Josephson Photonics: New sources for non-classical photon radiation

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The newly emerging field of Josephson photonics combines microwave cavities with dc-voltage biased Josephson junctions in generalization of circuit-QED set-ups. These devices open new ways to explore the interaction of charges and photons in stationary states far from equilibrium from the weak up to the ultra-strong coupling regime. Particular attention has been paid to their potential as versatile sources for the creation of non-classical photon radiation. In this talk I will provide the theoretical background and present recent experimental achievements such as the production of anti-bunched photons and entangled photon pairs.

The Curious Case of Tantalum 180

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The decay of a very long-lived state, such as the famous *J* = 9− isomeric state in 180Ta, when irradiated by *γ* rays or subjected to Coulomb excitation, can be accelerated by the existence of a doorway state for mixing an excited state of the isomeric band with the states of other bands decaying to the ground state. We describe the mechanism of such a decay similar to the chaos-assisted tunneling.

Importance of Exit Channel Fluctuations in Reaction Branching Ratios

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Statistical reaction theories such as Hauser-Feshbach assume that branching ratios follow Bohr's compound nucleus hypothesis by factorizing into independent probabilities for different channels. Corrections to the factorization hypothesis are known in both nuclear theory and quantum transport theory, particularly an enhanced memory of the entrance channel. We apply the Gaussian orthogonal ensemble to study a complementary suppression of exit channel branching ratios. The effect can be large enough to provide information on the number of exit channels. The effect is demonstrated for the branching ratios of neutron-induced reactions on a ^{235}U target.

Development of Cryogenic Memory for Superconducting Computers

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Large-scale computing facilities and data centers are using electrical power at an ever increasing rate. Current projections suggest that a future "exoscale" computer will require the power output of a typical nuclear power plant – clearly an untenable situation. One approach to addressing this problem is to build a computer out of all superconducting elements, which dissipate very little power. Such a computer would have to be cooled to cryogenic temperatures, so it must be extremely energy-efficient to justify the added complexity and cost associated with cooling.

Superconducting logic circuits based on manipulating single flux quanta have existed since 1991; what has been missing is a high-density, fast, and energy-efficient cryogenic memory. This talk will focus on proposals to use Josephson junctions containing ferromagnetic materials as the basic memory element for such a memory. In our approach, a Josephson junction contains two ferromagnetic layers whose magnetization directions can be switched between being parallel or antiparallel to each other, just as in a conventional spin valve. We have demonstrated successful switching of such a junction between the "0" phase state and the "π" phase state, from measurements of two junctions in a SQUID geometry. If there is time, we will also discuss other possible types of Josephson junction memory elements, such as those that carry spin-triplet supercurrent rather than the conventional spin-singlet supercurrent.

Magnetic Order and its Loss on Frustrated Honeycomb Monolayers and Bilayers: An Illustrative Use of the Coupled Cluster Method

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One of the most powerful of all *ab initio* formulations of microscopic quantum many-body theory is the coupled cluster method (CCM).[1] It has been very successfully applied to a diverse array of strongly correlated systems, spanning areas such as quantum field theory, nuclear and subnuclear physics, condensed matter physics, quantum optoelectronics, and quantum chemistry. The CCM has yielded numerical results that are among the most accurate available for an incredibly wide range of both finite and extended physical systems. These range from atoms and molecules of interest in quantum chemistry, where the method has long been the recognized "gold standard", to atomic nuclei; from the electron gas to dense nuclear and baryonic matter; and from models in quantum optics, quantum electronics, and solid-state optoelectronics to field theories of strongly interacting nucleons and pions.

This widespread success for both finite and extended physical systems defined on a spatial continuum[2] has led more recently to applications to corresponding systems defined on an extended regular spatial lattice. Such quantum lattice systems have become the subject of intense theoretical study. They include many examples of systems characterised by novel ground states which display *quantum order* in some region of the Hamiltonian parameter space that is delimited by critical values marking the corresponding *quantum phase transitions.* The quantum critical phenomena often differ profoundly from their classical counterparts, and the subtle correlations present usually cannot easily be treated by standard many-body techniques (e.g., perturbation theory or mean-field approximations). We have shown how the systematic inclusion of multispin correlations for a wide variety of quantum spin-lattice problems can be efficiently and effectively implemented with the CCM.[3] The method is not restricted to bipartite lattices or to non-frustrated systems, and can thus deal with problems where most alternative techniques, e.g., exact diagonalization of small lattices or quantum Monte Carlo (QMC) simulations, are faced with specific difficulties. A large corpus of work now attests to the power of the CCM in quantum magnetism.

I describe our recent work that has applied the CCM to strongly interacting and highly frustrated spin-lattice models of interest in quantum magnetism, especially in two spatial dimensions. I show how the CCM may readily be implemented to high orders in systematically improvable hierarchies of approximations, e.g., in a localised lattice-animal-based subsystem (LSUB*m*) scheme, by the use of computer-algebraic techniques. The raw LSUB*m* results are themselves generally excellent. I show explicitly how they converge rapidly and can also *be accurately extrapolated to the exact limit in the truncation index,* $m \rightarrow \infty$*. Values for both ground- and* excited-state properties are obtained which are fully competitive with those from other state-of-the-art methods, including the much more computationally intensive QMC techniques in the relatively rare (unfrustrated) cases where the latter can be readily applied. I describe the method itself, and illustrate its ability to give accurate descriptions of the ground-state phase diagrams of a wide variety of frustrated magnetic systems to which it has been applied, via some topical examples of its high-order implementations to frustrated antiferromagnets on honeycomb-lattice monolayers[4] and bilayers.[5]

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Cooperative shielding in many-body spin systems with long-range interaction

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We study the dynamics of many-body quantum spin-1/2 systems with long-range interaction, as the ones recently realized with trapped ions. Our analysis reveals a scenario that is richer than the usual expectation that interactions of longer range should necessarily lead to faster dynamics. Indeed they confine the dynamics to invariant subspaces, which are shielded from the long-range interaction. Consequently, the evolution may even freeze as the system size increases. We establish an analogy between this effective shielding and the onset of quantum Zeno subspaces, with the difference that here they are driven by system size, instead of interaction strength.

Exotic halo nuclei: from bare to induced pairing

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The poor overlap between halo neutrons and core nucleons can make subcritical the bare NN–$^1S_0$ interaction, allowing at the same time for the presence of exotic dipole collective modes at very low energies. Exchanged between the halo neutrons they provide the binding for a novel elementary mode of excitation: neutron halo pair addition mode. It is expected to carry a mainly isoscalar dipole mode on top of it, symbiotic partner which cannot ex-ist but in the halo regime and which in turn can be viewed as the tailored glue of the least bound nucleons. Candidates to that role are the monopole pair addition mode of the N = 6 closed shell isotones ^{9}Li$_6$ (ground state of ^{11}Li) and of ^{10}Be$_6$ (first excited 0^{+*} state of ^{12}Be). It is an open question whether the $J^\pi = 0^+$ of ^{14}C observed at 16.9 MeV populated in a two–nucleon trans-fer process and interpreted as a giant pairing vibration, constitutes another embodiment of the halo mode.

Quantum synchronization

Christoph Bruder
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Synchronization of self-oscillators is a universal phenomenon that is important both in fundamental studies and in technical applications. Recent experimental progress in optomechanical systems has motivated the study of synchronization in quantum systems. I will discuss some approaches to this question and will then describe our own work on quantum Van der Pol oscillators [1-3].

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Chaos, metastability and ergodicity in Bose-Hubbard superfluid circuits

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We clarify the role of "chaos" for the metastability criteria of flow states [1,2], and for the possibility to witness Rabi oscillations in a SQUID-like setup [3]. Additionally we consider both coherent and stochastic-like features in the dynamics of the thermalization process [4,5].

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Floquet dynamics and time-translation symmetry breaking in nonlinear oscillators

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Quantum dynamics of periodically driven systems is described in terms of the Floquet states. The description is based on the fact that a driven system has discrete time-translation symmetry with the period of the driving. Recently much interest have attracted systems where the time symmetry is broken, the "time crystal" effect. Nonlinear oscillators provide an ideal platform for studying this effect. A familiar example is parametric resonance: when a dissipative oscillator is modulated close to twice the eigenfrequency, the period of the parametrically excited vibrations is twice the modulation period. We will show that the symmetry breaking may occur also in the quantum coherent regime. The effect is most pronounced in the semiclassical range. We will discuss the peculiar features of the tunneling of a driven oscillator and how these features can be observed. Time permitting, we will also discuss the scaling behavior close to the critical parameter values where the period-two vibrational states emerge.

Rare isotopes: Probing many-body physics and the origin of the elements

Alexandra Gade
Michigan State University, USA

One goal of nuclear physics is a comprehensive understanding of the properties of nuclei from the interactions of the constituent protons and neutrons. This is of critical importance to address two fundamental challenges: Which combinations of protons and neutrons exist as bound systems and how are the elements synthesized in stars and their explosions? With new-generation rare-isotope facilities at the horizon, the field is at the brink of critical breakthroughs. The limits of nuclear existence can be mapped progressively with measurements of high sensitivity. An ever increasing range of short-lived nuclei (rare isotopes) becomes available for experiments that isolate specific features of the nuclear many-body problem. This presentation will show how experiments today measure complementary observables that advance our understanding of nuclear science and what exciting opportunities will be opened up once the Facility for Rare Isotope Beams (FRIB) comes online at Michigan State University.

Chaotic Scattering: New Exact Results and Comparison to Experiments

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A major part of our knowledge about quantum systems stems from scattering experiments. Often, the scatterer is a highly complex or chaotic system, allowing one to set up models involving random matrices. A long-standing problem was to compute the distribution of the scattering matrix elements and the corresponding cross sections which is of considerable practical and theoretical interest. While the distribution of the diagonal scattering matrix elements could be calculated some years ago, the distribution of the off-diagonal elements as well as the cross sections continued to resists analytical treatment. Recently we managed to fully solve this problem for systems with preserved and with violated time-reversal invariance. We validated our results with nuclear scattering data and data obtained from experiments with flat microwave billiards, which are known to simulate quantum mechanics in two dimensions.

Emergence and Universality in Diverse Physical Systems

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Our physics textbooks are dominated by examples of simple, weakly-interacting microscopic states. But the actual physical states of our world are often most effectively described as emergent, meaning that they are strongly-correlated and dominated by properties that emerge as a consequence of interactions and are not part of the description of the corresponding weakly-interacting system. Such states often have a phenomenologically description but no clear microscopic connection to the simple states described in our textbooks. This talk proposes a microscopic connection of weakly-interacting states and emergent states through dynamical symmetries that imply unique truncations of the full Hilbert space to a collective subspace where emergence lives. Much as Einstein used the equivalence principle to argue that gravity must be a property of spacetime and not of specific objects in spacetime, it will be proposed that emergence is in essence a property of a symmetry-truncated Hilbert space and not of specific microscopic systems whose wavefunctions may reside in that space. Thus emergent properties achieve a universality largely independent of underlying microscopic details, as is observed for many physical systems. As a concrete example of applying these ideas it will be shown that atomic nuclei, high-temperature cuprate and iron-based superconductors, and monolayer graphene in a strong magnetic field - which have little in common microscopically - exhibit a remarkable universality in emergent behavior that is described quantitatively by the ideas presented above.

Constant temperature description of the nuclear level densities

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The spin and parity dependent nuclear level densities (NLD) are calculated for medium-heavy nuclei using shell model techniques. The NLD are used to calculate cross sections and reaction rates of interest for nuclear astrophysics and applications. We investigate a new approach of describing the shell model NLD via a constant temperature parametrization. This approach provides new information about the effects of symmetries on the temperature of the low-lying nuclear states, and it is shown to be more versatile for applications.

Chaotic behavior of Dirac Quantum Dots and other Nanostructure

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It is well established that physical systems exhibit both ordered and chaotic behavior. The chaotic behavior of nanostructure such as open quantum dots has been confirmed experimentally and discussed exhaustively theoretically. This is manifested through random fluctuations in the electronic conductance. We discuss the universal fluctuations in the case of a Quantum Dot (QD) on the surface of a Graphene flake. The electrons inside this kind of QD behave according to the Dirac equation. We confirm that the general behavior of the conductance fluctuations in this Dirac QD is similar to that in the more widely studied, Schroedinger, QD. We use Chaotic Scattering Theory in conjunction with the Stub method [1, 2].

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The temperature of a single chaotic eigenstate

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and Michigan State University, USA

The onset of thermalization in a closed system of randomly interacting bosons, at the level of a single eigenstate, is discussed. We focus on the emergence of Bose-Einstein distribution of single- particle occupation numbers, and give a local criterion for thermalization. We show how to define the temperature of an eigenstate, provided that it has a chaotic structure in the basis defined by single-particle states. The analytical expression for the eigenstate temperature as a function of the inter-particle interaction and energy is complemented by numerical data.

Sachdev-Ye-Kitaev Model as a Liouville Quantum Mechanics

Alex Kamenev
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I will discuss Sachdev-Ye-Kitaev model of N randomly interacting Majorana fermions. It was recently coined as a possible toy model of AdS-CFT correspondence. I argue that its low-energy limit is described by an effective quantum mechanics and explore some consequences of this observation.

Transport Efficiency in Open Quantum Systems with Static and Dynamic Disorder

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We study, under very general conditions and in a variety of geometries, quantum enhancement of transport in open systems. Both static disorder and dephasing associated with dynamical disorder (or finite temperature) are fully included in the analysis. We show that quantum coherence effects may significantly enhance transport in open quantum systems even in the semiclassical regime (where the decoherence rate is greater than the inter-site hopping amplitude), as long as the static disorder is sufficiently strong. When the strengths of static and dynamical disorder are fixed, there is an optimal opening strength at which the coherent transport enhancement is optimized. Analytic results are obtained in two simple paradigmatic tight-binding models of large systems: the linear chain and the fully connected network. The physical behavior is also reflected, for example in the FMO photosynthetic complex, which may be viewed as intermediate between these paradigmatic models. We furthermore show that a nonzero dephasing rate assists transport in an open linear chain when the disorder strength exceeds a critical value, and obtain this critical disorder strength as a function of the degree of opening.

Nuclear shell model and phase transitions

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The nuclear shell model using an effective Hamiltonian which includes pairing and other collective interactions is capable of providing various collective or single-particle effects in nuclei. The prediction of nuclear observables comes through a large scale diagonalization, which however, hides the connection between the input effective Hamiltonian and the output nuclear properties. By varying the values of specific groups of interaction matrix elements we study the evolution of simple nuclear characteristics and try to link these matrix elements with the emergence or the absence of collective effects in nuclei. In this procedure, quantum phase transitions appear, which are stronger in nuclei with unpaired fermions. The nuclear level density is also sensitive to the features of the interactions and it is used for the indication of phase transitions.

Considerations on Bardeen Hysteresis: Violation or Vindication of the Second Law?

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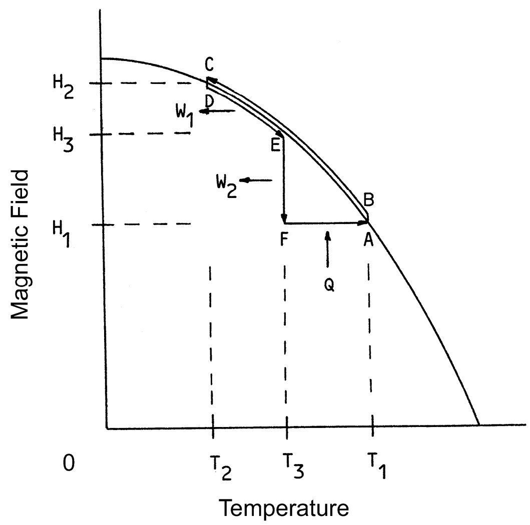
The Coherent Magneto-Caloric Effect of Type I superconductors presents a vexing issue with respect to the absolute status of the second law of thermodynamics. [1]



When confronted with this conundrum, John Bardeen posited "Apparently you would like to have an adiabatic step from the superconducting phase at T_1,H_1 to normal at T_2,H_2, but don't see how this can happen without violating the laws of thermodynamics. … The transition cannot take place at H_1, but there must be considerable 'superheating' to the higher field H_a." [2] [3] The author refers to this hypothesis as "Bardeen Hysteresis".

The talk will assess the intricacies of the Coherent Magneto-Caloric Effect (the magneto-caloric effect applied to mesoscopic-sized specimens), and then glean understanding from a close look at the phase transition dynamics of the magneto-caloric effect of macroscopic-sized specimens.

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Monodromy and entanglement in Dicke superradiance models

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We investigate properties of an extended Dicke model describing superradiance in a system of two-level atoms and a single-mode bosonic field. The model enables us to continuously connect an integrable, fully regular regime of dynamics (conserving the total number of atom and field excitations) with a non-integrable, partly chaotic Dicke regime. The integrable limit exhibits classical monodromy – a singular bundle of orbits disabling a trivial fibration of the phase space by global action-angle variables. We demonstrate quantum signatures of monodromy as point topological defects in the lattices of expectation values of various observables in individual eigenstates of the Hamiltonian. Using analogous lattice images of the spectra, we study also the atom-field and atom-atom entanglement properties of excited states (quantified by entropy and concurrence measures, respectively). We show that some eigenstates (including the critical state at the monodromy point) exhibit anomalous entanglement between the atom and field subsystems or between individual atoms. We study the persistence of these structures under the non-integrable perturbation of the system in transition to the Dicke regime.

Slip Transport of the Wigner Solid on Liquid He Surface

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Surface state electrons (SSE) on liquid helium realize the evident Wigner solid (WS) at low temperatures[1]. The WS is a lattice of electrons, which is dressed by a cloud of surface capillary waves, ripplons. The Bragg scattering of ripplons from the WS gives rise to a commensurate deformation of the He surface known as the dimple lattice (DL)[2]. The WS-DL system is analogous to polaron states in which electrons are dressed by a cloud of virtual phonons, or lattice deformation.

In contrast to other systems, the coupling of the WS with the DL is of a dynamical nature, due to interference between ripplons emitted by the moving WS. When the velocity of the WS-DL system approaches the phase velocity of ripplons of wavevector equal to the WS periodicity, refered to as v_{BC}, constructive interference resonantly deepens the DL. Accordingly, reaction from the DL increases by approaching v_{BC} so as to regulate the WS velocity below v_{BC}[3]. However, when the driving force exceeds the maximum resistive force, the WS eventually decouples from the DL. A stationary DL depth on the order of 10^{-12} m can grow more than one order of magnitude deeper at the decoupling point.

Recently, detailed dynamics of WS-DL systems can be studied by employing micro-fabricated devices (FIG. 1). Because of the capillary action, liquid He condensed in a channel of 1~2 micron deep and 10 micron wide can be used to support SSE on the channel. The resistance of WS on the channel is high enough to sustain a large electric filed along the channel so that the decoupling is finely controlled. By employing this device, we observed stick-slip motion of WS[4]. In this paper we describe recent further investigation of detailed dynamics of decoupling or slip of WS-DL systems. Unexpectedly, the slip of WS turns out to be more complex than simple dressing and undressing of a ripplon cloud.

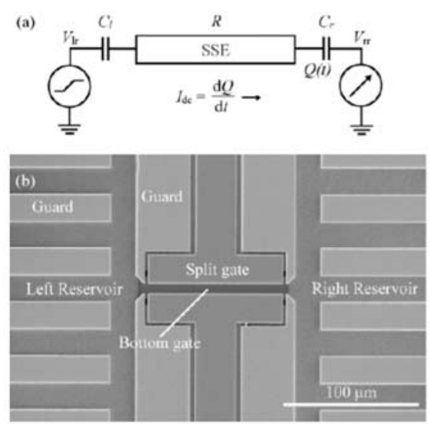

FIG. 1: Micro channel device and equivalent circuit of the device.

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Random Matrix Theory for Transition Strengths in Finite Quantum Many-particle Systems: Applications and Open Questions

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Embedded random matrix ensembles are generic models for describing statistical properties of finite isolated interacting quantum many-particle systems. A finite quantum system, induced by a transition operator, makes transitions from its states to the states of the same system or to those of another system. Examples are elec-tromagnetic transitions (then the initial and final systems are same), nuclear beta and double beta decay (then the initial and final systems are different) and so on. Using embedded ensembles (EE), there are efforts to derive a good statistical theory for transition strengths. With m fermions (or bosons) in N mean-field single par-ticle levels and interacting via two-body forces, we have with GOE embedding, the so called EGOE(1+2). Now, the transition strength density (transition strengths multiplied by the density of states at the initial and final energies) is a convolution of the density generated by the mean-field one-body part with a bivariate spreading function due to the two-body interaction. Using the embedding U(N) algebra, it is established, for a variety of transition operators, that the spreading function, for suf-ficiently strong interactions, is close to a bivariate Gaussian. Also, as the interaction strength increases, the spreading function exhibits a transition from bivariate Breit-Wigner to bivariate Gaussian form. In appropriate limits, this EGOE(1+2) theory reduces to the polynomial theory of Draayer, French and Wong on one hand and to the theory due to Flambaum and Izrailev for one-body transition operators on the other. Using spin cut-off factors for projecting angular momentum, the theory is applied to nuclear matrix elements for neutrinoless double beta decay (NDBD). In this talk we will describe: (i) various developments in the EGOE theory for transi-tion strengths; (ii) results for nuclear matrix elements for ^{130}Te and ^{136}Xe NDBD;(iii) important open questions in the current form of the EE theory.

Correlations within the Non-Equilibrium Green's Function Method

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Non-equilibrium Green's function (NGF) method is a powerful tool for studying the evolution of quantum many-body systems. Different types of correlations can be systematically incorporated within the formalism. The time evolution of the single-particle Green's functions is described in terms of the Kadanoff-Baym equations. In the current work I first focus on introducing the correlations in infinite nuclear matter and then in a finite system. Starting from the harmonic oscillator Hamiltonian, by switching on adiabatically mean-field and correlations simultaneously, a well-defined ground state of a correlated system is arrived at within the NGF method.

Multiferroic skyrmions

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Magnetic skyrmion is a topological defect with a complex non-coplanar spin structure. Low critical currents needed to manipulate skyrmions opened a new active field of research – skyrmionics, which has a goal of developing skyrmion-based magnetic memory and data processing devices. So far, skyrmions have only been observed in a few magnets with non-centrosymmetric crystal lattices. It was recently shown, however, that isolated skyrmions, skyrmion crystals and other unusual multiply periodic states states can exist in frustrated magnets with conventional centrosymmetric lattices [1-3]. These non-collinear magnetic orders break inversion symmetry and induce electric polarization. In my talk I will focus on ferroelectric properties of magnetic skyrmions and on possible ways to control these topological defects with an applied electric field.

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Randomly Interacting Bosons on 2 Spin Levels.

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The spectra of N bosons with spin j_1 or j_2 interacting via 2-body random J-conserving interactions are studied. Various regularities are described for a range of systems, beyond just the *s*-*d* bosons of the IBM. Various ensemble average quantities show striking regularities, even in the case of pure random interactions. The appearance of parabolic yrast lines and non-random ground states are seen with the canonical signatures of quantum chaos. The level spacing distribution and the spectral rigidity follow the GOE.

Anomalous transport in perturbed Heisenberg chains

Vadim Oganesyan
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Using exact sum-rules, memory function ansatz and exact diagonalization we investigate the response of anomalous integrable nearest-neighbor XXZ spin chains to next-nearest neighbor integrability breaking spin-flip perturbation. We find (i) the isotropic Heisenberg model to be superdiffusive, with frequency dependent conductivity $\sigma(\omega \to 0) \sim |\omega|^{-3/7}$ in close numerical agreement with a recent t-DMRG computation; (ii) the sign of integrability breaking perturbation can matter – for simple spin flips it enhances transport when ”frustrating”, i.e. same for nearest and next-nearest neighbors, and suppresses otherwise (iii) but in some cases it does not, either when n.n.n. spin flips dominate or for assisted spin-flip perturbations

Quantum LDPC codes, spin models, and random matrices

Leonid P. Pryadko
University of California, Riverside, USA

Quantum low-density parity-check (LDPC) codes is the only class of quantum error-correcting codes known to combine finite rates with finite fault-tolerant thresholds. I will discuss several constructions of such codes, decoding threshold bounds, and their connection with the multicritical point in random-bond Ising models, as well as certain random matrix models.

Topological frequency conversion in strongly driven quantum systems

Gil Refael
California Institute of Technology, Pasadena, USA

When a small quantum system is subject to multiple periodic drives, it may realize multidimensional topological phases. In my talk, I will explain how to make such constructions, and show how a spin-1/2 driven by two elliptically-polarized light beams could realize the Bernevig-Hughes-Zhang model of 2 topological insulators. The observable consequence of such construction is quantized pumping of energy between the two drive sources.

Universal quasi-steady states in periodically driven many-body systems

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At very high driving frequencies, energy absorption in a periodically driven many-body system may be suppressed, opening an exponentially long time window in which the system "prethermalizes" as if its dynamics were governed by an effective, local, time-independent Hamiltonian. Here we uncover a new regime of prethermalization, occurring for low-frequency driving in systems with multiple intrinsic energy scales (e.g., continuous bands separated by a large gap). In this case, the system rapidly absorbs energy from the driving field and heats the low-energy degrees of freedom to a restricted infinite-temperature-like state, which only gives way to full mixing with the high energy degrees of freedom on a timescale that is exponentially long in the inverse of the driving frequency. Such states off era new paradigm of topological transport in non-equilibrium many-body systems: in the calculation of observables such as the Hall conductivity in 2D or the pumping current in 1D, the infinite temperature state restricted to low-energy bands yields uniform momentum space averages over the Berry curvature and Floquet-Bloch band group velocity, respectively, yielding universal results proportional to corresponding topological invariants. Here we focus on the case of a partially-filled (and therefore gapless) version of the Thouless pump in one dimension, and show that rapid heating indeed leads to a universal current-carrying quasi-steady state for low-frequency driving. In such a state, which can be realized for both bosons and fermions, the pumped charge per driving period is determined solely by the product of the particle density and the Floquet band quasienergy winding number. This novel type of prethermalized state is fundamentally unlike any equilibrium state and cannot be described in terms of any local, static, effective Hamiltonian. Recently developed cold atom systems offer a promising platform for investigating this new regime of driven many-body dynamics

Powerlaw Decays and Thermalization in Isolated Many-Body Quantum Systems

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I will discuss the short- and long-time dynamics of isolated many-body quantum systems, using for this the survival probability of the initial state. The results are general, applying for systems that are integrable and chaotic, interacting and noninteracting, disordered and clean. Specifically, the decay of the survival probability at short times can be very fast, even faster than exponential when the system is strongly perturbed out of equilibrium. At long times, however, the evolution of any quantum system with bounded spectrum slows down and shows a powerlaw decay. The powerlaw exponent contains information about the shape and filling of the energy distribution of the initial state. An exponent greater than or equal to 2 indicates that the distribution is ergodically filled and that the system will eventually thermalize.

Particle-phonon coupling effects within Theory of Finite Fermi Systems

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A consistent consideration of particle-phonon coupling (PC) effects within the self-consistent Theory of Finite Fermi Systems (TFFS) or any other self-consistent approach based on the use of parameters fitted to experimental data is rather delicate problem. Indeed, the PC processes are included, on average, to these phenomenological parameters. Therefore, the direct inclusion of all the PC contributions to the predictions for nuclear characteristics should be inevitably accompanied with a readjustment of the initial parameters. Instead, we developed a model for consideration of the PC effects in odd nuclei in which the fluctuating part of such corrections is taken into account only. The main idea of this model is to separate and explicitly consider such PC diagrams that behave in a non-regular way, depending significantly on the nucleus under consideration and the single-particle state $|\lambda\rangle$ of the odd nucleon. The rest (and the major part) of the PC corrections is supposed to be regular and included in the initial values of the parameters.

The model is developed for semi-magic nuclei, which contain a superfluid subsystem and a normal one, and besides the odd nucleon belongs to the normal subsystem. It simplifies the problem drastically. In addition, a non-regular behavior of the PC corrections is typical namely for the normal subsystem of a semi-magic nucleus. The model was used for finding PC corrections to the magnetic [1] and quadrupole [2] moments of the proton-odd neighbors of the even Pb and Sn isotopes. As a rule, the PC corrections induced with the low-lying 2_1^+ state play the main role, and a strong mixture of the states $|\lambda\rangle$ and $|\lambda' \times 2_1^+\rangle$ often occurs, being the reason of the non-regular behavior mentioned above. Among the PC terms, the “end correction” and the induced interaction one are sufficiently bigger than all other. However, they have opposite signs and cancel each other significantly. Therefore, ”small corrections”, in particular the one due to the magnetic moment or quadrupole moment of the phonon, play also a role. In the last case, the so-called tadpole diagram is of primary importance.

The single-particle (SP) spectra of magic nuclei is a popular object of examining the PC corrections, see [3] and Refs therein. All the *L*-phonons we consider are of surface nature, the surface peak dominating in their creation amplitude $g_L(r) = \alpha_L dU/dr + \chi_L(r)$, where $U(r)$ is the mean field nuclear potential, and the in-volume term χ_L is small. If we neglect the latter, a rather simple form of the tadpole term of the PC correction to the mass operator Σ can readily be obtained:

$$\delta\Sigma_L^{\rm tad} = \frac{\alpha_L^2}{2}\frac{2L+1}{3}\triangle U(r).$$

Its contribution to the SP energies is, as a rule, comparable in the absolute value with that of the usual pole diagram, being usually of the opposite sign. In the result, neglect of the tadpole PC term results often in an overestimate of the PC correction to the SP energies.

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Electron bubbles and Weyl Fermions in chiral superfluid ^{3}He-A

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Abstract: Electrons embedded in liquid ^{3}He form mesoscopic bubbles with radii large compared to the interatomic distance between ^{3}He atoms, voids of $N_{bubble} \approx 200$ ^{3}He atoms, generating a negative ion with a large effective mass that scatters thermal excitations. I report results based on scattering theory of Bogoliubov quasiparticles by negative ions embedded in ^{3}He-A that incorporate the broken symmetries of ^{3}He-A, particularly *time-reversal* and *mirror symmetry* in a plane containing the chiral axis **l**. Multiple scattering by the ion potential, combined with Andreev scattering by the chiral order parameter, leads to a spectrum of Weyl Fermions bound to the ion that support a mass current circulating the electron bubble - the mesoscopic realization of chiral edge currents in superfluid ^{3}He-A films. A consequence is that electron bubbles embedded in ^{3}He-A acquire angular momentum, $\mathbf{L} \approx -(N_{bubble}/2)\,\hbar\,\mathbf{l}$ inherited from the chiral ground state. Extension of the scattering theory is used to calculate the forces on a moving electron bubble, both the Stokes drag and a transverse force, $\mathbf{F}_{\mathbf{W}}=(e/c)\,\mathbf{v}\times\mathbf{B}_{\mathbf{W}}$, defined by an effective magnetic field, $\mathbf{B}_{\mathbf{W}} \propto \mathbf{l}$, generated by the scattering of thermal quasiparticles off the spectrum of Weyl Fermions bound to the moving ion. The transverse force is responsible for the anomalous Hall effect for electron bubbles driven by an electric field reported by the RIKEN group. Results for the scattering cross section, drag and transverse forces on moving ions are compared with experiments, and shown to provide a quantitative understanding of the temperature dependence of the mobility and anomalous Hall angle for electron bubbles in normal and superfluid ^{3}He-A. Results are discussed in relation to earlier theoretical work on negative ions in superfluid ^{3}He.

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Dissipative transport in the localized regime

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A quantum particle moving in a strongly disordered random environment is known to be subject to Anderson localization, which results in the complete suppression of transport. However, localization can be broken by a small perturbation, such as thermal noise from the environment, resulting in diffusive motion for the particle. I will discuss this phenomenon in two models in which the Schroedinger equation for a particle in the strongly localized regime is perturbed by (1) a time dependent fluctuating random potential and (2) a Lindblad operator incorporating the interaction with a heat bath in the Markov approximation. In each case, it can be proved that diffusive motion results with a strictly positive and finite diffusion constant. Furthermore, the diffusion constant tends continuously to zero at a calculable rate, as the strength of the perturbation is taken to zero. (Part 2 is joint work with J. Fröhlich.)

Scaling analysis and instantons for quantum spin tunneling and Quantum Monte Carlo simulations

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We will provide an overview of recent results of Google quantum computing team on the role of collective tunneling in quantum annealing algorithm. We will discuss the comparison of theory and experiments performed on DWave machine. We will describe an instantonic calculus for the thermally-assisted tunneling decay rate in a fully connected quantum spin model. We show that the tunneling decay problem can be mapped onto the Kramers escape problem of a classical random dynamical field. This dynamical field is simulated efficiently by Path Integral Quantum Monte Carlo (QMC). We show that the exponential scaling with the number of spins of the quantum tunneling rate and the escape rate of the QMC process are identical. We provide further examples where QMC has quadratic speed up in scaling over quantum tunneling.

Non-equilibrium dynamics of molecular bridge model
Limits to simplified description by Generalized Master Equations

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The talk will deal with the problem of a proper description of electron dynamics of open quantum systems when initial conditions, quantum interferences and decoherence processes play important roles. The aim is to understand better the full time development of many-body open systems out of equilibrium from its initial state over its transient dynamics to its very long time dynamics.

To deal with the difficult task to find out a proper description of this dynamics, we consider a very simple structure which, however, represents well open quantum systems: a molecular bridge between two leads. In this model the dynamics of electrons depends on the joint effect of the initial state with correlations and of the driving external disturbances (represented here by the change in the coupling between the leads and the bridge) setting on at the finite initial time. After the disturbances cease acting and the initial correlations die out, the process enters the non-equilibrium quasi-particle mode permitting, under some circumstances, a reduced description.

The possibility of simplified descriptions will be discussed on non-equilibrium dynamics of the molecular bridge model represented by calculations of transient magnetic currents between two ferromagnetic electrodes linked by tunneling junctions to a molecular size island of an Anderson local center type. The coupling strength of the junctions is assumed to undergo rapid changes. This modulates the connectivity of the system. The resulting switching events lead to transient magnetic currents and changes of magnetization at the island. The constant galvanic bias between the electrodes serves as an external control parameter. The model can be treated using the non-equilibrium Greens functions (NGF) [1] numerically. This provides a reference framework for testing the possibility of a simpler and physically more transparent solution by a Generalized Master Equation resulting from the NGF scheme approximated by the Generalized Kadanoff - Baym Ansatz (GKBA) [1, 2]. The basic question addressed is the range of applicability of these approximations. It turns out that the decisive feature is the spectral structure of the tunneling functions of both electrodes and their positioning with respect to the island level depending on the bias and the exchange splitting. Favorable for the validity of an Ansatz are weak tunneling and spectrally flat tunneling functions. We find out how far it is possible to stretch these conditions. The advantages and limitations of the use of the GKBA and will be demonstrated [2,3]. If time permits the relation of the simplified description will be discussed from the point of view of a generalization of Fluctuation-dissipation theorems.

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Low-energy nuclear spectroscopy in a microscopic multiphonon approach

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The low-lying spectra of heavy nuclei are investigated within the microscopic Quasiparticle–Phonon model. The approach goes beyond the quasiparticle random-phase approximation by treating a Hamiltonian of separable form in a microscopic multiphonon basis. It is therefore able to describe the anharmonic effects of collective modes as well as the multiphonon states, whose experimental evidence is growing. The method can be put in close correspondence with the proton–neutron interacting boson model. By associating the microscopic isoscalar and isovector quadrupole phonons with proton–neutron symmetric and mixed-symmetry quadrupole bosons, respectively, the microscopic states can be classified to their phonon content and their symmetry. The states disclose the nuclear properties which are to be ascribed to shell effects, not included in the algebraic approach. Due to its flexibility, the method can be implemented numerically for systematic studies of spectroscopic properties throughout entire regions of vibrational nuclei. The spectra and multipole transition strengths so computed are in overall good agreement with the experimental data. It is shown how this task is accomplished through systematic investigations of magnetic dipole and, especially, electric dipole modes. It provides reliable descriptions of low-lying magnetic as well as electric multipole modes of nuclei.

The model is enlarged employing a finite rank approximation of Skyrme interaction. The distribution of dipole strength in tin isotopes is calculated by means of the quasiparticle random phase approximation. The low-lying part of dipole strength distribution reveals the existence of a group of slightly collective states, and the corresponding $E1$ transition strength increases with the enlargement of neutron excess. The group is associated with the Pygmy resonance.

Excited-State Quantum Phase Transitions: Classification and Thermal Properties

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An Excited-State Quantum Phase Transition (ESQPT) is a nonanalytic behavior of the quantum level density and flow rate in the infinite-size limit of a system with finite number of degrees of freedom f. It is shown that the singularities are induced by stationary points of the Hamiltonian and can be fully classified by their type. The presence of an ESQPT affects also the thermodynamic properties, making the microcanonical heat capacity singular, while the canonical heat capacity remains a smooth, though often non-monotonous function. This discrepancy is caused by the collective character of the system and in the limit of infinite f both capacities coincide.

Non-Hermitian Plasmonic Nanoantennas

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Non-Hermitian Hamiltonians have long been utilized in the investigation of open quan-tum systems in various disciplines, the shell model in nuclear physics [1] and solid state quantum computing devices in condensed matter physics [2, 3] to name a few. The hall-mark of these systems is the sharp redistribution of decay widths and the segregation of short-lived “superradiant” states and long-lived “trapped” states at sufficiently strong in-teraction with the continuum [4]. Here we extend the applicability of the non-Hermitian Hamiltonian framework to systems of spherical metallic nano particles where light can be manipulated via surface plasmonic resonances. The signature of superradiance emerges when the interaction between adjacent optical nano antennas occurs through a single con-tinuum channel, resulting in states with enhanced radiation and confined dark modes. The effect of these states on energy transmission through a one dimensional chain of spheres is also considered, with applications to optical-frequency nano-scale antennas and waveguide-like structures.

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Nuclear Spectra, Chaos and the SYK Model

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The two-body random ensemble has a long history in nuclear physics starting from work by Bohigas, Flores, French and collaborators. Contrary to the invariant random matrix ensembles, this model embodies the two-body nature of the nuclear reactions and provides us with a more realistic description of nuclear spectra. More recently this model was introduced to condensed matter physics by Sachdev, Ye and Kitaev (SYK). In one version of this model the fermions are Majorana particles, and because this model may be the simplest possible model with a gravity dual which is maximally chaotic, it may be a description of the quantum states of a black hole and has attracted quite some attention in the field of string theory. The two-body random matrix ensemble, which is a close relative of this model, provides a description of nuclear spectra, and in particular of the spectra of compound nuclei. Because of the chaotic nature of nuclear interactions, all information on creation of the compound nucleus has been lost, and in this sense the nucleus has no hair. What remains, in close analogy to quantum black holes, is the quantum hair in form of resonances that are distributed according to random matrix theory. We analyze the spectral correlations of the SYK model and find that they are given by the invariant random matrix ensembles of the universality class that is determined by the total number of particles mod 8 [1]. We show that the spectral density above the ground state of the SYK Hamiltonian is given by the Bethe formula, and argue that this result is also valid for the two-body random ensemble. Finally we discuss the macroscopic spectral density and obtain the simple analytical result, $\rho(E) \sim e^{2\arcsin^2(\frac{E}{E_0})/\log\eta}$, where E_0 is the ground state energy and η is the suppression factor of intersecting contractions relative to nested contractions [2].

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Characterization and Design of Topological Boundary Modes via Generalized Bloch's Theorem

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Characterizing and controlling Majorana boundary excitations has implications ranging from fundamental condensed-matter physics to topological quantum computation. Since in any system with an interface translation invariance is broken, the exact energy spectrum is not accessible using the standard Bloch's theorem -- which also precludes a rigorous understanding of the "bulk-boundary correspondence" for fermionic matter. I will describe a generalization of Bloch's theorem to disorder-free, finite-range lattice systems of independent fermions, subject to arbitrary boundary conditions on two parallel hyperplanes. The theorem provides a closed-form expression for all energy eigenstates in terms of a "boundary matrix," that encodes information about both the bulk properties and the boundary conditions. Using the boundary matrix, an indicator that accurately predicts the existence of Majorana surface modes may be derived. I will survey a number of applications, showing in particular how the approach can be leveraged to tune the Hamiltonian in a Kitaev wire, so that the resulting Majorana excitations decay in space exponentially with a power-law prefactor -- previously believed to arise only in long-range models.

Quest for superradiance in atomic nuclei

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Studies of light nuclei offer a possibility to explore physics of unstable quantum many-body systems. The many-body complexity, onset of collective behavior, and clustering aspects are all microscopically related to complex evolution and multiple avoided level crossing of individual quantum states. Interaction of overlapping resonances of the same spin and parity introduces yet another twist. The interaction with continuum of external states modifies structure and leads to strong redistribution of decay strength. This phenomenon, also known as superradiance, is closely related to the conservation of probability in reaction processes. In this presentation we discuss some aspects of superradiance targeting its manifestation in nuclear physics and the role that it plays in the physics of nuclei far from the region of stability. We precent select experimental data highlighting the phenomenon.

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Spin dynamics of interacting many-particle quantum systems

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We analyze relaxation dynamics of fidelity decay and information entropy of a many-particle fermionic (bosonic) system in a mean-field, quenched by a random two-body interaction (preserving many-particle spin) as a function of spin degree of freedom. The system Hamiltonian is represented by embedded Gaussian orthogonal ensemble (EGOE) of random matrices (for time-reversal and rotationally invariant systems) with one plus two-body interactions for fermions/bosons. Both fermion and boson systems show significant spin dependence on the relaxation dynamics of the fidelity and entropy. A simple general picture, in which the variances play a central role, is also achieved for describing the short-time spin dynamics of fidelity decay and entropy production.

Limitations of the Porter-Thomas Distribution

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Partial widths for neutron or gamma decay obey the Porter-Thomas distribution (PTD). This widely held tenet follows directly from random-matrix theory, more precisely, from the orthogonal invariance of the Gaussian Orthogonal Ensemble of random matrices. Orthogonal invariance is generically violated by terms that couple the Hamiltonian to channels. Dominant among these is the term that couples to the *s*-wave neutron channel at energies close to neutron threshold (Thomas-Ehrman shift). The coupling is shown to produce significant deviations of neutron partial widths from the PTD. That same term has a much smaller influence on the PTD for gamma decays.