the complex spreading processes of diseases and considering the countermeasures for epidemic spreading. Among them, metapopulation epidemic models consider populations distributed in spatially distant patches and migration of individuals between patches. We deal with a susceptible-infected-recovered (SIR) metapopulation model where the epidemic process in each patch is represented by an SIR model and the mobility of individuals is assumed to be a homogeneous diffusion [1]. By using the linear stability analysis, we theoretically derive the intervention threshold which indicates the critical fraction of low-risk patches for preventing a global epidemic outbreak. The result reveals that the intervention threshold depends on the human mobility network and mobility rate (Fig. 1). The theoretical results are validated by Monte Carlo simulations for synthetic and realistic scale-free patch networks.

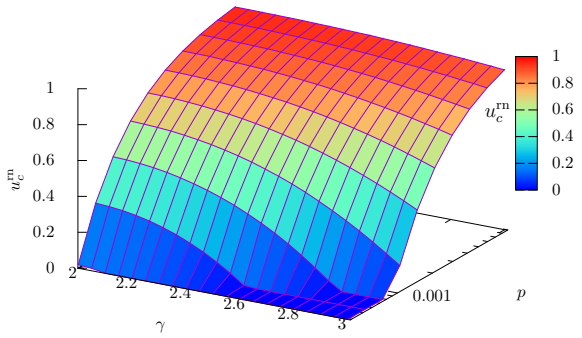

Figure 1: The theoretically derived intervention threshold u_c^{rn} as a function of the mobility rate p and the degree exponent γ of the human mobility network that is assumed to be a scale-free one.

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Transylvania: historical confluences and cultural heritage in Central-East Europe

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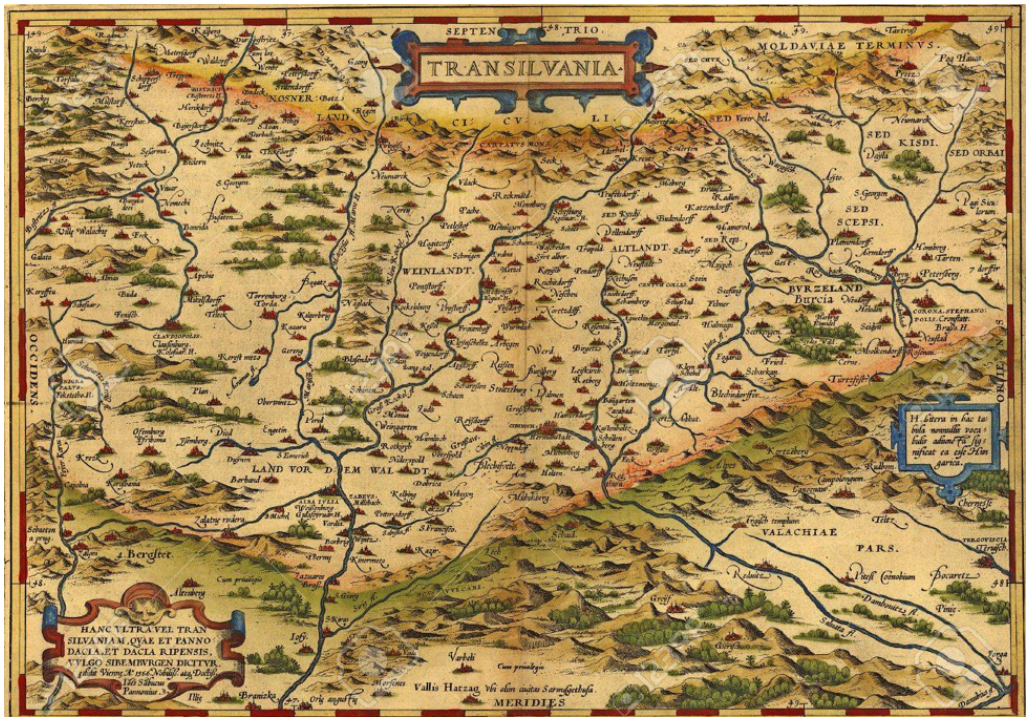
Transylvania became a legendary land of the vampires, mountains and multicultural communities due to the18-19th century travelers from Western Europe. This area of Europe however is more than just legends and myths: due to the geographic position of the region, Transylvania was a place of various historical mobility, cultural interconnectivities and it was always in a cultural connection with the West and the East. The talk will focus on the rich material, archaeological and built heritage of Transylvania of 2000 years history from classical antiquity till recent times.



The mathematical heritage of János Bolyai - Creating a new world out of nothing

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According to Steven Hawking, János Bolyai is on the shortlist of those scientists who profoundly changed our thinking paradigms. In his 26 page long seminal work written in latin (the "Appendix"), Bolyai independently from Lobachevski and Gauss constructed the basis of non-euclidean geometry. He became one of the founders of the modern, axiomatic mathematics and a scientific hero in Transylvania. In our presentation, we will shortly review his scientific achievements in connection with the works of Lobachevski and Gauss. We will also present some important moments of his troubled life and carrier, all related to places in Transylvania.

Mesmerized by light and colour: the Nagybánya (Baia Mare) Artists' Colony

Viktória Adrienn Barazsuly
Eszterházy Károly University, Hungary
Korzo Association, Romania

Baia Mare (Nagybánya) is a nowadays an industrial and cultural center in the north of Transylvania, in the picturesque region of Maramureş. In the summer of 1896 around 40 artists relocated here to establish the foundation of a world-famous art school. The group was composed both by young artists of different nationalities and consecrated painters from Hungary. Their work exposed in the Palace of Arts in Budapest led to a confrontation with the conservative painting schools, and resulted in a paradigm change for modern artistic visions. This colony became a meeting place for painters and many well-known personalities who fulfilled or started their carrier here.

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