SYQC 3: Quantum Cooperativity (joint session Q/SYQC)

Time: Friday 10:30–12:30 Location: Q-H15

SYQC 3.1 Fri 10:30 Q-H15

Interplay of periodic dynamics and noise: insights from a simple adaptive system — •Frederic Folz[1], Kurt Mehlhorn[2], and Giovanna Morigi[1] — [1]Theoretische Physik, Universität des Saarlandes, 66123 Saarbrücken, Germany — [2]Algorithms and Complexity Group, Max-Planck-Institut für Informatik, Saarland Informatics Campus, 66123 Saarbrücken, Germany

We study the dynamics of a simple adaptive system in the presence of noise and periodic damping. The system is composed by two paths connecting a source and a sink, the dynamics is governed by equations that usually describe food search of the paradigmatic Physarum polycephalum. In this work we assume that the two paths undergo damping whose relative strength is periodically modulated in time and analyse the dynamics in the presence of stochastic forces simulating Gaussian noise. We identify different responses depending on the modulation frequency and on the noise amplitude. At frequencies smaller than the mean dissipation rate, the system tends to switch to the path which minimizes dissipation. Synchronous switching occurs at an optimal noise amplitude which depends on the modulation frequency. This behaviour disappears at larger frequencies, where the dynamics can be described by the time averaged equations. Here, we find metastable patterns that exhibit the features of noise-induced resonances.

SYQC 3.2 Fri 10:45 Q-H15

A software pipeline for simulating and evaluating incoherent diffraction imaging — •Sebastian Karl[1], Stefan Richter[1], Fabian Trost[2], Henry Chapman[2], Ralf Röhlsberger[3], and Joachim von Zanthier[1] — [1]University of Erlangen-Nuremberg, Staudtstr. 1, 91058 Erlangen — [2]Center for Free-Electron Laser Science, Notkestraße 85, 22607 Hamburg — [3]Helmholtz-Institute Jena, Max-Wien-Platz 1, 07743 Jena

Conventional x-ray crystallography relies on coherent scattering for high resolution structure determination. However often the predominant scattering mechanism is an incoherent process like fluorescence, introducing severe background in the coherent diffractogram. Incoherent diffractive imaging (IDI) aims to use this incoherently scattered light for structure determination by measuring second order correlations n the far field [1]. While in theory single shot 3d imaging would be possible using IDI, careful theoretical examinations place thresholds on its feasibility in both the high [2] and low [3] photon limit. We present a software pipeline facilitating simulation and evaluation of IDI images of structures ranging from crystals to mircometer-size masks. Since this pipeline is able to account for mode mixing identified as the main obstacle in [3], it enables realistic estimations of necessary photon fluxes and image shot numbers for IDI experiments.

[1] A. Classen et al, PRL 119, 053401, 2017
[2] F. Trost et al., New J. Phys. 22, 083070, 2020
[3] L. M. Lohse, Acta Cryst. A 77, 480-496, 2021

SYQC 3.3 Fri 11:00 Q-H15

Twisted matter waves and reference frame motions. — •Alexey Okulov — Russian Academy of Sciences, 119991, Moscow, Russia

When superfluid is loaded in helical trap the external disturbances affect translational and rotational dynamics in nontrivial way. The conventional approach is to consider reference frame transformations corresponding to translations, rotations and linear accelerations. In mean-field Gross-Pitaevskii equation with a weakly modulated linear velocity, rotation and free-fall acceleration it is possible to obtain exact solutions which connect linear displacements of reference frame $\vec{V}$ to rotations of atomic ensemble and vise versa rotations of reference frame $\vec{\Omega}_{\oplus}$ are the cause of linear displacements of ensemble. Linear accelerations being equivalent to gravitational force induce phase modulation of macroscopic wavefunction.

SYQC 3.4 Fri 11:15 Q-H15

Quantum criticality of the long-transverse-field Ising model extracted by Quantum Monte Carlo simulations — •Jan Alexander Koziol, Anja Langheld, Sebastian C. Kapfer, and Kai Phillip Schmidt — Lehrstuhl für Theoretische Physik I, Staudtstraße 7, Friedrich-Alexander Universität Erlangen-Nürnberg, D-91058 Erlangen, Germany

The quantum criticality of the ferromagnetic transverse-field Ising model with algebraically decaying interactions is investigated by means of stochastic series expansion quantum Monte Carlo, on both the one-dimensional linear chain and the two-dimensional square lattice. Utilizing finite-size scaling (FSS), we extract the full set of critical exponents as a function of the decay exponents of the long-range interactions. We resolve the three different regimes predicted by field theory, ranging from the nearest-neighbor Ising to the long-range Gaussian universality classes with an intermediate regime giving rise to a continuum of critical exponents. Focusing on the non-trivial intermediate regime, we verify our study by the well-known limiting regimes. In the long-range Gaussian regime, we treat the effect of dangerous irrelevant variables on the homogeneity laws by means of a modern FSS formalism.

SYQC 3.5 Fri 11:30 Q-H15

Measuring the temperature of laser-cooled ions via resonance fluorescence — •Marvin Gajewski[1], Giovanna Morigi[1], Walther Hahn[2,3], Sebastian Wolf[4], Wenbing Li[2,4], Christoph Düllmann[2,4,5], Dmitry Budker[2,4,6], and Fedinand Schmidt-Kaler[4,2] — [1]Saarland University, Saarbrücken, Germany — [2]Helmholtz-Institut, Mainz, Germany — [3]IQOQI, Innsbruck, Austria — [4]Johannes Gutenberg-Universität, Mainz, Germany — [5]GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany — [6]University of California, Berkeley, USA

The fluorescence light emitted by atoms and ions carries information about their mechanical motion. We show how the temperature of an ion crystal could be inferred from the resonance fluorescence: By means of a theoretical formalism we identify the optimal conditions on saturation and detuning at which this thermometry is most efficient. We then argue that this theory is not only relevant for experimental identification of intruder ions traversing or captured in a large ion crystal, but also for investigating the heat capacity of such mesoscopic systems.

SYQC 3.6 Fri 11:45 Q-H15

Finite-Size Scaling at Quantum Phase Transitions Above the Upper Critical Dimension — •Anja Langheld, Jan Alexander Koziol, Patrick Adelhardt, Sebastian C. Kapfer, and Kai Phillip Schmidt — Lehrstuhl für Theoretische Physik I, Staudtstraße 7, Friedrich-Alexander Universität Erlangen-Nürnberg, D-91058 Erlangen, Germany

We present a modern formalism for finite-size scaling (FSS) at quantum phase transitions (QPT) above the upper critical dimension. The upper critical dimension becomes experimentally accessible, for instance, in systems with long-range interactions such as the long-range transverse-field Ising model, which can be realized in systems of trapped ions. In general, FSS at phase transitions above the upper critical dimension requires a special treatment as dangerous irrelevant variables (DIV) lead to modifications in the homogeneity laws, thereby causing the breakdown of hyperscaling and standard FSS. Following the recently developed Q-FSS formalism addressing this issue for thermal phase transitions, we transfer the idea to QPT while stressing the subtle differences and connections to the classical version. By relaxing the long-standing belief that the correlation length is unaffected by DIV, the presented FSS formalism fixes the aforementioned issues above the upper critical dimension and recovers a generalized hyperscaling relation. The influence of DIV on the correlation length is explicitly confirmed using numerical calculations of the long-range transverse-field Ising model.

SYQC 3.7 Fri 12:00 Q-H15

Cavity-induced long-range interactions in strongly correlated systems — •Paul Fadler[1], Jiajun Li[2], Kai Phillip Schmidt[1], and Martin Eckstein[1] — [1]Friedrich-Alexander Universität Erlangen-Nürnberg — [2]Paul Scherrer Institut

In recent years, the coupling of optical cavity modes to solid states systems has emerged as a possible way to control material properties. Here we investigate cavity-induced long-range interactions between spins in a Mott insulator, which are a new feature of the coupling to the quantized cavity field and are absent in the control of magnetism by classical light. In detail, we show that coupling a cavity mode to the Fermi-Hubbard model at half filling leads to long-range four-spin terms in the effective low spin model at large onsite-interaction U, in addition to the conventional local antiferromagnetic Heisenberg exchange interaction. To obtain these long-range interactions, we compare exact diagonalization, a perturbative approach based on the effective spin-photon Hamiltonian description of the system, and fourth-order perturbation theory in the Hubbard model. We show that knowing the phenomenologically determined spin-photon matrix elements is not sufficient to derive the photon-mediated spin-interactions; instead, long-range interactions are additionally mediated via virtual intermediate states, that involve multiple excitations in the charge sector. A similar point should be kept in mind for deriving photon-mediated long-range interactions between emergent low-energy degrees of freedom in interacting systems in general.

SYQC 3.8 Fri 12:15 Q-H15

Quantum Criticality of the long-range antiferromagnetic Heisenberg ladder — •Patrick Adelhardt and Kai Phillip Schmidt — FAU Erlangen-Nürnberg, Germany

The Mermin-Wagner theorem excludes the breaking of a continuous symmetry in one-dimensional spin systems at zero temperature for sufficiently short-ranged interactions. Introducing algebraically decaying long-range couplings on the antiferromagnetic Heisenberg two-leg ladder, we show that a direct second-order quantum phase transition between the topologically ordered rung-singlet phase in the short-range limit and a conventionally Néel-ordered antiferromagnet can be realized in a one-dimensional system. We study the quantum-critical breakdown in the rung-singlet phase using the method of perturbative continuous unitary transformations (pCUT) on white graphs in combination with classical Monte Carlo simulations for the graph embedding in the thermodynamic limit supplemented with linear spin-wave calculations and exact diagonalization to extract the critical point. Exploiting (hyper-)scaling relations, the pCUT method is used to determine the entire set of canonical critical exponents as a function of the decay exponent. We find that the critical behavior can be divided into a long-range mean-field regime and a regime of continuously-varying exponents similar to the long-range transverse-field Ising model despite the presence of distinct orders on different sides of the critical point and the absence of criticality in the short-range limit.