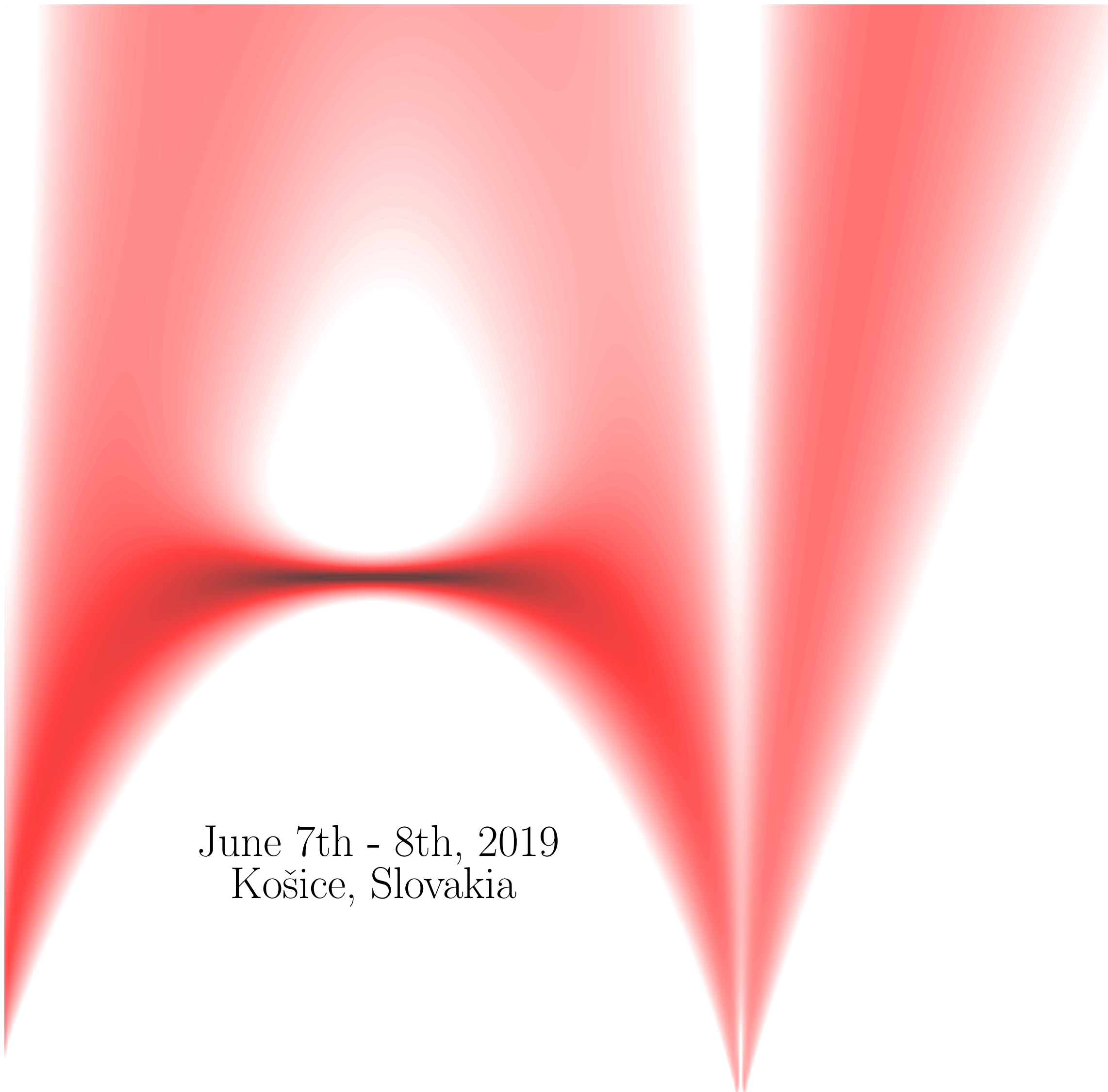
Workshop on Quantum Magnetism:

Theoretical Challenges and Future Perspectives



June 7th - 8th, 2019
Košice, Slovakia

Programme & Abstracts

Workshop on Quantum Magnetism:
Theoretical Challenges and Future Perspectives
Programme & Abstracts

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Conference website and email

https://ktfa.science.upjs.sk/conferences/
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Conference Date and Location

The workshop will be held on June 7th - 8th, 2019 in Promatech building, Watsonova 1935/47, 040 01 Košice, Slovakia.

Conference Language

The working language of the conference is English.

Financial support

The organization of this workshop is financially supported by the Slovak Research and Development Agency under the Contract No. APVV-16-0186.

Main conference topics:

1. Molecular magnetism
2. Highly frustrated magnetism
3. Magnetic phase transitions
4. Quantum spin liquids
5. Strongly correlated systems
6. Exotic quantum states
7. Flat-band systems
8. Quantum entanglement

List of Invited Speakers

Oleg Derzhko	Institute for Condensed Matter Physics, L'viv, Ukraine
Cesur Ekiz	Aydın Adnan Menderes University, Aydın, Turkey
Andrej Gendiar	Institute of Physics, SAS, Bratislava, Slovakia
Onofre Rojas	Universidade Federal de Lavras, Lavras, Brazil
Jürgen Schnack	Universität Bielefeld, Bielefeld, Germany
Sergio de Souza	Universidade Federal de Lavras, Lavras, Brazil
Karol Szałowski	University of Łódź, Łódź, Poland
Taras Verkholyak	Institute for Condensed Matter Physics, L'viv, Ukraine

Programme - Friday June 7th, 2019

14.30-15.00 Registration

15.00-15.30 Keynote lecture - K1:
J. Schnack, J. Schulenburg, and J. Richter
Magnetism of the $N = 42$ kagome lattice antiferromagnet

15.30-15.50 Invited lecture - I1:
T. Verkholyak and J. Strečka
The Ising-Heisenberg model on the distorted Shastry-Sutherland lattice: ground-state properties

15.50-16.05 Contributed talk - C1:
M. Jaščur, M. Rončík, T. Balcerzak, and K. Szałowski
Complex theory of localised spin systems with variable exchange interaction

16.10-16.40 Coffee break

16.45-17.15 Keynote lecture - K2:
T. Krokhmalskii, T. Hutak, O. Rojas, S.M. de Souza, and **O. Derzhko**
Towards Pseudo-transitions in Decorated Spin Systems

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Order by disorder in frustrated spin-1/2 Ising-Heisenberg model on triangulated Husimi lattices

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Ising and Potts critical points emergent in a low-temperature magnetization process of a fully frustrated spin-1/2 Heisenberg triangular bilayer

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Critical Behavior of Geometrically Frustrated Generalized XY Model

17.55-18.00 Short communication - S2:
H. Čenčariková and J. Strečka
Magnetoelectric effect of the exactly solved spin-electron model on a doubly decorated square lattice

18.00-18.05 Short communication - S3:
M. Semjan and M. Žukovič
Crossover from Two- to Three-Dimensional Kagome Lattice Ising Antiferromagnet

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Programme - Saturday June 8th, 2019

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Magnetocalorics and quantum entanglement in spin-1/2 molecular magnets with triangle-based geometry

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Nayara Ferrera, J. Torrico, **S.M. de Souza**, O. Rojas, and J. Strečka
Magnetoelastic Properties of Ising-Heisenberg Diamond Chain

09.50-10.05 Contributed talk - C3:
K. Karľová, J. Strečka, and T. Verkholyak
Spectacular quantum ground states of a mixed spin-1 and spin-1/2 Heisenberg octahedral chain

10.10-10.40 Coffee break

10.45-11.15 Keynote lecture - K4:
O. Rojas, J. Strečka, O. Derzhko, and S.M. de Souza
Peculiarities in pseudo-transition of coupled tetrahedral spin-(1/2, 1) Ising and Heisenberg chain in an external magnetic field

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A. Gendiar
Majorana bound states affected by Coulomb interaction

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Unconventional Low-Temperature Phase in a Frustrated $J_1 - J_2$ Ising Antiferromagnet on a Honeycomb Lattice

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R. Krčmár, T. Nishino, and A. Gendiar
Entanglement-entropy Study of Phase Transitions in Six-state Clock Model

12.05-12.10 Short communication - S4:
M. Mohylna and M. Žukovič
Interpenetrating Skyrmion Crystals in a Geometrically Frustrated Triangular Lattice Heisenberg Antiferromagnet

12.15-12.20 Short communication - S5:
A. Bobák, **T. Lučivjanský**, and M. Žukovič
Magnetism of the diluted Ising antiferromagnet in a magnetic field on the Kagome lattice: single-spin cluster approximation

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12.30-14.00 Lunch

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Keynote lectures

(25 min. talk + 5 min. discussion)

K1

Magnetism of the N = 42 kagome lattice antiferromagnet

Jürgen Schnack*[1], Jörg Schulenburg[2], and Johannes Richter[3]

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Abstract

For the paradigmatic frustrated spin-half Heisenberg antiferromagnet on the kagome lattice we performed large-scale numerical investigations of thermodynamic functions by means of the finite-temperature Lanczos method for system sizes of up to $N = 42$ [1]. We present the dependence of magnetization as well as specific heat on temperature and external field and show in particular that a finite-size scaling of specific heat supports the appearance of a low-temperature shoulder below the major maximum. This seems to be the result of a counterintuitive motion of the density of singlet states towards higher energies. Other interesting features that we discuss are the asymmetric melting of the 1/3 magnetization plateau as well the field dependence of the specific heat that exhibits characteristic features caused by the existence of a flat one-magnon band. By comparison with the unfrustrated square-lattice antiferromagnet the tremendous role of frustration in a wide temperature range is illustrated [1].

Acknowledgement

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K2

Towards Pseudo-transitions in Decorated Spin Systems

Taras Krokhmalskii[1], Taras Hutak[1], Onofre Rojas[2], Sergio Martins de Souza[2], and Oleg Derzhko*[1,3]

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Abstract

We discuss the origin of the peculiar low-temperature behavior of one-dimensional decorated spin systems [1, 2, 3, 4], which was coined the pseudo-transition [5]. Tracing out the decorated parts results in the standard Ising-chain model with temperature-dependent parameters and an unexpected low-temperature behavior of thermodynamic quantities and correlations of the decorated spin chains can be tracked down to the critical point of the standard Ising-chain model at $\mathsf{H} = 0$ and $\mathsf{T} = 0$ [6].

We illustrate this perspective using as examples the spin-1/2 Ising-XYZ diamond chain and the coupled spin-electron double-tetrahedral chain.We have verified that the pseudo-critical exponents satisfy the following universality relation: $\alpha = \alpha' = \gamma = \gamma' = 3\nu = 3\nu' = 3$ [7].

Further details can be found in Ref. [8].

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K3

Magnetocalorics and quantum entanglement in spin-1/2 molecular magnets with triangle-based geometry

Karol Szałowski*[1] and Pamela Kowalewska[1]

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Abstract

Molecular magnets, especially the single-molecule ones, constitute a highly interesting class of magnetic systems, offering rich physics manifesting itself in a multitude of fascinating phenomena [1]. Among such systems, nanostructures exhibiting magnetic frustration owing to the interplay of geometry and interactions between spins may seem particularly intriguing.

In the paper we discuss our theoretical results concerning two classes of properties: the measures of the magnetocaloric effect and the measures of the quantum entanglement. Our systems of interest are two example single-molecule magnets in which magnetic ions form triangle-based structures. The first one is V6 polyoxovanadate [2], with two weakly interacting triangles with all-antiferromagnetic couplings promoting the frustration, whereas the second one is Cu5 [3], in which spins form a hourglass-like unfrustrated structure. Both systems consist of spins $S = 1/2$ and their essential physics can be captured using the quantum Heisenberg model.

Our study is based on the exact numerical diagonalization of the Hamiltonians and the canonical ensemble formalism [4]. The Hamiltonian parameters are taken from the experimental studies [2, 3]. The magnetocalorics is characterized by isothermal entropy change, whereas the quantum entanglement is quantified by concurrence [5]. The behaviour of both quantities as a function of the temperature and the external magnetic field is extensively discussed.

Acknowledgement

This work has been supported by Polish Ministry of Science and Higher Education on a special purpose grant to fund the research and development activities and tasks associated with them, serving the development of young scientists and doctoral students.

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K4

Peculiarities in pseudo-transition of coupled tetrahedral spin-$(1/2, 1)$ Ising and Heisenberg chain in an external magnetic field

Onofre Rojas*[1], Jozef Strečka[2], Oleg Derzhko[3], and S. M. de Souza[1]

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Abstract

The investigation earlier considered in reference[1, 2] focuses on the spin-1/2 Heisenberg coupled tetrahedral chain. Later, in the references[3, 4] the authors studied the Ising-Heisenberg version of the model. A variant of this model was also investigated[5, 6], where the nodal site is assembled by localized Ising spin, and alternating with a pair of mobile electrons delocalized within a triangular plaquette. Recently, some evidence of "pseudo-critical" temperature was observed in one-dimensional spin models, mainly in Ising-Heisenberg spin models, among others. Here we consider the Ising-Heisenberg coupled tetrahedral chain with mixed spin-(1/2,1) in an external magnetic field.

Here we present the coupled tetrahedral spin-$(1/2, 1)$ Ising-Heisenberg model, and the corresponding Hamiltonian becomes

$$H = -\sum_{i=1}^{N} \left\{ \left(S^z_{a,i} + S^z_{b,i} + S^z_{c,i}\right) \left[h_z + J_0(\sigma_i + \sigma_{i+1})\right] + \tfrac{h}{2}\left(\sigma_i + \sigma_{i+1}\right) \right.$$
$$\left. + J(\boldsymbol{S}_{a,i}, \boldsymbol{S}_{b,i})_z + J(\boldsymbol{S}_{b,i}, \boldsymbol{S}_{c,i})_z + J(\boldsymbol{S}_{c,i}, \boldsymbol{S}_{a,i})_z \right\}, \tag{1}$$

where $J(\boldsymbol{S}_{a,i}, \boldsymbol{S}_{b,i})_z = JS^x_{a,i}S^x_{b,i} + JS^y_{a,i}S^y_{b,i} + J_zS^z_{a,i}S^z_{b,i}$, with $S^\alpha_{a,i}$ denoting the Heisenberg spin-1, and $\alpha = \{x, y, z\}$, while σ_i denotes the Ising spin ($\sigma_i = \pm\frac{1}{2}$). In a similar way the Heisenberg spin-1 operators are defined for sites b and c in (1).

In Fig. 1 the phase diagram exhibits at zero temperature three frustrated (FR) phases, three ferrimagnetic (FI) phases, and one saturated (SA) phase. By dashed lines, we describe the typical interface where usually phase boundary entropy is larger than their adjacent phase entropies. However, solid interface curve represents unusual phase boundaries, because the residual phase boundary is equal to the largest neighboring states[7]. Thus, there are five different interfaces of the system which exhibits pseudo-transitions at finite temperature. Four

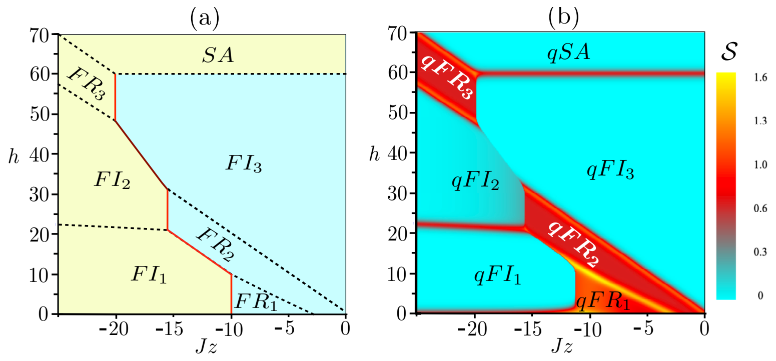

Figure 1: Zero temperature phase diagram in the plane of $J_z - h$, assuming fixed parameters $J = -10$, $J_0 = -10$ and $h_z = h$. (b) Density-plot of entropy $\mathcal{S}$ in the plane $J_z - h$, considering the same set of parameters as in (a) but for temperature $T = 0.4$.

of them are the interface between the ferrimagnetic phase and the frustrated phase, and one interface at the boundary of two types of ferrimagnetic phases.

We can get the free energy of this model through the transfer matrix technique, and result found is an analytic function; then no phase transition must be expected. So the entropy of the system in the low temperature region is discussed. In Fig.1b we illustrate the density plot of the entropy as a function of J_z and h, for a fixed $T = 0.4$, and using the same scale as that of Fig.1a, so we extend the seven phases at zero temperature by quasi-phases adding a prefix "q". Here, we can observe the entropy follows the vestige of zero temperature phase diagram. For all conventional interfaces (dashed lines in (a)) unquestionably, the thermal excitation influences in the phase boundaries and definitely the interface entropies increases faster than their neighboring phases. However, for unusual boundaries there is no increase in the phase boundaries entropy, compared to adjacent frustrated phase, virtually density-plot shows these as sharp boundaries.

Acknowledgement

This work was supported by Brazilian Agency FAPEMIG, CNPq and CAPES.

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Invited lectures

(17 min. talk + 3 min. discussion)

I1

The Ising-Heisenberg model on the distorted Shastry-Sutherland lattice: ground-state properties

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Abstract

The ground-state properties of the distorted Shastry-Sutherland model with the Heisenberg intradimer and Ising interdimer couplings is studied rigorously. We consider the model with different values of the intradimer couplings which depend on their bond orientation. Owing to the specific configuration of the interactions in the Hamiltonian, the z component of the total spin of each Heisenberg dimers is a conserved quantity. Moreover, the Hamiltonian can be reduced to the diagonal (Ising-like) representation by a set of unitary transformations [1] and its ground state is found rigorously. We study the effect of the Heisenberg bond distortion on the ground-state phase diagram of the model. In zero magnetic field a new modulated antiferromagnetic phase emerges in case of rather large distortion between horizontal and vertical bonds. This phase was also observed in the orthogonal-dimer chain, a one-dimensional counterpart of the Shastry-Sutherland model [2]. We also follow the effect of the external magnetic field for the different ratio of the bond distortion. The most remarkable feature is the appearance of the additional 1/4 plateau phase in comparison with the previously studied undistorted variant of the hybrid Shastry-Sutherland model [1]. In the latter case only the phases with the fractional plateaux 1/3 and 1/2 were obtained. In general the distortion of the Heisenberg bonds leads to the suppression of the stripe 1/3-plateau phase in favor of the 1/4- and 1/2-plateau phases.

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I2

Order by disorder in frustrated spin-1/2 Ising-Heisenberg model on triangulated Husimi lattices

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Abstract

The present work deals with the exact solution of the spin-1/2 Ising-Heisenberg model on the triangulated Husimi lattices in zero external magnetic field [1]. The generalized star-triangle mapping transformation and the exact recursion relations is used in the study. In particular, our attention was a rigorous determination of the ground-state and finite-temperature phase diagrams, which is verified by temperature dependences of the sublattice magnetizations of Ising and Heisenberg spins. It is convincingly evidenced that the spin-1/2 Ising-Heisenberg model defined on two closely related triangulated Husimi lattices may display fundamentally different magnetic behavior even if both lattices may differ from each other just in a connectivity of the same structural triangles-in-triangles unit. The spin-1/2 Ising-Heisenberg model on the triangulated Husimi lattices with the coordination number $q = 2$ and 3 exhibits the quantum disorder in a highly frustrated region.

On the other hand, the same model on the greater coordination numbers $q \geq 4$ displays the outstanding order due to the order-by-disorder effect. In addition, it is demonstrated that the spontaneous magnetizations of the Ising and Heisenberg spins undergo a quantum reduction in the peculiar quantum ordered state, which gradually shrinks with increasing a connectivity of the triangles-in-triangles units. The reentrant phase transitions can only be found in the model defined on the triangulated Husimi lattice with the coordination number $q = 3$.

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I3

Magnetoelastic Properties of Ising-Heisenberg Diamond Chain

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Abstract

Recently, considerable attention has been given to the rigorous treatment of various versions of the Ising-Heisenberg diamond chains [1, 2], as well as, the effects of the magnetoelastic coupling on the thermodynamics of lattices [3, 4, 5]. In this work we study the Ising-Heisenberg diamond chain, where the system is composed of two Heisenberg spins (dimer), one nodal Ising spin per unit cell and we assume that the Heisenberg spins are vibrating perpendicularly to the chain axis, while Ising spin are sufficiently rigid and we ignore any possible harmonic vibration. This model is exactly solved by a rigorous treatment based on the transfer-matrix method, using too the canonical coordinate transformation and the harmonic approximation. Our first focus is study the effects magnetoelastic coupling (oscillations) in the phase diagram and in the thermodynamic quantities. After we study the average displacement of dimer spins and average quadratic displacement as function of magnetic field, anisotropic constant and temperature. We verified changes, which depend on the physical parameters, in the phase diagram, thermodynamics, average number of phonons and average displacements.

Acknowledgement

O. Rojas and S. M. de Souza thank CNPq, Capes and FAPEMIG for partial financial support. Jordana Torrico thanks CNPq for financial support. Nayara Ferreira acknowledges Capes for full financial support.

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I4

Majorana bound states affected by Coulomb interaction

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Abstract

The existence of Majorana bound states has been confirmed for various low-dimensional fermion models. A weak electron interaction between fermions could also be considered, provided that Bosonization techniques are introduced by a linear approximation of the dispersion law. In our current study, we investigate the role of the Coulomb interaction on the stability of Majorana fermions. Having considered sufficiently strong repulsive interactions, a possible violation of the exponentially decaying Majorana bound states are addressed. For this purpose we impose both the on-site and the nearest-neighbor repulsive interactions on the system. We analyze the system numerically by the generalized Density Matrix Renormalization Group method without considering any symmetries (apart from the parity, which is conserved only). This spin-fermion model is described by a one-dimensional InSb wire in proximity of a superconductor which incorporates Cooper pairs into the wire. It also requires to include a spatially modulated spin-orbit coupling, Zeeman magnetic field, a tunable chemical potential, and the Coulomb interaction. We present the electron occupancy and the lowest-lying energies with respect to the magnetic field for a given set of model parameters. We graphically evaluate wave functions for the both Majoranas and discuss their stability with respect to the strong Coulomb interaction.

Acknowledgement

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Contributed talks

(12 min. talk + 3 min. discussion)

C1

Complex theory of localised spin systems with variable exchange interaction

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Abstract

Absolute majority of theoretical works in the field of localized magnetic spin systems takes the exchange interactions between relevant atoms of the lattice as a constant. Typical examples of such models are various versions of the Ising, Blume-Capel and Heisenberg models that have been widely studied over many decades. On the other hand, there are reliable experimental data demonstrating that the exchange interaction rapidly changes with the change of the distance between atoms in a crystalline lattice. Therefore the main purpose of our contribution is to develop a simple and versatile theoretical framework capable to account for the magneto-elastic phenomena in the insulating crystalline solids and to show some new results that cannot be observed in the models with constant exchange interactions. For this purpose we have investigated several complex spin models that include not only the magnetic contribution with variable exchange interaction, but also the static lattice energy and the anharmonic vibrational energy. In particular, we will discuss some new results for the phase diagrams of spin-1 Blume-Capel model, spin-1/2 Ising model in a transverse field and 1D XX Heisenberg linear chain.

Acknowledgement

This work has been supported by grants VEGA 1/0531/19 and APVV-16-0186.

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C2

Ising and Potts critical points emergent in a low-temperature magnetization process of a fully frustrated spin-1/2 Heisenberg triangular bilayer

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Abstract

A low-temperature magnetization process and thermodynamics of a fully frustrated spin-1/2 Heisenberg triangular bilayer with the antiferromagnetic intradimer interaction and either ferromagnetic or antiferromagnetic interdimer interaction are investigated in a highly frustrated parameter region, where localized many-magnon eigenstates provide the most dominant contribution to magnetothermodynamics [1]. Low-energy states of the highly frustrated spin-1/2 Heisenberg triangular bilayer can be accordingly found from a mapping correspondence with an effective triangular-lattice spin-1/2 Ising model in a field. A description based on the effective Ising model implies that the frustrated Heisenberg triangular bilayer with the ferromagnetic interdimer coupling displays in a zero-temperature magnetization curve discontinuous magnetization jump, which is reduced upon increasing of temperature until a continuous field-driven phase transition from the Ising universality class is reached at a certain critical temperature. The frustrated Heisenberg triangular bilayer with the antiferromagnetic interdimer coupling contrarily exhibits multistep magnetization curve with intermediate plateaus at 1/3 and 2/3 of the saturation magnetization, whereas discontinuous magnetization jumps observable at zero temperature change to continuous field-driven phase transitions from the universality class of three-state Potts model at sufficiently low temperatures. Exact results and Monte Carlo simulations of the effective Ising model are confronted with full exact diagonalization data for the Heisenberg triangular bilayer in order to corroborate these findings.

Acknowledgement

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C3

Spectacular quantum ground states of a mixed spin-1 and spin-1/2 Heisenberg octahedral chain

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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 is investigated using variational technique, localized magnon approach, exact diagonalization and density-matrix renormalization group method. The investigated model has in a magnetic field an extraordinarily rich ground-state phase diagram, which includes the uniform and cluster-based Haldane phases, two ferrimagnetic phases of Lieb-Mattis type, two quantum spin liquids and two bound magnon crystals in addition to the fully polarized ferromagnetic phase. The lowest-energy eigenstates in a highly-frustrated parameter region belong to flat bands and hence, low-temperature thermodynamics close to discontinuous field-driven quantum phase transitions related to the bound-magnon crystals and ferromagnetic ground states can be satisfactorily described within the localized-magnon approach [1, 2, 3]. The variational method provides an exact evidence for the magnon-crystal phase with a character of the monomer-tetramer ground state at zero magnetic field, while another magnon-crystal phase involving a single magnon bound state at each square plaquette is found in a high-field region. A diversity of quantum ground states gives rise to manifold zero-temperature magnetization curves, which may involve up to four wide intermediate plateaus at zero, one-sixth, one-third and two-thirds of the saturation magnetization in addition to two quantum spin-liquid regions and two tiny plateaus at one-ninth and one-twelfth of the saturation magnetization corresponding to the fragmentized cluster-based Haldane phases.

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C4

Unconventional Low-Temperature Phase in a Frustrated $J_1 - J_2$ Ising Antiferromagnet on a Honeycomb Lattice

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Abstract

Critical behavior of a frustrated $J_1 - J_2$ Ising model with nearest-neighbor (J_1) and next-nearest-neighbor (J_2) antiferromagnetic (AF) interactions on a square lattice has long been a subject of controversy. Nevertheless, more recent studies agreed on that it displays a transition to the AF (Néel) phase, for $R = J_2/J_1 < 1/2$, which belongs to the Ising universality class, and for $R > 1/2$ a transition to the striped or superantiferromagnetic (SAF) phase. The latter is believed to be of very weak first order, for $1/2 < R < R^*$, and showing a critical line of the Ashkin-Teller model, for $R > R^*$, with the estimates of R^* ranging from 1.1 to 0.67 [1, 2, 3, 4, 5].

For the corresponding model on a honeycomb lattice, an effective field theory predicted the existence of the AF phase for $R < 1/4$, with a tricritical behavior, but no long-range ordering was found for $R > 1/4$ [6]. Our present focus is the nature of a low-temperature phase in the honeycomb-lattice $J_1 - J_2$ AF model, for $R > 1/4$, studied by Monte Carlo simulations. Our results suggest the existence of at least one phase transition. The transition to the low-temperature phase is accompanied by a freezing to a highly degenerate state consisting of frozen domains with stripe-type SAF ordering separated by parallel zero-energy domain walls. In spite of the ordering within the respective domains there is no ordering among them and thus, unlike in the corresponding square-lattice model with $R > 1/2$, there is no conventional magnetic long-range ordering spanning the entire system in both horizontal and vertical directions.

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C5

Entanglement-entropy study of phase transitions in six-state clock model

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Abstract

The Berezinskii-Kosterlitz-Thoules (BKT) transitions of the six-state clock model on the square lattice are investigated by means of the corner-transfer matrix renormalization group method. A classical analogue of the entanglement entropy $S(L,T)$ is calculated for L by L square system up to $L = 129$, as a function of temperature T. The entropy exhibits a peak at $T = T^*(L)$, where the temperature depends on both L and the boundary conditions. Applying the finite-size scaling to $T^*(L)$ and assuming presence of the BKT transitions, the two distinct phase-transition temperatures are estimated to be $T_1 = 0.70$ and $T_2 = 0.88$. The results are in agreement with earlier studies. It should be noted that no thermodynamic functions have been used in this study.

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Short communications

(4 min. talk + 1 min. discussion)

S1

Critical Behavior of Geometrically Frustrated Generalized XY Model

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Abstract

Despite the absence of any true long-range ordering in the standard two-dimensional XY model, there is a transition to the quasi-long-range ordered (QLRO) phase with a power-law decaying correlation function that belongs to the Kosterlitz-Thouless (KT) universality class [1]. Generalization of this model by inclusion of a (pseudo)nematic q-order coupling into the Hamiltonian, i.e. $H = -J_1 \sum_{\langle i,j \rangle} \cos(\phi_i - \phi_j) - J_q \sum_{\langle i,j \rangle} \cos[q(\phi_i - \phi_j)]$, where $\phi_i - \phi_j$ is an angle between neighboring spins, leads for $q = 2$ to an additional phase transition belonging to the Ising universality class between ferromagnetic (F) and nematic (N) phases, for $J_1 > 0$ and $J_2 > 0$ [2], and antiferromagnetic (AF) and antinematic (AN) phases, for $J_1 < 0$, $J_2 < 0$ [3]. In the model with the F-N couplings inclusion of higher-order harmonics with $q \geq 5$ has surprisingly lead to a change of the phase diagram topology featuring new QLRO phases resulting from the competition between the ferromagnetic and pseudonematic terms [4].

In the present study, effects of geometrical frustration are investigated in such a generalized XY model by considering it on a triangular lattice with the AF-AN couplings. In particular, we consider higher-order ($q > 2$) AN interaction and study how the increasing value of the parameter q affects the phase diagram. The ground states of these models have recently suggested an interesting behavior with potential interdisciplinary applications [5]. Here we demonstrate that, unlike in the F-N case, inclusion of the higher-order terms leads to an overall change of the phase diagram topology already for $q = 3$, by introducing a complex noncollinear QLRO phase at lower temperatures wedged between the AF and AN phases.

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S2

Magnetoelectric effect of the exactly solved spin-electron model on a doubly decorated square lattice

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Abstract

The magnetoelectric properties of the coupled spin-electron model on the doubly decorated square lattice are rigorously investigated in the framework of the generalized decoration-iteration transformation [1, 2]. The phase diagrams, spontaneous magnetizations as well as electric dipole moment are comprehensively analyzed under the influence of temperature and electric field. It is found that, the increasing electric field at zero temperature leads to the stabilization of the antiferromagnetic order instead of the ferromagnetic one. At finite temperature, the increasing electric field has a reduction effect on the stability of magnetic-ordered phases and is responsible for an existence of a sharp kink in thermal phase diagram close to a quarter filling. Moreover, an enhanced magnetoelectric response is detected in the vicinity of the continuous phase transition at which the spontaneous magnetizations fadeout, whereas the electric dipole moment exhibits a weak-type of singularity.

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S3

Crossover from Two- to Three-Dimensional Kagome Lattice Ising Antiferromagnet

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Abstract

An Ising antiferromagnet on a kagome lattice (IAKL) is a well-known spin system with a large degree of geometrical frustration, resulting in no long-range ordering (LRO) at any temperature [1]. Its counterpart on a triangular lattice (IATL) is another paradigmatic example of a geometrically frustrated system with no LRO. Nevertheless, the latter has been shown to be rather sensitive to various perturbations, such as further-neighbor interactions or the presence of nonmagnetic impurities or dimensional crossover to 3D by vertical stacking of IATL planes, which relieve frustration and eventually can lead to LRO [2]. Recently, it has been demonstrated that critical behavior can also be induced by stacking of a finite number of IATL planes in the form of the reentrance of two Berezinskii-Kosterlitz-Thouless (BKT) transitions or even true LRO in the form of a partially disordered antiferromagnetic phase [3].

Similar investigations have also been performed for the stacked Heisenberg antiferromagnet on the kagome lattice (SHAKL) [4]. It has been found that if interlayer interactions are strong enough magnetic LRO can be established in the 3D model. Motivated by the dimensional crossover phenomena observed in both the IATL and SHAKL models we studied possibility of the emergence of any critical behavior either of the BKT type or true LRO in the layered IAKL model obtained by gradual stacking of the 2D planes on top of each other. Unlike in the IATL case, our preliminary Monte Carlo calculations on spin systems with rather limited lattice sizes showed no signs of any true or quasi-LRO as a result of stacking of a finite or infinite number of the 2D planes neither by increasing of the interlayer interaction strength.

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S4

Interpenetrating Skyrmion Crystals in a Geometrically Frustrated Triangular Lattice Heisenberg Antiferromagnet

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Abstract

Spiral spin field patterns possessing the property of being topologically protected, so-called magnetic skyrmions, have recently drawn much interest due to their small size of order of couple of nm, stability and sensitivity to currents with surprisingly low density [1]. In the past years, it was shown that such structures can be produced in many magnetic materials [2, 3]. Skyrmions formation can be driven by different mechanisms that cause the inversion symmetry breakdown in the system, such as the Dzyaloshinskii-Moriya interaction (DMI) [4]. These spin textures where mostly investigated in ferromagnetic systems but recent studies have shown that they can also be stabilized in antiferromagnets, for example, due to the weak next-nearest neighbor interaction [5].

Currently, we focus on a frustrated Heisenberg antiferromagnet on a triangular lattice in the presence of the DMI and an external magnetic field, which has been demonstrated to display an antiferromagnetic skyrmion phase on three different interpenetrating sublattices within some range of the field for sufficiently strong DMI [6]. We perform Monte Carlo simulations in a wide parameter space in effort to determine the phase diagram with the focus laid on the skyrmion phase. The latter is identified based on a lattice topological charge as an order parameter. Study of the stability of the skyrmion crystals, measured as their persistence after the external stabilizing magnetic field is turned off, pointed to their relative robustness.

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S5

Magnetism of the diluted Ising antiferromagnet in a magnetic field on the Kagome lattice: single-spin cluster approximation

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Abstract

An effective-field theory based on the single-spin cluster has been used in order to study diluted spin-1/2 Ising antiferromagnet on the Kagome lattice with nearest-neighbor interactions. We observe five plateaus in the magnetization curve of the diluted antiferromagnet when a magnetic field is applied which is in agreement with Monte Carlo data. The effect of the site- dilution on the magnetic susceptibility is also investigated. Our results are consistent with $T = 0$K being a critical point for this model system.

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S6

Nonuniversality of symmetric 16-vertex model

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Abstract

A symmetric 16-vertex model with a single parameter ε is studied by the Corner Transfer Matrix Renormalization Group method on the square lattice. The parameter ε (associated with the energies of the non-eight-vertex Boltzmann weights $w = e^{-\varepsilon}$) is allowed ti vary in range $0 \leq \varepsilon < +\infty$. The Ising and the 8-vertex universality classes are satisfied if $\varepsilon \to 0$ and $\varepsilon \to +\infty$, respectively. We determined an intermediate region, $2 < \varepsilon < 14$, with a strong nonuniversal behavior of the critical exponents.

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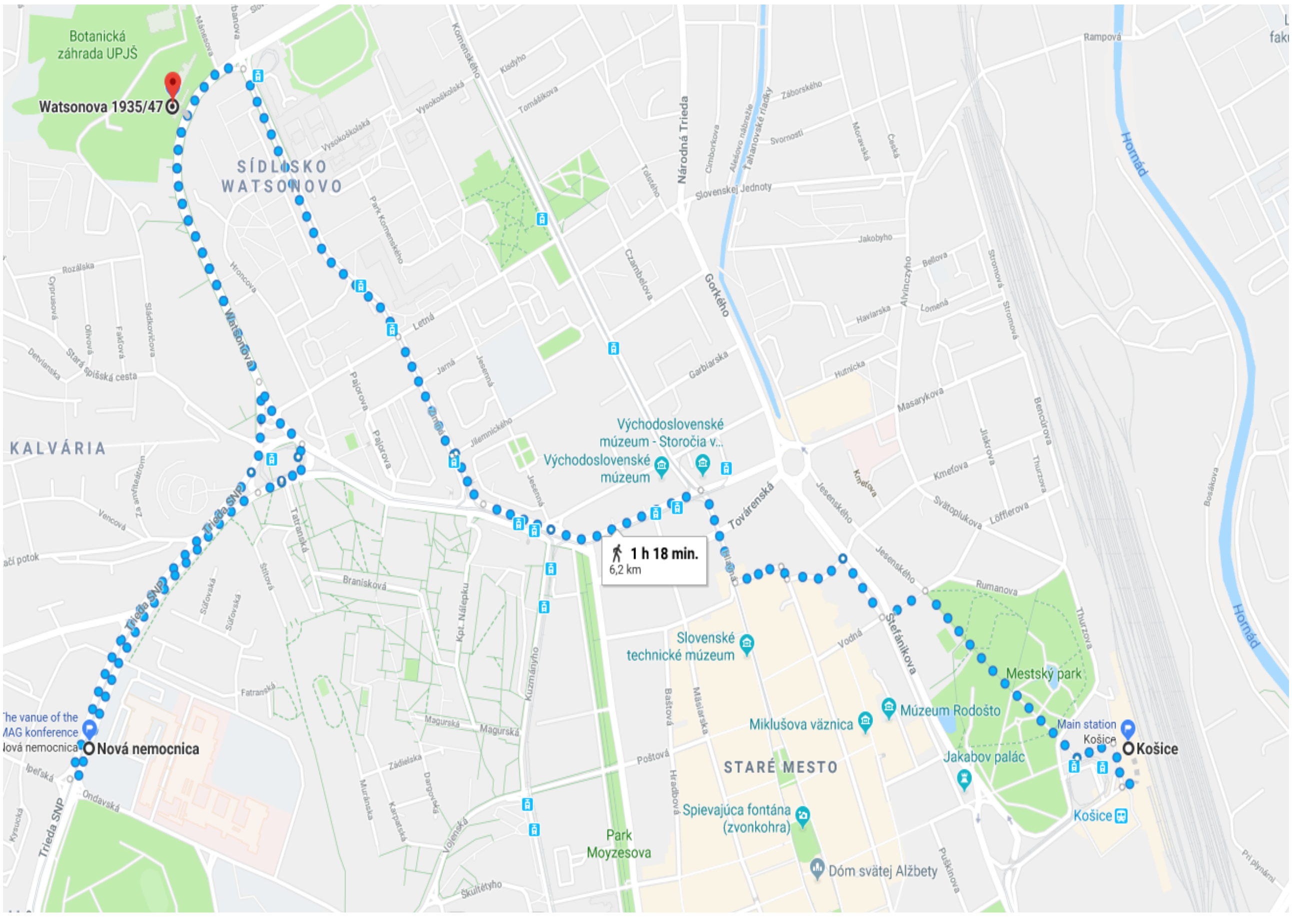

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Notes

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