Middle European Cooperation in Statistical Physics

Abbaye des Prémontrés
Pont-à-Mousson
May 18-22, 2026

MECO 51

Middle European Cooperation in Statistical Physics (51ème édition)

18-22 May 2026
Pont-à-Mousson
France

Table of contents

Failure process of a fiber bundle with random misalignment

Lynet Allan * [1], Ferenc Kun [1]

[1] University of Debrecen – Hungary

We investigate the failure process of a fiber bundle with structural disorder represented by the random misalignment of fibers. The strength of fibers is assumed to be constant so that misalignment is the only source of disorder, which results in a heterogeneous load distribution over fibers. We show by analytical calculations and computer simulations that increasing the amount of structural

disorder a transition occurs from a perfectly brittle behaviour with abrupt global failure to a quasi-brittle phase where failure is preceded by breaking avalanches. The size distribution of avalanches follows a power law functional form with a complex dependence of the exponent on the amount of disorder. In the vicinity of the critical point the avalanche exponent is 3/2, however, with increasing disorder a crossover emerges to a higher exponent 5/2. We show analytically that the mechanical behaviour of the bundle of misaligned fiber with no strength disorder can be mapped to an equal load sharing fiber bundle of perfectly aligned fibers with properly selected strength disorder.

---

*Speaker

Emergent Synchronization and Resilience in Adaptive Multilayer Social Networks

Seth Asare * [1], Abigail Agyapomaa *

[1] Jayee University College – Ghana

Social networks, by their very nature, are multilayered and adaptable-people interact in overlapping communities that evolve over time. We show a new way to model synchronization by constructing a framework for modeling synchronization mechanisms in adaptive multilayer social networks where the coupling strength of layers modulates dynamically with local information exchange and environmental changes. Based on agent-based modelling coupled to spectral graph theory, we show how dynamic adaptation can add resilience and emergent consensus to the network despite heterogeneity in initial conditions and enable strong adaptation of the network to cascade failure mechanisms. These results provide new policies to establish strong communication protocols in social and technological systems.

---

[*] Speaker

Directed autonomous motion of active Janus particles induced by wall-particle alignment interactions

Poulami Bag * [1]

[1] Presidency University [Kolkata] – India

We propose a highly efficient mechanism to rectify the motion of active particles by exploiting particle-wall alignment interactions. Through numerical simulations of active particles' dynamics in a narrow channel, we demonstrate that a slight difference in alignment strength between the top and bottom walls or a small gravitational drag suffices to break upside-down symmetry, leading to rectifying the motion of chiral active particles with over 60% efficiency. In contrast, for achiral swimmers to achieve rectified motion using this protocol, an unbiased fluid flow is necessary that can induce orbiting motion in the particle's dynamics. Thus, an achiral particle subject to Couette flow exhibits spontaneous directed motion due to an upside-down asymmetry in particle-wall alignment interaction. The rectification effects caused by alignment we report are robust against variations in self-propulsion properties, particle's chirality, and the most stable orientation of self-propulsion velocities relative to the walls. Our findings offer insights into controlled active matter transport and could be useful to sort artificial as well as natural microswimmers (such as bacteria and sperm cells) based on their chirality and self-propulsion velocities.

---

*Speaker

Phase separation of a magnetic fluid: Non-equilibrium kinetics and asymptotic states

Varsha Banerjee * [1,2]

[1] Indian Institute of Technology, Delhi (IIT Delhi) – Department of Physics, Indian Institute of Technology, Hauz Khas, New Delhi 110016, India
[2] New Delhi 110016 – India

We investigate self-assembly in a colloidal suspension of magnetic particles using comprehensive molecular dynamics (MD) simulations of the Stockmayer (SM) model. The SM potential, which combines Lennard-Jones interactions with dipole-dipole moments, successfully recovers the gas-liquid phase coexistence observed experimentally in magnetic fluids.
While Furukawa predicted that domain growth in binary fluids should scale as \$$\ell(t) \sim t\{2/3\}$\$$duetofluidinertia$

---

[*] Speaker

Quasistatic response for nonequilibrium processes: evaluating the Berry potential and curvature

Aaron Beyen * [1], Christian Maes [2], Faezeh Khodabandehlou [2]

[1] Department of Physics and Astronomy [Leuven] – Belgium
[2] Department of Physics and Astronomy [Leuven] – Belgium

Thermodynamic transformations are associated with quasistatic changes of control parameters of a system, such as coupling coefficients or environmental pressure and temperature. Under these slow, time-dependent perturbations, a nonequilibrium system agitated by a constant driving force remains close to the instantaneous steady state, and additional control parameters, such as the strength of a rotational force or agitation, are introduced. However, for such systems, the effect of quasistatic changes can be quite different and richer, *e.g.*, the response might not be expressible as the derivative of an appropriate free energy. In fact, the notion of excess enters when considering transformations between steady conditions. In this talk, we describe how, under cyclic thermodynamic transformations, the excesses coincide with a (geometric) Berry phase with corresponding Berry potentials and Berry curvatures quantifying the response. Focussing on Markov jump processes, a non-zero Berry curvature leads to a breakdown of the thermodynamic Maxwell relations and of the Clausius heat theorem. We also present a variant of the Aharonov-Bohm effect in which the parameters follow a curve with vanishing Berry curvature, but the system still experiences a non-zero Berry phase. Finally, we identify (sufficient) no-localization conditions in terms of mean first-passage times under which the corresponding Berry potentials and curvatures vanish at absolute zero, extending, for arbitrary driving, *e.g.*, the case of vanishing heat capacity as for the Nernst postulate.

---

*Speaker

A novel mechanism of ordering in a coupled driven system: vacancy induced phase separation

Sakuntala Chatterjee * [1], Chandradip Khamrai *

2

[1] S N Bose National Centre for Basic Sciences, Kolkata, India (SNBNCBS, Kolkata, India) – Block JD, Sector 3, Salt Lake City, Kolkata 700106, West Bengal, India
[2] S.N. Bose National Centre for Basic Sciences, Kolkata – India

We study a coupled driven system where two different species of particles, along with some vacancies or holes, move on a landscape whose shape fluctuates with time. The movement of the particles is guided by the local slope of the landscape, and the shape is also affected by the presence of different particle species. The nature of this coupling plays a crucial role in the formation of long range order in the system. When a particle species pushes the landscape in the same (opposite) direction of its own motion, it it called an aligned (a reverse) bias. Aligned bias promotes ordering while reverse bias destroys it. In the absence of vacancies, the system reduces to the previously studied LH model for which different kinds of ordered and disordered phases were observed upon tuning the coupling between the particle and landscape dynamics. These phases could be explained as a competition or cooperation between aligned bias and reverse bias coming from different particle species. This interplay is expected to remain unaffected even when vacancies are present since vacancies do not impart any kind of bias on the landscape. However, we find that the presence of vacancies effectively weakens the reverse bias and this significantly changes the outcome of the competition between the two bias types. As a result, novel ordered phases emerge which were not seen before. We analytically calculate the new phase boundaries within the mean field approximation. We show that even when the aligned bias is weaker than the reverse bias, it is possible to find long ranged order in the system. We discover two new phases where the particle species showing weaker aligned bias phase separate and the other species with stronger reverse bias stays mixed with the vacancies. We call these phases finite current with partial phase separation (FPPS) and vacancy induced phase separation (VIPS). The landscape beneath the phase separated species takes the shape of a macroscopic hill in FPPS phase. However, in the VIPS phase it has the shape similar to a plateau whose height scales as square root of the system size. We explain the formation of these phases using flux balance condition in steady state.

References:

1. Shauri Chakraborty, Sukla Pal, Sakuntala Chatterjee and Mustansir Barma, Phys. Rev. E 93, 050102(R) (2016)

---

*Speaker

2. Chandradip Khamrai and Sakuntala Chatterjee, Phys. Rev. E 109, 054125 (2024)
3. Chandradip Khamrai and Sakuntala Chatterjee, J Stat Mech (in press)

Self-assembly of dipolar nanoclusters on an attractive substrate

Harshita Chauhan [1], Denis Gessert * [2], Varsha Banerjee [1], Martin Weigel [2]

[1] Indian Institute of Technology Delhi – India
[2] Institut für Physik, Fakultät für Naturwissenschaften, Technische Universität Chemnitz – Germany

Recently, Thomas et al. (Nanoscale, 17, 18291 (2025)) found that bismuth oxido nanoclusters (BiO-NCs) with bismuth partially replaced by cerium form chains when deposited onto different types of substrates. This is considered to be a result of the dipolar moment induced by doping the otherwise non-polar nanoclusters. As a toy system for this process we use (magnetic) Stockmayer particles, as well as a mixture of (non-magnetic) Lennard-Jones and Stockmayer particles in the presence of an attractive substrate. The model is studied by means of molecular dynamics simulations. The deposition experiment is mimicked by a rapid quench from high temperature to below the coexistence curve. For low densities we find qualitative similarities between this setup and the experimental findings reported earlier.

---

*Speaker

Learning the non-Markovian features of subsystem dynamics

Michele Coppola * [1], Mari Carmen Bañuls [2], Zala Lenarčič [3]

[1] Jožef Stefan Institute – Slovenia
[2] Max-Planck-Institut fur Quantenoptik – Germany
[3] Jožef Stefan Insitute – Slovenia

The dynamics of local observables in a quantum many-body system can be formally described in the language of open systems. The problem is that the bath representing the complement of the local subsystem generally does not allow the common simplifications often crucial for such a framework. Leveraging tensor network calculations and optimization tools from machine learning, we extract and characterize the dynamical maps for single-and two-site subsystems embedded in an infinite quantum Ising chain after a global quench. We consider three paradigmatic regimes: integrable critical, integrable non-critical, and chaotic. For each we find the optimal time-local representation of the subsystem dynamics at different times. We explore the properties of the learned time-dependent Liouvillians and whether they can be used to forecast the long-time dynamics of local observables beyond the times accessible through direct quantum many-body numerical simulation. Our procedure naturally suggests a novel measure of non-Markovianity based on the distance between the quasi-exact dynamical map and the closest CP-divisible form and reveals that criticality leads to the closest Markovian representation at large times.

---

*Speaker

Simulating Many-Body Open Quantum Systems and Their Bosonic Environments with Matrix Product States

Grazia Di Bello * [1,2]

[1] University of Naples Federico II = Università degli studi di Napoli Federico II – Italy
[2] Istituto Nazionale di Fisica Nucleare, Sezione di Napoli – Italy

Describing open quantum systems often requires modelling strategies that go beyond weak-coupling and Markovian approximations. In this talk, I will present simulations based on matrix product states in which the system and the bath are treated together, so that one can access not only the reduced dynamics of the system, but also bath observables and system-environment correlations. This is particularly useful in situations where the environment is not simply a source of dissipation, but actively shapes the critical and non-equilibrium behavior of the dynamics. As concrete examples, I will discuss dissipation-driven quantum criticality in the open quantum Rabi model (1), where the environment plays an active role in shaping the phase structure and the dynamical response, and environment-induced dynamical quantum phase transitions in the open two-qubit Rabi model (2), where the interplay between interactions and dissipation gives rise to non-analytic real-time signatures. I will then briefly comment on related applications to work extraction protocols and information-theoretic diagnostics, including local ergotropy (the maximum extractable work) (3) and quantum Fisher information (a key quantity in quantum parameter estimation) (4). Finally, I will mention some recent extensions of this framework to other non-equilibrium phenomena, such as the Kibble-Zurek mechanism in the open quantum Rabi model (5) and the quantum Mpemba effect in the spin-boson model (6). Taken together, these examples show how treating the system and the bath explicitly can reveal features of the dynamics that are not easily accessible in reduced-dynamics approaches.

References

(1) G. De Filippis, A. de Candia, G. Di Bello, C. A. Perroni, L. M. Cangemi, A. Nocera, M. Sassetti, R. Fazio, and V. Cataudella, "Signatures of Dissipation Driven Quantum Phase Transition in Rabi Model," *Physical Review Letters* 130, 210404 (2023).

(2) G. Di Bello, A. Ponticelli, F. Pavan, V. Cataudella, G. De Filippis, A. de Candia, and C. A. Perroni, "Environment induced dynamical quantum phase transitions in two-qubit Rabi model," *Communications Physics* 7, 364 (2024).

(3) G. Di Bello, D. Farina, D. Jansen, C. A. Perroni, V. Cataudella, and G. De Filippis, "Local ergotropy and its fluctuations across a dissipative quantum phase transition," *Quantum Science and Technology* 10, 015049 (2024).

---

[*] Speaker

(4) D. Parlato, G. Di Bello, F. Pavan, G. De Filippis, and C. A. Perroni, "Quantum Fisher information as a witness of non-Markovianity and criticality in the spin-boson model," *Physical Review B* 112, 224314 (2025).

(5) T. Pirozzi, G. Di Bello, V. Cataudella, C. A. Perroni, and G. De Filippis, "Kibble-Zurek Mechanism in the Open Quantum Rabi Model," arXiv:2603.16709 (2026).
(6) P. Chirico, G. Di Bello, G. De Filippis, and C. A. Perroni, "Geometry and restoration of the quantum Mpemba effect beyond weak-coupling regime in the spin-boson model," arXiv:2603.17565 (2026).

Criticality of spin system with structural disorder and long-range interactions

Maxym Dudka * [1,2,3], Dmytro Shapoval [1,2], Yurij Holovatch [1,2,4,5]

[1] Yukhnovskii Institute for Condenced Matter Physics, National Academy of Sciences of Ukraine, 79011 Lviv – Ukraine
[2] L4 Collaboration Doctoral College of the Statistical Physics of Complex Systems, Leipzig-Lorrain-Lviv-Coventry – Germany
[3] Lviv Polytechnic National University, 79013 Lviv – Ukraine
[4] Centre for Fluid and Complex Systems, Coventry University, Coventry CV1 5FB – United Kingdom
[5] Complexity Science Hub Vienna, 1030 Vienna – Austria

The goal of our research is to analyze the changes in the critical behavior of a spin system under the mutual impact of two competing factors: long-range interactions and weak quenched structural disorder. Using a field-theoretical O(n) symmetric model in a d-dimensional space, we will investigate critical properties of structurally disordered spin system with the long-range interactions decaying with the distance x as $J(x){\sim}x\hat{}(-d{-}\sigma)$. It is well established that the long-range interactions and structural disorder lead to emergence of a new, random long-range universality class for certain region of model global parameters (d,n,σ) (1,2). Exploiting the field-theoretic renormalization group approach within the minimal subtraction scheme, we compute the three-loop renormalization group functions. On their basis, with the help of asymptotic series resummation methods, we estimate the correlation length critical exponent characterising the new universality class for spatial dimension d=3.

The work was supported by the National Research Foundation of Ukraine Project 2023.03/0099 "*Criticality of complex systems: fundamental aspects and applications*".

(1) D. Shapoval, M. Dudka, Yu. Holovatch, On the new universality class in structurally disordered n-vector model with long-range interaction, Low Temp.Phys. 48, 1049 (2022).

(2) M. Dudka, D. Shapoval, Yu. Holovatch, Critical behavior of structurally disordered systems with long-range interaction, Journal of Physical Studies 28, 2601 (2024)

---

*Speaker

Quantum surface critical phenomena

Andrei Fedorenko * [1], Eric Brillaux [2], Ilya Gruzberg [3]

[1] Laboratoire de Physique de l'ENS Lyon (Phys-ENS) – CNRS : UMR5672, École Normale Supérieure - Lyon – 46 allée d'Italie 69007 Lyon, France
[2] Laboratoire de Physique de l'ENS Lyon – CNRS : UMR5672, École Normale Supérieure - Lyon – France
[3] Ohio State University, Department of Physics – 191 W. Woodruff Ave, Columbus OH, 43210, United States

Phase transitions in the presence of boundaries have been a central topic of statistical physics over the past several decades. In semi-infinite systems, three distinct boundary universality classes emerge: the ordinary, the extraordinary, and the special. In the ordinary transition, the surface does not order independently but becomes critical together with the bulk, whereas in the extraordinary transition, bulk ordering occurs in the presence of an already ordered boundary. The special transition represents a multicritical point where the ordinary, extraordinary, and surface transition lines meet.

In contrast, much less is known about quantum phase transitions in the presence of boundaries, especially in systems that lie beyond the standard quantum-to-classical mapping. This includes a broad class of disorder-driven transitions, such as Anderson localization, as well as so-called non-Anderson transitions between nodal semimetals and diffusive metals, and interaction-driven metal-insulator transitions in Dirac materials.

In this talk, I will present a unified perspective on surface criticality in such quantum systems and highlight recent theoretical advances. Particular emphasis will be placed on the emergence of new boundary universality classes and on the interplay of disorder, interactions, and boundary effects.

1. E. Brillaux, A.A. Fedorenko, Phys. Rev. B 103, 081405 (2021).
2. E. Brillaux, A.A. Fedorenko, I.A. Gruzberg, Phys. Rev. B 109, 174204 (2024).
3. A.A. Fedorenko, I.A. Gruzberg, arXiv:2603.07637 (2026).

---

[*] Speaker

Time irreversibility, entropy production and effective temperature are independently regulated in the actin cortex of living cells

Elisabeth Fischer-Friedrich * [1], Narinder Narinder [1]

[1] Cluster of Excellence, Physics of Life, TU Dresden – Germany

Living cells exhibit non-equilibrium dynamics emergent from the intricate interplay between molecular motor activity and the viscoelastic cytoskeletal matrix. The deviation from thermal equilibrium can be quantified through frequency-dependent effective temperature or time-reversal symmetry breaking quantified e.g. through the Kullback-Leibler divergence.

Here, we investigate the fluctuations of an AFM tip embedded within the active cortex of mitotic human cells with and without perturbations that reduce cortex activity through inhibition of material turnover or motor proteins. While inhibition of motor activity significantly reduces both effective temperature and time irreversibility, inhibited material turnover leaves the effective temperature largely unchanged but lowers the time irreversibility and entropy production rate associated with the FDT-violation of tip dynamics. Our experimental findings in combination with a minimal model highlight that time irreversibility, effective temperature and entropy production rate can follow opposite trends in active living systems, challenging in particular the validity of effective temperature as a proxy for the distance from thermal equilibrium, particularly in the presence of mechanical changes.

Furthermore, we propose that biological activity regulates the occurrence of time-asymmetric deflection spikes in the dynamics of observables, providing a previously unrecognized link between entropy production and time irreversibility.

---

[*] Speaker

Magnetic polymers on regular and hierarchical lattices

Damien Foster * [1]

[1] Centre for Computational Sciences and Mathematical Modelling, Coventry University – United Kingdom

We explore the critical behavior of models of polymers in dilute solution where the monomers carry a magnetic moment which interacts ferromagnetically with nearest-neighbour monomers. Specifically, the model explored consists of a self-avoiding walk with Ising spins on the visited sites. We present results for the regular square and cubic lattices as well as on the 3-d Sierpinski Gasket. On the regular lattice it has been long known that the resulting collapse transition is first-order and that the magnetic and collapse transition occur at the same time. In two dimensions the transition is continuous but still occur simultaneously. This is not the case for the Sierpinski Gasket, where we observe two distinct transitions occuring. Critical behaviour is discussed and solvent effects are also included and discussed.

---

*Speaker

Spectral properties and form factors of the β ensemble

Anandamohan Ghosh * [1]

[1] Indian Institute of Science Education and Research Kolkata – India

The strength of level repulsion in random matrix ensembles is characterized by Dyson's index β, an indicator of quantum chaotic behavior. We study the spectral properties of a tridiagonal matrix ensemble that is isospectral to random matrices, in which β can be tuned continuously to interpolate between integrable and chaotic regimes. Our analysis reveals that the spatial inhomogeneity in the β-ensemble gives rise to Non-Ergodic Extended (NEE) states and is devoid of any mobility edge. This NEE phase is associated with an unconventional energy scale, reflected in relaxation dynamics that deviate from those observed in standard many-body systems. References: PRE **105**,054121(2022); PRL **131**,166401(2023); PRB **109**,064206(2024); PRB **112**,094206(2025)

---

*Speaker

Memory-induced active particle ratchets

Rosemary J. Harris * [1], Venkata Pamulaparthy [2]

[1] Department of Mathematics, University College London – United Kingdom
[2] Department of Mathematics, University College London – United Kingdom

I will discuss some recent work on a continuous-time random walker with stochastic reversals of direction, somewhat akin to "run-and-tumble" motion. There is no external potential in the model but the reorientation mechanism generates a non-zero current from asymmetry in the forward and backward waiting-time distributions (even when they have the same mean) so the system may be considered as a type of ratchet. I will elucidate some features of the ratchet current and explain in particular how a general renewal-theory framework can be used to obtain the full large deviations. Time-permitting, I will also comment on the possibility of dynamical phase transitions and mention the fluctuation properties of other models with reset or switching. (Based on V. D. Pamulaparthy and R. J. Harris, arXiv:2602.23327.)

---

[*] Speaker

Staggering domino-like behavior in a 1D cold gas

Taras Holovatch [1,2], Yuri Kozitsky [3], Krzysztof Pilorz [3], Yurij Holovatch * [1,2,4,5]

[1] Yukhnovskii Institute for Condensed Matter Physics of NAS of Ukraine – Ukraine
[2] L4 Collaboration Doctoral College for the Statistical Physics of Complex Systems, Leipzig-Lorraine-Lviv-Coventry – Germany
[3] Institute of Informatics and Mathematics, Maria Curie-Skłodowska University, Lublin – Poland
[4] Complexity Science Hub Vienna – Austria
[5] Centre for Fluid and Complex Systems, Coventry University – United Kingdom

We study the dynamics of a 1D chain of elastically interacting particles with alternating masses (M,m,M,m,.....). The dynamics is initiated by assigning a unit velocity in the positive direction to the particle at the origin. For random particle positions, the long-time behavior was previously found (1) to possess remarkable features: (i) a shock front develops in the bulk of the gas, governed by Euler hydrodynamics, and (ii) recoiled particles in the splatter move ballistically. In our study (2), we find that for equidistant particle positions, there exist mass ratios M/m for which: (i) the splatter is absent; (ii) the blast front moves ballistically; and (iii) the number of simultaneously moving particles is at most three. We refer to this regime-where motion is transferred sequentially from one triplet to the next-as 'staggering domino-like behavior.' This observation points to a breakdown of hydrodynamics and indicates non-ergodicity, as the system retains a dependence on the initial state at all times. We support our explicit calculations with molecular dynamics simulations. To examine the emerging scaling inherent in the hydrodynamics, we present results for the effective exponents governing the long-time behavior of the shock-wave front, the number of collisions, and the energy and momentum of different modes, evaluating their convergence toward universal values (3).

(1). S. Chakraborti, A. Dhar, P. L. Krapivsky, A splash in a one-dimensional cold gas. SciPost Phys. 13 (2022) 074.

(2). T. Holovatch, Yu. Kozitsky, K. Pilorz, Yu. Holovatch. Breakdown of hydrodynamics in a one-dimensional cold gas. Phys. Rev. E 112 (2025) L052101
(3). T. Holovatch, Yu. Kozitsky, K. Pilorz, Yu. Holovatch. Effective and asymptotic scaling in a one-dimensional billiard problem. Condens. Matter Phys. 28 (2025) 3401.

---

[*] Speaker

Si(001) surfaces and the anisotropic square lattice Ising model

Fred Hucht * [1], Christian Brand [1], Giriraj Jnawali [1], Jonas D. Fortmann [1], Björn Sothmann [1], Hamid Mehdipour [1], Peter Kratzer [1], Ralf Schützhold [2], Michael Horn-Von Hoegen [1]

[1] University of Duisburg-Essen [Duisburg] – Germany
[2] Helmholtz-Zentrum Dresden-Rossendorf – Germany

The coupling energies between the buckled dimers of the Si(001) surface were determined through analysis of the anisotropic critical behaviour of its order-disorder phase transition. Spot profiles in high-resolution low-energy electron diffraction as a function of temperature were analysed within the framework of the anisotropic two-dimensional Ising model. The validity of this approach is justified by the large ratio of correlation lengths, $\xi/\xi\perp = 5.2$ of the fluctuating c(4×2) domains above the critical temperature Tc = (190.6±10) K. Using a mapping onto the exact solution of the anisotropic square lattice Ising model, we obtain effective couplings J = (–24.9±1.3) meV along the dimer rows and J⊥ = (–0.8±0.1) meV across the dimer rows (1). Several critical exponents as well as the exact scaling function of the k-dependent susceptibility are compared, with excellent agreement (2). Finally, I give an outlook on the Kibble-Zurek mechanism in anisotropic Ising models (3). (1) Ch. Brand et al., Phys. Rev. Lett. 130, 126203 (2023)
(2) Ch. Brand et al., Phys. Rev. B 109, 134104 (2024)
(3) G. Schaller et al., Phys. Rev. Lett. 134, 246202 (2025)

---

*Speaker

Quench dynamics of the quantum XXZ chain with staggered interactions: Exact results and simulations on digital quantum computers

Ferenc Igloi * [1], Ching-Tai Huang [2], Yu-Cheng Lin [2]

[1] HUN-REN Wigner Research Centre for Physics, Budapest – Hungary
[2] Graduate Institute of Applied Physics, National Chengchi University, Taipei 11605 – Taiwan

We investigate quench dynamics in the quantum $S=1/2$ XXZ antiferromagnetic chain with staggered and anisotropic interactions in the flat-band limit. Our quench protocol interchanges the odd- and even-bond strengths of a fully dimerized chain, enabling us to derive exact time-dependent states for arbitrary even system sizes by working in the Bell basis. We obtain closed-form, size-independent expressions for the von Neumann and second-order Rényi entanglement entropies. We further calculate exact Loschmidt echoes and the corresponding return rate functions across various anisotropies and system sizes, and identify Loschmidt zeros in finite chains. Our analysis reveals the precise conditions on the anisotropy parameter that govern the periodicity of the dynamical observables. In addition to the analytic study, we perform two types of numerical experiments on IBM-Q quantum devices. First, we use the Hadamard test to estimate the Bell-basis expansion coefficients and reconstruct the dynamical states, achieving accurate entanglement entropies and the Loschmidt echo for small systems. Second, we implement Trotter-error-free time-evolution circuits combined with randomized Pauli measurements.

---

[*] Speaker

Post-processing via statistical correlations and classical shadows yields

reliable estimates of the second-order Rényi entanglement entropy and the Loschmidt echo, showing satisfactory agreement with exact results.

Still surprises of heat transport in harmonic crystals

Santra Ion * [1], Christian Maes

[1] Department of Physics and Astronomy [Leuven] – Belgium

We revisit the classical problem of heat transport in a harmonic crystal by coupling the elastic chain to a thermal bath via a soft-matter inspired interaction. Despite the standard equilibrium relations being still satisfied, we find that the stationary heat current is non-monotonic in the temperature gradient. This negative differential conductivity is solely due to the coupling of the chain oscillators with the soft matter bath, using a Bernoulli-Euler scheme where the bending of the elastic string enters. We have also computed the specific heat for such a thermally conducting chain, which should be widely relevant for high-temperature oscillations of heat-conducting molecules and gases.

---

[*] Speaker

Where is the correlation length encoded in long-range interacting systems?

Wolfhard Janke * [1], Max Kramer [1], Fabio Müller [1]

[1] Universität Leipzig, Institut für Theoretische Physik, IPF 231101, 04081 Leipzig, Germany – Germany

To answer this question we consider the one-dimensional long-range Ising model with couplings decaying as a function of distance \$x\$ algebraically $\$\propto 1/\hat{x}\{1+\sigma\}\$whichfor\$1/2<\sigma<1\$exhibitsafairl$

---

*Speaker

The Jaynes Cummings model as an autonomous Maxwell demon

Yashovardhan Jha * [1]

[1] LPCT – University of Lorraine, France, CNRS – France

Progress in experimental physics allows nowadays to study quantum machines with great detail. Specifically, research on autonomous quantum machines is increasing gradually since they play a significant role in thermodynamics. Autonomous machines are known to work without any external control, which helps the machines overcome the effect of decoherence due to the external environment. When these controllers perform thermodynamic tasks, such as work extraction or cooling, they are called autonomous Maxwell demons. A thorough characterization of these machines is of major fundamental interest, as it is linked to the long-standing question of how the dynamics induced by quantum measurements and the laws of thermodynamics emerge in an entirely quantum framework.

In a recent article (1), we study a two-level atom resonantly interacting with a harmonic oscillator via the Jaynes-Cummings interaction, where the cavity or the harmonic oscillator is initialized in a coherently displaced thermal state. We focus on the limit of very large coherent displacement, where the cavity is expected to behave as a classical drive.

We observe that this model actually exhibits different behaviors depending on the time scale, which divides the evolution into three regimes.

The first regime, or the unitary regime, indeed corresponds to a quasi-ideal work source behavior of the cavity, where the cavity induces a classical drive on the atom, which performs Rabi oscillations. Both the atom and cavity evolve almost unitarily. Using a framework of thermodynamics introduced for autonomous quantum systems (2), we quantify the residual heat exchange, showing that it goes to zero in the classical limit.

However, this regime breaks down on a time scale set by the qubit-cavity coupling constant, on which the Rabi oscillations start to collapse. This second regime corresponds to an autonomous measurement performed by the cavity on the atom. The cavity performs this measurement in a basis that is set by the initial phase of the field. During this measurement, the mutual information between the cavity and qubit rises as measurement results become available in the phase of the field.

Ultimately, we identify a third regime where the cavity provides autonomous feedback on the atom. The field in the cavity becomes dependent upon the measurement result, consequently

---

*Speaker

leading to a conditional drive on the atom. This feedback appears to purify the atom, whatever its initial state, by driving it towards a specific pure state set by the initial phase of the field.

Owing to our thermodynamic framework, we show that the cavity behaves as an autonomous Maxwell demon (1), trading mutual information for cooling power. This behavior emerges autonomously in the Jaynes-Cummings interaction. Our analysis demonstrates the potential of consistent thermodynamic approaches to understanding complex quantum dynamics.

References:

(1) Y. Jha, D. Karevski, and C. Elouard, Jaynes-Cummings model as an autonomous Maxwell demon, Phys. Rev. A (American Physical Society, Oct 2025), DOI: 10.1103/5f1z-m5cr

(2) Cyril Elouard and Camille Lombard Latune. Extending the Laws of Thermodynamics for Arbitrary Autonomous Quantum Systems. PRX Quantum, 4(2):020309, April 2023.

Minimal Local Antisymmetric Dynamics on Simplicial Complexes

Omer Korat * [1]

[1] Deloitte – Israel

A central question in dynamical systems is how much structure is required to represent conservative, oscillatory behavior. Standard formulations rely on continuous settings, differential operators, or complex-valued formalisms, resulting in representations that are often nonlocal, implicit, or structurally opaque.

We show how known properties of conservative oscillatory systems can be constructed from a single local rule, offering a simplified and structurally transparent alternative for representing such dynamics.

We construct a minimal local discrete system on simplicial complexes that realizes this class of dynamics directly. A purely local antisymmetric update rule induces a global skew-symmetric operator \$M\$ satisfying \$M = -MˆT\$, without assuming any global operator a priori. This local-to-global structure emerges solely from consistency constraints of the rule.

The resulting system guarantees both conservation laws and oscillatory behavior. In particular, a linear invariant \$$\sum u\$andaquadraticinvariant\$ \sum \hat{u}2\$arisenaturally, andoscillatorydynamicsfollowdirectly$

---

[*] Speaker

Deterministic Equations for Feedback Control of Open Quantum Systems

Gabriel Landi * [1]

[1] University of Rochester – United States

Feedback control in open quantum dynamics is crucial for the advancement of various coherent platforms. However, currently only a handful of feedback master equations exist in the literature, which are restricted to specific types of feedback. In this letter we first introduce a unifying framework, based on a single general equation, that describes all possible feedback schemes in sequentially (and continuously) measured systems, and from which all previous results follow. Next, we specialize it to the case of quantum jumps and introduce a new type of feedback based on the channel of the last detected jump, as well as the time elapsed since it occurred. Our description is experimentally grounded, and naturally allows for the introduction of realistic effects, such as time-delays in the feedback loop. We illustrate our results with two time-dependent feedback protocols conditioned on quantum-jump detections: one achieving population inversion of a two-level system against a thermal bath, and another enabling real-time reversal of quantum transitions, both admitting steady-state solutions.

---

*Speaker

Optimization of Brownian heat engines

Rahul Marathe * [1]

[1] Indian Institute of Technology Delhi – India

Brownian heat engines or stochastic heat engines have attracted a lot of attention in past decades. In this talk we will discuss a general variational technique for microscopic engines that is motivated from the optimal control theory used in optimization of macroscopic heat engines. We will show how this method is robust and superior over existing methods used for Brownian heat engine optimization and how it takes into account the realistic and experimentally relevant constraints. We will apply this technique to a generally damped Brownian particle confined in a harmonic potential, and discuss how simultaneous tunning of several target functions to achieve maximum power or efficiency. We will also discuss how optimizing temperature protocols, generally overlooked in existing literature, can influence the performance of the stochastic engines.

---

*Speaker

Phase diagram and Universality of the 4d Blume-Capel model

Leïla Moueddene * [1], Bertrand Berche , Nikolaos Fytas

[1] Physikalisches Institut, Albert-Ludwigs-Universität Freiburg – Germany

We present the first investigation of the phase diagram of the Blume–Capel model in four dimensions. Using Monte Carlo simulations and finite-size scaling analyses, we identify a line of second-order phase transitions in the Ising universality class, a first-order transition line, and a tricritical point separating these two regimes.

The four-dimensional case is particularly rich from a theoretical viewpoint. Along the second-order transition line $d=4$ corresponds to the upper critical dimension of the Ising universality class, allowing for a detailed study of multiplicative logarithmic corrections to mean-field scaling. At the tricritical point, the system lies above the upper tricritical dimension, providing - for the first time - the opportunity to test the predictions of QFSS theory in the tricritical universality class.

Our numerical results are fully consistent with the predictions of Q-finite-size scaling and confirm the expected universality properties in both the critical and tricritical regimes. These findings establish the 4D Blume–Capel model as a powerful framework for investigating universality and scaling behavior at and above upper critical dimensions.

---

*Speaker

Phase-ordering Kinetics in the Power-Law Interacting Ising Model

Fabio Mueller * [1], Henrik Christiansen [2], Wolfhard Janke [3]

[1] Leipzig University – Germany
[2] NEC Laboratories Europe – Germany
[3] Leipzig University – Germany

Phase-ordering kinetics (POK) describes the relaxation of systems from disordered to ordered states.
Usually, POK is characterized by dynamical scaling, i.e, the structures present at time t are determined by a single characteristic length growing as $ℓ(t) ∼ t̂α$, withgrowthexponent$α$.Forthenearest − ne

One important extension of the Ising model are long-range interactions, for which commonly power-law potentials of the form $J(r)∝ r̂{−(d + σ)}$areconsidered, with$σ$tuningtheinteractionrange.Whil

---

[*] Speaker

Aharonov-Bohm interferometry with interacting quantum dots

Oliver Oing * [1], Alexander Hahn [1], Jürgen König [1], Fred Hucht [1]

[1] University of Duisburg-Essen [Duisburg] – Germany

We describe an Aharonov-Bohm interferometer consisting of two leads and two tunnel-coupled quantum dots with on-site Coulomb interaction using first order perturbation theory in the tunnelling strength. In earlier work, a diagrammatic approach was chosen. The complexity of the diagrams for arbitrary parameters limited the calculations to symmetric systems in energies and couplings. By developing a systematic routine in *Mathematica* to generate all possible diagrams, we can explore a wider range of system configurations. Eleven system parameters can be arbitrarily tuned, namely the finite Coulomb interactions, the quantum dot level energies as well as the tunneling strengths, magnetic flux, bias voltage and temperature, enabling us to describe both symmetric and asymmetric systems. A finite bias voltage makes it possible to explore the non-linear response regime. The routine calculates density matrix elements and uses these to obtain the occupations of the quantum dots, the current and the conductance through the system. With this, we compare to analytic results and numerically exact results obtained with the TraSPI method (1). (1) S. Mundinar, A. Hahn, J. König, A. Hucht, Phys. Rev. B **106**, 165427 (2022)

---

*Speaker

Eigenstate thermalization and random matrix universality in classical many-body systems

Pavel Orlov * [1], Enej Ilievski [1], Tomaž Prosen [1,2]

[1] University of Ljubljana – Slovenia
[2] Institute of Mathematics, Physics and Mechanics [Ljubljana] – Slovenia

Our understanding of thermalization and chaos in quantum many-body systems largely relies on the statistical properties of the generator of unitary dynamics. The Eigenstate Thermalization Hypothesis (ETH) explains how quantum systems can thermalize by showing that locally individual eigenstates can already encode thermal properties. Similarly, comparing eigenvalue statistics with those of random matrices is a standard tool in the study of quantum chaos.
In this talk, we show that these probes of chaos and thermalization are not restricted to quantum systems, since classical dynamics can also be expressed in a unitary framework. By studying the spectrum of classical systems with discrete phase spaces – which is constructed from periodic orbits – we formulate a classical analog of the ETH ansatz and identify the corresponding random matrix universality classes. Finally, we verify our predictions numerically in realistic classical models.

Our framework offers a unified perspective on thermalization and chaos across both classical and quantum systems with discrete spectra. In particular, it raises intriguing questions about the relationship between well-established theories of classical and quantum chaos, some of which we briefly discuss.

---

*Speaker

Probabilistic Modeling in Classical and Quantum Mechanics

Rocchi Paolo * [1]

[1] Libera Università Internazionale degli Studi Sociali Guido Carli [Roma] – Italy

Abstract – This work includes three parts.
The probability theory has various questionable aspects. Beside the axiomatic approach, the frequentist and the subjective schools present diverging and irreconcilable interpretations of the concept of probability. The first part of this work presents two theorems establishing that the probability of long-term events (frequentist) and the probability of a single event (subjectivist and Bayesian) are not incompatible.

The second part infers two theorems from the previous pair of statements that describe the temporal evolution of the outcomes emitted from the long-term event and the single event respectively. In particular it is proved that the outcome of the single random event switches from the indeterministic to the deterministic state when the event winds up. This change is intrinsic to the random event and is not due to the observer. In conclusion, collapsing, impossible measurement, non-locality are properties typical of random results in both classical and quantum contexts.

The third part applies the mathematical results to quantum mechanics. The double slits experiment is analysed to verify the theoretical statements.

Other parts of the present ample research plan have been published (1).

(1) Rocchi P. – *Janus-Faced Probability* – Springer (2014).

Rocchi P., Gianfagna L. – Deux théorèmes et la nature multiple de la probabilité – *Comptes Rendus de la Société Canadienne d'Histoire et de Philosophie des Mathématiques*, Vol. 24: 110-118 (2011).
Rocchi P. – Probability, Information and Physics: Problems with quantum mechanics in the context of a novel probability theory – World Scientific (2023)

---

*Speaker

Polymer theory shows DNA motors extrude loops as monomers

Kirill Polovnikov [1,2], Dmitry Starkov * [1]

[1] Skolkovo Institute of Science and Technology, Moscow, Russia – Russia
[2] Institute for Physics and Astronomy, University of Potsdam, Potsdam-Golm, Germany – Germany

Cohesin-dependent loop extrusion is a key active mechanism of DNA organization, yet it remains unclear whether chromatin loops in living cells are generated primarily by individual cohesin motors or by higher-order structures. To fill this major gap, we build an analytical polymer-physics model that extracts a missing parameter - the linear density of loops - directly from Hi-C data. We focus on short genomic distances, where contact statistics simplify, resulting in a perturbative expression for the contact probability of a looped chain under a finite contact-detection radius. Our theory recapitulates a characteristic dip in the logarithmic derivative of the contact-probability that is broadly observed in experiments. By fitting this minimal model to a diverse range of mammalian Hi-C datasets, we infer approximately six loops per megabase. Independent imaging and mass spectrometry measurements of cohesin density are consistent with our inferred loop density, supporting the monomeric mode of DNA motors extrusion.

---

*Speaker

Tracer particles in correlated media — memory and fluctuation-induced forces

Marcin Piotr Pruszczyk * [1,2], Andrea Gambassi [1,2], Davide Venturelli [3]

[1] Scuola Internazionale Superiore di Studi Avanzati / International School for Advanced Studies – Italy
[2] Istituto Nazionale di Fisica Nucleare, Sezione di Trieste – Italy
[3] Laboratoire de Physique Théorique de la Matière Condensée – Sorbonne Universite, Centre National de la Recherche Scientifique – France

In the linear overdamped Langevin equation, the effect of collisions of a mesoscopic particle (e.g., a colloid) with the molecules of the surrounding medium is described by instantaneous friction and a random force modeled by Gaussian white noise, yielding a Markovian dynamics of the particle. Such a description assumes that the motion of the molecules occurs on time-scales much shorter than the one at which the motion of the particle is described.

Media undergoing a second-order phase transition exhibit collective fluctuations which are characterized by long-range correlations and macroscopic relaxation times, comparable with the typical time-scale of the motion of a colloidal particle.

We introduce a minimal model of a particle coupled to a spatio-temporally correlated medium. The medium is described by a fluctuating Gaussian field with a tunable correlation length
$\$\xi\$ whichfollowsrelaxationaldynamics.Theparticle-fieldcouplinggivesriseto:(i)amemory-$
$inducedcorrectioninthe particlepositioncorrelationfunction;(ii)arepulsiveCasimir-likeforceandanenhance$
$--abackwardsmotionofaparticlereleasedfromatrapmovingwithconstantvelocity;(iv)theMagnuseffect-$
$--atransverseforceactingonaspinningparticlemovingwithconstantvelocity.$

---

[*] Speaker

Two-dimensional melting scenarios and tricriticality in a generalized clock model

Antonin Roge * [1], Peter Holdsworth , Alexis Poncet

[1] ENS DE LYON – École Normale Supérieure - Lyon – France

The melting of two-dimensional spheres remains a fundamental problem in statistical mechanics, with the celebrated KTHNY scenario predicting a two-step melting, with two continuous transitions, via an intermediate hexatic phase. However, recent
studies have revealed deviations from this paradigm, including first-order hexatic-liquid transition or single-step melting. Here, we introduce a minimal on-lattice model, a clock model with vacancies, that captures
2D melting scenarios observed in continuous systems. By tuning the crystal field controlling vacancy density, we demonstrate three distinct melting behaviors: two continuous BKT-like transitions, a continuous low-temperature transition followed by a discontinuous high-temperature transition, and a single first-order transition.
To map the complete phase diagram and identify the universality classes of the transition lines and the tricritical point, we combine Monte Carlo simulations and tensor network renormalization techniques. Our results reveal the evolution of the high-temperature BKT transition with increasing crystal field and locate the tricritical point where the BKT line terminates. At this point we find a a magnetic critical exponent consistent with the tricritical Ising universality class, while the second critical exponent, related to density fluctuations, hints at new universality class.
This work provides a
framework for understanding the crossover between 2D melting scenarios and offers insights into the behavior of realistic systems.

---

*Speaker

Topology-Enhanced Arrest of Failure Avalanches in Complex Networks

Bence Joel Rácz * [1], Ferenc Kun *

2

[1] University of Debrecen Egyetem [Debrecen] – Hungary
[2] University of Debrecen Egyetem [Debrecen] – 4032 Debrecen, Egyetem tér 1., Hungary

Cascading failure in heterogeneous networks is strongly shaped by the topology of load redistribution. Using a network-based fiber bundle model on rewired lattices, we show that avalanches are not only controlled by strength disorder, but also by the connectivity of the nodes involved in the cascade. In the low-disorder regime, avalanches tend to start in poorly connected regions, where load increments are concentrated, and terminate when they reach highly connected nodes. Such nodes act as effective load sinks, diluting redistributed load over many intact neighbors and thereby suppressing further propagation. Motivated by this mechanism, we introduce a degree-weighted load redistribution rule that preferentially transfers load to highly connected intact neighbors. Simulations show that this protocol enhances avalanche arrest, reduces the size of stable cascades, increases the amount of damage tolerated before global failure, and delays catastrophic collapse. These results demonstrate how network topology can be exploited to improve the robustness of systems prone to cascading failure.

---

*Speaker

Calculation of optimal membrane shape and its application in biology

Raj Sadhu * [1]

[1] Indian Institute of Technology Kharagpur – India

A biological membrane always tends to optimize its shape by minimizing its free energy. There are several techniques to calculate the optimal shape of a membrane, such as, elastic theory of membrane, Monte Carlo simulation etc. Using elastic theory of membrane, we calculate the optimal shape of a membrane deformed by transmembrane protein transporters during the transport of molecules (such as nutrients, toxins, drugs) across the cell membrane. We use our calculations to explain the role of membrane mechanical properties on the transport process. Further, we use similar technique to calculate the membrane constriction during membrane scission, and explain the role of membrane tension in the scission process. We also use Monte Carlo simulation to generate optimal membrane shape by discretizing the membrane surface. We find that our model nicely captures the properties of cell migration on flat substrate, coiling of cellular protrusions around fibers, as well as cellular migration on curved surfaces.

---

*Speaker

When in doubt, reset!

Trifce Sandev * [1,2,3]

[1] Macedonian Academy of Sciences and Arts, Skopje, Macedonia – Macedonia
[2] Institute of Physics, Faculty of Natural Sciences and Mathematics, Ss Cyril and Methodius University in Skopje, Macedonia – Macedonia
[3] Department of Physics, Korea University, Seoul, Korea – South Korea

By repeatedly returning a search process to a known or random state, random resetting can unveil new trajectories, sidestep obstacles, and significantly enhance the efficiency of locating targets. In this talk, I will review key theoretical contributions to our understanding of random resetting across various stochastic processes. Furthermore, I will explore real-world applications where resetting optimizes outcomes in diverse fields, demonstrating its multifaceted influence as a search strategy.

---

*Speaker

Crossover from generalized to conventional hydrodynamics in nearly integrable systems under relaxation time approximation

Saikat Santra * [1]

[1] Faculty of Physics, University of Warsaw, – Poland

Upon breaking the integrability, the equations of generalized hydrodynamics (GHD) are supplemented by a Boltzmann collision term. Such terms are typically complicated and stem from a perturbative treatment of integrability-breaking terms in the hamiltonian. In our work, we study a simplified version of the collision operator in a form of relaxation time approximation familiar from kinetic theory. We explicitly compute transport coefficients which characterize the Navier-Stokes (NS) hydrodynamic regime emerging at large space-time scales. We also thoroughly study the crossover between GHD and NS hydrodynamic descriptions, identifying relevant characteristic space-time scales for the transition. In particular, we show how the emergence of NS hydrodynamics is visible in dynamics of conserved and non-conserved charge densities, and in hydrodynamic two-point functions.

---

[*] Speaker

Change in the order of a phase transition in the two-dimensional Potts model with equivalent neighbors

Petro Sarkanych * [1,2], Yurij Holovatch [1,2,3,4]

[1] Insitute for Condensed Matter Physics, National Academy of Sciences of Ukraine – Ukraine
[2] L4 Collaboration Doctoral College for the Statistical Physics of Complex Systems – Unknown Region
[3] Centre for Fluid and Complex Systems, Coventry University, Coventry – United Kingdom
[4] Complexity Science Hub Vienna – Austria

Two-dimensional (2D) Potts model is a classical example when the symmetry of the order parameter controls the order of a phase transition: on a square lattice with nearest-neighbors interaction, when the number of states is less than or equal to 4, the second-order phase transition is observed, while for the first-order phase transition occurs. Recent research shows that even when the number of states is fixed, increasing the interaction range allows one to reach the point where the order of the phase transition changes. I focus on a 2D Potts model and, from the analysis of the partition-function zeros, locate the number of interacting neighbors that change the order of the phase transition.

This research was funded by the National Research Foundation of Ukraine, Project No. 2023.03/0099, "Criticality of complex systems: fundamental aspects and applications." (1) P. Sarkanych, *Physical Review E* 113.1 (2026): 014108.
(2) P. Sarkanych *et al.* Europhys. Lett. 135, 37003 (2021).

---

[*] Speaker

Emergent interaction in attractively coupled active particles

Ritwick Sarkar * [1], Urna Basu [1]

[1] S. N. Bose National Centre for Basic Sciences – India

We investigate the dynamics of N pair-wise harmonically coupled active Brownian particles (ABPs) in the presence of thermal fluctuations. The harmonic coupling and the bounded nature of the active noise ensure that the relative distance r_ij between each pair of particles eventually reaches a stationary state. Depending on the interplay between the active time-scale and the relaxation time-scale associated with the harmonic coupling, three regimes emerge: strong, moderate, and weak coupling. We analytically show that in the strong coupling regime, an effective short-range repulsion emerges between ABP pairs with speed heterogeneity, both in the presence and absence of thermal fluctuations. The short-range repulsion also persists when the ABP pairs are coupled by a generic long-range attractive potential.

References:

(1) Ritwick Sarkar, Shreya Chatterjee and Urna Basu, *From Attraction to Repulsion: Emergent Interactions in Harmonically Coupled Active Binary System*, Journal of Physics A: Mathematical and Theoretical **58**, 415001 (2025).

(2) Ritwick Sarkar and Urna Basu, *Emergent short-range repulsion for attractively coupled active particles*, Soft Matter **21**, 3595 (2025).

---

*Speaker

Ensemble dependence of the critical behavior of a system with long range interaction and quenched randomness

Nir Schreiber * [1], Reuven Cohen , Simi Haber

[1] Department of Mathematics [Bar-Ilan] – Israel

A system with long range interaction (LRI) is usually non-additive. In other words, such a system with volume V and energy E, cannot be divided into two subsystems with energies E_1, E_2 , where $E = E_1 + E_2 + o(V)$.
The canonical and the microcanonical ensembles are expected to be equivalent when describing additive systems. Conversely, non-additivity may result in peculiar microcanonical phenomena that are not observed in the canonical ensemble, such as negative specific heat or the presence of microstates that are inaccessible to the system, leading to breaking of ergodicity.
The Blume-Emery-Griffiths (BEG) model with mean-field-like interaction is a simple example of a model with LRI. We employ that model to propose a mechanism which leads to an inequivalence of the two ensembles, without interfering with the interaction content. To be more specific, we consider a hybrid system governed by the BEG Hamiltonian, where the spins are randomly quenched such that some of them are "pure" Ising and the others admit the BEG set of states. It is found, by varying the concentration of the Ising spins while keeping the parameters of the Hamiltonian fixed, that the model displays different canonical and microcanonical phase portraits in concentration-temperature space. Phenomenological indications that these portraits are rich and rather unusual are provided

---

[*] Speaker

Barkhausen noise in disordered striplike ferromagnets: Experiment versus simulations

Djordje Spasojević [1], Dragutin Jovković * [2], Sanja Janićević [3], Lasse Laurson [4], Antonije orević [5]

[1] Faculty of Physics and Meteorology [Belgrade] – Serbia
[2] Faculty of mining and geology – Serbia
[3] University of Kragujevac – Serbia
[4] Tampere University of Applied Sciences [Finland] – Finland
[5] School of Electrical Engineering – Serbia

Barkhausen noise provides a prototypical example of avalanche dynamics in driven disordered magnetic systems and serves as a testing ground for nonequilibrium critical phenomena. In this work, we present a systematic comparison between experimental measurements of low-frequency Barkhausen noise and numerical simulations of the random-field Ising model (RFIM), focusing on the role of finite driving rates.
The experiments were performed at room temperature on a field-driven metallic glass stripe made of VITROPERM 800 R, a nanocrystalline iron-based material characterized by excellent soft magnetic properties. Barkhausen signals were recorded over a two-decade-wide range of external magnetic field driving rates, allowing for a detailed analysis of the influence of driving dynamics on avalanche statistics.

On the theoretical side, we consider the athermal nonequilibrium RFIM with a finite driving rate, which provides a minimal model for magnetization dynamics in disordered systems. Numerical simulations were carried out to generate magnetization time series and avalanche distributions directly comparable to experimental data. Particular attention was devoted to the statistical properties of avalanches, including size and duration distributions and their scaling behavior under varying driving conditions.

We find that, with an appropriate choice of model parameters, the RFIM reproduces the main statistical features of the experimentally observed Barkhausen noise over the investigated range of driving rates. In particular, the model captures the scaling behavior of avalanche distributions and their evolution with increasing driving rate, indicating a consistent description of the underlying dynamics. The agreement between experiment and simulation supports the applicability of the nonequilibrium RFIM to nanocrystalline magnetic materials, where disorder and domain-wall interactions play a dominant role.
These results demonstrate that a finite-rate nonequilibrium RFIM provides a realistic framework for describing Barkhausen noise in nanocrystalline systems and offers insight into the mechanisms governing avalanche dynamics in driven disordered media. More broadly, the present

---

[*] Speaker

study highlights the relevance of statistical physics models for interpreting experimentally observed crackling noise phenomena.

When the limit fails: ensemble dependence, emergent forces and finite-size thermodynamics in confined quantum gases

Alessio Squarcini * [1]

[1] Complex Systems and Statistical Mechanics - Department of Physics and Materials Science, University of Luxembourg, , 30 Avenue des Hauts-Fourneaux, L-4362 Esch-sur-Alzette, Luxembourg – Luxembourg

The thermodynamics of ideal quantum gases is traditionally formulated in the thermodynamic limit, where bulk behavior dominates and boundary effects are negligible. While this limit underlies most textbook treatments, it becomes inadequate in experimentally relevant situations where confinement and finite size play a central role. Moreover, it obscures rich structural features that emerge under geometric confinement.
In this talk, we revisit the equilibrium thermodynamics of an ideal quantum gas under geometric confinement, with a focus on deviations from the infinite-volume paradigm (1). Working in arbitrary spatial dimension and within a slab geometry, we show that confinement qualitatively reshapes thermodynamic behavior, giving rise to features that are absent in the bulk description and that cannot be captured from the infinite-volume limit.

We demonstrate that the presence of finite boundaries qualitatively transforms equilibrium features: traditional extensive thermodynamic relations become inadequate, and thermodynamic observables exhibit non-monotonic behavior tied to quantum correlations and statistics. In particular, entropy and compressibility-related measures display structural irregularities that cannot be reconciled with conventional limit-based formulations. These finite-size phenomena vanish upon returning to the thermodynamic limit but are dominant when system size competes with intrinsic quantum scales.

The analysis naturally connects to Casimir-type forces in confined quantum gases. We show that the Casimir interaction exhibits a pronounced **dependence on the statistical ensemble,** with marked differences between fixed-particle and fluctuating-particle descriptions. Despite these differences, a common crossover structure emerges, characterized by distinct power-law regimes at short and large separations, connected by a quantum scale set by confinement.

All results arise from an **exact analytic framework**, augmented by asymptotic analysis in regimes where closed expressions are intricate. Beyond providing a controlled finite-size extension of quantum gas thermodynamics, the results highlight how confinement and ensemble choice fundamentally alter equilibrium properties, even in the simplest quantum many-body systems.

References:
(1) A. Squarcini and M. Esposito, *to appear (2026).*

---

[*] Speaker

Exact valence bond ground states with and without translational invariance

Jedrzej Wardyn * , Miłosz Panfil [1]

[1] University of Warsaw (UW) – Krakowskie Przedmieście 26/28 00-927 Warsaw, Poland

Magnetically frustrated systems, while often governed by simple Hamiltonians, exhibit complex behavior and novel phases absent in unfrustrated ones.
They are also particularly difficult to study numerically as well as theoretically. However, exact results can be obtained in specific situations. One of which is the Majumdar-Ghosh (MG) model, a special case of the Heisenberg chain with the antiferromagnetic nearest neighbor J_1> 0 and next-to-nearest neighbor J_2> 0 interactions, where J_2/J_1=1/2. Frustration caused by competition of the two interactions causes formation of valence bonds (dimers). Dimers take a role of building blocks for the doubly degenerate ground state and high portion of excited states. High energy required to break dimers make the state highly resistant to perturbations. MG model is not the only one to host valence bond ground state, in fact it generalizes to a class of linear exchange models.

In our work, we show that the valence bond ground state is supported in an even larger class of Hamiltonians that includes models with broken translational invariance, anizotropy or 3-site and 4-site interactions.
Combining DMRG with analytical methods we investigate the spin gap for different Hamiltonians of this exact dimer ground state family.
We consider generalisations to models with easy-axis anisotropy using q-deformation by extending the ordinary SU(2) symmetry to a quantum group, with construction based on Temperley-Lieb operators.

Studying this class of systems lays the groundwork for understanding novel magnetic materials as well as exploration of possibilities for quantum information systems realized with valence bond states.

---

*Speaker

Dislocation Mediated Diffusion and the Endoplasmic Reticulum

Michael Wilkinson * [1]

[1] The Open University, Milton Keynes, UK – United Kingdom

I discuss a model for diffusion in a lamellar medium which is permeated by randomly positioned dislocations. There is two-dimensional diffusion on each layer, and paths which wind around dislocations make transitions between layers. Contrary to some earlier suggestions, the dispersion of trajectories across layers is found to be diffusive, rather than superdiffusive. Obtaining the correct result depends upon understanding the role of 'screening' in the distribution of dislocations.

I also argue that this apparently arcane problem has relevance to biology. The sheet-like endoplasmic reticulum (ER) of eukaryotic cells has been found to be riddled with spiral dislocations, known as 'Terasaki ramps'. The sheets of the ER are formed by lipid bilayers, which are a barrier to diffusion of water-soluble molecules. These dislocations provide an efficient mechanism for the diffusion of molecules within cells.

The talk reports collaborations with John Hannay, University of Bristol, and Greg Huber, Chan-Zuckerberg Biohub, San Francisco.

---

*Speaker

Order by disorder in a chiral fluid with obstacles

Pradeep Kumar Yadav [1], Sanjay Puri [2], Martin Weigel * [3,4]

[1] University of Barcelona – Spain
[2] Jawaharlal Nehru University (JNU) – New Mehrauli Road, New Delhi - 110 067. INDIA, India
[3] Chemnitz University of Technology – Germany
[4] Coventry University (UK) – United Kingdom

Active matter composed of self-propelled particles shows a rich phenomenology that is in stark contrast to the behavior of passive matter following the laws of equilibrium thermodynamics. The presence of quenched disorder that is common and often unavoidable in laboratory systems provides a significant perturbation to the collective behavior of active systems. We study the behavior of a swarm of self-propelled particles moving in a plane in the presence of a small concentration of disc-like obstacles. While without obstacles maximal order is observed for vanishing external noise, in the presence of obstacles the strongest order is only established for a significant amount of alignment noise. As we show here, this surprising *order by disorder* phenomenon can be understood from a competition of length scales in the system. Our arguments are supported by detailed numerical simulations of the Vicsek model in the presence of circular obstacles.

---

*Speaker

Liste des participants

- Adjaout Idriss
- Agyapomaa Abigail
- Agyapong Sussana
- Allan Lynet
- Banerjee Varsha
- Berche Bertrand
- Beyen Aaron
- Bezzaz Yasser
- Biham Ofer
- Bomont Jean-Marc
- Boubakour Mohamed
- Burgun Raphaël
- Chatelain Christophe
- Collet Olivier
- Collura Mario
- Coppola Michele
- Di Bello Grazia
- Dubail Jerome
- Dudka Maxym
- Elouard Cyril
- Fedorenko Andrei
- Fischer-Friedrich Elisabeth
- Foster Damien
- Fumeron Sébastien
- Gessert Denis

- Hövel Philipp
- Harris Rosemary
- Henkel Malte
- Holovatch Yurij
- Hucht Fred
- Igloi Ferenc
- Ion Santra
- Janke Wolfhard
- Jha Yashovardhan
- Kalinowski Wiktor
- Karevski Dragi
- Khaled Zeina
- Landi Gabriel
- Lopez Alexander
- Maffei Maria
- Moueddene Leïla
- Mueller Fabio
- Muller Thibaut
- Oing Oliver
- Orlov Pavel
- Owusu Ellen
- Panfil Miłosz
- Pruszczyk Marcin
- Rácz Bence Joel
- Rignon-Bret Antoine
- Roge Antonin
- Safranek Dominik
- Sandev Trifce
- Santra Saikat
- Sarkanych Petro
- Sarkar Ritwick
- Schehr Gregory

- Squarcini Alessio
- Starkov Dmitry
- Stoimenov Stoimen
- Takács Attila
- Wardyn Jedrzej
- Warkotsch Dustin
- Weigel Martin
- Zahra Ali

Author Index