TT 69: Cold Atomic Gases and Superfluids

Time: Friday 9:30–11:30 Location: H23

TT 69.1 Fri 9:30 H23

Diagrammatic Large-N approach to the Unitary Fermi Gas — •Gunnar Möller and Christopher R. Winterowd — University of Kent, Canterbury, UK

We explore a large-N, many fermion flavour, generalisation of the unitary Fermi gas [1] using diagrammatic Monte-Carlo techniques. Seminal work on the unitary Fermi gas problem has established a diagrammatic Monte-Carlo (diagMC) approach [2], which needs to be supplemented by exploring the high-order asymptotics of the series expansion [3]. Here, we extend the problem by introducing the inverse number of flavours as a small parameter via a large-N generalisation of the unitary gas [4,5], and we then apply diagMC. Using the Borel resummation technique developed by Rossi et al [3], we show that the convergence radius in the Borel plane is enlarged as a function of fermion flavours, thus facilitating the convergence of the series in the vicinity of the transition into the superfluid phase.

More generally, the combination of large-N field theory techniques with high-order numerical resummations opens up a new avenue for investigations of strongly interacting systems.

[1] W. Zwerger, Springer (2012)
[2] K. Van Houcke et al., Nat Phys 8, 366 (2012);
Van Houcke, et al., arXiv:1305.3901 (2013)
[3] R. Rossi, et al., PRL 121, 130405 (2018)
[4] M. Y. Veillette, et al., PRA 75, 043614 (2007)
[5] P. Nikolic and S. Sachdev, PRA 75, 033608 (2007)

TT 69.2 Fri 9:45 H23

Mechanical resonances of mobile impurities in a one-dimensional quantum fluid — •Thomas Schmidt[1], Karyn Le Hur[2], and Peter Orth[3] — [1]Physics and Materials Science Research Unit, University of Luxembourg, L-1511 Luxembourg — [2]Centre de Physique Theorique, Ecole Polytechnique, CNRS, Universite Paris-Saclay, F-91128 Palaiseau, France — [3]Department of Physics and Astronomy, Iowa State University, Ames, Iowa 50011, USA

We study a one-dimensional interacting quantum liquid hosting a pair of mobile impurities causing backscattering. We determine the effective retarded interaction between the two impurities mediated by the liquid. We show that for strong backscattering this interaction gives rise to resonances and antiresonances in the finite-frequency mobility of the impurity pair. At the antiresonances, the two impurities remain at rest even when driven by a (small) external force. At the resonances, their synchronous motion follows the external drive in phase and reaches maximum amplitude. Using a perturbative renormalization group analysis in quantum tunneling across the impurities, we study the range of validity of our model. We predict that these mechanical antiresonances are observable in experiments on ultracold atom gases confined to one dimension.

TT 69.3 Fri 10:00 H23

Floquet induced superfluidity — •Shijie Hu[1], Xue-Feng Zhang[2], Tao Wang[1,2,3], Axel Pelster[1], and Sebastian Eggert[1] — [1]Technische Universität Kaiserslautern — [2]Chongqing University — [3]Wuhan Institute of Technology

We consider two states of hard-core bosons with periodically modulated Rabi driving in a one dimensional (1D) optical lattice, which is equivalent to the 1D Hubbard model with time-periodic interactions. Using Floquet theory the model can be mapped to an effective Hamiltonian for high frequencies, which is described by a static interactions and hopping parameters that depend on the local densities. In particular, if the density difference of one species is non-zero on neighboring sites, the effective hopping of the other species is reduced and can even take on negative values. Using a combination of analytic calculations and different advanced numerical simulations we establish the full quantum phase diagram for half-integer filling for this system. Surprisingly, the density-dependent reduction of hopping drives a quantum phase transition into a superfluid phase. 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-dressed particles. The corresponding experimental signatures in time-of-flight experiments are calculated and show characteristic signatures of the different phases. The phase transition line between the two superfluid phases corresponds to an exactly solvable model with high degeneracy.

TT 69.4 Fri 10:15 H23

New probes of the t-J model in quantum gas microscopes — •Annabelle Bohrdt[1,2], Christie Chiu[2], Geoffrey Ji[2], Muqing Xu[2], Daniel Greif[2], Markus Greiner[2], Eugene Demler[2], Fabian Grusdt[1,2], and Michael Knap[1] — [1]Department of Physics and Institute for Advanced Study, Technical University of Munich, 85748 Garching, Germany — [2]Department of Physics, Harvard University, Cambridge, Massachusetts 02138, USA

Quantum gas microscopes for ultracold atoms can provide high-resolution real-space snapshots of complex many-body systems. We implement machine learning to analyze and classify such snapshots of ultracold atoms. Specifically, we compare the data from an experimental realization of the two- dimensional Fermi-Hubbard model to two theoretical approaches: a doped quantum spin liquid state of resonating valence bond type, and the geometric string theory, describing a state with hidden spin order. This approach considers all available information without a potential bias towards one particular theory by the choice of an observable and can therefore select the theory which is more predictive in general. Up to intermediate doping values, our algorithm tends to classify experimental snapshots as geometric-string-like, as compared to the doped spin liquid. Our results demonstrate the potential for machine learning in processing the wealth of data obtained through quantum gas microscopy for new physical insights.

TT 69.5 Fri 10:30 H23

Gross-Neveu-Wilson model and correlated symmetry-protected topological phases — Alejandro Bermudez[1], •Emanuele Tirrito[2], Matteo Rizzi[3], Maciej Lewenstein[4], and Simon Hands[5] — [1]Departamento de Fisica Teórica, Universidad Complutense, 28040 Madrid, Spain — [2]ICFO-Institut de Ciencies Fotoniques, The Barcelona Institute of Science and Technology, 08860 Castelldefels (Barcelona), Spain — [3]Johannes Gutenberg-Universität, Institut für Physik, Staudingerweg 7, 55099 Mainz, Germany — [4]ICREA, Lluis Companys 23, 08010 Barcelona, Spain — [5]Department of Physics, College of Science, Swansea University, Singleton Park, Swansea SA2 8PP, United Kingdom

We show that a Wilson-type discretization of the Gross-Neveu model, a fermionic N-flavor quantum field theory displaying asymptotic freedom and chiral symmetry breaking, can serve as a playground to explore correlated symmetry-protected phases of matter using techniques borrowed from high-energy physics. A large- N study, both in the Hamiltonian and Euclidean formalisms, yields a phase diagram with trivial, topological, and symmetry-broken phases separated by critical lines that meet at a tri-critical point. We benchmark these predictions using tools from condensed matter and quantum information science, which show that the large-N method captures the essence of the phase diagram even at N = 1. Moreover, we describe a cold-atom scheme for the quantum simulation of this lattice model, which would allow to explore the single-flavor phase diagram.

TT 69.6 Fri 10:45 H23

Rhombi-chain Bose-Hubbard model: Geometric frustration and interactions — Christine Cartwright[1], Gabriele De Chiara[1], and •Matteo Rizzi[2] — [1]Centre for Theoretical Atomic, Molecular and Optical Physics, Queen's University Belfast, Belfast BT7 1NN, United Kingdom — [2]Institut für Physik, Johannes Gutenberg Universität, Staudingerweg 7, 55099 Mainz, Germany

We explore the effects of geometric frustration within a one-dimensional Bose-Hubbard model using a chain of rhombi subject to a magnetic flux. The competition of tunneling, self-interaction, and magnetic flux gives rise to the emergence of a pair-superfluid (pair-Luttinger liquid) phase besides the more conventional Mott-insulator and superfluid (Luttinger liquid) phases. We compute the complete phase diagram of the model by identifying characteristic properties of the pair-Luttinger liquid phase such as pair correlation functions and structure factors and find that the pair-Luttinger liquid phase is very sensitive to changes away from perfect frustration (half-flux). We provide some proposals to make the model more resilient to variants away from perfect frustration. We also study the bipartite entanglement properties of the chain. We discover that, while the scaling of the block entropy pair-superfluid and of the single-particle superfluid leads to the same central charge, the properties of the low-lying entanglement spectrum levels reveal their fundamental difference.

[1] Phys. Rev. B 98, 184508 (2018)

TT 69.7 Fri 11:00 H23

The longitudinal and transverse structure factors in impurity-doped spin chains with a magnetic field — Imke Schneider[1], Kevin Jägering[1], Annabelle Bohrdt[2], Sofia Brenner[1], Daniel Wessel[1], and •Sebastian Eggert[1] — [1]Technische Universität Kaiserslautern — [2]Technische Universität München

We consider the dynamic structure factor in impurity doped spin-1/2 chains for general anisotropy, magnetic field and momentum. The impurities lead to effectively isolated finite chain segments with a discrete spectrum and characteristic correlations, which have distinct effects on the longitudinal and transverse structure factors. We present very accurate results for the low energy spectral weight obtained by numerical Density Matrix Renormalization Group techniques and identify the character of dominant excitations for a large range of doping concentrations, anisotropies, and fields. In comparison with bosonization and find surprisingly good agreement with the numerical results. This has direct relevance for recent experiments on spin chains and ultracold gases and shows that, contrary to expectations, bosonization works especially well for short chains and in the vicinity of divergences.

TT 69.8 Fri 11:15 H23

Phonon-mediated Casimir interaction between finite mass impurities — Andrei Pavlov, Jeroen van den Brink, and •Dmitri Efremov — IFW Dresden

The Casimir effect, a two-body interaction via vacuum fluctuations, is a fundamental property of quantum systems. In solid state physics it emerges as a long-range interaction between two impurity atoms via virtual phonons. In the classical limit for the impurity atoms in D dimensions the interaction is known to follow the universal power-law $U(r) \sim r^{-D}$. However, for finite masses of the impurity atoms on a lattice, it was predicted to be $U(r) \sim r^{-2D-1}$ at large distances. We examine how one power-law can change into another with increase of the impurity mass and in presence of an external potential. We provide the exact solution for the system in one-dimension. At large distances it indeed $U(r) \sim r^{-3}$ for finite impurity masses, while for the infinite impurity masses or in an external potential it crosses over to $U(r) \sim r^{-1}$. At short distances the Casimir interaction is not universal and depends on the impurity mass and the external potential.