Mini-Workshop

"Quantum Gases of Cold Atoms and Many-body correlations"

Oct 12-14, 2015

Wuhan Institute of Physics and Mathematics
Chinese Academy of Sciences

In recent years, quantum physics of ultracold atoms and quantum liquids of spins and electrons has attracted much attention from theory and experiment. In such systems the particles interact with each other via either short-range or long-range forces (magnetic or electric), which drastically changes the nature of quantum degenerate regimes. This opens wide possibilities to reveal novel many-body states. Of particular interest are Bose-Einstein condensates of bosons, superfluids of fermions, universal laws in Fermi and Luttinger liquids, topological insulators, spin-orbit coupling phenomena, and nonconventional transport in disordered systems etc. Actually, ultracold atoms with large spin symmetries present another “hot topic” in the field of quantum gases, together with correlated atoms in optical lattices and Fermi mixtures. The underlying key idea is to study various types of quantum phase transitions, quantum magnetism, critical phenomena, and/or make quantum simulators of complex solid state systems.

This mini-workshop aims to focus on recent theoretical and experimental developments of ultracold atoms and condensed matter physics. We shall also discuss current experimental developments with cold atoms, matter waveguides and few atom collisions at WIPM. The workshop will consist of 12 lectures on these topics. 45 minutes for each talk and 15 minutes for questions.

Location:

Room 410, Pinbiao building, Wuhan Institute of Physics and Mathematics

Schedule:

Time	Title	Speaker	Affiliation
Oct 12 (Monday) Morning session			
9:20-9:30	Opening speech		
9:30-10:30	Off-diagonal Bethe Ansatz and its applications	Yupeng Wang	Institute of Physics, CAS, China
10:40:11:40	Synthesizing Majorana zero modes in a periodically gated quantum wire	Henrik Johannesson	University of Gothenburg,Sweden

Oct 12 (Monday) Afternoon session			
14:40-15:40	Parity symmetry breaking quantum phase transition with ultracold atoms in a double well potential	Augusto Smerzi	QSTAR, INO-CNR and LENS, Italy
15:50-16:50	P-wave Contacts	Zhenhua Yu	Tsinghua University, China
17:00-18:00	Progress in manipulating single-atoms	Peng Xu	Wuhan Institute of Physics and Mathematics, CAS, China

Off-diagonal Bethe Ansatz and its applications

Yupeng Wang

I will review the off-diagonal Bethe Ansatz method, a newly developed analytic theory to approach exact solutions of generic quantum integrable models, especially those without obvious reference states that have not been solved via conventional Bethe Ansatz methods. Taking the XXX spin chain with generic non-diagonal boundary fields as an example, I show how this new method works to obtain the operator identities, to derive the eigenvalues in terms of an inhomogeneous T-Q relation and to retrieve the eigenstates. Possible applications in a variety of subjects will also be introduced.

Synthesizing Majorana zero modes in a periodically gated quantum wire

Henrik Johannesson

We explore a scheme for engineering a one-dimensional spinless p-wave superconductor hosting Majorana zero modes, using an all-electric setup with a spin-orbit coupled quantum wire in proximity to an s-wave superconductor. The required crossing of the Fermi level by a single spin-split energy band is ensured by employing a periodically modulated Rashba interaction, which, assisted by electron-electron interactions and a uniform Dresselhaus interaction, opens a gap at two of the spin-orbit shifted Fermi points. While an implementation in a hybrid superconductor-semiconductor device requires improvements upon present-day capabilities, a variant of our scheme where spin-orbit-coupled cold fermions are effectively proximity-coupled to a BEC reservoir of Feshbach molecules may provide an immediately workable platform.

[1] G. I. Japaridze, H. Johannesson, and M. Malard, Phys. Rev. B 89, 201403(R) (2014).

[2] M. Malard, G. I. Japaridze, and H. Johannesson, to appear

Parity symmetry breaking quantum phase transition with ultracold atoms in a double well potential

Augusto Smerzi

Parity symmetry breaking quantum phase transitions (PSB) are an interdisciplinary theme relevant to condensed matter physics, cosmology and nuclear physics. I will present a theoretical and experimental investigation of PSB realized with an ultra-cold gas trapped in a spatially symmetric double-well potential. At a critical value of an attractive interatomic interaction strength, we observe a continuous quantum phase transition where the gas spontaneously localizes in one well or the other thus breaking the underlying spatial symmetry of the system. Furthermore, we investigate hysteresis associated to an additional discontinuous quantum phase transition. These results pave the way to the study of quantum critical phenomena at finite temperature and to the investigation of macroscopic quantum tunneling of the order parameter in the hysteretic regime.

P-wave Contacts

Zhenhua Yu

P-wave interactions underly the unconventional superfluidity of He-3 and are thought to give rise to topological superconductivity in Sr2RuO4. Studying many-body physics due to p-wave interactions in cold atoms has been plagued by quick atom loss. However a recent quench experiment in a degenerate atomic Fermi gas reveals peculiar p-wave interaction effects before substantial atom loss sets in [1]. Motivated by the experimental observation, we introduce two p-wave contacts which we show encapsulate the interaction effects [2]. We derive a set of universal relations which link the p-wave contacts with closed channel molecule population, energy variation, radio-frequency and photo-association spectroscopies of the system. Our results open up a new perspective on atomic Fermi gases with resonant p-wave interactions.

[1]C. Luciuk, S. Trotzky, S. Smale, Zhenhua Yu, Shizhong Zhang, J. H. Thywissen, arXiv:1505.08151, submitted to Nature Physics.

[2]Zhenhua Yu, Joseph H. Thywissen, Shizhong Zhang, arXiv:1505.02526, accepted by PRL.

Time	Title	Speaker	Affiliation
Oct 13 (Tuesday) Morning session			
9:30-10:30	Orbital Angular Momentum and Spectral Flow in Two-Dimensional Chiral Superfluids	Masaki Oshikawa	University of Tokyo, Japan
10:40:11:40	Superfluidity properties of a spin-orbit coupled Bose Gas	Shizhong Zhang	The University of Hong Kong, China

Oct 13 (Tuesday) Afternoon session			
14:40-15:40	Strongly Interacting Quantum Gases in One Dimension	Han Pu	Rice University, USA
15:50-16:50	Spin-Orbit Coupled Cold Atoms in Real and Effective Lattices	Xiaolin Cui	Institute of Physics, CAS, China
17:00-18:00	Test of Equivalence Principle by Atom Interferometer	Lin Zhou	Wuhan Institute of Physics and Mathematics, CAS, China

Superfluidity properties of a spin-orbit coupled Bose Gas

Shizhong Zhang

We investigate the superfluid properties of the spin-orbit coupled Bose-Einstein condensate realized in experiments. Unlike the usual spineless bosons like Helium four, the normal density at zero temperature does not vanish, and depends on the external parameters like the Raman coupling strength. We show how the non-zero normal density arises from the peculiar dispersion of the spin-orbit coupled Bose gas and calculate its temperature dependences within Bogoliubov approximation. Importantly, we show that despite the lack of Galilean invariance, the sum superfluid and normal density is still given by total density at zero temperature, which paves the way for the construction of two-fluid hydrodynamics at zero temperature.

Time	Title	Speaker	Affiliation
Oct 14 (Wednesday) Morning session			
9:00-10:00	Atomic spin entanglement in optical lattices	Zhen-Sheng Yuan	University of Science and Technology of China
10:10-11:10	Quantum phase transition in a Tavis-Cummings model	Mang Feng	Wuhan Institute of Physics and Mathematics, CAS, China
11:10-12:10	Novel Atomic Devices and Witnessing Multipartite Entanglement	Weidong Li	Shanxi University, China

Oct 14 (Wednesday) Afternoon session	
15:00-18:00	Free Discussion

Atomic spin entanglement in optical lattices

Zhen-Sheng Yuan

Ultracold atoms in optical lattices offer a great promise to generate entangled states for scalable quantum information processing owing to the inherited long coherence time and controllability over a large number of particles. We report on the generation, manipulation and detection of atomic spin entanglement in an optical superlattice. Spin entanglement of the two atoms in the double wells of the superlattice is generated via dynamical evolution governed by spin superexchange. By observing collisional atom loss with in-situ absorption imaging we measure spin correlations of atoms inside the double wells and obtain the lower boundary of entanglement fidelity and the violation of a Bell's inequality. This represents an essential step towards scalable quantum computation with ultracold atoms in optical lattices.

Novel Atomic Devices and Witnessing Multipartite Entanglement

Weidong Li

Based on the dynamics of ultra-cold Bose atoms with simple external trap and the correlation properties of many-body atoms, we developed novel atomic devices to improve the accuracy and one paradigm to witness the multipartite entanglement. In this talk, i will introduce the multipartite entanglement witness.

Quantum mechanics predicts the existence of correlations between composite systems -- multipartite entanglement (ME) -- that, while puzzling our physical intuition, enable technologies not accessible in a classical world. Notwithstanding, there is still no efficient general method to theoretically quantify and experimentally detect ME. Here we propose a novel paradigm based on the measurement of the statistical response of a quantum systems to a collective parametric evolution. As a major difference with respect to current approaches based on the implementation of entanglement witness operators, we witness ME without relying on measurement efficiencies or tomographic reconstructions of the quantum state. The protocol requires only two settings for any number of parties. To illustrate its user-friendliness we demonstrate ME in different experiments with ions and photons by analyzing published data on fidelity visibilities and averaged observables.