48th Conference of the Middle European Cooperation in Statistical Physics

Program & Abstracts

Stará Lesná, High Tatras, Slovakia
May 22nd-26th, 2023

Sponsors:

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48th Conference of the Middle European Cooperation in Statistical Physics (MECO48)

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Preface

The 48th Conference of the Middle European Cooperation in Statistical Physics (MECO48) will be held on May 22nd-26th, 2023, in Stará Lesná, High Tatras, Slovakia. The MECO48 conference continues a long tradition of regular international meetings in the domain of statistical physics established in the early 1970s with the aim of bridging the gap between the communities of scientists from the Eastern and Western parts of Europe separated by the iron curtain. In the modern era the MECO conferences attract attention of the community of scientists who are active in the field of statistical physics including various interdisciplinary applications to biology, medicine, geography, finance, quantum information theory, and machine learning.

The MECO48 conference is organized jointly by Faculty of Science of Pavol Jozef Šafárik University in Košice, Institute of Experimental Physics of Slovak Academy of Sciences in Košice, Institute of Physics, Slovak Academy of Sciences in Bratislava and Faculty of Humanities and Natural Sciences, University of Prešov under the financial support of Slovak Research and Development Agency (grant No. APVV-20-0150) and other sponsors. The main focus of the MECO48 conference are the topical issues of statistical physics as specified below.

The conference will consist of 10 invited lectures (40 min.), 22 contributed talks (20 min.) and 26 poster presentations. The working language of the conference is English.

The main conference topics:

- Disordered and Frustrated Systems
- Strongly Correlated Systems
- Quantum Many-Body Systems
- Quantum Computation and Information
- Topological Phases of Matter
- Soft and Active Matter
- Networks and Complex Systems
- Non-equilibrium Phenomena
- Interdisciplinary Applications

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Past MECO conferences

MECO1 (1974, Wien, Austria)
MECO2 (1975, Regensburg, West Germany)
MECO3 (1976, Bled, Yugoslavia)
MECO4 (1977, Unterägeri, Switzerland)
MECO5 (1978, Boszkowo, Poland)
MECO6 (1979, Trieste, Italy)
MECO7 (1980, Budapest, Hungary)
MECO8 (1981, Saarbrücken, West Germany)
MECO9 (1982, Wien, Austria)
MECO10 (1983, Bled, Yugoslavia)
MECO11 (1984, Gernrode, East Germany)
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MECO18 (1991, Duisburg, Germany)
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MECO23 (1998, Trieste, Italy)
MECO24 (1999, Lutherstadt, Germany)
MECO25 (2000, Pont-a-Mousson, France)
MECO26 (2001, Prague, Czech Republic)
MECO27 (2002, Sopron, Hungary)
MECO28 (2003, Saarbrücken, Germany)
MECO29 (2004, Bratislava, Slovakia)
MECO30 (2005, Cortona, Italy)
MECO31 (2006, Primošten, Croatia)
MECO32 (2007, Ladek Zdroj, Poland)
MECO33 (2008, Wels, Austria)
MECO34 (2009, Leipzig, Germany)
MECO35 (2010, Pont-a-Mousson, France)
MECO36 (2011, Lviv, Ukraine)
MECO37 (2012, Matliare, Slovakia)
MECO38 (2013, Trieste, Italy)
MECO39 (2014, Coventry, United Kingdom)
MECO40 (2015, Esztergom, Hungary)
MECO41 (2016, Wien, Austria)
MECO42 (2017, Lyon, France)
MECO43 (2018, Krakow, Poland)
MECO44 (2019, Kloster Seeon, Germany)
MECO45 (2020, Cluj, Romania)
MECO46 (2021, Riga, Latvia)
MECO47 (2022, Erice, Italy)

Practical information

Venue

The MECO48 conference will take place in the lecture hall of *Congress Center Academia*

Stará Lesná No. 176
059 52 Stará Lesná
Slovak republic
GPS Location: 49.1516667 N, 20.2869444 E

Poster session will take place in the foyer of the lecture hall.

Accommodation

Most of the participants booked their accommodation either in the *Hotel Academia* directly belonging to the *Congress Center Academia* or in the nearby located *Kontakt Wellness Hotel*

Stará Lesná No. 180
059 52 Stará Lesná
Slovak republic
GPS Location: 49.151003 N, 20.285777 E.

All participants booking their accommodation through the organizers will be kindly asked to move on the Thursday morning, May 25th, from the *Hotel Academia* to the *Kontakt Wellness Hotel* at no additional cost due to a subsequent event starting in the *Congress Center Academia* on the Friday morning, May 26th. Please do not forget to bring your swimming suit if you would like to use a pool, a Jacuzzi bar, whirlpools, massages or SPA treatments within the *Kontakt Wellness Hotel.*

Registration

The registration desk will be located in the lobby of the *Hotel Academia* and the registration will be open on Monday, May 22nd, 2023, from 14:00 to 18:00. If you have not paid your conference fee yet, you will have the possibility to do so, but only payment in cash will be accepted. On the other days please consult conference organizers designated by special badges in order to complete registration. As you register you will receive the following documents:

- conference booklet
- badge
- certificate of attendance
- lunch and dinner coupons
- stickers for the best poster award

All participants are kindly requested to wear their badge when attending the meeting; only participants who are wearing their name badges will be admitted to the lecture halls, coffee breaks, welcome reception, conference banquet, lunches and dinners. The same holds true for accompanied persons.

Oral presentations

Oral presentations will be given in the lecture hall of *Congress Center Academia*. It is preferred to use our computer for the presentation, but only pdf or ppt(x) files are accepted for technical reasons. You can alternatively use your personal laptop for the presentation, but you are kindly asked to check half a day before your talk if all details of your file are properly projected onto the screen. Please use preferentially coffee breaks for this check; Dr. Tomáš Lučivjanský will provide you technical support.

Invited talks are scheduled for 40 minutes (35 minutes presentation + 5 minutes discussion), while contributed talks are scheduled for 20 minutes (15 minutes presentation + 5 minutes discussion). Chair persons will be instructed to follow the time schedule rigorously.

Poster presentations

Poster presentations will take place in the foyer of the lecture hall of *Congress Center Academia*. The main poster session is scheduled on Tuesday, May 22nd, 2023 from 17:10 to 18:30, but the posters should be mounted already on the Tuesday morning and dismounted on the Wednesday evening in order to leave more space for scientific discussions during the coffee breaks. Posters that have not been dismounted on the Wednesday evening will be removed by the organizers. Please check the conference booklet in the "Posters" section to find out the number assigned to your poster. **The poster boards are 100 cm high and 93 cm wide**. Pins will be provided to fix the posters. We kindly ask all presenters to stay close to their respective posters during the poster session. There will be two *best poster awards* - one will be decided by all participants voting through the provided stickers and another one will be selected by the MECO48 jury.

Lunches & Dinners

Lunches and Dinners will be served for all participants in the restaurant of *Hotel Academia*. Lunch and dinner coupons will be provided at the registration according to your selection made by filling out the google form prior the MECO48 conference. The participants without selection will be automatically assigned the first choice from the list.

Welcome reception & Conference banquet

The Welcome reception will be held on Monday, May 22nd, from 18:00 until 21:00 in the restaurant of *Hotel Academia*. Meals and drinks will be served in the form of buffet. The Conference banquet will be held on Wednesday, May 24th, rom 18:00 until 21:00 in the restaurant of *Kontakt Wellness Hotel*. Meals and drinks will be served in the form of buffet.

Additional information

The conference staff will be happy to assist participants during the whole MECO48 conference; the members of organizing team will carry on special badges. Possible changes in the program will be announced on a message board in the foyer of the *Congress Center Academia*. We recommend never walk alone in the surrounding forests due to a chance to meet bear(s).

Trip to waterfalls "Vodopády Studeného potoka"

On Thursday afternoon, May 25th, we will organize a trip to waterfalls "Vodopády Studeného potoka". It is a pleasant walk which takes about 4 and half hours and does not require a high level of physical fitness. We start from Hotel Kontakt in Stará Lesná and head to the nearby Tatranská Lesná. Then we cross the road and the guidepost immediately directs us towards Vodopády Studeného potoka that will take about 1 and half hour on the yellow trail. We follow first a forest path, later a rocky trail. The ascent is light at first but gradually, especially till the end, turns into steep. The natural scenery is beautiful, we pass through the areas with the crystal clear Studenovodský brook, at least we can hear it somewhere. We will see the waterfalls: Dlhý ("Long"), higher up Vel'ký ("Great"), Skrytý ("Hidden") and Malý ("Small") vodopád. If we would like to, we can extend the route by a few minutes and see the Obrovský vodopád ("Huge waterfall"). We cross the bridge at the Vel'ký vodopád and head to Tatranská Lomnica, which can be reached in about 1 and half hour (blue trail). The rocky trail turns into a forest path. We get off the trail at the cable car station to Štart and Skalnaté pleso. From there it takes about 40 minutes to get back to Stará Lesná. Optionally, we can return from Vodopády Studeného potoka to Stará Lesná more quickly following the same trail instead of making the loop through Tatranská Lomnica. It is advisable to wear sturdy walking shoes and pack the raincoat as the weather in mountains is changeable. The walk is relatively easy but to be on the safe side we recommend to get mountain insurance (see e.g. https://regiontatry.sk/en/tourist-information/mountain-insurance/).

"Vodopády Studeného potoka" waterfalls

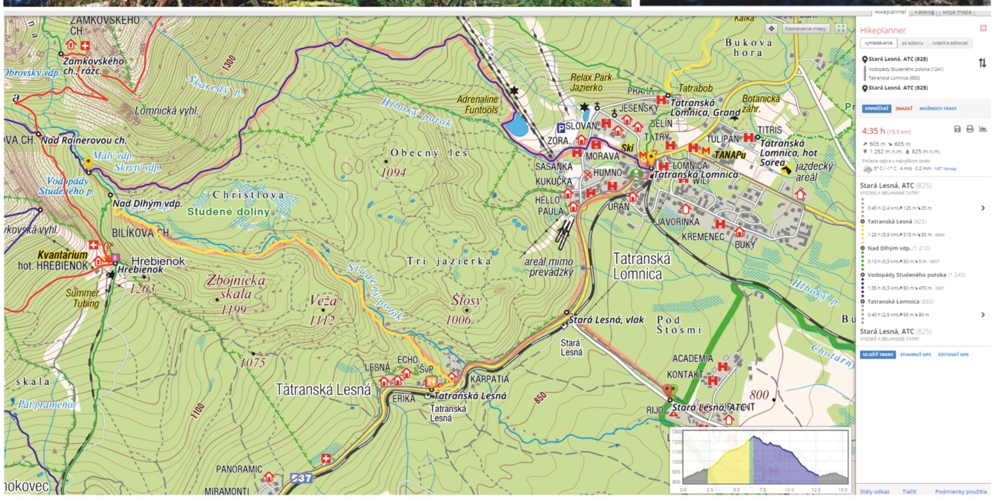
One of the tourist attractions in the environs of Starý Smokovec and Tatranská Lomnica in the High Tatras is the group of the cascaded Vodopády Studeného potoka waterfalls. These waterfalls are among the most frequently visited in the Tatras. They form a complex system of multi-terraced cascades. The upper, called Obrovský vodopád (The Giant waterfall) is well visible from the bridge on the main tourist path (magistrála) in the Tatras. The white-foamed water tumbles down the trough passing between two rocks into a 20-meter-deep profusion. The name of the lower waterfall, Trojitý vodop'ad, in Hungarian and German languages is rather poetic - "the waterfall of artists". It is hidden deep in the forest hence seldom visited. Below the confluence of the Vel'ký and Malý Studený potok brooks there are another four waterfalls. The tallest of them is the cascade of the Malý vodopád waterfall. At an altitude of 1,247 m there is the Skrytý vodopád waterfall and somewhat lower at 1,226 m above sea level is the lower end of the cascades of the Vel'ký vodopád waterfall. Its tallest cascade is 13 meters. The Dlhý vodopád waterfall is also on the brook Studený potok, immediately opposite the cottage Bilíkova chata at Hrebienok and is accessible by the yellow-marked path leading to the small commune Tatranská Lesná. For further details see

https://slovakia.travel/en/vodopady-studeneho-potoka-waterfalls-high-tatras

A few pictures from the path to "Vodopády Studeného potoka" waterfalls







List of Invited Speakers

Oleg Derzhko	Institute for Condensed Matter Physics, Ukraine
Yurij Holovatch	Institute for Condensed Matter Physics, Ukraine
Juha Honkonen	National Defence University, Finland
Dionissios Hristopulos	Technical University of Crete, Greece
Christophe Chatelain	Université de Lorraine, France
Katarína Karl'ová	Pavol Jozef Šafárik University in Košice, Slovakia
Zoltán Néda	Babes-Bolyai University, Romania
Sofian Teber	Sorbonne Université, France
Emmanuel Trizac	Université Paris-Saclay, France
Lenka Zdeborová	Ecole Polytechnique Fédérale de Lausanne, Switzerland

Program - Monday May 22nd, 2023

14.00-18.00 Registration in Hotel Academia - Lobby

18.00-21.00 Welcome reception in Hotel Academia

Program - Tuesday May 23th, 2023

08.45-10.20 Chair: J. Strečka
08.45-09.00 Conference opening
09.00-09.40 Invited presentation - I1:
Y. Holovatch
The fate of Ernst Ising and the fate of his model: a hundred years on

09.40-10.00 Oral presentation - O1:
W. Janke and S. Kazmin
Critical Behavior of the 3D Ising Model with Longe-Range Power-Law Correlated Defects

14.30-14.45 Oral presentation - O2:
W. Niedziółka and J. Wojtkiewicz
On the non-integrability of three-dimensional Ising model

10.20-10.50 Coffee break

10.50-12.10 Chair: L. Zdeborová
10.50-11.30 Invited presentation - I2:
S. Metayer, D. Mouhanna, and **S. Teber**
Field theoretic approach to a flat polymerized membranes

11.30-11.50 Oral presentation - O3:
S. Metayer and D. Mouhanna
Flat phase of quenched disordered membranes at three-loop order

11.50-12.10 Oral presentation - O4:
M. Dudka, D. Shapoval, and Y. Holovatch
Influence of a weak quenched disorder on critical properties of long-range interacting systems

12.10-14.00 Lunch in Hotel Academia

14.00-15.20 Chair: Z. Néda

14.00-14.40 Invited lecture - I3:
L. Zdeborová
Understanding Machine Learning via Exactly Solvable Statistical Physics Models

14.40-15.00 Oral presentation - O5:
Z. Drogosz, J. Grela, J. Janarek, J. Ochab, and P. Oświęcimka
Do strokes affect the brain's criticality? The role of connectome integrity in network models of the brain

15.00-15.20 Oral presentation - O6:
M. Wątorek, **W. Tomczyk**, M. Gawłowska, J. K. Ochab, and P. Oświęcimka
Multifractal organization of EEG signals in Multiple Sclerosis

15.20-15.50 Coffee break

15.50-17.10 Chair: S. Teber

15.50-16.30 Invited presentation - I4:
J. Honkonen
Functional methods in nonequilibrium quantum statistics

16.30-16.50 Oral presentation - O7:
L. Ts. Adzhemyan, M. Hnatič, E. V. Ivanova, **T. Lučivjanský**, M. V. Kompaniets, and L. Mižišin
Higher order calculations in field-theoretic model of directed percolation

17.35-17.50 Oral presentation - O8:
S. Deng and G. Ódor
Critical behavior of the diffusive susceptible-infected-recovered model

17.10-18.30 Chairs: W. Janke, Z. Néda

Poster session P1-P26

18.30-20.00 Dinner in Hotel Academia

Program - Wednesday June 24th, 2023

09.00-10.20 Chair: D. Hristopulos
09.00-09.40 Invited presentation - I5:
T. S. Biró, M. Józsa, S. Kelemen, I. Gere, and **Z. Néda**
The Local Growth and Global Reset (LGGR) model and its applicability for complex systems

09.40-10.00 Oral presentation - O9:
G. Ódor, S. Deng, B. Hartmann, and J. Kelling
Non-local cascade failures and synchronization dynamics on power grids

10.00-10.20 Oral presentation - O10:
B. Sándor, A. Rusu, D. Károly, Z. I. Lázár, and M. Ercsey-Ravasz
Novel measures for state-transition networks

10.20-10.50 Coffee break

10.50-12.10 Chair: E. Trizac
10.50-11.30 Invited presentation - I6:
Ch. Chatelain
From classical Potts models with correlated disorder to quantum Potts models

11.30-11.50 Oral presentation - O11:
I. Horváth and **P. Markoš**
Low-dimensional life of critical electron

11.50-12.10 Oral presentation - O12:
I. Horváth
Effective Numbers and Effective Dimensions

12.10-14.00 Lunch in Hotel Academia

14.00-15.20 Chair: Y. Holovatch
14.00-14.40 Invited presentation - I7:
D. T. Hristopulos
Boltzmann-Gibbs distributions beyond statistical physics: Gaussian processes, spatiotemporal statistics and machine learning

14.40-15.00 Oral presentation - O13:
M. Lach and **M. Žukovič**
Local-equilibrium conditional simulation of modified XY model on GPU for fast gap-filling of massive spatial data

15.00-15.20 Oral presentation - O14:
S. Kelemen, **M. Józsa** and Z. Néda
The Gini coecient from incomplete data

15.20-15.50 Coffee break

15.50-17.10 Chair: K. Karl'ová

15.50-16.30 Invited presentation - I8:
O. Derzhko
Flat-band lattices: Recent results for Heisenberg spins and Hubbard electrons

16.30-16.50 Oral presentation - O15:
R. Juhász
Exact bounds on the energy gap of transverse-field Ising chains by mapping to random walks

16.50-17.10 Oral presentation - O16:
D. Gessert, H. Christiansen, and W. Janke
Superdiffusion-like behavior in zero-temperature coarsening of the $d = 3$ Ising model

17.10-17.30 Coffee break

17.30-18.10 Chair: Ch. Chatelain

17.30-17.50 Oral presentation - O17:
P. Keim
Mermin-Wagner-Hohenberg fluctuations in 2D amorphous solids

17.50-18.10 Oral presentation - O18:
A. Jędrzejewski and L. Hernández
Symmetric conformity functions prioritize the mean over the distribution of behaviors in collective decision-making

18.30-21.00 Conference banquet in Kontakt Wellness Hotel

Program - Thursday June 25th, 2023

09.00-10.20 Chair: W. Janke

09.00-09.40 Invited presentation - I9:
I. Palaia, A. Goyal, E. Del Gado, L. Šamaj, and **E. Trizac**
Like-charge attraction: old and new

09.40-10.00 Oral presentation - O19:
A. Gendiar
Anisotropic deformation of the 6-state clock model: Tricritical-point classification

10.00-10.20 Oral presentation - O20:
B. Tyukodi, F. Mohajerani, and M. F. Hagan
Icosahedral shells under cyclic compression

10.20-10.50 Coffee break

10.50-12.10 Chair: O. Derzhko

10.50-11.30 Invited presentation - I10:
K. Karl'ová, J. Strečka, and J. Richter
Frustrated magnetism of a quantum mixed spin-(1,1/2) Heisenberg octahedral chain from a statistical-mechanical monomer-dimer model

11.30-11.50 Oral presentation - O21:
A. Ghannadan and J. Strečka
The bipartite quantum and thermal entanglement of a spin-1/2 Ising-Heisenberg diamond-decorated square lattice

11.50-12.10 Oral presentation - O22:
M. Rončík, M. Jaščur, T. Balcerzak, and K. Szałowski
Effect of magnetoelastic coupling in the isotropic Heisenberg spin-1/2 chain

12.10-12.20 Conference closing

12.20-13.30 Lunch in Hotel Academia

13.30-18.30 Trip to waterfalls (hiking tour)

18.30-21.00 Dinner in Kontakt Wellness Hotel

Index of Abstracts

Invited lectures

(35 min. talk + 5 min. discussion)

I1

The fate of Ernst Ising and the fate of his model: a hundred years on

Yurij Holovatch[1,2,3,4]

[1]*Institute for Condensed Matter Physics, NAS of Ukraine, Lviv, Ukraine*
[2]$\mathbb{L}^4$ *Collaboration & Doctoral College for the Statistical Physics of Complex Systems, Leipzig-Lorraine-Lviv-Coventry, Europe*
[3]*Centre for Fluid and Complex Systems, Coventry University, Coventry, UK*
[4]*Complexity Science Hub Vienna, Vienna, Austria*

Abstract

The talk is based on an ongoing project that aims to prepare a bilingual, commented edition of the doctoral thesis of Ernst Ising [1]. This project emerged through collaborations enabled by the Ising lectures [2], a workshop that started in Lviv (Ukraine) in 1997 with 'traditional' statistical physics and has recently broadened its scope to encompass a more general context of complex systems. Gradually the workshop gave rise to various research projects centered around the Ising model and its history [3, 4, 5], some collected historical documents and memoirs are displayed publicly with permission of Ernst Ising's family at http://www.icmp.lviv.ua/ising .

The model suggested by Wilhelm Lenz for ferromagnetism in 1920 was formulated and solved in one dimension by his doctoral student Ernst Ising in 1924. That work of Lenz and Ising marked the start of a scientific direction that delivered extraordinary successes in explaining collective behaviour in a vast variety of systems, both within and beyond the natural sciences. Some of the milestones in this direction will be a subject of this talk. Examples of 1D models with phase transitions [6] and complex systems [7] will be given. However, another goal of the talk is to present a personal story of Ernst Ising who had to struggle to survive during the years of the Nazi regime. The story of his fate stirs special feelings today, when its background is repeated by an (academic) community supporting a dictator, and supporting aggression - in this case Russian aggression in Ukraine.

References

[1] B. Berche, R. Folk, Yu. Holovatch, R. Kenna, *in preparation*

[2] *Ising lectures in Lviv (1997 - 2017).* Ed. by M. Krasnytska, R. de Regt, P. Sarkanych. Lviv, ICMP, 2017, 218 p.

[3] T. Ising, R. Folk, R. Kenna, B. Berche, Yu. Holovatch, *Journ. Phys. Stud.* **21** (2017) 4001.

[4] R. Folk, Yu.. Holovatch, *Eur. J. Phys. H* **47** (2022) 9.

[5] R. Folk, In: *Order, Disorder and Criticality. Advanced Problems of Phase Transition Theory. Yu. Holovatch (editor)* vol. 7, World Scientific, Singapore, 2023, pp. 1-77.

[6] P. Sarkanych, Yu. Holovatch, R. Kenna, *Journ. Phys. A* **51** (2018) 505001.

[7] Yu. Holovatch, R. Kenna, S. Thurner, *Eur. Journ. Phys.* **38** (2017) 023002.

I2

Field theoretic approach to flat polymerized membranes

S. Metayer[1], D. Mouhanna[2], and S. Teber*[1]

[1]*Sorbonne Université, CNRS, Laboratoire de Physique Théorique et Hautes Energies, LPTHE, 75005 Paris, France*
[2]*Sorbonne Université, CNRS, Laboratoire de Physique Théorique de la Matière Condensée, LPTMC, 75005 Paris, France*

Abstract

This talk focuses on the field theoretic approach to the flat phase of polymerized membranes. Within the modified minimal subtraction scheme, and following the pioneering one-loop order computation of Aronovitz and Lubensky [1], we present the recent three-loop [2] (and also mention previous two-loop [3]) order renormalization group equations associated to the flat phase in both the two-field model and the effective flexural model of polymerized membranes. We analyze the fixed points of these equations and the associated field anomalous dimension η. Our results display a marked proximity with those obtained using nonperturbative techniques and reexpanded in powers of $\epsilon = (4 - D)/2$. Moreover, the three-loop order value that we get for η at the stable fixed point, $\eta = 0.8872$, in $D = 2$, is compatible with known theoretical results and within the range of accepted numerical values.

References

[1] J. A. Aronovitz and T. C. Lubensky, *Phys. Rev. Lett.* **60** (1988) 2634

[2] S. Metayer, D. Mouhanna and S. Teber, *Phys. Rev. E* **105** (2022) L012603

[3] O. Coquand, D. Mouhanna and S. Teber, *Phys. Rev. E* **101** (2020) 062104

*Presenting author: sofian.teber@sorbonne-universite.fr

I3

Understanding Machine Learning via Exactly Solvable Statistical Physics Models

Lenka Zdeborová*[1]

[1]*Statistical Physics of Computation Laboratory, EPFL, Lausanne, Switzerland*

Abstract

The affinity between statistical physics and machine learning has a long history. I will describe the main lines of this long-lasting friendship in the context of current theoretical challenges and open questions about deep learning. Theoretical physics often proceeds in terms of solvable synthetic models, I will describe the related line of work on solvable models of simple feed-forward neural networks. I will highlight a path forward to capture the subtle interplay between the structure of the data, the architecture of the network, and the optimization algorithms commonly used for learning.

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I4

Functional methods in nonequilibrium quantum statistics

Juha Honkonen*[1]

[1]*National Defence University, Santahaminantie 2, 00860 Helsinki, Finland*

April 24, 2023

Abstract

Functional-integral representation for the density operator and full Green functions suitable for construction of renormalized perturbation theory for open nonrelativistic quantum systems shall be analyzed. Application of the subsequent functional differential equations for generating functions of connected and one-irreducible Green functions to description of systems with broken symmetry shall be discussed. Particular attention shall be paid to basic equations of the functional renormalization group. As an example, an effective field theory for critical dynamics of boson gas brought about by renormalized real-time Green functions in the grand canonical ensemble shall be compared with the field theory obtained on the basis of Lindblad equations.

*Presenting author: juha.honkonen@mil.fi

I5

The Local Growth and Global Reset (LGGR) model and its applicability for complex systems

Tamás S. Biró[1,2,3], Máté Józsa[1], Szabolcs Kelemen[1], István Gere[1], and Zoltán Néda *[1]

[1] *Babeş-Bolyai University, Department of Physics, str. Kogalniceanu 1, RO-400084, Cluj, Romania*
[2] *Wigner Research Center for Physics, Konkoly Thege Miklós út, Budapest, H-1121, Humgary*
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Abstract

Complex systems are often characterized by distributions that present universalities across different ensembles and for different proxies. A well-known example in this sense is the Tsallis-Pareto type shape of the income and wealth distribution detected across many societies [1, 2, 3]. Statistical physicists are always fascinated by such universalities and are in search of simple models that are able to explain them with basic and realistic assumptions. Here, we present a simple evolutionary model [4], based on a master equation with growth and reset terms, which in the stationary limit is able to explain realistically experimentally revealed universalities in complex systems. Nowadays the large amount of digitally available data, offers excellent possibilities to test both the assumptions of such dynamical models (growth and reset rates) and the model predictions in the stationary limit. We support our arguments with such data.

Acknowledgement

Work supported by UEFISCDI, under the contract PN-III-P4-ID-PCE-2020-0647. T.S.B. thanks NKFIH for support in the framework of the Hungarian National Laboratory Program under 2022-2.1.1-NL-2022-00002. M.J. and Sz.K. are also supported by the Collegium Talentum Programme of Hungary.

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I6

From classical Potts models with correlated disorder to quantum Potts models

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Abstract

Due to its rich phase diagram (first and second-order phase transitions, tricritical point), the q-state Potts model is an interesting lattice spin model for testing theoretical ideas about the influence of disorder. In 2D, homogeneous disorder softens the discontinuous phase transition and a new q-dependent universality class emerges. Another fixed point appears in presence of correlation between the disordered couplings. In the first part of this talk, we will discuss the universality class at this correlated fixed point and in particular, the question of whether this universality class depends on the number of states of the Potts model. In the second part of this talk, we will consider the limit of infinite correlation in one direction, as in the McCoy-Wu model, which amounts to considering a random quantum Potts model in d-1 dimensions. In this case, the universality class is independent of the number of states in 1D and possibly, as will be discussed, in 2D and 3D.

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I7

Boltzmann-Gibbs distributions beyond statistical physics: Gaussian processes, spatiotemporal statistics and machine learning

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Abstract

In Boltzmann-Gibbs (BG) models of spatial/spatiotemporal processes, statistical dependence is enforced by means of interactions between neighboring sites and/or times. Thus, the paradigmatic Ising model [1] inspired the work of Besag in spatial statistics [2]. The interactions are controlled by respective parameters and contribute to a scalar energy term which enters the exponent of the exponential BG density. In spatiotemporal data problems, the BG representation can lead to sparse networks of connections between neighboring sites and times.

The covariance (two-point correlation) function of BG models depends on the structure and the parameters that control the local interactions. For Gaussian BG models, the spatial structure of the interactions determines the model's precision matrix (i.e., the inverse covariance matrix). The latter is sparse by construction if the interactions are local. The sparsity of the precision matrix can lead to efficient predictive algorithms with considerable computational gains compared to standard geostatistical and Gaussian process regression approaches.

This presentation reviews recent progress in the application of Boltzmann-Gibbs models to space-time data. Three different topics are discussed: (1) The construction of new covariance models based on continuum-space BG models [4, 6]. (2) The connection of lattice-based BG models with Gauss-Markov random fields and stochastic partial differential equations [4]. (3) Extensions for scattered data by means of interactions modulated via compactly supported kernel functions [5, 7]. Gaussian BG models provide a flexible and computationally efficient framework which is useful for big spatiotemporal datasets.

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I8

Flat-band lattices: Recent results for Heisenberg spins and Hubbard electrons

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Abstract

Some lattices in one, two, and three dimensions support dispersionless (i.e., flat) one-particle bands. Moreover, the flat-band states occupy only a finite number of lattice sites. For such lattices, quantum many-body physics in the presence of interactions may be elaborated in great detail using specific tools like mapping onto classical lattice gas of hard-core objects, correlated percolation or perturbative treatment around the flat-band point [1].

In my talk, I focus (i) on the spin-half Heisenberg antiferromagnet on several frustrated bilayers to demonstrate how an order-disorder phase transition emerges at the low-temperature high-field regime [2,3,4] and (ii) on the single-orbital repulsive Hubbard model on the frustrated ladder/bilayer lattices to illustrate how the kinetic-energy-driven ferromagnetic ground state may show up [5,6]. I also discuss candidate materials, where these theoretical findings can be observed [7].

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I9

Like-charge attraction: old and new

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Abstract

Like-charge attraction, driven by ionic correlations, challenges our understanding of electrostatics both in soft and hard matter. It escapes traditional approaches, and is of importance in a number of phenomena, from DNA condensation to cement cohesion, including colloidal phase separation, vesicule docking, or anomalous bilayer interactions. In some situations, the combined effects of confinement-induced water structure and hydration of small charged species play a key role. For two charged planar surfaces confining counterions and water, we prove that even at relatively low electrostatic couplings, the relevant physics is of ground-state origin, oblivious of fluctuations. Based on this, we derive a simple and accurate interaction pressure, that fulfills known exact requirements. We test this equation against implicit-solvent Monte Carlo simulations and, more importantly, against explicit-solvent simulations of cement and several types of clays. We argue that water destructuring under nanometric confinement drastically reduces dielectric screening, enhancing ionic correlations. Our equation of state at reduced permittivity, versatile, explicit and particularly simple, therefore explains the exotic attractive regime reported for these materials, even in absence of multivalent counterions.

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I10

Frustrated magnetism of a quantum mixed spin-(1,1/2) Heisenberg octahedral chain from a statistical-mechanical monomer-dimer model

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Abstract

The mixed spin-1 and spin-1/2 Heisenberg octahedral chain with regularly alternating monomeric spin-1 sites and square-plaquette spin-1/2 sites has, in a magnetic field, an extraordinarily rich groundstate phase diagram, which includes the uniform and cluster-based Haldane phases, two ferrimagnetic phases of Lieb-Mattis type, two quantum spin liquids, two bound magnon crystals in addition to the fully polarized ferromagnetic phase [1]. In the highly frustrated parameter region the lowest-energy eigenstates of the mixed-spin Heisenberg octahedral chain belong to flat bands, which allow a precise description of low-temperature magnetic properties within the localized-magnon approach exploiting a classical lattice-gas model of hard-core monomers. Moreover, we have found a more comprehensive version of the localized-magnon approach, which extends the range of its validity down to a less frustrated parameter region involving the Haldane and cluster-based Haldane ground states. A comparison between results of the developed localizedmagnon theory and accurate numerical methods like full exact diagonalization and finite-temperature Lanczos methods convincingly evidence that the low-temperature magnetic properties above the Haldane and the cluster-based Haldane ground states can be extracted from a classical lattice-gas model of hardcore monomers and dimers, which is additionally supplemented by a hard-core particle spanned over the whole lattice representing the gapped Haldane phase.

Acknowledgement

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Oral presentations

(15 min. talk + 5 min. discussion)

O1

Critical Behavior of the 3D Ising Model with Longe-Range Power-Law Correlated Defects

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Abstract

We study the critical behavior of the three-dimensional Ising model with long-range correlated point defects whose correlation decays with distance r like to a power law r^{-a}. By applying finite-size scaling techniques to our data of extensive Monte Carlo simulations, we estimate the critical exponents ν, γ, β, and ω in dependence of the correlation exponent $1.5 \leq a \leq 3.5$, based on "global" fits of results for several defect concentrations [1, 2]. We briefly show that the estimated exponents ν and γ are compatible with an alternative temperature-scaling analysis [3]. The discussion of the results will be centered on the long-standing theoretical conjecture by Weinrib and Halperin that $\nu = 2/a$.

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O2

On the non-integrability of three-dimensional Ising model

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Abstract

It is well known[1][3] that the partition function of two-dimensional Ising model can be expressed as a Grassman integral over the action bilinear in Grassman variables. The key aspect of the proof of this equivalence is to show that all polygons, appearing in Grassman integration, enter with fixed sign. For three-dimensional model, the partition function can also be expressed by Grassman variables[2]. However, the action resulting from low-temperature expansion contains quartic terms, which does not allow explicit computation of the integral. We wanted to check the possibility - apparently not explored - to use the high-temperature expansion, which produces only bilinear terms. (in two dimensions, low-T and high-T expansions are equivalent, but in three dimensions, they are not.) It turned out however that polygons obtained by Grassman integration are not of fixed sign for any ordering of Grassman variables on sites. This way, it is not possible to express the partition function of three-dimensional Ising model as Grassman integral over bilinear action.

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O3

Flat phase of quenched disordered membranes at three-loop order

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Abstract

In the recent paper [1] we study quenched disordered polymerized membranes in their flat phase by means of a three-loop perturbative analysis performed in dimension $D = 4 - \epsilon$. We derive the renormalization group equations at this order and solve them up to order ϵ^3. Our results confirm those obtained by Coquand *et al.* within a nonperturbative approach [2] predicting a finite-temperature, finite-disorder *wrinkling* transition and those obtained by Coquand and Mouhanna within a recent two-loop order approach [3], while correcting some of the results obtained in this last reference. We compute the anomalous dimensions that characterize the scaling behavior at the various fixed points of the renormalization group flow diagram. They appear to be in strong agreement with those predicted within the nonperturbative context. This work is a continuation of the study carried in the pure (non-disordered) case [4].

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O4

Influence of a weak quenched disorder on critical properties of long-range interacting systems

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Abstract

We study the critical behaviour of systems with long-range interactions at the presence of structural disorder (*e.g.*, weak quenched dilution) using an n-vector model in d-dimensional space. In particular, we consider interactions to be power-law decaying $\sim x^{-d-\sigma}$ on distance x with control parameter σ. Such model is known to belong to the new dilution-induced universality class for some region in the parametric $n-d-\sigma$ space. We analyse stability boundary of this region given by the marginal dimension of the order parameter $n_c(d,\sigma)$ within renormalization-group approach exploiting Harris criterion [1]. We get n_c as a three loop $\epsilon = 2\sigma - d$-expansion. Our results on the base of numerical estimates of n_c for fixed d and σ show that not only Ising systems ($n = 1$) can belong to the dilution-induced long-range interaction universality class [2]. We calculate critical exponents characterising new universality class within three loop approximation as perturbative ϵ-expansions. We provide numerical values for them applying resummation methods.

Acknowledgement

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O5

Do strokes affect the brain's criticality? The role of connectome integrity in network models of the brain

Zbigniew Drogosz*[1], Jacek Grela[1,2], Jakub Janarek[1], Jeremi Ochab[1,2], and Paweł Oświecimka[1,2,3]

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March 31st, 2023

Abstract

Given that operating at the critical state provides optimal functioning of the healthy brain, there arises a question whether a brain injury such as a stroke may be associated with a loss of the brain's criticality. In order to investigate this problem, we simulate a post-stroke brain via network models with "artificial strokes" performed by removing a subset of connections between two subsystems. Our results demonstrate that the brain's criticality survives, despite the injury. This is evinced by behavior of all quantities that are commonly used as indicators of criticality except the size of the second-largest cluster of active nodes in the network; we show, however, that this single observable behaves in an anomalous way not as a result of a genuine non-critical behavior but only as a result of the decrease of the network's integrity, which is possible to be quantified using methods of graph theory. Our interpretation of the results is confirmed by an analysis of real connectomes acquired from post-stroke patients and a control group. The part of our findings that explains the behavior of the second-largest node cluster is relevant not only within the realm of computational neurobiology but also for the study of other complex systems simulated via network models.

Acknowledgement

This work was carried out within the research project "Bio-inspired artificial neural networks" (grant no. POIR.04.04.00-00-14DE/18-00) within the Team-Net program of the Foundation for Polish Science co-financed by the European Union under the European Regional Development Fund. The research has been supported by a grant from the Priority Research Area DigiWorld under the Strategic Programme Excellence Initiative at Jagiellonian University. JJ acknowledges the support of the Faculty of Physics, Astronomy and Applied Computer Science of the Jagiellonian University through grant no. LM/3/JJ.

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O6

Multifractal organization of EEG signals in Multiple Sclerosis

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Abstract

In this contribution, we present a multifractal analysis of the electroencephalography (EEG) data obtained from patients with multiple sclerosis (MS) and the control group. We compared the complexity of the EEG time series, paying particular attention to analysing the correlations between the degree of multifractality, disease duration, and level of disease progression quantified by the Expanded Disability Status Scale (EDSS).

Our results reveal a significant correspondence between the complexity of the time series and the stage of MS progression. Namely, we identified brain regions whose EEG signals were characterised by a well-developed multifractality and lower persistence of the time series (spectra localised above but closer to $\alpha = 0.5$) for patients with a higher level of disability, whereas for the control group and patients with low-level EDSS they were characterised by monofractality and higher persistence. The link between multifractality and disease duration has not been observed, indicating that the multifractal organisation of the data is a hallmark of developing the disease. Our conclusions are supported by the analysis of the cross-correlations between EEG signals. The most significant difference in the brain areas coupling has been identified for the cohort of patients with EDSS > 1 and the combined group of patients with EDSS ≤ 1 and the control group.

Acknowledgement

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O7

Higher order calculations in field-theoretic model of directed percolation

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Abstract

The direct bond percolation model, which covers a broad class of non-equilibrium stochastic processes is studied within the framework of the field-theoretic renormalization group approach. Perturbative expansion in a form of Feynman diagrams reveals divergent structures. At the upper critical dimension 4, it is possible to renormalize the model and thus obtain a quantitative prediction on the large-scale behavior of the system. Successful renormalization of the model, i.e., eliminating all these singularities in observed physical quantities, allows us to derive differential renormalization group equations describing their scaling behavior at large space and time scales. In this work, within the framework of the ε-expansion, which characterizes the deviation of the space dimension from its upper critical value 4, all renormalization constants that determine the corresponding scaling indices are calculated to the third order in ε.
Keywords: non-equilibrium physics, field theoretic renormalization group, directed bond percolation, multi-loop calculations

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O8

Critical behavior of the diffusive susceptible-infected-recovered model

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Abstract

The critical behavior of the non-diffusive susceptible-infected-recovered model on lattices had been well established in virtue of its duality symmetry. By performing simulations and scaling analyses for the diffusive variant on the two-dimensional lattice, we show that diffusion for all agents, while rendering this symmetry destroyed, constitutes a singular perturbation that induces asymptotically distinct dynamical and stationary critical behavior from the non-diffusive model. In particular, the manifested crossover behavior in the effective mean-square radius exponents reveals that slow crossover behavior in general diffusive multi-species reaction systems may be ascribed to the interference of multiple length scales and timescales at early times.

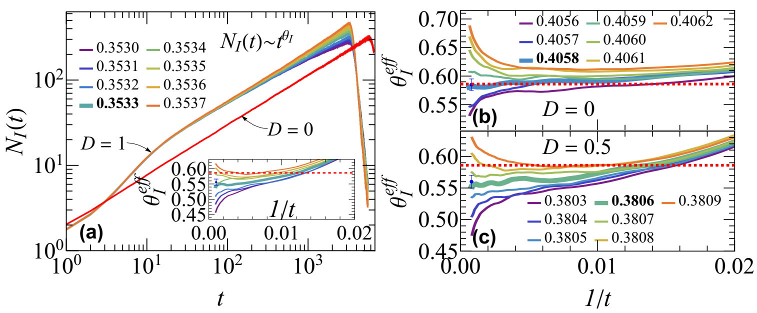

Figure 1: Growth of the I population $N_I(t)$ from a single infectious seed on a $L = 4001$ square lattice in the vicinity of criticality for (a) $D = 1$, and the evolution of the corresponding effective exponent θ_I^{eff} in the inset, in (b) for $D = 0$, and in (c) for $D = 0.5$. The horizontal dashed red line indicates the DIP value.

Acknowledgement

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O9

Non-local cascade failures and synchronization dynamics on power grids

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April 24, 2023

Abstract

Dynamical simulation of the cascade failures on the EU, USA and Hungarian [1] high-voltage power grids has been done via solving the second-order Kuramoto equation. We show that synchronization transition happens by increasing the global coupling parameter K with meta-stable states depending on the initial conditions so that hysteresis loops occur. We provide analytic results for the time dependence of frequency spread in the large K approximation and by comparing it with numerics of $d = 2, 3$ lattices [2], we find agreement in the case of ordered initial conditions. However, different power-law (PL) tails occur, when the fluctuations are strong. After thermalizing the systems we allow a single line cut failure and follow the subsequent overloads with respect to threshold values T. The PDFs $p(N_f)$ of the cascade failures exhibit PL tails near the synchronization transition point K_c. Below K_c we find signatures of T-dependent PL-s, caused by frustrated synchronization, reminiscent of Griffiths effects [3]. Here we also observe stability growth following blackout cascades, similar to intentional islanding, but for $K > K_c$ this does not happen. For $T < T_c$, bumps appear in the PDFs with large mean values, known as "dragon king" blackout events. We also analyze the delaying/stabilizing effects of instantaneous feedback or increased dissipation and show how local synchronization behaves on geographic maps. We demonstrate the occurrence of non-local cascade failure events at the weak points of the networks.

Acknowledgement

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O10

Novel measures for state-transition networks

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Abstract

Dynamics of various complex systems can be encoded by state-transition networks (STN) via constructing the transition matrix of the corresponding Markov chains with discrete states. Using an adequate sampling of both space and time, continuous-time dynamical systems can also be mapped to STNs. Inspired by the classical Lyapunov exponents [1], here we introduce two network measures for STNs, characterizing the mean and the variance of trajectory lengths for different realizations of random walks on the network. These measures are able to reflect the dynamical behavior of the underlying complex dynamics, furthermore, unlike the traditional network measures, they may be used to predict upcoming bifurcations when changing the control parameters. We provide an algorithm for constructing the STNs and derive closed-form expressions of these measures in terms of the transition matrix of the Markov process. Finally, we demonstrate their applicability on the STN counterparts of the Henon map and the Lorenz system, discussing also the natural limitations arising for finite length time-series.

Acknowledgement

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O11

Low-dimensional life of critical electron

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Abstract

We calculate numerically the effective spatial dimension d_{rmIR} of electron wave function at critical points of 3D Anderson models in various universality classes (orthogonal, unitary and symplectic). The obtained values are statistically equal and yield the most probable common value $d_{\rm IR} = 2.666(3) \approx 8/3$ [1]. Such super-universality may provide useful means to identify natural processes driven by Anderson localization and usher a new understanding of the geometry involved in Anderson-type criticality. In particular, our data imply that critical Anderson electron in 3 dimensions occupies a region of fractal dimension $\approx 8/3$, with probability 1 in infinite volume [2]. Hence, its physics is fully confined to space of this lower dimension.

We compare our results with predictions of the multifractal theory of critical state [3, 4].

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O12

Effective Numbers and Effective Dimensions

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Abstract

Many, if not most, quantitative methods of analyzing the natural world can be readily deconstructed into nested layers of ordinary counting. This “building block” quality of elementary counting lends it a special place in the development and applications of quantitative science. Yet, the descriptive value of the ordinary count alone is very limited when it comes to characterizing collections of objects whose relevance varies widely. I will argue that the concept of ordinary counting can be meaningfully extended to collections of objects distinguished by an additive weight, such as probability or mass. This leads to elementary concept of *effective counting*, which alone provides novel insight into the nature of the system in question, and leads to conceptually new composite characteristics such as *quantum effective number* and *effective counting dimension* among others. The approach recently led to new perspectives on quantum states arising in 3D Anderson criticality and in quantum chromodynamics. I will give a bottom-up overview of the ideas behind these developments.

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O13

Local-equilibrium conditional simulation of modified XY model on GPU for fast gap-filling of massive spatial data

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Abstract

As massive remotely sensed spatio-temporal datasets are becoming more and more common, scalable statistical methods are needed for their efficient and automated (preferably real time) processing. In particular, the data often include gaps that need to be filled. CUDA-based parallelization on GPU has become a popular way of a dramatic increase of the computational efficiency of various approaches. Recently, we have proposed a computationally efficient and competitive, yet simple spatial prediction approach based on the XY or planar rotator model, called modified planar rotator (MPR) method [1]. It employs Gibbs Markov random fields on Cartesian grids based on the MPR model and spatial correlations are imposed by means of short-range interactions between random field variables instead of the empirical variogram used in geostatistics. The short-range nature of the interactions allowed its GPU implementation leading to additional impressive computational acceleration which exceeded two orders of magnitude in comparison with CPU calculations [2].

However, important aspect of massive spatial data sets is heterogeneity, which should be considered in their analysis. In the presentation we propose a rather general approach to modelling spatial heterogeneity in GPU-implemented spatial prediction methods by introducing spatial variability to model parameters by so-called double-checkerboard decomposition. We demonstrate this approach on the MPR method to obtain two modifications with spatially varying parameters specific to small blocks of spatial data and even individual sites. Then, predictions of unknown values are obtained from non-equilibrium conditional simulations, assuming "local" equilibrium conditions corresponding to the local parameters. We demonstrate on various real world data sets that the proposed methods lead to significant improvements in both prediction performance and computational efficiency.

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O14

The Gini coefficient from incomplete data

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Abstract

Agent-level, exhausted data on income and wealth statistics are seldom available for large and well-delimited social systems [1, 2]. The absence of such data poses challenges for characterizing the inequality level in the population and more specifically for calculating the generally used Gini coefficient [3]. Here, a new methodology is presented that enables the computation of the Gini coefficient from the knowledge of the average income/wealth and population at a hierarchically lower level. In order to do this, a one-parameter wealth/income distribution is assumed to be valid at the lower organization level. Our working hypothesis is validated using various data sources, including exhaustive income data for Cluj county and average income data on settlement level, as well as percentile and average income data for US cities. As a result, we provide compact analytical formulae for calculating the Gini coefficient from datasets where only averages are available for the lower hierarchical levels, instead of the much desired individual level data. Our model's limitations are discussed along with the potential risks of using traditional Gini coefficient calculation methods that may lead to coarse-graining some of the inequalities.

Acknowledgement

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O15

Exact bounds on the energy gap of transverse-field Ising chains by mapping to random walks

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Abstract

Based on a relationship with continuous-time random walks discovered by Iglói, Turban, and Rieger [1], we derive exact lower and upper bounds on the lowest energy gap of open transverse-field Ising chains, which are explicit in the parameters and are generally valid for arbitrary sets of possibly random couplings and fields. In the homogeneous chain and in the random chain with uncorrelated parameters, both the lower and upper bounds are found to show the same finite-size scaling in the ferromagnetic phase and at the critical point, demonstrating the ability of these bounds to infer the correct finite-size scaling of the critical gap. Applying the bounds to random transverse-field Ising chains with coupling-field correlations, a model which is relevant for adiabatic quantum computing, the finite-size scaling of the gap is shown to be related to that of sums of independent random variables. We determine the critical dynamical exponent of the model and reveal the existence of logarithmic corrections at special points.

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O16

Superdiffusion-like behavior in zero-temperature coarsening of the $d = 3$ Ising model

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Abstract

For coarsening to a temperature below the critical temperature of the non-conserved Ising model in three dimensions a power-law growth of domains of like spins with exponent $\alpha = 1/2$ is predicted. Including recent work, it was not possible to clearly observe this growth law when the quench temperature was set to zero. In an attempt to verify the prediction we run large-scale Monte Carlo simulations of lattice sizes up to $L = 2048$ and make a surprising discovery. At late times domains show superdiffusive growth, i.e., $\alpha > 1/2$, which we show may be caused by sponge-like structures emerging at early times.

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O17

Mermin-Wagner fluctuations in 2D amorphous solids

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Abstract

The lack of globally broken continuous symmetries in dimensions $D < 3$ - doubting the existence of long range magnetism and crystals in 2D – was discussed over decades. First ideas date back to F. Bloch, R. Peierls, and L. Landau [1, 2, 3]. However, a rigid theoretical proof was given by D. Mermin and H. Wagner for classical systems and by P. Hohenberg for quantum systems [4, 5]. For 2D crystals, it proposes that long-range order cannot exist due to long wavelength density fluctuations. Interestingly, Mermin-Wagner fluctuations are now found in amorphous systems, which principally do not show any symmetry breaking [6, 7, 8]: long wavelength fluctuations do not only have structural impact but additionally a dynamical one; they cause the Lindemann criterion to fail in 2D crystals since the mean squared displacement of atoms is not limited. Davide Cassi established a dualism in 2D between the lack of globally broken symmetries and the recurrence probability of random walks on amorphous graphs in 2D [9]. The central statement about Mermin-Wagner fluctuations is also valid in amorphous ensembles: the means squared displacement should diverge logarithmically with system size. Comparing experimental data from 3D and 2D amorphous solids with 2D crystals, we disentangle Mermin-Wagner fluctuations from glassy structural relaxations [8]. The smoking gun of long wavelength density fluctuations is now established in glass - fifty years after their prediction: crystallinity is not a precondition for Mermin-Wagner fluctuations.

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O18

Symmetric conformity functions prioritize the mean over the distribution of behaviors in collective decision-making

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Abstract

Making decisions is an integral part of human behavior. In social situations, people may either adopt the behaviors of others or assess options on their own. These are two cogitative strategies known as social and individual learning [1]. Social learning is modeled in the form of conformity functions that connect an individual's probability of adopting a behavior with its frequency within the group, which creates a frequency-dependent bias [2]. Conversely, in individual learning, people independently evaluate the options on their merits or adoption difficulties. This process is typically represented as a fixed probability of choosing one practice over the other [1, 3]. However, in many real-life situations, the perceived merits may change based on how many people adopt the practice. This phenomenon is known as a network effect [4]. In our study, we extend the dynamical system model from Ref. [1] to capture this effect, and we show that it may be responsible for sudden changes in the collective decision. While various distributions can be used to model the inclination towards individual learning in the population, our findings indicate that the exact shape of the distribution is not important for a specific class of the conformity functions. The only significant factor is the mean inclination towards this behavior. Interestingly, this class of functions is not only described by the formal models of frequency-dependent bias but also observed in some empirical experiments [2].

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O19

Anisotropic deformation of the 6-state clock model: Tricritical-point classification

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Abstract

The two-dimensional q-state clock models exhibit the Berezinskii-Kosterlitz-Thouless (BKT) transition for $q \geq 5$ since they are a subset of the isotropic XY model. We examine the 6-state clock model with an anisotropic deformation. Selecting the 6-state Potts model as a source of the deformation, the model naturally violates the discrete rotational symmetry of the clock model. We introduce the anisotropic deformation parameter α in the clock model interpolating the clock ($\alpha = 1$) and the Potts ($\alpha = 0$) models. We employ the corner transfer matrix renormalization group method to analyze the phase transitions on the square lattice in the thermodynamic limit. Three different phases and phase transitions are identified. The phase diagram is constructed, and we determine a tricritical point at $\alpha_\mathrm{c} = 0.21405(4)$ and $T_\mathrm{c} = 0.834017(5)$. Analyzing the latent heat and the entanglement entropy in the vicinity of the $T_\mathrm{c}(\alpha_\mathrm{c})$, we observe a single discontinuous phase transition and two BKT phase transitions meeting in the tricritical point. The tricritical point exhibits a phase transition of the second order with the critical exponents $\beta \approx 1/10$ and $\delta \approx 14$. We conjecture that an infinitesimal surrounding of the tricritical point consists of the three fundamental phase transitions, in which the first and the BKT orders gradually weaken into the second-order tricritical point.

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O20

Icosahedral shells under cyclic compression

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Abstract

Icosahedral shells with various functions are recurrent motifs in nature. Examples include protein-shelled viruses, bacterial microcompartments, and synthetic nanocages. The reversible self-assembly process of such shells has been extensively studied during the past two decades, both theoretically and experimentally [1]. In comparison, there has been much less study of shell disassembly. However, recent experiments that use atomic force microscopy (AFM) perform cyclic nanoindentation on shells have driven and characterized disassembly through mechanical forcing [2]. In this talk, I will describe a minimal computational model investigation that aims to elucidate the mechanisms underlying disassembly driven by mechanical forcing. To this end, we use dynamical Monte Carlo simulations to investigate icosahedral shells undergoing compression between two parallel walls. We apply a cyclic load to the shells, and measure the degree of recovery and accumulation of structural defects over the course of multiple cycles. We particularly focus on the onset and propagation of cracks leading to shell disassembly. Depending on key control parameters, such as the shell stretching and bending moduli, we identify three qualitatively different mechanisms of failure, which correspond to either failure of brittle materials or progressive fatigue of compliant materials by defect or crack accumulation.

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O21

The bipartite quantum and thermal entanglement of a spin-1/2 Ising-Heisenberg diamond-decorated square lattice

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Abstract

The bipartite quantum and thermal entanglement of a spin-1/2 Ising-Heisenberg model on a diamond-decorated square lattice is quantified through the quantity concurrence [1], which can be rigorously calculated with the framework of an exact mapping to the effective spin-1/2 Ising square lattice with temperature-dependent coupling constant established using the decoration-iteration transformation. It is evidenced that the bipartite concurrence is zero in a classical ferrimagnetic ground states, whereas it acquires a maximal value in a quantum monomer-dimer ground state due to formation of a singlet state within all decorating Heisenberg spin pairs. The competition between a spontaneous long-range order inherent to the classical ferrimagnetic phase and the bipartite thermal entanglement of the Heisenberg spin pairs emergent within the disordered quantum monomer-dimer phase is examined in detail at finite temperatures depending on a relative strength of the Heisenberg and Ising coupling constants. The most intriguing behavior of the bipartite thermal entanglement can be found in a close vicinity of the quantum critical point between the classical ferrimagnetic phase and the quantum monomer-dimer phase, where the bipartite entanglement may strikingly display a thermally-induced rise due to proliferation of excited states with nonzero bipartite entanglement. The exact critical temperature assigned to vanishing of the spontaneous ferrimagnetic long-range order is confronted with the exact threshold temperature, above which the thermal bipartite entanglement disappears.

Acknowledgement

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O22

Effect of magnetoelastic coupling in the isotropic Heisenberg spin-1/2 chain

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Abstract

We developed a complex theory for spin-1/2 isotropic Heisenberg XY systems with magnetoelastic interaction. This theory consists of the analytical construction of the total Gibbs free energy as the sum of magnetic energy, static lattice energy, and thermal vibrational energy. Magnetic exchange integral depends exponentially on the distance between interacting magnetic moments. Magnetic and lattice subsystems interconnect one parameter, which characterizes the relative change in the length of the crystal. In the static elastic free energy, we use Morse potential. To express the dependence of the frequency of quantum oscillators on the relative change in the length of the chain, we used Gruneisen's assumption that allows straightforward expression of all relevant thermodynamic quantities. The employed approach allows us to derive equations of state that, together with the total Gibss energy, allow a straightforward expression of all thermodynamic quantities. The most exceptional result is discovering the phase transition of the first kind even at finite temperatures, which is a novel critical behavior of the studied model.

Acknowledgement

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Poster session

(May 23th, 17.10-18.30)

List of posters and presenting authors

P1 - **Y. Holovatch**: *Individual bias and fluctuations in collective decision making: analytical results and simulations*
P2 - **Y. Holovatch**: *Potts model with invisible states, old and new*
P3 - **Y. Holovatch**: *Numerical exploration of finite-size scaling above the upper critical dimension*
P4 - **M. Dudka**: *Survival in a two-species reaction-diffusion system with Lévy flights*
P5 - **O. Krupnitska**: *Second-harmonic generation in the Kitaev model at finite temperatures*
P6 - **O. Dobush**: *Phase behavior of a binary mixture with Curie-Weiss interaction*
P7 - **H. Chamati**: *Exact diagonalization approach to the magnetic properties of single-ion magnets*
P8 - **M. Georgiev**: *Quantum constraints to the origin of fine structure in 3d8 trigonal bipyramidal coordination complexes*
P9 - **S. Kelemen**: *Tree size distribution in the perspective of the Local Growth and Global Reset (LGGR) model*
P10 - **G. Roosz**: *Front dynamics at a localization transition*
P11 - **A. Gergely**: *Stick-slip dynamics of a 1D Burridge-Knopoff type spring-block system on a treadmill*
P12 - **J. K. Ochab**: *Comparing cross-correlation estimators in fMRI data*
P13 - **M. Lotka**: *EEG signal segmentation for assessing the time-course of brain response to stimuli*
P14 - **I. Papp**: *Synchronization and criticality on connectome graphs*
P15 - **A. Zoshki**: *Phase transition and magnetization of the spin-1/2 double sawtooth ladder with cyclic four-spin Ising interaction*
P16 - **H. Arian Zad**: *Ground-state phase diagram and low-temperature thermodynamics of a spin-1 Heisenberg diamond chain*
P17 - **M. Mohylna**: *Effect of impurities and lattice finitness on the skyrmion phase in triangular Heisenberg AFM with DMI*
P18 - **M. Kecer**: *Velocity-fluctuations in two-species reaction-diffusion system: Renormalization group study*
P19 - **A. Ovsiannikov**: *Stochastic MHD with mirror symmetry breaking in the two-loop approximation*
P20 - **D. Sivý**: *Exactly solved spin-1/2 Ising-Heisenberg branched chain as a theoretical model of Fe_2Cu_2 coordination polymers*
P21 - **J. Strečka**: *Spin-1/2 Ising-Heisenberg diamond-decorated square lattice in a magnetic field: exact results for phase transitions and critical points*
P22 - **H. Vargová**: *Genuine tripartite entanglement in a mixed spin-(1/2,1,1/2) Heisenberg trimer*
P23 - **R. Krčmár**: *Ising ferromagnets and antiferromagnets in an imaginary magnetic field*
P24 - **I. Travěnec**: *Generation of off-critical zeros for multidimensional Zeta functions*
P25 - **K. Benedek**: *Heterogeneity of the European grids: edge weight, community structure and structural improvements*
P26 - **D. Gessert**: *Population Annealing Monte Carlo Using the Rejection-Free n-Fold Way Update Applied to a Frustrated Ising Model on a Honeycomb Lattice*

P1

Individual bias and fluctuations in collective decision making: analytical results and simulations

Petro Sarkanych[1,2], Mariana Krasnytska[1,2], Luis Gómez-Nava[3], Pawel Romanczuk[4,5], and Yurij Holovatch*[1,2,6,7]

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Abstract

We reconsider the spin model suggested recently to understand some features of collective decision making among higher organisms [1]. Within the model, the state of an agent i is described by the pair of variables: its opinion $S_i = \pm 1$ and a bias ω_i towards any of the opposing values of S_i. Collective decision making is interpreted as an approach to the equilibrium state within the non-linear voter model subject to social pressure and a probabilistic algorithm. Here, we push such physical analogy further and give the statistical physics interpretation of the model, describing it in terms of the Hamiltonian of interaction and looking for the equilibrium state via explicit calculation of its partition function. We show that depending on the assumptions about the nature of social interactions two different Hamiltonians can be formulated. In such an interpretation the temperature serves as a measure of fluctuations, not considered before in the original model. We find exact solutions for the thermodynamics of the model on the complete graph. The general analytical predictions are confirmed using individual-based simulations. The simulations allow us also to study the impact of system size and initial conditions in the collective decision making in finite-sized systems, in particular with respect to convergence to metastable states. We discuss advantages and flaws of such an approach as well as its utility to understand impact of population heterogeneity, type of local interaction and fluctuations on the collective decision making [2].

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P2

Potts model with invisible states, old and new

Mariana Krasnytska[1,2,3], Petro Sarkanych[1,2], Bertrand Berche[3,2], Yurij Holovatch*[1,2,4,5], and Ralph Kenna[4,2]

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Abstract

The Potts model with invisible states was introduced to explain discrepancies between theoretical predictions and experimental observations of phase transitions in some systems where Z_q symmetry is spontaneously broken [1]. It differs from the ordinary q-state Potts model in that each spin, besides the usual q visible states, can be also in any of r so-called invisible states. Spins in an invisible state do not interact with their neighbours but they do contribute to the entropy of the system. As a consequence, an increase in r may cause a phase transition to change from second to first order. Potts models with invisible states describe a number of systems of interest in physics and beyond and have been treated by various tools of statistical and mathematical physics. In this report we aim to review some of our old and new results in this fundamental topic [2, 3, 4, 5, 6, 7]. In particulat, we show how adding invisible states turns transition in the bond-percolation model into strong first-order [2] as well as how a negative number of invisible states or complex external field may lead to a phase transition at non-zero temperature [3, 4].

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P3

Numerical exploration of finite-size scaling above the upper critical dimension

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While mean-field theory is successful in describing critical phenomena in high-dimensional systems in the thermodynamic limit, it hides subtle physics for finite-size systems. In the renormalization group formalism, critical behaviour is governed by the Gaussian fixed point whose naïve application matches mean-field theory in the correlation sector, but it fails to do so in the free energy sector. Fixing only what was obviously broken, dangerous irrelevant variables were introduced in the free energy sector to match the Gaussian fixed point with mean field results. While this worked very well in the thermodynamic limit, finite-size scaling did not, and various ad-hoc attempts were made to repair it. Recent extensions of the concept of dangerous irrelevant variables to the correlation sector neatly repaired both hyperscaling and finite-size scaling there. This new step resulted in the introduction of a new (pseudo-)critical exponent ϙ. While well verified numerically with periodic boundary conditions, ϙ-adjusted finite-size scaling with free boundary conditions proved more challenging.[1] Here we report on numerical investigations of the 5D Ising model with free boundaries using Monte-Carlo simulations and a wide range of theoretical tools including partition-function zeroes.

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P4

Survival in a two-species reaction-diffusion system with Lévy flights

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Abstract

We analyze the two-species reaction-diffusion system of mobile traps (A) that can mutually annihilate or coagulate, $A + A \to (0, A)$, and mobile targets (B) that can be adsorbed by traps, $A + B \to A$, [1]. Both species perform superdiffusion Lévy flights with control parameter $0 < \sigma < 2$. It is known, that replacing the diffusive propagation with long-ranged Lévy flights modifies the dynamics of reactive systems, moreover, the upper critical dimension, below which fluctuations are crucial, depends on the Lévy index σ [2]. We are interested in the question of how superdiffusion modifies the scaling of observable quantities below the upper critical dimension $d \leq d_c = \sigma$. Universal non-trivial exponents for the scaling behavior of the density and the correlation function of B particles were calculated using the field-theoretical renormalization group method [3] within the one-loop approximation. Calculated quantities demonstrate that the surviving probability of the target particles in a superdiffusive regime is higher than that in a system with ordinary diffusion [4]. Obtained analytical results for the density decay exponent of targets are confirmed by the numerical simulations in the one-dimensional case [4].

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P5

Second-harmonic generation in the Kitaev model at finite temperatures

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Abstract

We consider the Kitaev model, which is a bond-anisotropic Ising model on the honeycomb lattice and exactly solvable by fractionaling spins in terms of Majorana particles and Z2 visons. These quasiparticles may have been observed in several spectroscopic probes like inelastic neutron scattering, Raman light scattering, and ultrasound attenuation. Recently nonlinear optical spectroscopies have come under scrutiny as a new tool to also study fractionalization. In the present work, we investigate the second-harmonic generation in the Kitaev model induced by external electric fields. The prime interest is to identify fingerprints of the Majorana particles and gauge excitations. For that purpose, second order response functions are calculated within the equation of motion approach. Analytical results for these response functions in the homogeneous and random gauge sectors at finite temperatures are presented.

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P6

Phase behavior of a binary mixture with Curie-Weiss interaction

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Abstract

We consider a model of a continuous, binary system within the framework of the grand canonical ensemble. The particles interact via the Curie-Weiss potential, which contains attractive and repulsive components. The values of the interaction parameters of each species are different, which ensures the asymmetry of the mixture. Moreover, the interaction between particles of distinct sorts is taken into account. We calculated the grand partition function of the model and obtained critical values of the intensive properties for specific values of the interaction parameters. The phase behaviour of such a model, namely the first-order phase transitions, is analysed in a wide range of density and temperature.

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P7

Exact diagonalization approach to the magnetic properties of single-ion magnets

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Abstract

Single-ion magnets with large magnetic anisotropy are particularly attractive to researchers working in the field of molecular magnetism. Among all manomagnetic systems, single-ion magnets stand as the most reliable building blocks for implementation in spintronics and future semi classical molecular based high density information storage devices. Therefore, gaining insights into the microscopic processes that underlie their magnetic properties is of a great importance to the scientific community. Of particular interest are the self-consistent methods that have the potential to provide the complete set of physical quantities characterizing the fine structure of these systems and hence revealing the origin of all relevant magnetic features.

In exploring the magnetic properties of single-ion magnets, we adopted a computational approach based on exact diagonalization based on the principles of multi-configurational self consistent method. The devised method allows a comprehensive analysis of the contribution of electrons' exchange interactions, crystal field, spin-orbit interactions and Zeeman ones in the formation and evolution of the obtained fine structure. The method was successfully applied to study the magnetic properties of $3d^8$ and $3d^2$ based single-ion magnets [1-3].

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P8

Quantum constraints to the origin of fine structure in 3d8 trigonal bipyramidal coordination complexes

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Abstract

The origin of the fine structure underlying the magnetic behavior of mononuclear 3d8 molecule magnets with trigonal bipyramidal crystal field symmetry is a captivating example for the complex electrons dynamics in these systems [1, 2, 3, 4]. Unraveling the occurrence of the corresponding zero-field splitting turns out to be unfeasible within the conventional approach accounting for the electrons' phases as independent variables over an infinite time span. Despite all efforts to shed light on the genuine electronic correlations underlying the spin-orbit coupling in the absence of quantum constraints, the zero- and low-field magnetic behavior of these systems remains not fully understood. In order to comprehend the intricate features that give rise to a fine structure in 3d8 single-ion magnets, we perform a thorough investigation on the contribution of the crystal field, spin exchange and spin-orbit interactions. We apply the exact diagonalization approach presented in Ref. [4]. The named approach is based on the multi-configurational self-consistent field method and unambiguously shows that under the existing trigonal bipyramidal coordination the spin-orbit coupling alone can neither give rise to a zero-field splitting nor magnetic anisotropy. However, it clearly points out to the key mechanism that underpin the origin of fine structure. The basis for the intricate magnetic behavior is shown to be the restricted orbital dynamics of the unpaired electrons. In particular, the occurrence of phase constraints over the processes of direct exchange of electrons under the conservation of all observables.

Acknowledgement

This work was supported by the Bulgarian National Science Fund under grant No K-06-H38/6.

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P9

Tree size distribution in the perspective of the Local Growth and Global Reset (LGGR) model.

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Abstract

Tree growth and mortality play a fundamental role in shaping the forest as an ecosystem. Understanding such dynamical mechanisms is essential for predicting the ecosystem's response to environmental changes. Tree size evolution and mortality has been intensively studied in the past decades [1, 2] and most of the models found in the literature are motivated by applications in the design of sustainable forest management plans.

In the present study we approach the phenomena from a statistical physicist's point of view, aiming to describe universality in the tree diameter distribution for compact tree ensembles. First, we present statistical data that supports the generality of the Gamma distribution for the trees diameter at breast height (DBH) in three different ecosystems: (1) natural forest, (2) forest pasture and (3) plantation. Then, we consider the Local Growth and Global Reset (LGGR) model, which is a master equation with unidirectional growth and stochastic resetting processes [3]. By using realistic kernel functions for the growth and reset rates [4], the LGGR model can accurately capture DBH distributions in both natural and human-managed forests.

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P10

Front dynamics at a localization transition

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Abstract

The dynamics of the Harper model is investigated in a setting where initially ($t = 0$) the two halves of the one dimensional model are prepared in different conditions. Two kinds of initial states are used, in the first one the two halves are at different temperatures at $t = 0$, in the second one the system is at zero temperature, however the chemical potential and the particle number is different in the two halves. For $t > 0$ the whole system is driven by the Harper Hamiltonian, and an equilibration between the two halves start. The propagating of the front between the two kinds is different if the Hamiltonian is in the extended state, in the localized state or at the critical point. We characterize the dynamics calculating the particle number of the two halves the energy content of the two halves and at zero (finite) temperature the entanglement entropy (mutual information) between the two halves. Near the critical point a scaling relationship is found between the aforementioned quantities and the localization length.

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P11

Stick-slip dynamics of a 1D Burridge-Knopoff type spring-block system on a treadmill

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Abstract

Spring-block chains are commonly used as a model for emergent phenomena in complex systems [1, 2]. As a well-known example, the Burridge-Knopoff (BK) spring-block model, is a basic approach to understand the scale-free distribution of earthquake energies [3, 4]. The one-dimensional (1D) version consists of a chain of blocks connected to each other and to a fixed platform by springs. The platform moves with a constant speed, while the blocks experience nonlinear friction forces, generating earthquake-like stick-slip dynamics. Here, we investigate this spring-block chain both numerically and experimentally using a treadmill-based experimental setup. The movement of the blocks was monitored and digitized. The experimental results revealed that the dynamics of the spring-block chain is qualitatively influenced by the treadmill's velocity. A quasi-periodic behavior was observed at high speeds and avalanche-like (stick-slip) dynamics at low speed values. Avalanches were quantified according to the total kinetic energy of the blocks. Experimental results revealed in the low speed regime a power-law type probability density of avalanche-size distribution, with a scaling exponent of -2. Numerical simulations confirm the experimentally observed power-law scaling of the probability density of avalanches in the stick-slip regime.

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P12

Comparing cross-correlation estimators in fMRI data

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Abstract

Functional magnetic resonance imaging (fMRI) signals are notoriously challenging to analyse due to their very low temporal resolution (seconds), leading to a considerably larger number of time series than time points ($N/T \gg 1$), and a non-trivial auto-correlation and cross-correlation (CC) structure. In this contribution, we present an analysis of a memory distortion experiment [1] based on sample Pearson correlation, detrended CC [2] and non-linear asymmetric CC based on filtering high-amplitude events, rBeta [3], and their shrinkage estimators [5].

Uncovering regionally coordinated changes in brain activity between experimental conditions involved comparing distributions of correlation matrices' eigenvalues. For that purpose, we additionally performed agglomerative hierarchical clustering of eigenvectors based on their similarity. The rBeta correlation matrix was symmetrised before shrinking. The signals considered in this work were averages over all voxels belonging to an anatomical atlas region.

The CC between brain areas were found indicative of differences between spontaneous brain activity (resting state) and other tasks, as well as between different tasks (verbal vs non-verbal) and experimental stages (memorisation and recollection). Other statistically significant effects associated with smaller eigenvalues are yet to be interpreted psychologically. Detailed statistical analyses were performed for the rBeta method, providing additional results on the different types of memorised stimuli (matching, non-matching, intentionally confusing). In terms of methodology, the detrended correlations turned out to be more sensitive (leading to stronger statistical effects) than Pearson correlations, and clustered eigenvalues to unclustered ones. The rBeta yielded qualitatively different results than other methods. The stability of the eigenvector clustering is still to be scrutinised together with the optimisation of the detrending parameters in detrended CC. The shrinkage makes the results more consistent across correlation matrix estimation methods.

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P13

EEG signal segmentation for assessing the time-course of brain response to stimuli

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Abstract

Signal detected by electroencephalography (EEG) exhibits a power spectrum with a predominant $1/f$ component. As such, the signal is nonstationary. When EEG is applied to the study of cortical response to stimuli, the event-related potential (ERP) technique is commonly used. It led to innumerable insights into the mechanisms of cognition. However, it has significant limitations: A) it relies on averaging the EEG signal around the stimuli over many experimental trials; as such, it does not fully exploit the data's non-stationarity, B) it requires careful pre-processing of the signals to ensure reliable results.

We propose an alternative technique utilizing an algorithm introduced by [1], which recursively divides the series into segments based on maximizing the Kolmogorov-Smirnov (KS) distance between them. The method's performance was tested on standardized EEG recordings included in the ERP CORE dataset [2] and compared with the ERP technique. Impact of the details of implementation on the results will be discussed: the method of finding the critical value of the KS statistic, the choice of kernel smoothing parameters, and pre-processing steps.

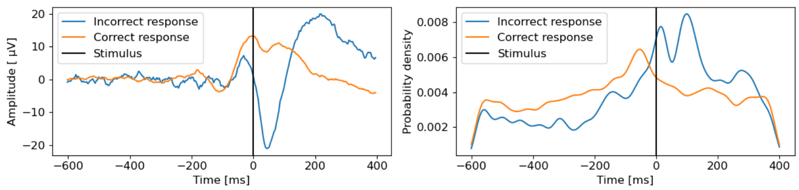

Figure 1: The ERP waveform (left) and probability density of partition by the KS-segmentation algorithm (right) for a single subject and one electrode (FCz) in the Eriksen Flanker Task. Comparison of trials with erroneous and correct subject response.

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P14

Synchronization and criticality on connectome graphs

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Abstract

The criticality hypothesis for neural systems proposes that optimal information processing, sensitivity, and memory capacity occur near criticality. We investigate the synchronization transition of the Shinomoto-Kuramoto (SK) model on fruit-fly and human connectomes, showing nontrivial critical behavior with continuously changing exponents, frustrated synchronization, and chimera states in the resting state [1, 2, 3]. By numerical solution, we determine the crackling noise durations with and without thermal noise, and show extended non-universal scaling tails characterized by the exponent $2 < \tau < 2.8$, in contrast with the Hopf transition of the Kuramoto model, without the force $\tau = 3.1(1)$. Comparing the phase and frequency order parameters, we find different transition points and fluctuations peaks as in the case of the Kuramoto model. Using the local order parameter values, we also determine the Hurst (phase) and β (frequency) exponents and compare them with recent experimental results obtained by fMRI [4]. Our findings suggest that these exponents are smaller in the excited system than in the resting state and exhibit module dependence.

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P15

Phase transition and magnetization of the spin-1/2 double sawtooth ladder with cyclic four-spin Ising interaction

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Abstract

In recent years, various first-order magnetic phase transitions of the so-called Ising-Heisenberg spin models have been discovered [1, 2, 3]. The main feature of the Ising-Heisenberg spin models is a special alternation of small clusters of quantum Heisenberg spins embedded in between the Ising spins in such a way that the local Hamiltonians for the blocks commute with each other. This allows one to obtain an exact solution in terms of the generalized transfer-matrix method. The cyclic four-spin Ising coupling can be considered as the Ising limit of the cyclic permutation of the quantum spins, or higher-order exchange interactions [4]. In this work, the ground-state phase transition and magnetization of the antiferromagnetic spin-1/2 Ising-Heisenberg model on a double sawtooth ladder is rigorously investigated. The model includes the XXZ interaction between the interstitial Heisenberg dimers, the Ising coupling between nearest-neighbor spins from the legs and rungs, and the additional cyclic four-spin Ising term in each square plaquette configured by Ising spins of successive blocks. We find that for a particular value of the cyclic four-spin exchange there is a quadruple point in the ground-state phase diagram at which four different ground states coexist together. The coordinates of this point strongly depend on the exchange interactions of the interstitial Heisenberg dimers. The magnetization value of the model remarkably changes close to this point under the magnetic-field variations.

Acknowledgement

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P16

Ground-state phase diagram and low-temperature thermodynamics of a spin-1 Heisenberg diamond chain

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Abstract

Among a wide class of frustrated quantum Heisenberg spin models, the diamond chains with different spin magnitudes have recently attracted a lot of attention [1, 2]. The magnetic material $[Ni_3(OH)_2(O_2C - C_2H_2 - CO_2)(H_2O)_4].H_2O$ affords an experimental realization of the spin-1 Heisenberg distorted diamond chain [3, 4]. A full energy spectrum of the spin-1 Heisenberg diamond chain in a magnetic field still represents an open problem, which may uncover a variety of intriguing features of this frustrated quantum spin chain. In this work, we show how the ground-state phase diagram, magnetization curves and low-temperature thermodynamics of the spin-1 Heisenberg diamond chain in a magnetic field can be elaborated within the analytical approaches such as a variational technique and an extended localized-magnon theory in combination with the numerical techniques such as exact diagonalization and density-matrix renormalization-group method. The bound one- and two-magnon eigenstates allow a complete analytical description of low-temperature magnetization curves and thermodynamics of the spin-1 Heisenberg diamond chain in a highly frustrated parameter region. In addition, we uncover the Haldane phase and the cluster-based Haldane phases of the spin-1 Heisenberg diamond chain in a parameter region with the moderate spin frustration.

Acknowledgement

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P17

Effect of impurities and lattice finitness on the skyrmion phase in triangular Heisenberg AFM with DMI

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Abstract

Skyrmions, topologically stable twisted spin configurations, initially found in bulk ferromagnets (FM) with the Dzyaloshinskii–Moriya interaction (DMI), have now been observed in a number of other materials, including antiferromagnetic (AFM) ones. A monolayer Heisenberg AFM with DMI is one of such materials, where the stabilization of the skyrmion lattice phase (SkX) is supported by the presence of frustration [1]. The model has been extensively studied in a wide parameter space [2, 3, 4]. However, real systems often involve some imperfections, such as non-magnetic impurities, and the underlying lattice is actually of finite size.

Here we study the influence of the impurities on the stabilization of SkX and show that in this AFM model, unlike the FM one [5], SkX is robust against the distortion caused by the impurities up to impressively large concentrations of them. The skyrmions tend to reorganize so that the impurities are localized between them, leading to a decrease in the number of skyrmions on the lattice, an effect similar to the one caused by an increase in temperature. The stronger DMI tends to somewhat reduce this effect. We demonstrate that SkX can also be stabilized on finite-size spin clusters. In the case of a relatively strong DMI the characteristic size of the skyrmions can be very small and then SkX can form on tiny nanoclusters comprising merely tens or hundreds of spins. On the other hand, for smaller values of DMI much larger clusters are needed for the stabilization of SkX.

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P18

Velocity-fluctuations in two-species reaction-diffusion system: Renormalization group study

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Abstract

We study the influence of random velocity fluctuations on anomalous kinetics of two-species reaction-diffusion system $A + A \to (\emptyset, A)$, $A + B \to A$ near its upper critical dimension $d_c = 2$. The velocity-fluctuation effects are modeled by random advective field described by stochastic Navier-Stokes equations. The analysis is performed by means of field-theoretic renormalization group formalism and two-parameter (ϵ, Δ) expansion, where ϵ denotes deviation from Kolmogorov scaling and Δ is the deviation from space dimension $d = 2$. All stable macroscopic regimes are identified and density decay exponents for both particle types are calculated to leading order.

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P19

Stochastic MHD with mirror symmetry breaking in the two-loop approximation

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Abstract

Magnetohydrodynamic (MHD) turbulence driven by the stochastic Navier-Stokes equation always has been a subject of intense study [1, 2, 3]. We investigate a specific property of electrically conducting fluid in developed turbulence related to magnetic field fluctuations that lead to the creation of a non-zero average large-scale magnetic field, known as a turbulent dynamo. This effect is most evident in gyrotropic liquids with violated parity and is associated with the conservation of magnetic helicity. Our research uses field-theoretic methods to propose a general scenario for the generation and renormalization of arising homogeneous magnetic field. To refine earlier results [4], we employ two-loop calculations. The investigation herewith focuses on studying the system's stability, which is necessary for the self-consistency of previously made predictions about the mechanism of system stabilization.

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P20

Exactly solved spin-1/2 Ising-Heisenberg branched chain as a theoretical model of Fe_2Cu_2 coordination polymers

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Abstract

This study rigorously investigates the spin-1/2 Ising-Heisenberg branched chain in a magnetic field, which is inspired by a magnetic structure of three isotructural polymeric coordination compounds $[(Tp)_2Fe_2(CN)_6(HX)(bdmap)Cu_2(H_2O)]_\infty$ (Tp = tris(pyrazolyl)fudroborate, bdmapH = 1,3-bis(dimethylamino)-2-propanol, HX = acetic, propionic or trifluoroacetic acid) [1] to be further abbreviated as Fe_2Cu_2. Within the framework of the spin-1/2 Ising-Heisenberg branched chain the nearly isotropic Cu^{2+} magnetic ions are represented by the Heisenberg spins 1/2, whereas the highly anisotropic Fe^{3+} magnetic ions are represented by the Ising spins 1/2. Using the transfer-matrix method, we calculated exact expressions for correlation functions and basic magnetothermodynamic quantities such as the magnetization, magnetic susceptibility, entropy and specific heat. The ground-state phase diagram reveals the presence of a quantum antiferromagnetic phase, a quantum ferrimagnetic phase, and a classical ferromagnetic phase. In addition, we have predicted the occurrence of two intermediate magnetization plateaus in the zero-temperature magnetization process, as well as, the existence of bipartite quantum entanglement between nearest-neighbor Heisenberg spin pairs quantified through the measure called as the concurrence. Finally, we analyzed available experimental data [1] for a magnetic susceptibility multiplied by temperature and a low-field magnetization curve, finding a relatively good agreement with our theoretical predictions. This work thus sheds light on the magnetic behavior of the polymeric coordination compounds Fe_2Cu_2.

Acknowledgement

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P21

Spin-1/2 Ising-Heisenberg diamond-decorated square lattice in a magnetic field: exact results for phase transitions and critical points

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Abstract

The thermal phase transitions of a spin-1/2 Ising-Heisenberg model on the diamond-decorated square lattice in a magnetic field are investigated by making use of a decoration-iteration mapping transformation and classical Monte Carlo simulations [1]. A generalized decoration-iteration transformation exactly maps this classical-quantum lattice-statistical model onto an effective classical spin-1/2 Ising model on the square lattice with temperature-dependent effective nearest-neighbor interaction and magnetic field. The effective magnetic field vanishes along a ground-state phase boundary of the original classical-quantum model, separating a classical ferrimagnetic phase and a quantum monomer-dimer phase. At finite temperatures this phase boundary gives rise to an exactly solvable surface of discontinuous (first-order) phase transitions, which terminates in a line of Ising critical points. The existence of discontinuous reentrant phase transitions emergent within a narrow parameter regime is reported and explained in terms of the low-energy excitations from both phases. These exact results, obtained from the mapping to the zero-field effective Ising model, are independently corroborated by classical Monte Carlo simulations of the effective classical spin-1/2 Ising model on the square lattice with temperature-dependent effective nearest-neighbor interaction and magnetic field.

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P22

Genuine tripartite entanglement in a mixed spin-(1/2,1,1/2) Heisenberg trimer

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Abstract

A genuine tripartite entanglement of a mixed spin-(1/2,1,1/2) Heisenberg trimer is rigorously analyzed in presence of external magnetic field. Two different coupling constants, J and J_1, describing the Heisenberg exchange interactions between two spins with different and identical magnitudes are taken into account. The degree of a genuine negativity is evaluated according to the geometric mean of three various bipartite negativities between a single spin and the remaining spin dimer. It was identified that the genuine tripartite negativity below $J_1/J = 1$ can arise in each ground state until the classical ferromagnetic ground state is achieved at the threshold magnetic field. In contrast, the genuine tripartite negativity is possible solely at low-enough magnetic field, where the antiferromagnetic ground state is realized. It was shown furthermore, that the genuine tripartite negativity in a ferrimagnetic ground state at $J_1/J > 1$ is prohibited due to the absence of a bipartite negativity between the spin-1 and respective spin-1/2 dimer. Moreover, it was demonstrated that the increasing magnetic field has a reduction effect on the genuine tripartite negativity of a mixed spin-(1/2,1,1/2) Heisenberg trimer in the whole parametric space. Finally, the correlation between the bipartite negativity of two single spins and the genuine tripartite negativity was discussed in detail.

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P23

Ising ferromagnets and antiferromagnets in an imaginary magnetic field

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Abstract

We study classical Ising spin-$\frac{1}{2}$ models on the 2D square lattice with ferromagnetic or antiferromagnetic nearest-neighbor interactions, under the effect of a pure imaginary magnetic field [1, 2]. The complex Boltzmann weights of spin configurations cannot be interpreted as a probability distribution which prevents from application of standard statistical algorithms. In this work, the mapping of the Ising spin models under consideration onto symmetric vertex models leads to real (positive or negative) Boltzmann weights. This enables us to apply accurate numerical methods based on the renormalization of the density matrix, namely the corner transfer matrix renormalization group and the higher-order tensor renormalization group. For the 2D antiferromagnet, varying the imaginary magnetic field we calculate with a high accuracy the curve of critical points related to the symmetry breaking of magnetizations on the interwoven sublattices. The critical exponent β and the anomaly number c are shown to be constant along the critical line, equal to their values β=$\frac{1}{8}$ and c=$\frac{1}{2}$ for the 2D Ising in a zero magnetic field. The 2D ferromagnets behave in analogy with their 1D counterparts defined on a chain of sites, namely there exists a transient temperature which splits the temperature range into its high-temperature and low-temperature parts. The free energy and the magnetization are well defined in the high-temperature region. In the low-temperature region, the free energy exhibits singularities at the Yang-Lee zeros of the partition function and the magnetization is also ill-defined: it varies chaotically with the size of the system. The transient temperature is determined as a function of the imaginary magnetic field by using the fact that from the high-temperature side both the first derivative of the free energy with respect to the temperature and the magnetization diverge at this temperature.

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P24

Generation of off-critical zeros for multidimensional Zeta functions

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Abstract

According to the Riemann hypothesis, the analytic continuation of the 1D Riemann zeta function $\zeta(s) = \sum_n 1/n^s$ is equal to non-trivial zero exclusively on the critical line $\mathrm{Re}(s) = 1/2$. This is no longer true for the generalization of the Riemann zeta function to d-dimensional ($d = 2, 3, ...$) hypercubic lattices (the Epstein zeta function). Constructing numerically the map of critical zeros as functions of continuously changing dimension d we define the topology of special critical zeros which give rise to continuous curves of off-critical zeros. An analogous generation mechanism was revealed for anisotropic 2D Epstein zeta functions where the role of spatial dimension is played by the anisotropy parameter. The generation mechanism of off-critical zeros from the special critical ones resembles that of symmetry breaking in statistical models.

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P25

Heterogeneity of the European grids: edge weight, community structure and structural improvements

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Abstract

Making a given high-voltage power grid more stable and reliable has become a relevant question, especially when considering the current energetic situation or future development plans to augment and interconnect the existing network with renewable energy sources. Understanding the behavior and identifying the critical nodes and links of the network constructed from the power grid data, give us insight into possible ways to optimize its stability.

We investigate the European high-voltage power grid by not only considering the actual connections between the nodes but also calculating the edge admittances and weights based on the 2016 SciGRID project data. We perform community detection analysis and show the level of synchronization on the 2016 European HV power grids, by solving the set of swing equations. By investigating these synchronization levels and communities, we identify critical nodes and links that play a key role in power transmission between different power regions and propose two ways to improve the synchronization level in the network.

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P26

Population Annealing Monte Carlo Using the Rejection-Free n-Fold Way Update Applied to a Frustrated Ising Model on a Honeycomb Lattice

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Abstract

Population annealing (PA) is a Monte Carlo method well suited for problems with a rough free energy landscape such as glassy systems. PA is similar to repeated simulated annealing, with the addition of a resampling step at each temperature. While a large population may to some extent compensate for imperfect equilibration, it is clear that PA must fail if almost no spins are flipped during equilibration.

This is the case in systems with a phase transition at a very low temperature where a high Metropolis rejection rate makes sampling phase space near infeasible. To overcome this slow-down we propose a combination of the PA framework with the rejection-free "n-fold way" update and achieve an exponential speed-up at low temperatures as compared to Metropolis.

To test our method we study the Ising model with competing ferromagnetic ($J_1 > 0$) nearest and antiferromagnetic ($J_2 < 0$) next-to-nearest neighbor interactions on a honeycomb lattice. As T_c becomes arbitrarily small when approaching the special point $J_2 = -J_1/4$ with $T_c = 0$ we consider this a good choice to test the efficiency of our method.

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Notes

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Monday, 22.5.		Tuesday, 23.5.		Wednesday, 24.5.		Thursday, 25.5.	
		Chair: Strečka		**Chair: Hristopulos**		**Chair: Janke**	
		08.45 – 09.00 09.00 – 09.40 09.40 – 10.00 10.00 – 10.20	Conference opening I1 - Holovatch O1 - Janke O2 - Niedziółka	09.00 – 09.40 09.40 – 10.00 10.00 – 10.20	I5 - Néda O9 - Ódor O10 - Sándor	09.00 – 09.40 09.40 – 10.00 10.00 – 10.20	I9 - Trizac O19 - Gendiar O20 - Tyukodi
		10.20 – 10.50	**Coffee break**	10.20 – 10.50	**Coffee break**	10.20 – 10.50	**Coffee break**
		Chair: Honkonen		**Chair: Trizac**		**Chair: Derzhko**	
		10.50 – 11.30 11.30 – 11.50 11.50 – 12.10	I2 - Teber O3 - Metayer O4 - Dudka	10.50 – 11.30 11.30 – 11.50 11.50 – 12.10	I6 - Chatelain O11 – Markoš O12 - Horváth	10.50 – 11.30 11.30 – 11.50 11.50 – 12.10	I10 - Karľová O21- Ghannadan O22 - Rončík
						12.10 – 12.20	**Conference closing**
		12.10 – 14.00	**Lunch**	12.10 – 14.00	**Lunch**	12.20 – 13.30	**Lunch**
		Chair: Neda		**Chair: Holovatch**		13.30 – 18.30	**Trip to waterfalls**
14.00 – 18.00	**Registration**	14.00 – 14.40 14.40 – 15.00 15.00 – 15.20	I3 - Zdeborová O5 - Drogosz O6 – Tomczyk	14.00 – 14.40 14.40 – 15.00 15.00 – 15.20	I7 - Hristopulos O13 - Žukovič O14 - Józsa		
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		Chair: Teber		**Chair: Karľová**			
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		Chairs: Janke, Néda		**Chair: Chatelain**			
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