Q 59: Quantum gases: Optical lattices III

Time: Friday 11:00–12:30 Location: F 342

Q 59.1 Fri 11:00 F 342

Mott transitions in the half-filled SU(2*M*) symmetric Hubbard model — •Nils Blümer and Elena Gorelik — Institute of Physics, Johannes Gutenberg University, Mainz, Germany

The SU(N) symmetric Hubbard model with total degeneracy $N > 2$ has recently gained direct physical relevance in the context of ultracold earth alkali atoms. A Mott insulating state has already been observed in a SU(6) symmetric system of fermionic ytterbium atoms (^{173}Yb) on a cubic optical lattice [1], opening the door to detailed experimental investigations of Mott metal-insulator transitions in SU(N) symmetric Hubbard models (with $N > 2$). This breakthrough clearly calls for corresponding theory data in the full relevant range of N.

We compute static properties of the Hubbard model in the SU($2M$) symmetric limit for up to $M = 8$ bands at half filling within dynamical mean-field theory, using the numerically exact multigrid Hirsch-Fye quantum Monte Carlo approach. Based on this unbiased data, we establish scaling laws which predict the phase boundaries of the paramagnetic Mott metal-insulator transition at arbitrary orbital degeneracy M with high accuracy.

[1] S. Taie, R. Yamazaki, S. Sugawa, and Y. Takahashi, Nature Physics **8**, 825 (2012).

Q 59.2 Fri 11:15 F 342

Quantum dynamics of a single, mobile spin impurity — •Takeshi Fukuhara[1], Adrian Kantian[2], Manuel Endres[1], Marc Cheneau[1], Peter Schauss[1], Sebastian Hild[1], David Bellem[1], Ulrich Schollwöck[3], Thierry Giamarchi[2], Christian Gross[1], Immanuel Bloch[1,3], and Stefan Kuhr[4] — [1]Max-Planck-Institut für Quantenoptik, 85748 Garching, Germany — [2]DPMC-MaNEP, University of Geneva, 24 Quai Ernest-Ansermet, 1211 Geneva, Switzerland — [3]Fakultät für Physik, Ludwig-Maximilians-Universität München, 80799 München, Germany — [4]University of Strathclyde, Department of Physics, SUPA, Glasgow G4 0NG, United Kingdom

Quantum magnetism plays an important role in many materials such as transition metal oxides and cuprate superconductors. One of its elementary processes is the propagation of spin excitations. Here we study the quantum dynamics of a deterministically created spin-impurity atom, as it propagates in a one-dimensional lattice system. We probe the full spatial probability distribution of the impurity at different times using single-site-resolved imaging of bosonic atoms in an optical lattice. In the Mott-insulating regime, a post-selection of the data allows to reduce the effect of temperature, giving access to a space- and time-resolved measurement of the quantum-coherent propagation of a magnetic excitation in the Heisenberg model. Extending the study to the bath's superfluid regime, we determine quantitatively how the bath affects the motion of the impurity, showing evidence of polaronic behaviour.

Q 59.3 Fri 11:30 F 342

Creation and dynamics of remote spin-entangled pairs in the expansion of strongly correlated fermionic atoms — •Stefan Kessler[1], Ian McCulloch[2], and Florian Marquardt[1,3] — [1]Institute for Theoretical Physics, Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen, Germany — [2]School of Physical Sciences, University of Queensland, Brisbane, Australia — [3]Max Planck Institute for the Science of Light, Erlangen, Germany

We consider the nonequilibrium dynamics of an interacting spin-$\frac{1}{2}$ fermionic gas in a one-dimensional optical lattice after switching off the confining potential. In particular, we study the creation and the time evolution of spatially separated, spin-entangled fermionic pairs. This results in entanglement between pairs of singly occupied lattice sites across the cloud, which we quantify by the concurrence. The time-dependent density-matrix renormalization group is used to simulate the time evolution and evaluate the two-site correlation functions, from which the concurrence is calculated. We find that the entangled fermionic pairs are found at different locations, depending on the onsite interaction strength. Moreover, we briefly discuss the prospects of experimentally observing these phenomena by measuring the spin-entanglement using single-site and spin-dependent detection of the particle number.

Q 59.4 Fri 11:45 F 342

Observation of Ising symmetry breaking in a triangular optical lattice — •Christoph Ölschläger[1], Julian Struck[1], Malte Weinberg[1], Juliette Simonet[1], Robert Höppner[1], Ludwig Mathey[1], Philipp Hauke[2], Maciej Lewenstein[2], André Eckardt[3], Patrick Windpassinger[1], and Klaus Sengstock[1] — [1]Institut für Laserphysik, Universität Hamburg, Germany — [2]ICFO - Institut de Ciències Fotòniques, Castelldefels, Spain — [3]MPI für Physik komplexer Systeme, Dresden, Germany

Ultracold quantum gases in optical lattices are well suited to investigate and simulate systems connected to solid state physics. Here we report on the experimental realization of ultracold atoms in a triangular lattice with an emergent discrete Ising (Z2) and continuous (U(1)) symmetry by engineering fully tunable artificial staggered gauge fields via lattice shaking. For staggered pi-fluxes the ground state is twofold degenerate and we observe a thermally driven phase transition between an unordered (paramagnetic-like) state and an ordered (ferromagnetic-like) state, where the system shows a spontaneous magnetization. Via the full control over the flux strength, it is in addition possible to lift the degeneracy on purpose, e.g. to break the Ising symmetry, and thus measure the magnetization depending on the field and temperature. This can be viewed as in close analogy to a classical Ising-spin model in an external homogeneous magnetic field showing characteristic magnetization dependences below and above a critical temperature. We acknowledge support from the Deutsche Forschungsgemeinschaft within SFB925 and FOR801.

Q 59.5 Fri 12:00 F 342

Quantum magnetism of ultracold fermions in an optical lattice — •Thomas Uehlinger[1], Daniel Greif[1], Gregor Jotzu[1], Leticia Tarruell[1,2], and Tilman Esslinger[1] — [1]Institute for Quantum Electronics, ETH Zurich, 8093 Zurich, Switzerland — [2]LP2N UMR 5298, Univ. Bordeaux 1, Institut d'Optique and CNRS, 351 cours de la Libération, 33405 Talence, France

Quantum magnetism is a fundamental phenomenon in condensed matter physics, which manifests itself for example in antiferromagnets or spin-liquids and is believed to play a crucial role in high-temperature superconductivity. Remarkably, even simple models of the underlying many-body physics are often intractable with state-of-the-art theoretical methods. While ultracold atoms in optical lattices have been successfully used to investigate simple condensed matter model systems, the regime of quantum magnetism could so far not be accessed due to the low temperatures required.

We report on the first observation of quantum magnetism of a Fermi gas in an optical lattice. The key to obtaining and detecting the short-range magnetic order is a tunable geometry optical lattice set to either a dimerized or an anisotropic simple cubic geometry. For a low-temperature gas we find magnetic correlations on neighbouring sites, which manifest as an excess number of singlets as compared to triplets consisting of two atoms with opposite spins. For the anisotropic lattice, we determine the transverse spin correlator from the singlet-triplet imbalance and observe antiferromagnetic correlations along one spatial axis.

Q 59.6 Fri 12:15 F 342

Monte-Carlo simulation of frustrated magnetic phases of ultracold bosonic atoms in an optical lattice — •Robert Höppner and Ludwig Mathey — Zentrum für Optische Quantentechnologien/Institut für Laser-Physik, Hamburg, Germany

Recent experiments have demonstrated that ultracold Rubidium-87 atoms in frustrated optical lattices can be used to simulate classical magnetism (1). Here, we use classical Monte-Carlo to understand the equilibrium phase diagram of such systems. We consider a frustrated triangular lattice in which the tunnelling energy in two spatial directions is negative, and is complex in the third spatial direction. We model the bosonic field by using a thermally fluctuating complex field. We obtain several observables, such as the momentum space distribution of the atoms, both above and below the critical point, and the chirality of the state. We discuss the relevance of our results to experiments.

[1] Struck, J., et al. (2011). Quantum simulation of frustrated classical magnetism in triangular optical lattices. Science, 333 (6045)