# Q 9: Quantum gases (Bosons) I

Time: Monday 14:00–16:00 Location: e214

**Invited Talk** Q 9.1 Mon 14:00 e214

**Critical dynamics and prethermalization in lattice gauge theories** — •Jad Halimeh[1,2,3] and Philipp Hauke[1,2,3] — [1]Kirchhoff Institute for Physics, Ruprecht-Karls-Universität Heidelberg, Im Neuenheimer Feld 227, 69120 Heidelberg, Germany — [2]Institute for Theoretical Physics, Ruprecht-Karls-Universität Heidelberg, Philosophenweg 16, 69120 Heidelberg, Germany — [3]Department of Physics, University of Trento, Via Sommarive 14, 38123 Povo (TN), Italy

Local gauge invariance is always violated to some extent in quantum simulation experiments. A rigorous understanding of gauge-invariance violation and how to protect against it are thus of paramount importance. We present analytic and numerical results showing that gauge-invariance violation in a quantum simulator resulting from inherent gauge-noninvariant processes grow only perturbatively at short times, before entering long-lived prethermal plateaus, and eventually settling at long times into an equal admixture of all gauge-invariant sectors of the system. An energy constraint penalizing terms driving the system away from the initial gauge-invariant sector suppresses the violation up to infinite times. In congruence with our numerical results that show that this suppression is independent of system size, we argue analytically why this suppression will hold even in the thermodynamic limit. Finally, we present experimental results for the quantum simulation of a U(1) quantum link model mapping on a single-species bosonic lattice, where we sweep through a quantum phase transition and certify the emergent gauge-invariant dynamics.

Q 9.2 Mon 14:30 e214

**Anomalous Floquet topological phases in periodically-driven hexagonal lattices** — •Karen Wintersperger[1,2], Christoph Braun[1,2,3], Immanuel Bloch[1,2,3], and Monika Aidelsburger[1,2] — [1]Ludwig-Maximilians-Universität, Schellingstraße 4, 80799 München — [2]Munich Center for Quantum Science and Technology (MCQST), Schellingstraße 4, 80799 München — [3]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching

Ultracold atoms in periodically-driven optical lattices can be used to simulate systems with nontrivial topological properties. Due to the periodic driving, energy conservation is relaxed which makes it possible to realize systems with properties that go beyond those of conventional static systems. For instance, chiral edge modes can exist even if the bulk is topologically trivial [1].

We study such anomalous Floquet phases experimentally using a BEC of K39 in an optical honeycomb lattice with periodically modulated tunnel couplings. By monitoring the closing and reopening of energy gaps in the band structure we are able to track the transitions between different Floquet phases. Moreover, we probe the topological porperties of the bulk by measuring the Hall deflection induced by local changes in the Berry curvature. Combining these measurements enables us to extract the topological invariants of the bulk bands and the energy gaps, which are both required to accurately classify the topological phases of Floquet systems [2, 3].

[1] T. Kitagawa et al., Phys. Rev. B 82, 235114 (2010) [2] M. Rudner et al., PRX 3, 031005 (2013) [3] N. Ünal et al., PRL 122, 253601 (2019)

Q 9.3 Mon 14:45 e214

**Floquet-Induced Superfluidity with Periodically Modulated Interactions of Two-Species Hardcore Bosons in a One-dimensional Optical Lattice** — Tao Wang[1], Shijie Hu[2], Sebastian Eggert[2], Michael Fleischhauer[2], •Axel Pelster[2], and Xue-Feng Zhang[3] — [1]Hubei Key Laboratory of Optical Information and Pattern Recognition, Wuhan Institute of Technology, China — [2]Physics Department and Research Center OPTIMAS, Technische Universität Kaiserslautern, Germany — [3]Department of Physics, Chongqing University, China

We consider two species of hard-core bosons with density dependent hopping in a one-dimensional optical lattice, for which we propose experimental realizations using time-periodic driving. The quantum phase diagram for half-integer filling is determined by combining different advanced numerical simulations with analytic calculations. We find that a reduction of the density-dependent hopping induces a Mott-insulator to superfluid transition. For negative hopping a previously unknown state is found, where one species induces a gauge phase of the other species, which leads to a superfluid phase of gauge-paired particles. The corresponding experimental signatures are discussed.

Q 9.4 Mon 15:00 e214

**Scaling analysis of localization effects in the disordered two-dimensional Bose-Hubbard-model** — •Andreas Geissler[1,2] and Guido Pupillo[1,3] — [1]ISIS, University of Strasbourg, Strasbourg, France — [2]Institut für Theoretische Physik, Goethe-Universität, Frankfurt am Main, Germany — [3]IPCMS, University of Strasbourg, Strasbourg, France

Recent experiments have shown signatures of many-body localization (MBL) in the disordered Bose-Hubbard model in one and two dimensional ultra cold atomic lattice gases [1] as well as the related superfluid to Bose-glass transition in three dimensions [2]. A proper theoretical understanding of the MBL phenomenon depends on knowledge about the full eigenstate spectrum. Therefore, exact numerical studies have been limited to small system sizes. In contrast, the Bose-glass phase can already be understood via the ground state. So, by applying the fluctuation operator expansion method [3] to obtain beyond mean-field insight into the full fluctuation spectrum, we have performed a scaling analysis of both phenomena within a single framework. With the collection of obtained critical points, we are able to map out a phase diagram showing no direct superfluid to fully localized transition due to the intermediate Bose-glass phase. We further discuss the scaling of correlations for various quenches.

[1] C. D'Errico et al., PRL 113, 095301 (2014); J.-y. Choi et al., Science 352, 1547 (2016)
[2] C. Meldgin et al., Nature Physics 12, 646 (2016)
[3] A. Geissler et al., PRA 98, 063635 (2018)

Q 9.5 Mon 15:15 e214

**Eigenstate versus Spectral Structure of Interacting Bosons on a Lattice** — •Lukas Pausch[1], Edoardo Carnio[1], Alberto Rodríguez[1,2], and Andreas Buchleitner[1] — [1]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Straße 3, D-79104 Freiburg, Germany — [2]Departamento de Física Fundamental, Universidad de Salamanca, Plaza de la Merced, E-37008 Salamanca, Spain

We study the transition from regular to chaotic spectral and eigenvector structure in the Bose-Hubbard Hamiltonian. Using the framework of generalized fractal dimensions to characterize the eigenstates' localisation properties in Fock space, we show that the change of the latter with the ratio of tunneling to interaction strength correlates with a qualitative change of the energy level statistics: In the regime of fully developed spectral chaos each individual eigenstate delocalizes over the entire Fock basis. This is corroborated by a very narrow distribution of generalized fractal dimensions, which becomes ever sharper as the Hilbert space dimension is increased.

Q 9.6 Mon 15:30 e214

**Macroscopic boundary effects in the one-dimensional extended Bose-Hubbard model** — •Sebastian Stumper, Junichi Okamoto, and Michael Thoss — Insitute of Physics, University of Freiburg, Freiburg, Germany

We study the effect of different open boundary conditions on the insulating ground states of the one-dimensional extended Bose-Hubbard model at and near unit filling. To this end, we employ the density matrix renormalization group method. To characterize the system, various order parameters and entanglement entropies are calculated. When opposite edge potentials are added to the two ends of the chain, the inversion symmetry is explicitly broken, and the bulk phases appear. On the other hand, simple open boundary conditions often exhibit non-degenerate ground states with a domain wall in the middle of the chain, which induces a sign-flip of an order parameter. Such a domain wall can lead to an algebraic behavior of the off-diagonals of the single particle density matrix. We show that this algebraic behavior adds only a finite contribution to the entanglement entropy, which does not diverge as the system size increases. Therefore, it is not an indication of a superfluid phase. We confirm this picture by analytical calculations based on an effective Hamiltonian for a domain wall.

Q 9.7 Mon 15:45 e214

**Superfluid phases of dipolar gases in low dimensions** — •Rebecca Kraus[1], Krzysztof Biedroń[2], Jakub Zakrzewski[2,3], and Giovanna Morigi[1] — [1]Theoretische Physik, Universität des Saarlandes, D-66123 Saarbrücken, Germany — [2]Instytut Fizyki imienia Mariana Smoluchowskiego, Uniwersytet Jagielloński, Łojasiewicza 11, 30-048 Kraków, Poland — [3]Mark Kac Complex Systems Research Center, Jagiellonian University, Łojasiewicza 11, 30-348 Kraków, Poland

We determine the quantum ground state of ultracold dipolar bosons by means of DMRG. The bosons are confined in an optical lattice in a quasi-one dimensional geometry, their dynamics is modeled by an extended Bose-Hubbard model whose terms and coefficients account for the power-law decay of the dipolar potential and of its spatial anisotropy. We show that the dipolar interactions give rise to superfluid phases at vanishing kinetic energies, which exhibit a site-dependent phase. We characterize these phases as a function of the Bose-Hubbard parameters and analyse the entanglement entropy as a function of the strength of the dipolar interactions.