SUN2024 abstracts

SUN2024: SU(N) physics in quantum many-body systems:
theory, experiment, and numerics

We will gather together theorists, experimentalists, and experts on numerical methods in the field of SU(N) physics.

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Contents

Novel Mott states and enhanced reponses in systems with controlled broken SU(N) symmetry

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Abstract

A large repulsion between quantum particles on a lattice can lead to their localization, as it happens for the electrons in Mott insulating materials. When we consider fermions with N $>$ 2 flavours and the global SU(N) is broken, even slightly, we can have novel quantum states that we can label as flavour-selective Mott states. We discuss the path from the theoretical prediction to the experimental detection of these states, with a particular emphasis on the results of a quantum simulation with Yb atoms where flavour-selective localization has been realized experimentally in a three-component system in the presence of a Raman coupling between two components (1). We briefly discuss the relation with solid-state counterparts (2).
We finally address how the combined presence of large Hubbard-like repulsion and Raman processes can lead to an enhancement of chiral currents close to the Mott transition (3) in one- or two-dimensional geometries.

This work reports about different manuscripts written with my coworkers including L. Del Re, M. Ferraretto, A, Richaud and L. de' Medici and with the group of L. Fallani in Florence, who performed the cold-atom experiments. The work is supported by MUR via PRIN 2020 (Prot. 2020JLZ52N 002) programs, PRIN 2022 (Prot. 20228YCYY7),MUR Project No. PE0000023-NQSTI and ICSC–Centro Nazionale di Ricerca in High Performance Computing, Big Data and Quantum Computing, funded by European Union – NextGenerationEU (Grant number CN00000013)

(1) D. Tusi et al., Nat. Phys, **18**, 1201 (2022); L. Del Re and M. Capone, Phys. Rev. A, **98**, 063628 (2018)

(2) L. de' Medici, G. Giovannetti and M. Capone, Phys. Rev. Lett., **112**, 177001(2014)
.
(3) M. Ferraretto, A. Richaud, L. Del Re, L. Fallani, and M. Capone, SciPost Phys. 14, 048 (2023)

*Speaker

TBA

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Abstract

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What can the SU(N) Hubbard model teach us about correlated matter?

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Abstract

The interplay of recent ultracold alkaline-earth atom experiments in optical lattices and theoretical calculations of the SU(N) Hubbard model describing them is opening a new window into strongly correlated matter. I will argue that these SU(N) systems have unique, important attributes that are absent in conventional SU(2) cold atom experiments. One such attribute is that some SU(N) experiments are now firmly out of the regime reachable with controlled numerical calculations, which makes the experiments powerful quantum simulators.

I will first discuss the current state of theoretical calculations in understanding the experiments, and then suggest avenues for algorithm development guided by these powerful quantum simulations.

I will also show how conceptual questions, such as the nature of holes doped into antiferromagnets, are ripe to be probed in these systems. As a concrete example, I will discuss the intriguing picture of the one-hole doped SU(3) Hubbard model presented by geometric string theory and its corroboration in DMRG calculations. I will present how this emerging can be studied in the first generation of alkaline-earth atom quantum gas microscope now coming online.

*Speaker

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iDMRG simulations of the SU(N) J1-J2 spin chains

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Abstract

According to field theory computations, the zero-temperature phase diagram of the J1-J2 SU(N) spin chains depends on the parity of N. While a transition from critical to a gapped SU(N) valence bond solid is always observed at small J2s, we find that for odd N a gapless phase reopen in the large J2 limit. This phase is in the SU(N)1 universality class due to the existence of a massless renormalization group flow from SU(N)2 to SU(N)1 conformal field theories.

In this talk, after presenting our RG analysis, I will discuss the strengths and limits of (i)DMRG applied to SU(N) spin chains, which allowed us to confirm (some of) the field theory predictions, and also revealed the existence of a commensurate to incommensurate transition within the valence bond phase for even N.

*Speaker

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Density matrix renormalization group boosted by Gutzwiller projected wave functions and its applications to SU(4) quantum magnetism

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Abstract

In this talk, I will discuss recent progress in combining fermionic Gaussian states with matrix product state. This method development not only enriches the tools for characterizing many fermionic parton ansatzes but also provides suitable initial states for improving the performance of the density matrix renormalization group method in two-dimensional systems. As an application, I will present our results on the SU(4) spin-orbital antiferromagnetic Heisenberg model on a triangular lattice, for which we provide evidence that its ground state is a spinon Fermi surface consisting of open orbits in the reciprocal space. We also study the SU(4) model on the honeycomb lattice and find that the ground states can be well described by a Gutzwiller projected π-flux state with Dirac-type gapless excitations.

*Speaker

sciencesconf.org:sun2024:510127

SU(N) symmetric Projected Entangled Pair States : construction and applications

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Abstract

In the context of SU(N) two-dimensional SU(N) spin system, discrete (point group) and continuous symmetries can be implemented at a local (tensor) level in a PEPS (Projected Entangled Pair States) scheme. This construction makes it possible to design wavefunction manifolds with controlled broken/unbroken symmetries (1) while considerably reducing the number of free parameters.

This framework is not only useful for engineering particular states (such as chiral spin liquids (5,6,7)), but also for ground-state optimization procedures for a given Hamiltonian (2,3,4), for studying thermodynamic properties (8) or for investigating the real-time dynamics of 2d quantum systems (9,10,11).

In this talk, I will explain the main ideas of this construction and illustrate with some recent examples.

(1) M. Mambrini, R. Orús, and D. Poilblanc Phys. Rev. B 94, 205124 (2016).
(2) D. Poilblanc and M. Mambrini Phys. Rev. B 96, 014414 (2017).
(3) D. Poilblanc, M. Mambrini and S. Capponi SciPost Phys. 7, 041 (2019).
(4) O. Gauthé, S. Capponi, M. Mambrini, and Didier Poilblanc Phys. Rev. B 101, 205144 (2020).
(5) J.-Y. Chen et al. Phys. Rev. Lett. 125, 017201 (2020).
(6) J.-Y. Chen et al. Phys. Rev. B 104, 235104 (2021).
(7) Y. Xu et al. Phys. Rev. B 108, 195153 (2023).
(8) D. Poilblanc, M. Mambrini and F. Alet SciPost Phys. 10, 019 (2021).
(9) R. T. Ponnaganti, M. Mambrini and D. Poilblanc Phys. Rev. B 106, 195132 (2022).
(10) R. T. Ponnaganti, M. Mambrini and D. Poilblanc SciPost Phys. 15, 158 (2023).
(11) M. Mambrini and Didier Poilblanc arXiv 2402.14141.

*Speaker

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Numerical methods to investigate SU(N) Fermi-Hubbard models.

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Abstract

Systems of multicolor fermions have recently raised considerable interest due to the possibility to experimentally study those systems on optical lattices with ultracold atoms. To describe the Mott insulating phase of N-colors fermions, one can start with the SU(N) Fermi-Hubbard Model (FHM) (which encompass the standard Fermi-Hubbard model for electrons with spins 1/2 which corresponds to N = 2) . The theoretical description of such a model is however difficult due to the exponentially large dimension of the Hilbert space, scaling as 2NL, where L is the number of sites. We found a way to perform exact diagonalizations (ED) of SU(N) FHM on L-sites clusters separately in each irreducible rep- resentation (irrep) of SU(N), which leads to a dramatic reduction of the dimension of the matrices to diagonalize. It is based on the representation theory of the unitary groups U(L), and is the proper generalization of the protocole developed for the Heisenberg SU(N) models, which was based on the representation theory of the symmetric group SL. This leads to a dramatic reduction of the dimension of the matrices to diagonalize. As an application of this color factorization, we study the robustness of some SU(N) phases predicted in the Heisenberg limit upon decreasing the on-site interaction on various lattices of size L $\leq$ 12 and for 2 $\leq$ N $\leq$ 6. In particular, we show that a long range color ordered phase emerges for intermediate U for N=4 at filling 1/4 on the triangular lattice. We finally present the numerical observation of the SU(N) Nagaoka's Ferromagnetism in the presence of one hole away from filling 1/N.

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Theory and experiment on current noise of SU(N) Anderson impurity

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Abstract

Development in experimental techniques has led to remarkable progress in investigating quantum many-body effects through artificially controlled quantum states in various physical systems. We will delve into recent theoretical and experimental developments regarding the SU(N) Kondo effect, manifested in quantum dots fabricated on semiconductor substrates with nanoscale.
The many-body low-energy state resulting from the Kondo effect is described by the local Fermi liquid theory, an extension of Landau's Fermi liquid. The values of the Fermi liquid parameters characterizing the system depend on the N of the SU(N) symmetry. The renormalized interaction gives rise to excited states, influencing nonlinear currents and current noise. Specifically, the renormalized interaction enhances current noise by generating charge-pair states within the current. Then the influence of the symmetry of the system can be seen in the measurement of the Fano factor. It is found that, beyond the previous understanding of the Fermi fluid theory, the correction introduced by the three-body correlation function significantly affects nonlinear current and current noise in SU(N) quantum dots (1, 2, 3). Using numerical renormalization group calculations, we elucidate this effect in quantum dots with SU(N) symmetry under the influence of a magnetic field to control the electronic state.

Carbon nanotube quantum dots have orbital states corresponding to the degrees of freedom of the motion of the electrons confined therein in the winding direction of the nanotube, in addition to the spin degrees of freedom. This allows the entire system to be described by the Anderson impurity model with SU(4) or SU(2) symmetry. We discuss the nonlinear current and current noise in carbon nanotube quantum dots by comparing theory with experimental observations (4).

(1) Christophe Mora, Pavel Vitushinsky, Xavier Leyronas, Aashish A. Clerk, and Karyn Le Hur, Phys. Rev. B 80, 155322 (2009)

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(2) Akira Oguri and A.C. Hewson, Phys. Rev. Lett. 120, 126802 (2018).

(3) Yoshimichi Teratani, Rui Sakano, and Akira Oguri, Phys. Rev. Lett. 125, 216801 (2020).

(4) Meydi Ferrier, Tomonori Arakawa, Tokuro Hata, Ryo Fujiwara, Raphaëlle Delagrange, Richard Deblock, Yoshimichi Teratani, Rui Sakano, Akira Oguri, and Kensuke Kobayashi, Phys. Rev. Lett. 118, 196803 (2017).

Quantum Simulation Studies of the SU(3) Fermi-Hubbard Model

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Abstract

We present the results of quantum Monte Carlo simulations and numerical linked cluster expansion calculations of the SU(3) symmetric Fermi-Hubbard model on a square lattice at 1/3-filling. Using an exact, finite temperature method, we first present the different regimes of the model in the T-U plane, which are characterized by local correlations, and capture signatures of the metal-insulator transition and magnetic crossovers. These signatures are detected as the temperature scales characterizing the rise of the compressibility, and an interaction-dependent change in the sign of the diagonal spin-spin correlation function. The analysis of the compressibility estimates the location of the metal-insulator quantum critical point at Uc/t ˜ 6, and provides a temperature scale for observing Mott physics at finite T. Furthermore, from the analysis of the spin-spin correlation function we observe that for U/t ˜ 6 and T ˜ J = 4 tˆ2/U, there is a development of a short-range two sublattice antiferromagnetic structure, as well as an emerging three sublattice antiferromagnetic structure as the temperature is lowered below T/J ˜ 0.57. In order to examine the low temperature properties, we next employ a self-consistent variant of the constrained path quantum Monte Carlo approach. We find clear evidence of multiple, successive quantum critical points separating a non-magnetic uniform metallic phase at weak coupling from regimes with long range 'spin' order, whose symmetry changes as the interaction strength increases.

*Speaker

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Towards encoding a qudit in the nuclear spin of 87-Sr

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Abstract

Qudits are generelizations of qubits to higher dimensional Hilbert spaces. They allow to store more quantum information in a single atom compared to qubits, potentially enabling more complex algorithms to be executed on quantum computers with a given number of atoms. 87-Sr has a nuclear spin of I=9/2 that is not coupled to the electronic structure in the atom's ground state, making it well suited to encode a qudit. As a first step towards this goal, I'll present a precision measurement of the 87-Sr nuclear g-factor made possible by using 87-Sr as co-magnetometer. Applying a tensor shift will allow to selectively drive rf transitions between neighboring m_I states. m_I state selective coupling to Rydberg states can allow 2-qudit gates.

*Speaker

Inter-valley coherence, intrinsic and extrinsic spin-orbit coupling in rhombohedral graphene

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Abstract

Rhombohedral graphene multilayers provide a clean and highly reproducible platform to explore the emergence of superconductivity and magnetism in a strongly interacting electron systems. The high density of states near the van Hove singularities lead to a variety of broken symmetry phases – including exotic forms of spin and valley ferromagnetism (2, 3). Because of their combined spin and valley 'isospin' degrees of freedom, these Stoner magnets exhibit an approximate SU(4) symmetry with a near degeneracy in the many body phase diagram. In reality, this SU(4) symmetry is only approximate, weak symmetry breaking arises even at the single particle level – in the form of intrinsic spin-orbit coupling. Here, we use high resolution thermodynamic compressibility measurements and nanoSQUID on tip (nSOT) magnetometry to study the effects that intrinsic spin-orbit coupling has on the magnetic phase diagram in rhombohedral graphene. By supporting rhombohedral graphene on a WSe2 substrate, 'extrinsic' strong spin-orbit coupling can be proximitized, significantly altering the phase diagram. We demonstrate the presence of an inter-valley coherent quarter metal which becomes strongly spin-valley locked when supported by WSe2. Our results shed light on the role proximity induced Ising spin-orbit coupling and intrinsic spin-orbit coupling plays in selecting the ground state in correlated graphene systems.

(1) Zhou, H., Xie, T., Taniguchi, T. et al. Nature **598**, 434–438 (2021).

(2) Zhou, H., Xie, T., Ghazaryan, A., et al. Nature **598**, 429–433 (2021).

(3) Arp, T., et. al. arXiv:2310.03781 (2023).

*Speaker

Quantum simulation using ultracold Yb atoms with SU(N) symmetry

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Abstract

Two-electron atoms such as Yb and Sr have been applied to quantum simulations due to the existence of narrow transitions (clock transitions) and fermionic isotopes with SU(N) degrees of nuclear spin freedom. Through the development of various observational techniques, our research group at Kyoto University has recently been studying quantum simulations of quantum many-body systems, for example, short-range spin correlations and dynamics under dissipation using fermionic Yb atoms with SU(N) symmetry in optical lattices. We are now developing new methods for measuring spin-correlation, such as a quantum gas microscope technique. In this talk, I will report the latest experimental results.

*Speaker

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QSpace: An open-source tensor library for Abelian and non-Abelian symmetries

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Abstract

I will present the open-source tensor library QSpace built for tensor network states.
QSpace permits arbitrary combinations of symmetries including the Abelian symmetries Zn and U(1), as well as all non-Abelian symmetries based on the semi-simple classical Lie algebras An, Bn, Cn, and Dn, or respectively, the special unitary group SU(n), the odd orthogonal group SO(2n+1), the symplectic group Sp(2n), and the even orthogonal group SO(2n).
QSpace is designed as a bottom-up approach that starts from the defining representation and the Lie algebra. By explicitly computing and utilizing generalized Clebsch-Gordan coefficient tensors, this makes QSpace versatile in the type of operations that it can perform across all symmetries. At the level of an application, much of the symmetry-related details are hidden within the QSpace core libraries. Hence when developing tensor network algorithms with QSpace, these can be coded (nearly) as if there are no symmetries at all, despite being able to fully exploit general non-Abelian symmetries. This allows one to focus on the tensor algorithms of interest, irrespective of the symmetries used, as these are taken care of within QSpace.

*Speaker
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Fractional quantization of SU(N) matter-wave persistent currents

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Abstract

Neutral atoms guided in ring-shaped atomtronic circuits present quantized values of the angular momentum per particle. Depending on the specific parameters characterizing the system (eg: nature of the particle statistics, interactions), the winding number present different quantization properties. In this talk, I will showcase how such a phenomenon occurs in an atomtronic circuit with a quantum fluid consisting of strongly interacting N-component fermions, the so-called SU(N) fermions. For repulsive interactions a specific emerging phenomenon of attraction from repulsion appears, providing a quantization with similar properties to the attracting bosonic case. For attractive interactions, the quantization is determined by the number of components N . Schemes to read-out the persistent current fractionalization in cold atoms experiments will be provided.

*Speaker

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Probe for bound states of SU(3) fermions and colour deconfinement

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Abstract

In this talk, I will present our work on a mesoscopic ring-shaped potential comprised of strongly interacting SU(N) fermions pierced by an effective magnetic flux. By employing a combination of Bethe ansatz and numerical techniques (exact diagonalization and DMRG), we find that the formation of N-body bound states causes the angular momentum quantization per particle to acquire fractional values. Such a phenomenon manifests itself in the matter-wave flow of the system as a $1/N$ periodicity. Of particular interest in our analysis is the SU(3) case due to its relation with quantum chromodynamics (QCD). By taking trions and colour superfluid states (two types of SU(3) bound states) to be the analogues of hadrons and quark-quark pairs in QCD, we demonstrate that one can explore this crossover through persistent currents. Lastly, we consider finite temperature effects, where we find that an interplay between temperature and interaction can lead to a specific bound state deconfinement without explicitly breaking the SU(3) symmetry.

*Speaker

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Flow of an SU(N) fermionic matter-wave through a localized barrier

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Abstract

In this talk, I will present our recent investigations of matter-wave flow of SU(N) fermions through a localized impurity in a mesoscopic ring pierced by an effective magnetic field.

In SU(N) fermionic rings, the flow of particles can be controlled by the effective magnetic field, with a strong dependence on the interactions, which give rise to fractional values of the angular momentum. The underlying origin this phenomenon is due to the formation of composite bound states (attraction) and spinon excitations (repulsion).

I will explain how an impurity affects the persistent current in a complementary regime to the seminal work of Kane and Fisher, where we now focus on the mesoscopic regime. In bosonic systems, the barrier renormalizes the amplitude of the persistent current in a non-monotonous behavior, whereas for multi-component fermions, this has not been explored until now. Moreover, we observe that the smoothing out of the current, corresponding to a gap opening in the spectrum, only happens for particular states. We analyze the system through a combination of numerical and analytical approaches, including DMRG, Luttinger liquid theory, and Bethe ansatz, which allows us to understand the underlying reasons for the observed behavior.

*Speaker

Symmetry Breaking Patterns in Itinerant SU(N) Ferromagnetism

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Abstract

Ferromagnetic transitions in systems with SU(N) symmetry are attracting much attention in recent years motivated by experiments on graphene multilayers and the possibility of realizing SU(N > 2) symmetry in alkaline-earth ultracold atomic gases. Unlike SU(2) systems where only one transition pattern between paramagnetic and ferromagnetic phases is possible, the enlarged unitary symmetry allows richer patterns of ferromagnetic transitions. In connection to this, it is interesting to note that graphene multilayer systems, where an approximate SU(4) symmetry is realized when combining the electron spin and valley degrees of freedom, a cascade of phase ferromagnetic transitions has been experimentally observed. In this oral contribution, we will report results for the phase diagram and ferromagnetic phase transitions of interacting Fermi systems with SU(N) symmetry with both short-range contact and long-range Coulomb interactions. Within Hartree-Fock approximation, we find a Fermi gas with short-range interactions undergoes a transition from the paramagnetic state to the fully polarized state. On the other hand, the paramagnetic state of the Fermi gas with long-range Coulomb interaction undergoes a cascade of N − 1 first-order phase transitions where one component is depopulated at a time until all electrons have identical SU(N) spin. These two systems exhibits distinct ferromagnetic transition patterns at means-field (Hartree-Fock) level. However, going beyond mean-field theory and accounting for the correlation energy within the random-phase approximation,

the cascade of phase transitions disappears and the transition pattern becomes the same as for the Fermi gas with short-range interactions. Nevertheless, we show that this resemblance is only superficial as the energy balance that drives the transition from the paramagnetic to the fully polarized state is dominated by different contributions to the total ground state energy.

In addition, we also report results for a different SU(N) Fermi system on the Bethe lattice with short-range interactions in the mean field limit. In this system, an unconstrained minimization of the free energy obtained within Hartree-Fock yields a cascade of phase transitions as a function of the particle density and interaction strength, which shows that the phenomenology (i.e. cascade of transitions) observed in twisted bilayer graphene can be also realized in other models.

*Speaker

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Ferromagnetic instability for the SU(N) Hubbard model

Juntaro Fujii[1] and Akihisa Koga*[1]

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Abstract

Low-temperature properties in correlated fermion systems have attracted much attention since the discovery of the highTc cuprates. In the strongly correlated electron systems, the spin degrees of freedom play a crucial role in stabilizing interesting phenomena at low temperatures such as magnetism, superconductivity, and Mott phase transitions. The orbital degrees of freedom enrich the system. Recently, an optical lattice system, where the periodic potential is loaded into ultracold atoms, has been realized. In the system, various parameters can be controlled experimentally such as the hopping integrals, interaction strength, and lattice structure. Furthermore, spin and orbital degrees of freedom can be introduced, which makes strongly correlated fermion systems with multicomponents more interesting.
One of the interesting and fundamental questions is how the symmetry-breaking state is realized in a multicomponent system. In our previous paper (1), we have considered the half-filled Hubbard model with repulsive interactions to clarify the instability for the antiferromagnetically ordered state. By contrast, the ferromagnetic instability in the SU(N) Hubbard model is less understood except for the SU(2) case. In the strong coupling limit in the SU(2) Hubbard model, itinerant nature of one hole on a lattice with a closed-loop structure leads to a fully polarized ferromagnetically ordered ground state, which is so-called Nagaoka ferromagnetism. Although similar results have been obtained in the SU(3) case (2), still controversial how this ordered state relates to the system with the finite hole density. What is the most important in this strong-coupling region is that large Coulomb interactions and low energy itinerant properties of electrons are necessary to deal with precisely in an equal footing.

In this study, we consider the multicomponent fermionic system, which is described by the SU(N) Hubbard model. We discuss how the ferromagnetically ordered state is realized at low temperatures, making use of dynamical mean-field theory with the continuous-time quantum Monte Carlo method.

(1) H. Yanatori and A. Koga, Phys. Rev. B **94**, 041110 (2016).
(2) H. Katsura and A. Tanaka, Phys. Rev. A **87**, 013617 (2013).

*Speaker

Dynamics of SU(3) spin coherent states: semiclassical method and its application to spin nematics and spin liquids in spin-1 magnets

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Abstract

Spin-1 magnets allow for dipolar and quadrupolar moments on a single site, leading to rich physical properties as seen in spin nematic phases (1), Fe-based superconductors (2) and cold atom systems (3). However, experimental probing of these unconventional phases remains challenging, and therefore requires new theoretical tools to describe and interpret their ground state and excitation properties.

In this talk, we introduce a new Monte Carlo and Molecular Dynamics method designed for SU(3) spin coherent states, which can be used to study thermodynamic and dynamic properties of spin-1 magnets (4). We benchmark our numerical implementation by studying the ferroquadrupolar phase of the spin-1 bilinear-biquadratic (BBQ) Hamiltonian on the triangular lattice, and show excellent agreement with analytical flavour-wave theory and low-temperature expansion results.

Moreover, we demonstrate the advantage of this method through real-time dynamics simulations of topological vortices in a spin nematic (5) and unveiling a novel chiral spin liquid in the spin-1 Kitaev model with BBQ interactions (6).

(1) H. Tsunetsugu and M. Arikawa, J. Phys. Soc. Jpn **75**, 083701 (2006).

(2) R. M. Fernandes, A. V. Chubukov, and J. Schmalian, Nature Physics **10**, 97 EP (2014).

(3) E. Demler and F. Zhou, Phys. Rev. Lett. **88**, 163001 (2002).

(4) K. Remund, R. Pohle, Y. Akagi, J. Romhányi, and N. Shannon, Phys. Rev. Research **4**, 033106 (2022).

(5) R. Pohle, N. Shannon, and Y. Motome, Phys. Rev. B **107**, L140403 (2023).

(6) L. Chojnacki, R. Pohle, H. Yan, Y. Akagi, N. Shannon, arXiv.2310.10078.

*Speaker

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Three-body Fermi-liquid effects on transport through the U=∞ SU(N) Anderson impurity

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Abstract

In this study, we explore how three-body Fermi-liquid corrections influence transport properties in an Anderson model with N degenerate energy levels. We consider the strong coupling limit where the interaction strength U approaches infinity and the impurity level occupancy, nd, varies between 0 and 1, which includes the Kondo regime and the valence fluctuation regime, depending on the impurity level ϵd. The three-body correlations among the impurity electrons emerge in the case where the system does not have the electron-hole or the time-reversal symmetries. Recent findings highlight the role of the three-body correlations which contribute to the low-energy behavior of transport coefficients, in addition to the other well-known Fermi-liquid parameters such as the phase shifts, the Wilson ratio, and the renormalization factors (1-3). Using the numerical renormalization group (NRG) method, we calculate these next-leading order terms of nonlinear conductance, current noise, and thermal conductance of SU(N) quantum dots for N=4. In this presentation, we also disscuss the implications of three-body effects on transport phenomena. (1) A. Oguri, and A. C. Hewson, PRL 120, 126802 (2018). (2) M. Filippone, C. Moca, A. Weichselbaum, J. von Delft, and C. Mora, PRB 98, 075404 (2018). (3) C. Mora, P. Vitushinsky, X. Leyronas, A. A. Clerk, and K. Le Hur, PRB 80, 155322 (2009). *K.M. was supported by JST Establishment of University Fellowships towards the Creation of Science Technology Innovation Grant No. JPMJFS2138.

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Interaction effects on the itinerant ferromagnetism phase transition

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Abstract

We present a thorough study of the transition nature of Fermi gases. The exploration can be done thanks to the use of a third order perturbation formula for the energy system. At this level, there are three scattering parameters in play, those are, the S-wave scattering length a_0, the S-wave effective range r_0 and the P-wave scattering length a_1. We show that the spin value is not determinant in saying the nature of the phase transition. For any spin value, any kind of phase transition can happen depending on the potential. We show how the different transitions are encountered as a function of r_0 and a_1, which are in units of a_0, for S=1/2 up to S=9/2. Moreover, we then present a model based on Landau theory in order to proof this rich variability.

*Speaker

Interpretable phase classification on trapped ion experiment data by tensorial-kernel SVM

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Abstract

Experimental progress in qubit manufacturing calls for the development of new theoretical tools to analyze quantum data. We show how an unsupervised machine-learning technique can be used to understand SU(N) models using data of local measurements from trapped-ion experiments. We demonstrate the method by constructing the phase diagram of a SU(2) and SU(3) model and show that it detects the respective order parameters of its phases, including string order parameters. Prior information of the underlying Hamiltonian or the quantum states is not needed; instead, the machine outputs their characteristic observables. Our work opens the door for a first-principles application of hybrid algorithms that aim at strong interpretability without supervision.

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