TT 86: Correlated Magnetism – Spin Liquids II

Time: Thursday 15:00–16:45 Location: CHE/0091

TT 86.1 Thu 15:00 CHE/0091

Classical spin liquids from frustrated Ising models in hyperbolic space — •Fabian Köhler[1], Johanna Erdmenger[2], Roderich Moessner[3], and Matthias Vojta[1] — [1]Institut für Theoretische Physik and Würzburg-Dresden Cluster of Excellence ct.qmat, Technische Universität Dresden, 01062 Dresden, Germany — [2]Institute for Theoretical Physics and Astrophysics and Würzburg-Dresden Cluster of Excellence ct.qmat, Julius-Maximilians-Universität Würzburg, Am Hubland, 97074 Würzburg, Germany — [3]Max-Planck-Institut für Physik komplexer Systeme and Würzburg-Dresden Cluster of Excellence ct.qmat, Nöthnitzer Str. 40, 01187 Dresden

Antiferromagnetic Ising models on frustrated lattices can realize classical spin liquids, with highly degenerate ground states and, possibly, fractionalized excitations and emergent gauge fields. Moti- vated by the recent interest in many-body system in negatively curved space, we study hyperbolic frustrated Ising models. Specifically, we consider nearest-neighbor Ising models on tesselations with odd-length loops in two-dimensional hyperbolic space. For finite systems with open boundaries we determine the ground-state degeneracy exactly, and we perform extensive finite-temperature Monte-Carlo simulations to obtain thermodynamic data as well as correlation functions. We show that the shape of the boundary, constituting an extensive part of the system, can be used to control low-energy states: Depending on the boundary, we find ordered or disordered ground states. Our results demonstrate how geometric frustration acts in curved space to produce classical spin liquids.

TT 86.2 Thu 15:15 CHE/0091

Unconventional Spin Dynamics and Supersolid Excitations in the Triangular-Lattice XXZ Model — •Rafael Alvaro Flores Calderon[1], Roderich Moessner[2], and Frank Pollmann[1] — [1]Department of Physics, Technical University of Munich, 85748 Garching, Germany — [2]Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Strasse 38, D-01187 Dresden, Germany

Motivated by recent experiments, we investigate the spin-1/2 XXZ model on the triangular lattice with strong Ising anisotropy, combining large-scale numerical simulations and analytical methods to uncover unconventional spin dynamics at $T = 0$. First, we compute the dynamical spin structure factor using density matrix renormalization group (DMRG) simulations and find excellent agreement with inelastic neutron scattering data on the layered compound $K_2Co(SeO_3)_2$. The low-energy spectrum reveals a roton-like minimum at the M point, absent in linear spin-wave theory, accompanied by peak intensity and a broad continuum above it. Near the Γ point, we observe an approximately linear dispersion with vanishing spectral weight. Second, we compare multiple analytical frameworks that reproduce the observed features. Remarkably, a variational supersolid QDM wavefunction and the DMRG ground state exhibit nearly identical structure factors with pronounced transverse photon-like excitations. Together, our comprehensive theoretical and numerical analysis elucidates the microscopic origin of supersolid excitations in the XXZ triangular lattice model and their proximity to a spin liquid phase observed experimentally.

TT 86.3 Thu 15:30 CHE/0091

Magnetization-driven spinon Landau levels and ordering instabilities in a Dirac spin liquid — Wen Wang[1], •Urban F.P. Seifert[2], Oleg A. Starykh[3], and Leon Balents[1] — [1]Kavli Institute for Theoretical Physics, University of California, Santa Barbara, California 93106-4030, USA — [2]Institute for Theoretical Physics, University of Cologne, Zülpicher Str. 77a, 50937 Cologne, Germany — [3]Department of Physics and Astronomy, University of Utah, Salt Lake City, UT 84112, USA

A particularly fascinating example of a quantum spin liquid is the U(1) Dirac spin liquid (DSL), which at low energies is described by emergent quantum electrodynamics (QED3), a strongly coupled conformal field theory. Motivated by recent numerical evidence for its realization in triangular lattice J1-J2 Heisenberg antiferromagnets as well as the identification of several candidate materials, we revisit the problem of the U(1) DSL in a Zeeman magnetic field. Equipped with recent numerical and field-theoretical insights into the field-induced behaviour of the QED3 low-energy theory, we analyze a microscopic (lattice) model using Gutzwiller-projected wavefunctions. We analyze how the applied field may induce an instability towards in-plane antiferromagnetic ordering, and discuss observables that may be unique to such a field-induced state. In experiments, these may allow one to infer the presence of an underlying DSL at zero field.

TT 86.4 Thu 15:45 CHE/0091

Monopole condensation in U(1) Dirac spin liquids: AFM and VBS orders — •João C. Inácio[1] and Fakher Assaad[1,2] — [1]Institut für Theoretische Physik und Astrophysik, Universität Würzburg, 97074 Würzburg, Germany — [2]Würzburg-Dresden Cluster of Excellence ct.qmat, Am Hubland, 97074 Würzburg, Germany

Quantum spin liquids are states of matter where quantum fluctuations prohibit magnetic order down to zero temperature. Such states cannot be described by conventional mean-field theories. In U(1) Dirac spin liquids (DSL), the low-energy degrees of freedom are emergent gauge fields coupled to fractionalised spinon excitations. Spinons behave like Dirac fermions coupled to a compact U(1) gauge field, giving rise to QED_3. Within this framework instanton excitations of the gauge fields, i.e. monopoles, are central to understand the spin liquid state. Monopoles carry antiferromagnetic (AFM) or valence bond solid (VBS) charge leading to a Dirac mass upon their condensation, creating a large competition between different magnetic orders. We study a U(1) lattice gauge theory coupled to phonons by the means of exact fermionic quantum Monte Carlo simulations in order to understand this competition. By doing a scan over the spinon-phonon coupling (g) and the gauge field fluctuations (J) we are able to create a phase diagram where AFM, VBS and DSL phases coexist.

TT 86.5 Thu 16:00 CHE/0091

Exactly solvable spin liquids in Kitaev bilayers and moiré superlattices — •Ivan Dutta[1,2], Anamitra Mukherjee[1,2], Onur Erten[3], and Kush Saha[1,2] — [1]National Institute of Science Education and Research, Jatni, 752050, India — [2]Homi Bhabha National Institute, Training School Complex, Anushakti Nagar, Mumbai 400094, India — [3]Department of Physics, Arizona State University, Tempe, Arizona 85287, USA

Building on the recent advancements on moiré superlattices, we propose an exactly solvable model with Kitaev-type interactions on a bilayer honeycomb lattice for both AA stacking and moiré superlattices. Employing Monte Carlo simulations and variational analysis, we uncover a rich variety of phases where the intra and interlayer Z2 fluxes (visons) are arranged in a periodic fashion in the ground state, tuned by interlayer coupling and out-of-plane external magnetic field. We further extend our model to moiré superlattices at various commensurate twist angles around two distinct twist centers represented by C3z and C6z of the honeycomb lattice. Our simulations reveal generalized patterns of plaquette values correlated with the AA or AB stacking regions across the moiré unit cell. In addition, depending on the twist angle, twist center and interlayer coupling, moiré superlattices exhibit a variety of gapped and gapless spin liquid phases and can also host corner and edge modes. Our results highlight the rich physics in bilayer and twisted bilayer models of exactly solvable quantum spin liquids.

TT 86.6 Thu 16:15 CHE/0091

N-state Potts ices as generalizations of classical and quantum spin ice — •Mark Potts[1], Roderich Moessner[1], and Siddharth Parameswaran[2] — [1]Max Planck Institute for the Physics of Complex Systems, Dresden, Germany — [2]Rudolf Peierls Centre for Theoretical Physics, Oxford, UK

Classical and quantum spin ice models are amongst the most popular settings for the study of spin liquid physics. N-state Potts ice models have been constructed that generalize spin ice, hosting multiple emergent U(1) gauge fields and excitations charged under non-trivial combinations of these fields. We present a general treatment of classical N-state Potts ices relating their properties to the su(N) Lie algebras, and demonstrate how the properties of charged excitations in the classical model can be related to this symmetry group. We also introduce quantum generalizations of the Potts Ice models, and demonstrate how charge flavour changing interactions unique to $N > 2$ models dominate their low energy phase diagram. We further show how symmetries inherited from the su(N) algebra can lead to the frustration of flux vacuum states.

TT 86.7 Thu 16:30 CHE/0091

Phases and dynamics of the quadrupolar Kitaev model —
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The study of multipolar exchange interactions for local spin moments ($S > \frac{1}{2}$) has rapidly expanded in recent years. A crucial inquiry in this research landscape is whether the concept of quantum spin liquid can be generalized to multipolar liquids where multipolar moments fractionalize, giving rise to novel emergent phenomena. Recently, a model involving frustrated quadrupolar interactions between local $S = 1$ moments has been numerically shown to host a deconfined phase with $\mathbb{Z}_2$ topological order. We investigate various phases and dynamics of this model using a combination of mean-field and perturbative methods.

We first analytically demonstrate the existence of an extensively large set of ground states by probing the bare Hamiltonian with trivial deformations within the framework of generalized spin wave theory. The extensive degeneracy can be explained by the explicit construction of mean field ground states. These mean field ground states map to emergent electrostatics and can be divided into topological sectors in periodic boundary condition. Although perturbative analysis for anisotropic exchange coupling does not exhibit any evidence of deconfined excitations or topological ground state degeneracy, using parton analysis we can show that near the isotropic point the system hosts fractionalized gauge excitations. Finally, using parton mean field theory, we analyze the spectrum and various correlation functions.