00-01

Non-Hermtian Linear Response Theory

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Recently, a remarkable experiment find a slowing down of the decay process and a sub-diffusion in momentum distribution in a dissipative non-Hermtian Bose Hubbard model. In our talk, we present a general response theory when a system receives a non-Hermtian perturbation. We find the slowing down of the decay process is related the behavior of the single particle spectrum. Anomalous critical exponent can be extracted from the decay. We also find when there are two-body loss in the system, the momentum distribution spreading and the peak momentum occupation deviation follow an universal function up to a constant. These predictions are tested in experimental data and we find the experimental data follows our theory in high accuracy.

[1]
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00-02

Scale Invariance meets Non-Equilibrium: Universality & Quantum Fractal

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In this talk I discuss several universal behaviors of various quantum systems quenched to be scale-invariant. In the first part, we study the dynamics of a bosonic system with the binary interaction quenched to unitarity [1]. Using an Bogoliubov-type time-dependent variational ansatz, we discover that, in the long-time limit, the momentum distribution obeys a universal form, matching with a recent experimental work [2]. In the second part, we study the dynamics of a generic quantum system with its external potential quenched to be inverse-square-like. Surprisingly, fractal structure will possibly emerge in some dynamical observables, say, the Loschmidt echo and zero-momentum occupation[3]. We analyze the key ingredient and conditions for such quantum fractal.

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00-03

Kondo dynamics in ultracold alkaline-earth-like atoms at finite temperatures

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Thanks to technical developments in controlling ultracold alkaline-earth-like atoms, analog quantum simulators of multiorbital many-body systems are being realized [1, 2]. Specifically, the experimental observation of the antiferromagnetic interaction between stable and metastable states of ^{171}Yb atoms [2] makes it highly possible to simulate the Kondo model, one of the most fundamental multiorbital many-body systems. A characteristic feature of the Kondo model is the anomalous temperature dependence of the electric resistivity, namely the Kondo effects.

In this study, we discuss how to observe the Kondo effects in ultracold atoms. For this purpose, we numerically simulate the center-of-mass (COM) motion of itinerant fermions induced by the sudden shift of a trap center. For quasi-exact numerical simulations, we restrict systems to one spatial dimension and use the minimally entangled typical thermal states (METTS) [3], which is a Markov-chain Monte Carlo algorithm for simulating finite-temperature systems based on matrix product states. We also resolve the autocorrelation problem of the METTS algorithm by applying Trotter gates.

As shown in Fig.1, the mobilities of the COM velocities decrease as temperature decreases; this tendency is consistent with the Kondo effects. We also confirm that such temperature dependence is absent in systems where the Kondo effects do not occur: the fully spin-polarized system and the ferromagnetic Kondo model. Furthermore, the temperature dependence of the peak COM velocities shows a logarithmic dependence. From these results, we conclude that one can detect the Kondo effects in ultacold atoms from the temperature dependence of the COM velocities.

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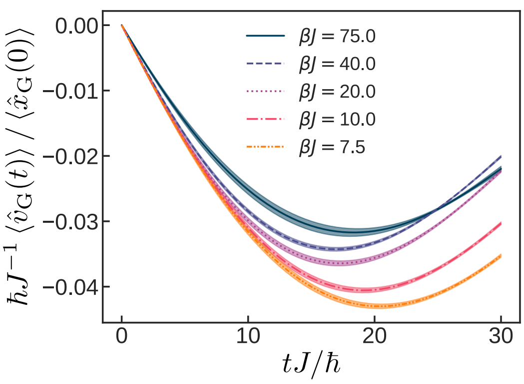

Fig. 1: Dynamics of the normalized center-of-mass velocities.

00-04

Quantum simulation with ytterbium atoms : from topological matter to SU(N) fermions

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Alkaline-earth-like atoms have opened new possibilities to explore synthetic quantum systems ranging beyond the condensed matter model from topological matter to large spin Fermi gases. In particular, the rich electronic structure of such atoms enables us to use a narrow optical transition with minimal heating as well as a large spin manifold with SU(N) symmetry. In this talk, I will briefly discuss two sets of recent experiments with ^{173}Yb atoms. First, I will describe the realization of 3D topological band using Raman-induced spin-orbit coupling in an optical lattice [1,2]. Despite the significant progresses, the observation of topological band beyond 2D has remained challenging due to the experimental complexity. We developed a novel way to probe 3D band structure in the presence of emergent magnetic group symmetry. This symmetry allows for effectively reconstructing the 3D topological band from a series of measurements of integrated spin textures. As a result, we demonstrate that 3D topological band structure with gapless nodal-lines are realized in simple optical lattice potentials with Raman-coupling.
In the second part of my talk. I will report the experimental study of 2D Fermi gases with SU(N) tunable spin [3]. We investigate collective excitations of a harmonically trapped 2D SU(N) Fermi gas confined to a stack of layers formed by a one-dimensional optical lattice. Quadrupole and breathing modes are monitored in the collisionless regime with tunable spin. We observe the quadrupole mode frequency decreases with increasing number of spin component N due to the amplification of the interaction effect by N. Toward the end of the talk, I will discuss bottom-up characterization of such SU(N) fermions with the measurement of Tan's contact.

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00-05

Towards Optimal Quantum Simulations

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Abstract: Quantum simulations have been attracting tremendous efforts in the last decade. With the rapid developments in quantum control techniques in synthesised quantum systems such as optical lattices and trapped ions, we are at a stage to perform quantum simulations of complicated models. However the commonly existing problem of finite lifetime or finite coherence time in these systems requests quantum simulations to be performed in an optimal way. Considering the adiabatic approach, optimising quantum simulation performance is also fundamentally related to quantum computing complexity. In this talk, I will describe ways and examples to optimise the adiabatic approach of quantum simulations. The first one is about to optimize quantum simulations of doped Fermi-Hubbard model [1]. I will present an approach of quantum adiabatic doping using incommensurate optical lattices. Optimizing the quantum simulations from exponential complexity to polynomial in this problem turns out to be equivalent to driving a dynamical phase transition of the system from a localized to ergodic phase. The second one is about an automatic design of quantum adiabatic algorithm for Grover search that automatically leads to a quadratic quantum speedup [2]. This automated design of quantum adiabatic algorithms with optimal quantum speedup can be generalised to optimize quantum simulations.

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00-06

Realizing the Hayden-Preskill Protocol with Coupled Dicke Models

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Hayden and Preskill proposed a thought experiment that Bob can recover the information Alice throws into a black hole if he has a quantum computer entangled with the black hole, and Yoshida and Kitaev recently proposed a concrete decoding scheme. The parallel question is that after a small system is thermalized with a large system, how one can decode the initial state information with the help of two entangled many-body systems. Here we propose to realize this protocol in a physical system of two Dicke models, with two cavity fields prepared in a thermofield double state. We show that the Yoshida-Kitaev protocol allows us to read out the initial spin information after it is scrambled into the cavity. We show that the readout efficiency reaches a maximum when the model parameter is tuned to the regime where the system is the most chaotic, characterized by the shortest scrambling time in the out-of-time-ordered correlation function. Our proposal opens up the possibility of discussing this profound thought experiment in a realistic setting.

00-07

Collisional properties of Fermi gases with p-wave interactions

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Fermionic p-wave superfluidity presents a rich variety of novel phenomena caused by the complex order parameters. Ultracold gas of fermionic atoms would offer great opportunities to study p-wave superfluid phases with the precise control of atomic physics. In contrast to the case of fermionic atoms near a s-wave Feshbach resonance, fermions near a p-wave Feshbach resonance suffer from serious inelastic collision losses. Therefore, it is not obvious how p-wave superfluidity can actually be achieved in a system of ultracold atoms. As a first step toward realization of the p-wave superfluidity, we investigate p-wave elastic and inelastic collisional properties of ^{6}Li atoms near a p-wave Feshbach resonance. We measure the two-body dipolar relaxation rate coefficients as functions of p-wave interaction strength and atomic temperature. We find that the results can be explained by the model which takes into account the two-body loss as an imaginary part to the inverse scattering volume. It is also confirmed that the treatment of the two-body loss works in three-dimensionally and two-dimensionally trapped gases. We also investigate the three-body loss in a single component gas of ^{6}Li atoms near a p-wave Feshbach resonance. We have successfully observed the scaling law of three-body loss coefficients as a function of the scattering volume at the weak interaction limit[1], and unitality-limited behavior of the three-body loss coefficients at the strong interaction limit for the first time [2,3]. We have also successfully observed the control of orbital angular momentum of p-wave molecules using optical lattices. In the presentation, we discuss the elastic and inelastic collisional properties of ^{6}Li atoms near a p-wave Feshbach resonance.

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00-08

Non-Hermitian Kondo/Hubbard physics in ultracold atoms

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The Kondo effect and the Hubbard model offer two paradigmatic examples of quantum many-body physics and play an essential role in our understanding of strongly correlated materials. Quantum simulation of the Kondo/Hubbard physics with ultracold atoms has remarkably progressed in recent years [1, 2]. However, as a possible drawback, ultracold atoms may be suffered from atom loss due to inelastic collisions, as indeed observed in the Kondo [1] and Hubbard [3] simulators. Although those inelastic collisions have been considered to be detrimental to quantum many-body effects, recent studies have revealed that engineering the atom loss provides a new control knob of quantum phases of ultracold gases [4]. Motivated by these experimental developments, here we show that ultracold atoms subject to inelastic collisions provide a novel platform of quantum many-body physics described by effective *non-Hermitian* Hamiltonians. In particular, we discuss how non-Hermiticity alters the two paradigmatic examples of quantum many-body effects, i.e. the Kondo effect [5] and magnetism in the Hubbard model [6]. First, we show that non-Hermiticity induces anomalous reversion of renormalization-group flows which is prohibited in Hermitian systems, leading to a quantum phase transition induced by inelastic collisions [5]. Second, we demonstrate that a finite lifetime of intermediate states in virtual spin-exchange processes stabilizes high-energy spin states, realizing magnetic correlations characterized by a negative absolute temperature [6].

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00-09

Conformality, bulk viscosity, and contact correlation

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This talk is intended to present the interrelationship among conformality, bulk viscosity, and contact correlation, based on Refs. [1-3]. I will first review the conformal invariance in nonrelativistic systems and its physical consequences. In particular, the conformal invariance is useful to constrain how the spacetime-dependent scattering length enters hydrodynamics and it proves to naturally couple with the bulk viscosity. This finding can also be derived microscopically by expressing the bulk viscosity in terms of the contact-contact correlation function, which is useful evaluate the bulk viscosity systematically with the quantum virial expansion.

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00-10

Quantum simulation using itenerant $^1S_0$ atoms and localized $^3P_0$ atoms in a state-dependent optical lattice

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One of the motivation of our work is the quantum simulation of the Kondo effect, which is the quantum many-body phenomenon which arises from an antiferromagnetic spin-exchange interaction between conduction electrons and magnetic impurities. It was originally studied in the context of the enhancement of the resistivity in magnetic alloys at low temperature, and now it is a ubiquitous problem in condensed matter physics.
Recently, alkaline-earth atoms have been intensively studied as an experimental platform for quantum simulations with two-orbital degrees of freedom owing to the existence of the metastable states $^3P_0$ and $^3P_2$ as well as the ground state $^1S_0$, and the two-orbital system using the $^1S_0$ and $^3P_0$ states is proposed as a promising candidate of the quantum simulation of the Kondo effect [1]. One of essential ingredients for the mechanism of the Kondo effect is an interorbital antiferromagnetic coupling. The interorbital collisional properties in fermionic isotopes of ^{173}Yb and ^{87}Sr are previously investigated, finding that the spin-exchange interactions are ferromagnetic. Also, the interorbital spin-exchange dynamics using ^{173}Yb atoms is observed [2].
In this talk, I will report the measurement of the interorbital spin-exchange interaction of another fermionic isotope of ^{171}Yb [3]. The results show that the interorbital spin-exchange interaction is antiferromagnetic. Also, I will talk about our experiments in the 0+1 dimensional system where atoms in the ground state $^1S_0$ and in the metastabe state $^3P_0$ are itenerant and localized, respectively. In this system, the interorbital spin-exchange dynamics is obaserved.

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00-11

Probing topology and geometry through periodic shaking in ultracold atomic gases and beyond

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Topological and geometrical property of energy bands have attracted great attention during the past decade. Probably the most well-studied geometrical property is the Berry curvature, integral of which gives rise to the topological Chern number. A less well known geometrical property is the quantum metric, or the Fubini-Study metric, which provides a Riemannian metric structure in the Brillouin zone. The Berry curvature and the quantum metric can be united by introducing the concept of the quantum geometric tensor, real and imaginary parts of which are the quantum metric and the Berry curvature, respectively.
It was found in [1] that the Berry curvature and the Chern number can be experimentally measured by looking at the excitation rate of the system upon adding a time periodic modulation. In this talk, I explain that an analogous method can be used to also measure the quantum metric [2], which has been implemented in an experimental [3]. I will also discuss that the concept of the quantum geometric tensor can be defined in a general parameter space as well, and time periodic modulation can be used to measure it [2]. Experiments have been performed to detect the quantum geometric tensor in the Bloch sphere for diamond NV centers [4] and superconducting qubits [5]. I conclude the talk by extending the quantum geometric tensor to interacting systems, and showing that the quantum metric is related to localization of a quantum state and how it can be measured through response under time periodic modulation [6].

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00-14

Symmertry-protected topological phases with ultra-cold SU(N) fermions

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Great controllability and cleanness of ultra-cold gases enable us to realize exotic states of matter that are hardly possible in the traditional solid-state settings. In particular, generalizing the spin-SU(2) symmetry to general SU(N) provides us with a variety of intriguing phases [1]. In this talk, I consider (bosonic) symmetry-protected topological (SPT) phases in one dimension realized in ultra-cold fermions with SU(N) symmetry [2]. Specifically, I show that we can realize various SPT phases, including the ones that spontaneously break spatial-inversion symmetry (dubbed *chiral* SPT phases), with alkaline-earth-like (e.g., Sr, Yb) fermions loaded into an array of double-well optical lattices by controlling the number (N) of fermion multiplet and interactions [3]. I also discuss a closely related spin problem, i.e., the phase diagram of a two-leg ladder of SU(N) spins [4], that is derived as an effective Hamiltonian of the original fermion problem, with particular emphasis on the difference from that of the well-known SU(2) spin ladder.

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00-15

Super Hamiltonian in superspace for incommensurate superlattices and quasicrystals

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The concept of extra dimensions in the description of quasiperiodic structures dates back to their early developments in mathematics. In fact, quasiperiodic functions are defined as domain restrictions or projections of periodic functions with a higher-dimensional domain. To this date, however, there has been no clear path to constructing periodic Hamiltonian operators in a higher dimensional space – superspace – whose eigenfunctions, or at least some of them, are eigenfunctions of the original Hamiltonian when projected back onto physical space. In my talk I will show how to construct Hamiltonians in superspace which are periodic and, moreover, some or all of their eigenfunctions are also eigenstates of the physical Hamiltonian. I show, among other things, how to get rid of unphysical and degenerate states that necessarily roam in higher dimensions. Upon achieving this goal, it is possible to define a continuous index for the eigenfunctions of the physical Hamiltonian with dimension of momentum, and obtain the density of states from the properly labelled energy dispersion. Comparison is made to the density of states calculated via the exact Green's function of the system, which is obtained in closed form, being in perfect agreement. With this information at hand, I show that scattering states off defects or impurities can be easily calculated, which are of relevance for the transport properties of quasiperiodic systems and quasicrystals. The topologically non-trivial nature of these systems is probed by calculating edge states directly in the infinite size limit. As a bonus, the effective mass near the ground state is also obtained and subsequently used to obtain the critical point and critical exponent for the localisation-delocalisation transition in one dimension. I will also discuss future directions and improvements.

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00-16

Non-Hermitian skin effect, non-Bloch bands, and generalized bulk-boundary correspondence

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Non-Hermitian Hamiltonians can exhibit the counterintuitive behavior that all the eigenstates are localized at the boundary, which is dubbed the non-Hermitian skin effect. It implies a remarkable departure from the conventional Bloch band theory. In this talk, we will introduce the basic idea of non-Bloch band theory. In the first part, we show that the non-Bloch topological invariants defined in the generalized Brillouin zone faithfully predict the number of topological edge modes, embodying a generalized (non-Bloch) bulk-boundary correspondence. In the second part, we show that the non-Hermitian skin effect and non-Bloch bands have dramatic consequences in the dynamics of open quantum systems governed by the Lindblad master equation. Specifically, we show that the non-Hermitian skin effect induces the chiral damping and novel long-time behaviors.

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00-17

Machine Learning for Quantum Experiments

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With the development of technology and society, artificial intelligence and machine learning play a very important role in our daily life, like experimental control, pattern recognition, language translation and so on. Here we take care of machine learning for quantum experiments, especially using neural networks. As we all know, the neural network is a kind of fitting function. In order to make the function fitted well, generally we need a lot of labeled data to optimize parameters. However, while the experimental data are not abundant, we need to think about another way to make the fitting as well as possible with un-sufficient training data.

First we request labeled data in an economical way. Here we the active learning to make labeled data containing useful information which is benefit for fitting. We apply this to the evaporative cooling in cold atomic system. Evaporative cooling which is decreasing the trap depth with time to release atoms with high energy to make residual system reach to lower temperature. It's impossible to do the experiments with all kinds of decreasing procedure. So we use active learning to help us find a good cooling procedure with doing less times experiments.

Second is while experimental data are not sufficient, we can use theoretical data to help us analyze data. In this case we consider about analyzing scanning tunneling microscopy(STM) data to find the impurities in the patterns. While there is an impurity existed, the long-range behavior of the wave function is Friedel oscillation. Thus we simulated the theoretical data to train the neural network and using this trained network to predict the experimental data to help us find the impurities. But the 'fake' data is fake after all, there are lots of differences in the short-range details. So here we add the confidence term in our loss function while training, which makes the prediction of the experimental data better.

00-18

Two-fluid hydrodynamics of two-dimensional atomic superfluids across the BKT transition

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We study the sound propagation in two-dimensional atomic superfluids across the Berezinskii-Kosterlitz-Thouless transition. Landau's two-fluid hydrodynamic equations for sound propagation are modified, taking into account the responses of quantised vortices to the superfluid velocity field. Such responses are described by the dynamical dielectric constant, which we calculate using the dynamical Kosterlitz-Thouless theory. From the new hydrodynamic sound equations we determine the sound velocities and dampings both below and above the transition temperature. We find that the sounds propagate well above the transition temperature, albeit at a finite wave vector. This is qualitatively consistent with the recent experiment but contradicts other theory predictions.

00-19

Simulating frustrated quantum magnetism using negative-temperature Bose gases in triangular optical lattices

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We propose an experimental protocol and provide the necessary theoretical analysis for analog quantum simulation of frustrated quantum magnetism by using Bose gases in optical lattices [1]. Supposing a triangular-lattice system, we show that an analogous situation to geometrically frustrated antiferromagnets could be created at negative absolute temperatures [2] by performing a phase imprinting together with sudden inversion of the interatomic interaction and the trap potential. In the framework of the time-dependent Gutzwiller approach, we demonstrate that the frustrated (chiral) superfluid state created along the protocol is dynamically stable, and exhibits a Mott-insulator transition under a slow sweep of the hopping energy. In the process, the system simulates a state near equilibrium of the Bose-Hubbard model with sign-inverted hoppings. Besides, considering general cases with spatial anisotropy of hoppings, we provide a quantitative prediction on the quantum critical point of the chiral superfluid-Mott insulator transition by means of the cluster mean-field method with a cluster size scaling [3]. The result shows a significant interplay of frustration and quantum fluctuations, which serves as a benchmark for quantum simulation.

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00-20

d-wave three-body problem and speeding up the calculation with active learning

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Motivated by recent experimental progresses [1], we investigate few-body properties of interacting spinless bosons near a d-wave resonance. Using the Skorniakov-Ter-Martirosion (STM) equations, we calculate the scattering length between an atom and a d-wave dimer, and we find that the atom-dimer scattering length is positive and is much smaller the result from the mean-field approximation. We also reveal unique properties of the three-body recombination rate for a degenerate Bose condensate near the d-wave resonance [2]. In the above large-scale scientific calculations, it encounters the problem of determining a multi-dimensional function, which is time-consuming when computing each point in this multi-dimensional space is already demanding. In the talk, we will use a quantum three-boson problem to demonstrate that active learning algorithm can speed up this calculation. The basic idea is to fit this multi-dimensional function by neural networks, and the key point is to make the query of labeled date economically by using a stratagem called "query by committee". We will present the general protocol of this fitting scheme, as well as the procedure of how to further compute physical observable with the fitted results. In the three-boson example we present, the algorithm can capture the Efimov resonance and predict the atom-dimer scattering length with an error of a few thousandths, with only a few percents of total data points required [3].

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00-21

Quenching a Quantum Ising model with Z_2 Gauge Field

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Gauge theory has been playing a fundamental role in our understanding of the deepest mysteries of physics. And recent advances in cold atoms physics have also made the study of dynamical gauge systems a new frontier in our community. Using Floquet approach, we propose to realize a one-dimensional (1D) Z2 lattice gauge model, featuring extensive local constants of motions, using two specifies of atoms. Within a given symmetry sector of good quantum numbers, the system can be viewed as a 1D quantum Ising model with a uniform transverse field and a random longitudinal field. Numerical studies of the quench dynamics and its statistical descriptions will be presented.

00-22

Non-Hermitian Bulk-Boundary Correspondence in Quantum-Walk Dynamics

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Bulk-boundary correspondence, a central principle in topological matter relating bulk topological invariants to edge states, fails in a general class of non-Hermitian systems. In this talk, we show that the breakdown of bulk-boundary correspondence also occurs for discrete-time quantum walks, a particular type of Floquet dynamics, when an appropriate form of non-unitarity is introduced. Based on the understanding of static non-Hermitian topological models, we define non-Bloch topological invariants for the quantum-walk dynamics, which give rise to the non-Hermitian bulk-boundary correspondence. We experimentally confirm our theoretical predictions by observing non-Hermitian skin effect and non-Hermitian bulk-boundary correspondence in discrete-time non-unitary quantum-walk dynamics of single photons. Our work unequivocally establishes the non-Hermitian bulk-boundary correspondence as a general principle underlying non-Hermitian topological systems, and paves the way for a complete understanding of topological matter in open systems.

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00-23

Impurity-induced multibody resonances in a Bose gas

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A quantum impurity interacting with a bosonic field is ubiquitous in nature. A canonical example is the so-called Bose polaron, an impurity immersed in a Bose-Einstein condensate. Recent advances in cold-atom experiments have enabled Bose polarons to be realized and investigated experimentally. However, there are conflicting theories about their properties in the regime of the strong boson-impurity attraction. One view is that the impurity binds many bosons to form a superpolaronic state, while others argue that the Bose polaron is a highly correlated object involving only a few bosons.
In this work, we shed light on this issue by considering the problem of an infinite-mass impurity that is coupled to N non-interacting bosons. We show that a dynamical impurity-boson interaction, mediated by a closed-channel dimer, can induce an effective boson-boson repulsion, which strongly modifies the bound states consisting of the impurity and N bosons. In particular, we demonstrate the existence of two “multibody” resonances, where all multibody bound states involving any N emerge and disappear. The first multibody resonance corresponds to infinite impurity-boson scattering length, $a \to +\infty$, while the second corresponds to the critical scattering length $a_* > 0$ beyond which the trimer ($N = 2$ bound state) ceases to exist. We show that the behavior at these “multibody resonances” is universal, since it occurs for any model with an effective three-body repulsion involving the impurity. We also discuss implications of these findings for the nature of the Bose polaron currently being studied in cold-atom experiments.

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00-24

Interaction effects on $\mathcal{PT}$-symmetry breaking transition in atomic gases

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Non-Hermitian systems having parity-time ($\mathcal{PT}$) symmetry can undergo a transition, spontaneously breaking the symmetry. Ultracold atomic gases provide an ideal platform to study interaction effects on the transition. We consider a model system of N bosons of two components confined in a tight trap [1]. Radio frequency and laser fields are coupled to the bosons such that the single particle Non-Hermitian Hamiltonian $h_{\mathcal{PT}} = -i\Gamma\sigma_z + J\sigma_x$, which has $\mathcal{PT}$-symmetry, can be simulated in a *passive* way, namely in the physical system there is only incurred atom loss but no gain. We show that when interatomic interactions are tuned to maintain the symmetry, the $\mathcal{PT}$-symmetry breaking transition is affected only by the SU(2) variant part of the interatomic interactions. We find that the transition point $\Gamma_{\rm tr}$ decreases as the strength of this interaction part or N increases; in the strong strength limit for this interaction part, $\Gamma_{\rm tr}$ scales as the strength to the power of $-(N-1)$. We also give signatures of the $\mathcal{PT}$-symmetric and the symmetry breaking phases for the interacting bosons in experiment. .

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00-25

Morphological superfluid in a nonmagnetic spin-2 Bose-Einstein condensate

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Superflow is usually generated by a gradient of the U(1) phase. In spinor Bose-Einstein condensates (BECs), the spin-gauge symmetry provides the second mechanism of superfluidity. In the case of a spin-1 BEC, a superflow can be induced by a spin texture via the spin-gauge symmetry in the ferromagnetic phase, while it can only be carried by the gradient of the U(1) phase in the polar phase. However, it has not been clarified if a superflow is essentially zero in a nonmagnetic phase for any spin degrees of freedom.
In this presentation, we report that for the case of a spin-2 BEC, a spatial variation of the order parameter shape can generate a supercurrent even in the nonmagnetic phases, such as the nematic and cyclic phases, offering the hitherto unexplored the third mechanism of superfluidity [1]. We analytically derive the superfluid current in a nonmagnetic spin-2 BEC, that involves components that originate from the magnetic degrees of freedom and determine the symmetry of the order parameter. These components can be induced between two weakly coupled BECs with different order-parameter symmetries. We also demonstrate that the morphological supercurrent can be generated by the spatially dependent quadratic Zeeman effect, which is numerically shown.

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00-26

Information Scrambling in Quantum Neural Network

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A quantum neural network encodes information of the entire input wave function into few qubits, and the concept of information scrambling describes how local information scrambles into the entire system. In this talk I will point out that these two are reverse processes of each other. Therefore, we can apply the tripartite information developed for describing information scrambling to diagnose the training process of a quantum neural network. We find an empirical two-time-scale rule by examining two different tasks with different algorithms and different initializations. For sufficiently random initialization, we find that the training process contains two-time scales. In a short early time scale, the performance of the neural network improves rapidly, and the tripartite information increases with a universal slop. This means that the neural network becomes less scrambled than the initial random unitary. By analyzing two-point correlation, we show evidence that during this time scale of training, the neural network is performing locally construction. In a longer later time scale, the performance improves with a much slower rate, and the tripartite information decreases. By analyzing the performance of the neural network on the testing set with large domain structure, we show that during this time scale of training, the neural network starts to develop global structure and therefore the information is more scrambled. We believe that our work builds up a significant connection between two research topics and opens up a new way to understand the quantum neural network.

00-27

Analytical solution for the spectrum of two ultracold atoms in a completely anisotropic confinement

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We study the system of two ultracold atoms in a three-dimensonal (3D) or two-dimensional (2D) completely anisotropic harmonic trap, whose trapping frequencies are different in each direction. We derive the algebraic equation $J_{3D}(E) = 1/a_{3D}$ ($J_{2D}(E) = \ln a_{2D}$) for the eigen-energy E of this system in the 3D (2D) case, with a_{3D} (a_{2D}) being the 3D (2D) s-wave scattering length, and provide the analytical expressions of the functions $J_{3D}(E)$ and $J_{2D}(E)$. Although in previous researchs this type of equation was obtained for the cases with a spherically or axially symmetric harmonic trap [1,2], for our cases with a completely anisotropic trap people has only derived the equation for the ground-state energy [3]. Our results are applicable for arbitrary eigen-energy of this system, and can be used for the studies of dynamics and thermaldynamics of interacting ultracold atoms in this trap, e.g., the calculation of the 2nd virial coefficient or the evolution of two-body wave functions. In addition, our approach for the derivation of the above equations can also be used for other two-body problems of ultracold atoms.

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00-28

Role of effective range in the p-wave Fermi gas: Energetics and dynamics

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I will discuss the role of the effective range in a p-wave Fermi gas, in particular, its effect on the Fermi liquid descriptions as well as transport coefficients. Whenever possible, we will compare to the s-wave case where the effective range plays an entirely different role.

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00-29

Flat-band Ferromagnetism of SU(N) Hubbard Model on Tasaki Lattices

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We investigate the para-ferro magnetic transition of the repulsive SU(N) Hubbard model on a type of one-dimensional and two dimensional decorated cubic lattices originally designed by Tasaki. Under certain restrictions for constructing localized many-particle ground states of flat-band ferromagnetism, the quantum model of strongly correlated electrons is mapped to a classical statistical geometric site-percolation problem, where the nontrivial weights of different configurations must be considered. We prove rigorously the existence of para-ferro transition for the SU(N) Hubbard model on one-dimensional Tasaki lattice and determine the critical density by the transfer-matrix method. In two dimensions, we numerically investigate the phase transition of SU(3), SU(4) and SU(10) Hubbard models by Metropolis Monte Carlo simulation. We find that the critical density exceeds that of standard percolation, and increases with spin degrees of freedom, implying that the effective repulsive interaction becomes stronger for larger N. We further rigorously prove the existence of flat-band ferromagnetism of the SU(N) Hubbard model when the number of particles equals to the degeneracy of the lowest band in the single-particle energy spectrum.

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