TUE 8: Correlated Quantum Matter: Contributed Session to Symposium I

Time: Tuesday 14:15–16:00 Location: ZHG009

TUE 8.1 Tue 14:15 ZHG009

Optical signatures of dynamical excitonic condensates — •Alexander Osterkorn[1], Yuta Murakami[2], Tatsuya Kaneko[3], Zhiyuan Sun[4], Andrew J. Millis[5,6], and Denis Golež[1,7] — [1]Jožef Stefan Institute, Ljubljana, Slovenia — [2]RIKEN, Wako, Japan — [3]Osaka University, Toyonaka, Japan — [4]Tsinghua University, Beijing, P.R. China — [5]Columbia University, New York, USA — [6]Flatiron Institute, New York, USA — [7]University of Ljubljana, Ljubljana, Slovenia

Excitons, or bound electron-hole pairs, can condense into an excitonic insulator state, similarly to Cooper pairs in superconductors. A non-equilibrium carrier concentration, such as the one transiently induced by photo-doping or sustained by a tuneable bias voltage in bilayers, can create a dynamical excitonic insulator state. However, proving phase coherence in such setups remains challenging. We examine the condensate phase behavior theoretically and show that optical spectroscopy can distinguish between phase-trapped and phase-delocalized dynamical regimes. In the weak-bias regime, trapped phase dynamics result in an in-gap absorption peak nearly independent of bias voltage, while at higher biases its frequency increases approximately linearly. In the large bias regime, the response current grows strongly under the application of a weak electric probe leading to negative weight in the optical response, which we analyze relative to predictions from a minimal model for the phase. This work opens new avenues for experimentally probing coherence in excitonic condensates and the detection of their dynamical regimes. Preprint: arXiv:2410.22116

TUE 8.2 Tue 14:30 ZHG009

Dissipative loading of ultracold atom tweezer arrays — •Lara Giebeler[1], Alexander Schnell[1], Monika Aidelsburger[2,3,4], and André Eckardt[1] — [1]Institute for Physics and Astronomy, Technical University Berlin — [2]Munich Center for Quantum Science and Technology — [3]Max-Planck-Institut für Quantenoptik — [4]Fakultät für Physik, LMU Munich

Using ultracold atoms in quantum computing and simulation often requires arbitrary single-atom control, typically achieved with optical tweezer arrays. However, defect-free loading of large-scale arrays remains challenging due to the slow speed of adiabatic preparation methods.

To overcome these limitations, in this work we introduce a dissipative scheme for loading fermionic atoms into tweezers, mediated by lasercoupled interactions with a fermionic bath. In particular, we explore the trade-off between loading time and efficiency depending on the system bath coupling and the impact of reservoir size and temperature.

TUE 8.3 Tue 14:45 ZHG009

A general scheme for detecting phases of lattice-confined ultracold atomic clouds — •Niklas Euler[1,2], Christof Weitenberg[3], and Martin Gärttner[1] — [1]Institut für Festkörpertheorie und Optik, FSU Jena, Jena — [2]Physikalisches Institut, Universität Heidelberg, Heidelberg — [3]Fakultät Physik, TU Dortmund, Dortmund

Over the past decade, quantum-gas microscopes have become an invaluable tool for cold-atom experiments, delivering unprecedented single-site resolution. The now available high-precision density measurements have been used successfully to probe strongly correlated quantum matter, perform quantum simulation tasks, or investigate out-of-equilibrium dynamics, among other applications. However, reconstructing phase distributions of ultracold atomic clouds from matter-wave images has remained challenging, especially for large phase fluctuations. Here, we propose a new measurement scheme that reliably reconstructs initial-state phases and density fluctuations from a single matter-wave inference image in an efficient manner. Our method works by decomposing the initial state into individual spatially localized modes and evolving them independently, which is well justified in the regime of weak nonlinear interactions. Furthermore, by comparing the reconstructed image with measurement data, the plausibility of the resulting distributions can easily be verified. Finally, we show first numerical results, demonstrating that our method is robust under typical experimental conditions.

TUE 8.4 Tue 15:00 ZHG009

Modelling of collisional spin entanglement beyond the Born-Markov approximation — •Robert Weiss[1], Scott Parkins[2,3], Mikkel F. Andersen[3,4], and Sandro Wimberger[5,6] — [1]Institut für theoretische Physik, Universität Heidelberg — [2]Department of Physics, University of Auckland — [3]Dodd-Walls Centre for Photonic and Quantum Technologies — [4]Department of Physics, University of Otago — [5]Department of Mathematical, Physical and Computer Sciences, Parma University — [6]INFN, Sezione Milano-Bicocca, Parma group

It was shown experimentally that colliding cold atoms produce entanglement between their spin states [1]. A thorough theoretical foundation and prediction was restricted in modelling the internal and external atomic degrees of freedom due to computational constraints. We demonstrate why established analytical techniques restricting to the spins only and relying on the Born-Markov approximation fail to reproduce the experimental results. The Markov approximation is not applicable because the correlations in the motional degree of freedom do not decay on a short enough time scale. The Born approximation is questionable as the interatomic interaction is too strong. Numerical models are presented which capture the observed dynamics well including non-Markovian effects and the relative motion.

[1] P. Sompet et. al., Nat. Comm. **10**, 1889 (2019)

TUE 8.5 Tue 15:15 ZHG009

Universal theory for heavy impurities in ultracold Fermi gases — •Eugen Dizer, Xin Chen, Emilio Ramos Rodriguez, and Richard Schmidt — Institut für Theoretische Physik, Universität Heidelberg, D-69120 Heidelberg, Germany

Single impurities immersed in a degenerate Fermi gas exhibit fascinating many-body phenomena, such as the polaron-to-molecule transition and Anderson's orthogonality catastrophe (OC). It is known that mobile impurities of finite mass can be described as quasiparticles, so called Fermi polarons. In contrast, Anderson showed in 1967 that the ground state of a static, infinitely heavy impurity in a Fermi sea is orthogonal to the ground state of the system without impurity - a hallmark of the OC and a fundamentally non-perturbative effect. As a result, conventional variational approaches or path integral methods fail to capture this phenomenon accurately. Despite decades of research, a unified approach connecting the quasiparticle description of Fermi polarons with Anderson's OC has remained elusive. In this work, we present a theoretical framework for arbitrary-mass impurities in a Fermi sea that incorporates Anderson's OC, the polaron-to-molecule transition and the quasiparticle picture. Our theory provides new insights into the nature of impurity physics and many-body correlations, describing how quasiparticle behavior and the polaron-to-molecule transition emerge from the OC.

TUE 8.6 Tue 15:30 ZHG009

Quantum phases of bosonic mixture with dipolar interaction — •Rukmani Bai and Luis Santos — Institut für Theoretische Physik, Leibniz Universität Hannover, Appelstrasse 2, D-30167 Hannover, Germany

Ultracold dipoles in optical lattices, characterized by strong inter-site interactions, open new possibilities for ground-state phases as well as an intriguing dynamics. Recent experiments on dipolar mixtures of magnetic lanthanide atoms are especially interesting, not only due to the dipolar interaction, but also because these atoms are particularly suitable for realizing component-dependent lattices. Using a combination of DMRG and cluster Gutzwiller methods, we study the ground-state physics that may result when the two components experience mutually intertwined optical lattices, which resemble interacting bilayer geometries.

TUE 8.7 Tue 15:45 ZHG009

Static impurity in a mesoscopic system of SU(N) fermionic matter-waves — •Juan Polo[1], Wayne Chetcuti[1], Andreas Osterloh[1], Anna Minguzzi[3], and Luigi Amico[1,2] — [1]Quantum Research Center, Technology Innovation Institute, Abu Dhabi 9639, UAE — [2]Dipartimento di Fisica e Astronomia Ettore Majorana University of Catania, Via S. Sofia 64, 95123 Catania, Italy — [3]Université Grenoble Alpes, CNRS, LPMMC, 38000 Grenoble, France

We investigate the effects of a static impurity, modeled by a localized barrier, in a one-dimensional mesoscopic system comprised of strongly correlated repulsive SU(N)-symmetric fermions. For a mesoscopic sized ring under the effect of an artificial gauge field, we analyze the particle density and the current flowing through the impurity at varying interaction strength, barrier height and number of components. We find a non-monotonic behaviour of the persistent current, due to the competition between the screening of the impurity, quantum fluctuations, and the phenomenon of fractionalization, a signature trait of SU(N) fermionic matter-waves in mesoscopic ring potentials. This is also highlighted in the particle density at the impurity site. We show that the impurity opens a gap in the energy spectrum selectively, constrained by the total effective spin and interaction. Our findings hold significance for the fundamental understanding of the localized impurity problem and its potential applications for sensing and interferometry in quantum technology.