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Causality and quantum criticality with long-range interactions

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Causality and quantum criticality with long-range interactions,
M. F. Maghrebi, Z.-X. Gong, M. Foss-Feig, A. V. Gorshkov,
arxiv:1508.00906

Abstract:Quantum lattice systems with long-range interactions often exhibit drastically different behavior than their short-range counterparts. In particular, because they do not satisfy the conditions for the Lieb-Robinson theorem, they need not have an emergent relativistic structure in the form of a light cone. Adopting a field-theoretic approach, we study the one-dimensional transverse-field Ising model and a fermionic model with long-range interactions, explore their critical and near-critical behavior, and characterize their response to local perturbations. We deduce the dynamic critical exponent, up to the two-loop order within the renormalization group theory, which we then use to characterize the emergent causal behavior. We show that beyond a critical value of the power-law exponent of long-range interactions, the dynamics effectively becomes relativistic. Various other critical exponents describing correlations in the ground state, as well as deviations from a linear causal cone, are deduced for a wide range of the power-law exponent.

Quantum phases emerging from competing short- and long-range interactions in an optical lattice,
Renate Landig, Lorenz Hruby, Nishant Dogra, Manuele Landini, Rafael Mottl, Tobias Donner, Tilman Esslinger,
arXiv:1511.00007

Abstract: The competition between interactions acting on different length scales lies at the core of a variety of processes leading to structure formation in nature. Examples range from the folding mechanisms of proteins to the appearance of stripe phases in quantum matter. Theoretical characterization of such emerging structures is often exceedingly challenging even if simple toy models are used. A complementary approach to gain insights into complex phenomena has been advanced for quantum matter, where simulation experiments with ultracold atoms are carried out. However these experiments are mostly limited to short-range collisional interactions. Recently observed perturbative effects of long-range interactions were too weak to reach novel quantum phases. Here we experimentally realize a bosonic lattice model with competing short- and infinite-range interactions, and observe the appearance of four distinct phases - a superfluid, a supersolid, a Mott insulator and a charge density wave. Our system is based on an atomic quantum gas trapped in an optical lattice inside a high finesse optical cavity. The strength of the short-ranged on-site interactions is controlled by means of the optical lattice depth. The infinite-range interaction potential is mediated by a vacuum mode of the cavity and is independently controlled by tuning the cavity resonance. When probing the phase transition between the Mott insulator and the charge density wave in real-time, we discovered a behaviour characteristic of a first order phase transition. Our measurements have accessed a regime for quantum simulation of many-body systems, where the physics is determined by the intricate competition between two different types of interactions and the zero point motion of the particles.

Crystallisation of a dilute atomic dipolar condensate,
R. N. Bisset, P. B. Blakie,
arXiv:1510.09013

Abstract: We present a theory that explains the experimentally observed crystallisation of a dilute dysprosium condensate into a lattice of droplets. The key ingredient of our theory is a conservative three-body interaction which stabilises the droplets against collapse to high density spikes. Our theory reproduces the experimental observations, and provides insight into the many-body properties of this new phase of matter. Notably, we show that it is unlikely that a supersolid was obtained in experiments, however our results suggest a strategy to realize this phase.

Evolution of Cooper pairs with zero-center-of-mass momentum and their first-order correlation function in a two-dimensional ultracold Fermi gas near the observed Berezinskii-Kosterlitz-Thouless transition,
Morio Matsumoto, Daisuke Inotani, Yoji Ohashi
arXiv:1511.00421

ABSTRACT: We investigate the center-of-mass momentum distribution nQ of Cooper pairs and their first-order correlation function g1(r) in a strongly interacting two-dimensional Fermi gas. Recently, the BKT (Berezinskii-Kosterlitz-Thouless) transition was reported in a two-dimensional 6Li Fermi gas, based on (1) the observations of anomalous enhancement of nQ=0 [M. G. Ries, et. al., Phys. Rev. Lett. 114, 230401 (2015)], as well as (2) a power-law behavior of g1(r) [P. A. Murthy, et. al., Phys. Rev. Lett. 115, 010401 (2015)]. However, including pairing fluctuations within a T-matrix approximation (TMA), we show that these results can still be explained as strong-coupling properties of a normal-state two-dimensional Fermi gas. Our results indicate the importance of further experimental observations, to definitely confirm the realization of the BKT transition in this system. Since the BKT transition has been realized in a two-dimensional ultracold Bose gas, our results would be useful for the achievement of this quasi-long range order in an ultracold Fermi gas.

Time-dependent Landauer-Büttiker formalism for superconducting junctions at arbitrary temperatures,
Riku Tuovinen, Robert van Leeuwen, Enrico Perfetto, Gianluca Stefanucci
arXiv:1511.00109

ABSTRACT: We discuss an extension of our earlier work on the time-dependent Landauer–Büttiker formalism for noninteracting electronic transport. The formalism can without complication be extended to superconducting central regions since the Green's functions in the Nambu representation satisfy the same equations of motion which, in turn, leads to the same closed expression for the equal-time lesser Green's function, i.e., for the time-dependent reduced one-particle density matrix. We further write the finite-temperature frequency integrals in terms of known special functions thereby considerably speeding up the computation. Numerical simulations in simple normal metal – superconductor – normal metal junctions are also presented.

Floquet engineering with quasienergy bands of periodically driven optical lattices,
Martin Holthaus
arXiv:1510.09042

ABSTRACT: A primer on the Floquet theory of periodically time-dependent quantum systems is provided, and it is shown how to apply this framework for computing the quasienergy band structure governing the dynamics of ultracold atoms in driven optical cosine lattices. Such systems are viewed here as spatially and temporally periodic structures living in an extended Hilbert space, giving rise to spatio-temporal Bloch waves whose dispersion relations can be manipulated at will by exploiting ac-Stark shifts and multiphoton resonances. The elements required for numerical calculations are introduced in a tutorial manner, and some example calculations are discussed in detail, thereby illustrating future prospects of Floquet engineering.