1st WHU Summer Theory Institute

Frontiers in condensed matter and cold atoms

June 15 – 26, 2015

School of Physics and Technology

Wuhan University

The First WHU Summer Theory Institute will cover two areas: condensed matter physics and ultracold atomic physics. We appreciate very much for your participation.

The purpose of the Summer Theory Institute is to bring together leading experts from the national and international communities to discuss the latest developments in both areas, to address fundamental issues and major challenges, and, in particular, to facilitate new research directions and collaborations across the borders.

Advisory Committee

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Time	Title	Speaker	Affiliation
June 15 (Monday) Morning session			
9:15—9:30	Welcome speech	Zhenyu Zhang	University of Science and Technology of China
9:30—11:00	Quantum Magnetoconductivity in Topological Semimetals	Shunqing Shen	University of Hong Kong
11:00—12:00	Free discussion		
June 15 (Monday) Afternoon session			
15:00—16:30	Topological phases with interaction in cold atom systems with less heating problem	Hui Zhai	Tsinghua University
16:30—17:30	Free discussion		

June 16 (Tuesday) Morning session			
9:00—10:30	Weak localization and Weak Antilocalization of Dirac/Weyl Fermions in Topological Insulators and Semimetals	Shunqing Shen	University of Hong Kong
10:30-11:00	Break		
11:00—12:00	Phase diagram in bilayer graphene in electric and weak out-of-plane magnetic fields	Junji Jia	Wuhan University
June 16 (Tuesday) Afternoon session			
15:00—16:30	Electronic transport properties of the topological 1D zero-line mode	Zhenhua Qiao	University of Science and Technology of China
16:30—17:30	Free discussion		

会议地点：新物理楼五楼多功能报告厅

Time	Title	Speaker	Affiliation
June 17 (Wednesday) Morning session			
9:00—10:30	Insight from few-body on many-body Physics in cold atom systems	Hui Zhai	Tsinghua University
10:30—10:50	Free discussion		
10:50—12:10	Robustness, Tunability, and Functional Properties of Topological Surface States in Topological Insulator Heterostructures	Zhenyu Zhang	University of Science and Technology of China
June 17 (Wednesday) Afternoon session			
14:30—16:00	Optical properties of 2D transition metal dichalcogenides	Xiaodong Cui	University of Hong Kong
16:00—16:20	Free discussion		
16:20—17:50	Chiral Valley Phonons in TMD	Qian Niu	University of Texas, Austin

June 18 (Thursday) Morning session			
9:30—11:00	Topological and Strong correlation physics in orbital-active honeycomb lattice -- from solid states to optical lattices	Congjun Wu	University of California, San Diego
11:00—12:00	Free discussion		
June 18 (Thursday) Afternoon session			
14:30—16:00	Electronic Properties of Novel Two-dimensional Materials	Yuanbo Zhang	Fudan University
16:00—16:20	Break and Free discussion		
16:20—17:50	Nanowire spin-orbit qubits: Electric-dipole spin resonance and anisotropic exchange coupling	Jianqiang You	Beijing Computational Science Research Center

Time	Title	Speaker	Affiliation
June 19 (Friday) Morning session			
9:30—11:00	Valley and spin physics in 2D transition metal dichalcogenides	Wang Yao	University of Hong Kong
11:00—12:00	Free discussion		
June 19 (Friday) Afternoon session			
14:30—16:00	On the foundation of quantum statistical mechanics	Biao Wu	Peking University
16:00—16:30	Free discussion		
16:30—17:30	Cluster density matrix embedding theory for quantum spin systems	Quanlin Jie	Wuhan University

June 22 (Monday) Morning session			
9:30—11:00	Searching for the Fulde-Ferrell-Larkin-Ovchinnikov states in ultracold atomic Fermi gases in 3D continuum	Qijin Chen	Zhejiang University
11:00—12:00	Free discussion		
June 22 (Monday) Afternoon session			
14:30—16:00	Landau-Zener transition in a superconducting qubit system	Shiliang Zhu	Nanjing University
16:00—16:30	Free discussion		
16:30—17:30	High precision calculations of Helium and Lithium	Haoxue Qiao	Wuhan University

会议地点：新物理楼五楼多功能报告厅

Time	Title	Speaker	Affiliation
June 23 (Tuesday) Morning session			
9:00—10:30	Physics of ultracold diatomic polar molecules	Su Yi	Institute of Theoretical Physics, CAS
10:30—11:00	Break and Free discussion		
11:00—12:00	Magnetization resonance of nonsecular dipolar interaction in spin-1 Bose-Einstein condensates	Wenxian Zhang	Wuhan University
June 23 (Tuesday) Afternoon session			
15:00—16:30	Time-Reversal-Invariant Topological Superconductivity (I)	Fan Zhang	The University of Texas, Dallas
16:30—17:30	Free discussion		

June 24 (Wednesday) Morning session			
9:00—10:30	Interacting fermions in one dimension: from zero temperature to high temperatures	Xiwen Guan	Wuhan Institute of Physics and Mathematics, CAS
10:30—11:00	Break and Free discussion		
11:00—12:00	New effects in optimizing the thermoelectric performance of some example systems	Huijun Liu	Wuhan University
June 24 (Wednesday) Afternoon session			
14:30—16:00	Novel quantum magnetism with SU(2N) and Sp(2N) symmetries -- large spin fermions are different	Congjun Wu	University of California, San Diego
16:00—16:20	Free discussion		
16:20—17:50	Many-body physics with ultracold quantum gases in disorder	Gora Shlyapnikov	LPTMS, Orsay, France

Time	Title	Speaker	Affiliation
June 25 (Thursday) Morning session			
9:30—11:00	Localization-delocalization transition and many-body localization in interacting quasiperiodic systems	Shu Chen	Institute of Physics, CAS
11:00—12:00	Free discussion		
June 25 (Thursday) Afternoon session			
14:30—16:00	Production and dissociation of Feshbach molecules in Fermi gas with SOC	Pengjun Wang	Shangxi University
16:00—16:30	Free discussion		
16:30—17:30	Collective excitations in gaped 2D systems with strong spin orbit coupling	Li Mao	Wuhan University

June 26 (Friday) Morning session			
9:00—10:30	Time-Reversal-Invariant Topological Superconductivity (II)	Fan Zhang	The University of Texas, Dallas
10:30—10:50	Free discussion		
10:50—12:20	Three-body scattering hypervolumes for bosons	Shina Tan	Georgia Institute of Technology
June 26 (Friday) Afternoon session			
15:00—16:30		Wuming Liu	Institute of Physics, CAS
16:30—17:30	Free discussion		
17:30—18:00	Closing remarks	Zhenyou Liu	Wuhan University

会议地点：新物理楼五楼多功能报告厅

Abstracts

Quantum Magnetoconductivity in Topological Semimetals

Shun-Qing Shen
The University of Hong Kong

Weyl semimetals are three-dimensional topological states of matter, in a sense that they host paired monopole and anti-monopole of Berry curvature in momentum space, leading to the chiral anomaly. The chiral anomaly has long been believed to give a positive magnetoconductivity in strong and parallel fields. However, several recent experiments on both Weyl and Dirac topological semimetals show a negative magnetoconductivivity in high fields. Here, we study the magnetoconductivity of Weyl and Dirac semimetals in the diffusive regime. In a strong magnetic field applied along the direction that connects two Weyl nodes, we find that the conductivity along the field direction is determined by the Fermi velocity instead of by the Landau degeneracy. We identify three cases in which the high-field magnetoconductivity is negative. Our findings show that the high-field positive magnetoconductivity may not be a compelling signature of the chiral anomaly and will be helpful for interpreting the inconsistency in the recent experiments and earlier theories.

Topological phases with interaction in cold atom systems with less heating problem

Hui Zhai
Tsinghua University

Though recently significant progresses have been made in studying synthetic gauge field, heating is a serious problem that prevents more exciting progress in many aspects. In this talk I first explain the source of heating problem. Then I will discuss recent progresses in overcoming the heating problem. These include the idea of synthetic dimension, utilizing shaking optical lattices or with the help of atoms other than alkali-metal atoms.

Weak localization and Weak Antilocalization of Dirac/Weyl Fermions in Topological Insulators and Semimetals

Shun-Qing Shen
The University of Hong Kong

Topological insulators and Weyl semimetals are topological states of quantum matters, which are determined by topology of electronic band structures, and characteristic of their surface electrons. Massless Dirac fermions in two-dimensional surface and Weyl fermions within three-dimensional bulk, in which each electron momentum is locked with its spin, are expected to be robust against impurities and disorder, and tend to be delocalized. A key feature of quantum transport of these fermions is weak anti-localization due to quantum interference effects. A magnetic field can destroy the quantum interference effect, giving rise to a cusp-like positive magnetoconductivity as the signatures of weak anti-localization. These effects have been widely observed in topological insulators and Weyl semimetals. In this talk, recent progresses in both theory and experiment of quantum transport in topological insulators and Weyl semimetals are reviewed. I state with the modified Dirac equation with its boundary solutions, and present a unified description of these topological matters. Then I focus on the quantum transport of Dirac fermions and Weyl fermions, and comparison between theoretical prediction and experimental observation in topological insulators and newly discovered Weyl semimetals.

Phase diagram in bilayer graphene in electric and weak out-of-plane magnetic fields

Junji Jia
Wuhan University

We study using the non-perturbative Schwinger-Dyson equations the various quantum Hall states of bilayer graphene in the presence of electric field, parallel and weak perpendicular magnetic field. We took into account dynamical polarization and four-fermion interactions. It is found that when there is no electric or magnetic field, the layer-antiferromagnetic (LAF) state is indeed the ground state. However as the electric field increases and pass a critical value, the quantum valley Hall state becomes realized. The phase separation line in the parameter space spanned by the electric and parallel magnetic takes the form $E=E_{01}+c_1B^2_parallel$. In the parameter space spanned by the electric and perpendicular magnetic field, there is also a phase separation with phase boundary given by $E=E_{02}-c_2B^2_perp$. These phase boundaries are compared with experimental result and quantitative agreement is found.

Electronic transport properties of the topological 1D zero-line mode

Zhenhua Qiao
University of Science and Technology of China

Various topological states of two dimensional systems have attracted much attention partly for the promising applications in dissipationless devices. Based on the quantum valley Hall effect in graphene, the topological channels or topological zero line modes are proposed at the boundary of two topological systems with different topological indexes. One simple way to obtain the topological channel is varying the mass term spatially in monolayer graphene. The electrons are localized cross the channel while propagate along the channel. Such channel possesses striking properties including both chiral propagation and suppressed backscattering. Because of such properties, at the intersection of two topological channels, the current partition can be described by only one parameter. Counterintuitively, we find the current partition prefers a sharp-turn path and depending on the geometry of the intersection only. These properties also apply to zero-line intersections in AB-stacking bilayer graphene, which can be realized by applying spatial varying out-of-plane electric field via external gates. In this system, a gate tunable beam splitter has been proposed which is achievable in room temperature. Moreover, by applying weak external magnetic field, the sensitivity of the beam splitter can be remarkably increased. These properties make zero-line beam splitter conceptually promising for switching applications.

Insight from few-body on many-body Physics in cold atom systems

Hui Zhai

Tsinghua University

In this talk I will give some examples of how the study of few-body physics can give insight on many-body physics in cold atom systems. One example is the confinement induced resonance in orbital spin-exchanging scattering in alkali-earth atoms, with which we can identify a regime to observe high temperature Kondo effect in this system. The second example is dipolar interaction induced resonance, where we can find fermion superfluid that spontaneously breaks time-reversal symmetry.

Robustness, Tunability, and Functional Properties of Topological Surface States in Topological Insulator Heterostructures

Zhenyu Zhang

University of Science and Technology of China and Wuhan University

The recently discovered quantum materials of topological insulators (TIs), characterized by being insulating in the bulk but with topologically protected surface states (TSS), have been the focus of much current research effort. In particular, how robust such TSS are under diverse physical conditions and their functional properties are of significant fundamental and technological importance. This talk attempts to review some of our latest developments surrounding these two aspects of topological insulator thin films and heterostructures. We first show that an overlayer of gold on a TI substrate may exhibit enhanced catalytic properties due to the presence and robustness of the TSS. Next, we replace the overlayer by different conventional semiconductors, and demonstrate counterintuitive tunability in the vertical location of the TSS. Thirdly, when the systems are further expanded to superconductor/TI interfaces, the TSS-mediated ferromagnetic ordering of magnetic dopants at the interfaces helps to define a more promising platform for detection of Majorana fermions. We conclude by presenting a new V-I codoping scheme that enables the TI thin films to harbor high-temperature quantum anomalous Hall effects.

Optical properties of 2D transition metal dichalcogenides

Xiaodong Cui

The University of Hong Kong

Atomically thin Group VI transition metal dichalcogenides crystals (TMD) emerge as a family of intrinsic 2 dimensional (2D) semiconductors and come across a transition from indirect gap materials at the bulk form to direct band gap semiconductors at the monolayer limit. Monolayer TMDs are ideal quasi-two-dimensional semiconductors with a sizeable bandgap in the visible and near infrared range, satisfying the fundamental requirements for ultimate electronics and optoelectronics. In addition, the characteristic inversion symmetry breaking presented in monolayer TMDs leads to non-zero but contrasting but non-zero Berry curvatures and opposite orbit magnetic moments at K/K'valleys located at the six corners of the first Brillouin zone. These features provide the opportunity to manipulate electrons'additional internal degrees of freedom, namely the valley degree of freedom, making monolayer TMDs a promising candidate for the conceptual valleytronics. In this talk, I will introduce our progress in the optical study of 2D TMDs.

Topological and Strong correlation physics in orbital-active honeycomb lattice -- from solid states to optical lattices

Congjun Wu

University of California, San Diego

Different from graphene which is orbitally inactive, the p_x/p_y-orbital bands in the 2D honeycomb lattice are orbitally active, which apply to both optical lattices and several classes of solid state systems including organic materials, fluoridated tin film, BiX/SbX(X=H, F, Cl, Br). The interplay between the orbital structure and spin-orbit coupling gives rise to the 2D quantum spin Hall state and quantum anomalous Hall state with large topological gaps. The gap magnitudes are equal to the spin-orbit coupling strength at the atomic level, and thus are much larger than those based on the *s-p* band inversion. The energy spectra and eigen-wavefunctions are solved analytically based on the Clifford algebra, which greatly facilitates the topological analysis. Flat bands also naturally arise and the consequential non-perturbative physics includes Wigner crystallization and ferromagnetism. In the Mott-insulating state, orbital exchange is highly frustrated described by a quantum 120° model which is similar to but different from the Kitaev model. An f-wave Cooper pairing arises if the band is filled with spinless fermions exhibiting boundary zero energy Andreev modes. Although the pairing mechanism is conventional, the unconventional pairing symmetry is driven by the non-trivial band structure.

Electronic Properties of Novel Two-dimensional Materials

Yuanbo Zhang

Fudan University

Two-dimensional atomic crystals, best exemplified by graphene, have emerged as a new class of material that may impact future science and technology. In this talk I will first discuss the physics and material aspect of graphene. Drawing from our experiences in graphene study, I will then discuss other 2D materials, including black phosphorus and 1T-TaS2 thin film - two new materials with vastly different properties. We explore their electronic properties while the doping and dimensionality of the 2D systems are modulated.

Nanowire spin-orbit qubits: Electric-dipole spin resonance and anisotropic exchange coupling

Jianqiang You

Beijing Computational Science Research Center

A semiconductor nanowire quantum dot with strong spin-orbit coupling (SOC) can be used to achieve a spin-orbit qubit. In contrast to a spin qubit, the spin-orbit qubit can respond to an external a.c. electric field, an effect called electric-dipole spin resonance. Here we develop a theory that can be applied in the strong SOC regime. We find that there is an optimal SOC strength, where the Rabi frequency induced by the a.c.

electric field becomes maximal. Also, we show that both the level spacing and the Rabi frequency of the spin-orbit qubit have periodic responses to the direction of the external static magnetic field. These responses can be used to determine the SOC in the nanowire. In addition, our study is extended to a semiconductor nanowire double quantum dot with strong SOC. We show that both spin-conserved and spin-flipped tunnelings exist and they can compete with each other when increasing the SOC. Moreover, strong Coulomb repulsion in the nanowire double quantum dot can be combined with the SOC-dependent tunnelings to yield an anisotropic exchange coupling between the two spin-orbit qubits. Furthermore, we give an explicit physical picture for this anisotropic exchange coupling.

Valley and spin physics in 2D transition metal dichalcogenides

Wang Yao

The University of Hong Kong

The Bloch bands in many crystals have a degenerate set of energy extrema in momentum space known as valleys. For band-edge carriers, the valley index becomes a discrete degree of freedom in addition to spin. In this talk, I will show that in monolayer transition metal dichalcogenides, the pair of valleys which are time-reversal of each other are distinguishable by their opposite values of magnetic moment, Berry curvature, and circularly-polarized optical transition selection rule. This allows the use of valley pseudospin as information carrier for valley based electronics. I will discuss mechanisms to generate and control the spin and valley pseudospin currents, which are at the heart of spin and valley based electronics. These include: (I) the valley and spin Hall current arising from the Berry curvatures; and (II) the nonlinear valley and spin currents arising from Fermi pocket anisotropy. I will also discuss the valley Hall effect and valley current injection of excitons in TMDs monolayers and heterobilayers.

On the foundation of quantum statistical mechanics

Biao Wu

Peking University

Cold atom experiments have renewed people’s interests on the foundation of quantum statistical mechanics as it is now very promising that the equilibration of an isolated many-body quantum system can be investigated experimentally. I shall examine the foundation of quantum statistical mechanics in light of these new developments. I shall discuss quantum ergodicity and prove a new quantum H-theorem. With these results, we can now establish a novel micro-canonical ensemble without any hypothesis or postulate. These results not only provide a new perspective on the foundation of quantum statistical mechanics but also lead to prediction of new physics, such as quantum equilibrium state with multiple temperatures.

Cluster density matrix embedding theory for quantum spin systems

Quanli Jie

Wuhan University

We applied cluster density matrix embedding theory, with some modifications, to a spin lattice system. The reduced density matrix of the impurity cluster is embedded in the bath states, which are a set of block-product states. The ground state of the impurity model is formulated using a variational wave function. We tested this theory in a two-dimensional spin-1/2 J1 -J2 model for a square lattice. The ground-state energy (GSE) and the location of the phase boundaries agree well with the most accurate previous results obtained using the quantum Monte Carlo and coupled cluster methods. Moreover, this cluster density matrix embedding theory is cost effective and convenient for calculating the von Neumann entropy, which is related to the quantum phase transition.

Searching for the Fulde-Ferrell-Larkin-Ovchinnikov states in ultracold atomic Fermi gases in 3D continuum

Qijin Chen
Zhejiang University

The elusive Fulde-Ferrell-Larkin-Ovchinnikov (FFLO) states have attracted enormous attention in the condensed matter and AMO communities. They have not been observed experimentally in three-dimensional (3D) Fermi gases thus far. This has been largely attributed to their predicted small region and very low temperature in the phase space. In this talk, I will discuss the stability of the FFLO states in 3D homogeneous Fermi gases, both in equal-mass and mass imbalanced systems, within a pairing fluctuation theory. I will show that the effective mass of noncondensed pairs in the directions perpendicular to any presumed FFLO wavevector would be negative, leading to instability of the FFLO states previously predicted in the literatures. As a result, symmetry breaking factors such as optical lattices and spin-orbit coupling are necessary in order to stabilize the FFLO states.

Landau-Zener transition in a superconducting qubit system

Shiliang Zhu
Nanjing University

In this talk, I will present two contents of Landau-Zener transition in a superconducting qubit system. In the first part, I will talk about geometric Landau-Zener interferometry. In a recent experiment, we demonstrate Landau-Zener interferometry based on the pure geometric phases and observe its robustness. The full controllability of the qubit state as a function of the intrinsically robust geometric phase provides a promising approach for quantum state manipulation.

In the second part, I will present a direct experimental observation of the correspondence between Landau-Zener transition and Kibble-Zurek mechanism also with a superconducting qubit system. We develop a time-resolved approach to study quantum dynamics of the Landau-Zener transition. By using this method, we observe the key features of the correspondence between Landau-Zener transition and Kibble-Zurek mechanism, e.g., the boundary between the adiabatic and impulse regions, the freeze-out phenomenon in the impulse region. Remarkably, the scaling behavior of the population in the excited state, an analogical phenomenon originally predicted in Kibble-Zurek mechanism, is predicted and then observed in the Landau-Zener transition.

High precision calculations of Helium and Lithium

Haoxue Qiao

Wuhan University

Physics of ultracold diatomic polar molecules

Su Yi

Institute of Theoretical Physics, CAS

Following the rapid experimental development, ultracold molecular gases have attracted tremendous interest in the cold atom society. It is believed that ultracold molecular gases may offer remarkable new frontiers for many areas of science, such as precision measurement, quantum information, quantum computation, ultracold collisions, cold controlled chemistry, and quantum simulation. In this talk, I first give a long introduction to the physics of ultracold diatomic polar molecules, then I will present our recent work on the spinor condensates of rotating polar molecules.

Magnetization resonance of nonsecular dipolar interaction in spin-1 Bose-Einstein condensates

Wenxian Zhang

Wuhan University

The nonsecular terms in dipolar interaction are usually neglected due to an applied medium/strong external field. However, the effect of these nonsecular terms is of great importance in low/zero fields. Here, we analytically investigate the zero-field magnetic dipolar interaction effect, with an emphasis on the nonsecular terms, on the spin dynamics of a spin-1 Bose-Einstein condensate under the single spatial mode approximation within the mean field theory. Due to the biaxial nature of the dipolar interaction, the spin components, particularly the z-component (magnetization), exhibit periodic oscillations where a novel resonance occurs if the two terms along each axis are balanced for a certain initial spin state. To detect this dipolar spin resonance, we propose an experimentally feasible dynamical-decoupling method, which suppresses only the Zeeman effect of an external stray magnetic field and restores the magnetization dynamics. Moreover, we explore the dipolar spin resonance beyond the single mode approximation by numerically solving the coupled Gross-Pitaevskii equations.

Time-Reversal-Invariant Topological Superconductivity (I)

Fan Zhang

The University of Texas, Dallas

The discovery of topological insulators has created a revolution in condensed matter science that has far ranging implications over coming decades. I will introduce a simple way to understand the essential ideas of band inversion and symmetry protection. I will then apply these ideas to insulators, semimetals, and superconductors. In the superconductor case, Majorana fermion(s) may appear on the boundary and induces fractional Josephson effects. All these topological aspects in solid-state systems can be fit into an elegant "periodic building", with the Kitaev table being its ground floor. Experimental signatures, potential applications, and future directions will be discussed.

Interacting fermions in one dimension: from zero temperature to high temperatures

Xiwen Guan

Wuhan Institute of Physics and Mathematics, CAS

One of professor C N Yang's most important papers is about a rigorous approach to the thermodynamics of the one-dimensional system of bosons with delta-function interactions, published with his brother professor C P Yang in 1969. This brilliant method yields significant applications in a wide range of fields in physics, including recent elegant applications in ultracold atoms. In this lecture, I will discuss the advanced application of the Yang-Yang equilibrium statistical mechanics to the study of correlation functions and universal thermodynamics of interacting fermions. I will demonstrate how Bethe ansatz results provide a fundamental understanding of many-body phenomena, including asymptotics of correlation functions, spin-charge separation, Tan's contact, Wilson ratio, ferromagnetism and Boltzmann statistics.

New effects in optimizing the thermoelectric performance of some example systems

Huijun Liu

Wuhan University

In this talk, we discuss several new effects in optimizing the thermoelectric performance of some example systems. We first show that band convergence in the $Mg_2Si_{1-x}Sn_x$ solid solutions at a particular Sn conent leads to a high value of the Seebeck coefficient, which has been confirmed by explicit calculations and experimental measurements. We then emphasize the importance and necessity that only when the vdW and GW effects are both taken into account, can we give an accurate prediction of the electronic and transport properties of Bi_2Te_3 and other similar systems. Finally, we demonstrate that the very existence and robustness of the topological surface states offers unique new design strategies to not only significantly enhance the thermoelectric performance of Bi_2Te_3 thin films, but also potentially bridge the long-standing *ZT* asymmetry of *p*- and *n*-type Bi_2Te_3 systems.

Novel quantum magnetism with SU(2N) and Sp(2N) symmetries -- large spin fermions are different

Congjun Wu

University of California, San Diego

The large spin ultra-cold fermionic systems provide a whole new opportunity to investigate large symmetries, say, Sp(2N) and SU(2N), which are usually studied in high energy physics. In our early works, we proved an exact and generic Sp(4), or, isomorphically SO(5) symmetry in hyperfine spin-3/2 systems without fine-tuning. This symmetry provides a unified framework to understand quantum magnetism, and superconductivity in such a system. For the recent experimental system of Yb atoms with the SU(6) symmetry, its quantum magnetic fluctuations are much stronger than that of spin-1/2 electrons in solids. We employ the determinant projector quantum Monte-Carlo method to investigate the ground state magnetic properties in the Mott insulating states of the half-filled Fermi-Hubbard model in the 2D square lattice, which is free of the sign problem. Long-range Néel orders are found for at small and intermediate values of *U*, and exhibit nonmonotonic behavior with respect to *U*, which first grow and then drop as *U* increases. This result is fundamentally different from the SU(2) case in which the Néel moments increase monotonically and saturate. A transition to the columnar dimer phase is found in the strong interaction regime. We also have also investigated the thermodynamic properties which shows the effectiveness of Pomeranchuk cooling in the SU(6) system.

Many-body physics with ultracold quantum gases in disorder

Georgy Shlyapnikov

LPTMS, Universite Paris Sud, France

I will first give a brief overview of the studies of ultracold quantum gases in disorder and then turn to one-dimensional interacting disordered bosons at finite temperatures. It will be shown that they may undergo an interaction-induced non-conventional insulator-fluid transition, and I will present the phase diagram. The next issue will be interacting bosons in the quasiperiodic potential (superposition of two incommensurate one-dimensional lattices). I will demonstrate the presence of finite temperature many-body localization-delocalization transition induced by the interaction between the bosons. It will be shown that in a wide range of parameters an increase in temperature favors the insulator state, so that in this sense one has an anomalous “freezing with heating” phenomenon. The origin of this phenomenon lies in a peculiar behavior of single-particle states.

Localization-delocalization transition and many-body localization in interacting quasiperiodic systems

Shu Chen

Institute of Physics, CAS

I shall introduce our recent work on the localization problem of one-dimensional interacting spinless fermions in an incommensurate optical lattice, which changes from an extended phase to a nonergoic many-body localized phase by increasing the strength of the incommensurate potential. We identify that there exists an intermediate regime before the system enters the many-body localized phase, in which both the localized and extended many-body states coexist, thus the system is divided into three different phases, which can be characterized by normalized participation ratios of the many-body eigenstates and distributions of natural orbitals of the corresponding one-particle density matrix. This is very different from its noninteracting limit, in which all eigenstates undergo a delocaliztion-localization transition when the strength of the incommensurate potential exceeds a critical value.

Production and dissociation of Feshbach molecules in Fermi gas with SOC

Pengjun Wang
Shangxi University

I will present the spin orbit coupling (SOC) in ultracold Fermi gases, which plays a vital role in creation and dissociation of Feshbach molecules in our experiment. In the production, we demonstrate a dynamic process in which spin-orbit coupling coherently produces s-wave Feshbach molecules from a fully polarized Fermi gas, and induces a coherent oscillation between these two. This demonstrates experimentally that spin-orbit coupling does coherently couple singlet and triplet states, and implies that the bound pairs of this system have a triplet p-wave component, which can become a topological superfluid by further cooling to condensation and confinement to one dimension.

In the dissociation of Feshbach molecules in ultracold Fermi gases with spin-orbit (SO) coupling. Since SO coupling can induce a quantum transition between Feshbach molecules and the fully polarized Fermi gas, the Feshbach molecules can be dissociated by the SO coupling. We experimentally realize this type of dissociation in ultracold gases of 40K atoms with SO coupling created by Raman beams and observe that the dissociation rate is highly nonmonotonic on both the positive and negative Raman-detuning sides. Our results show that the dissociation of Feshbach molecules can be controlled by different degrees of freedoms. We expect our work to open a door for using cold gases to recreate and explore the physics of topological insulators and superconductors.

Collective excitations in gaped 2D systems with strong spin orbit coupling

Li Mao
Wuhan University

Plasmons, the collective excitations of electrons, are studied in 2D systems with strong spin orbit coupling (SOC) and external Zeeman field. We calculate the plasmon dispersions by numerical method with different parameters, such as the strength of Zeeman field, the type of SOC, and the relative strength of Rasba and Dresselhuas SOC. We also get the dispersions when the systems have superconductivity, in this case, we have different Chern numbers (+1,0,-1) corresponding to different relative SOC strength.

Time-Reversal-Invariant Topological Superconductivity (II)

Fan Zhang
The University of Texas, Dallas

We generalize the essential idea of band inversion and symmetry protection to experimentally feasible superconducting systems with time-reversal symmetry. When such a one-dimensional system becomes topological nontrivial, a Majorana Kramers pair appears on the boundary, producing tabletop supersymmetry, high critical temperature, quantized tunneling conductance plateaus, and unprecedented fractional

Josephson effects. The latter effects have two significant implications: (i) the existence of a "periodic building" unifying all the free-fermion topological systems and (ii) the possibility of fractionalization in superconductors.

Three-body scattering hypervolumes for bosons

Shina Tan

Georgia Institute of Technology

In the physics of ultracold atoms, the two-body scattering length is a well-known parameter. Much less is known about the analogous parameter for three particles, such as three identical bosons. I show that one can expand the three-body wave function for zero collision energy and zero orbital angular momentum at large hyperradii rho. At the order 1/rho^4, the three-body scattering hypervolume D appears. D is directly related to the three-body coupling constant g_3 in the low-energy effective field theory. I also show the values of D for some interaction potentials. As a fundamental parameter, D affects virtually ALL the properties of three or more bosons at low temperatures.

TBA

Wuming Liu

Institute of Physics, CAS

Participants

1.	Qijin Chen	Zhejiang University
2.	Shu Chen	Institute of Physics, CAS
3.	Xiaodong Cui	The University of Hong Kong
4.	Xiwen Guan	Wuhan Inst. of Phys. and Math., CAS
5.	Junji Jia	Wuhan University
6.	Quanlin Jie	Wuhan University
7.	Huijun Liu	Wuhan University
8.	Wuming Liu	Institute of Physics, CAS
9.	Zhengyou Liu	Wuhan University
10.	Li Mao	Wuhan University
11.	Qian Niu	University of Texas, Austin
12.	Haoxue Qiao	Wuhan University
13.	Zhenhua Qiao	University of Science and Technology of China
14.	Shunqing Shen	The University of Hong Kong
15.	Georgy Shlyapnikov	LPTMS, Orsay, France
16.	Shina Tan	Georgia Institute of Technology
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24. Hui Zhai	Tsinghua University
25. Fan Zhang	The University of Texas, Dallas
26. Wenxian Zhang	Wuhan University
27. Yuanbo Zhang	Fudan University
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Note

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