Poster Presentation

Coherent control of symmetry protected excitations of magnetic clusters

Lorenzo Amato (PSI)

In this poster, I will present some ideas on how to characterize and coherently control special excited states living on symmetric clusters of rare-earth ions (embedded in a non-magnetic crystal host). These states carry non-trivial cluster symmetry representations, hence can be proven to be well protected from the environment. The preparation of these states could be useful in the future for quantum sensing and quantum technologies.

Polarization superlattices for controlling the electronic structure in graphene/h-BN multilayers

Marta Brzezinska (EPFL)

Moiré superlattice systems based on twisted heterostructures of two-dimensional materials represent an emerging design principle for realizing novel physical phenomena. Motivated by the recent discovery of polarization superlattices in twisted multilayers of hexagonal boron nitride (h-BN), we investigate the possibility of using these systems for controlling the properties of multilayer graphene by means of the polarization proximity effect. In particular, by using first-principles and tight-binding model calculations, we address the possibility of creating topological flat bands in the multilayer graphene subsystem.

From hyperbolic drum towards hyperbolic topological insulators

Tomáš Bzdušek (PSI)

Hyperbolic lattices correspond to regular tessellations of the sheet of constant negative curvature, known as the hyperbolic plane. Over the past few years, the study of classical and quantum dynamics on hyperbolic lattices has witnessed a fascinating progress: On the experimental side, hyperbolic heptagon-kagome lattice has been realized with coupled waveguide resonators [1], while on the theory side, characterization of eigenstates using a hyperbolic extension of band theory has been achieved [2]. Curiously, the momentum space associated with two-dimensional hyperbolic lattices is inevitably four- (or higher-)dimensional. In this talk, I will discuss our simulation of a negatively curved “hyperbolic drum” in an electric-circuit network [3], and show how fingerprints of the emergent curvature enter both static and dynamical experiments on the set-up. Subsequently, after shedding light on the key theoretical concepts, I will demonstrate how the hyperbolic band theory can be applied to characterize topological insulators [4] and flat bands [5] on hyperbolic lattices.

[1] A. J. Kollár, M. Fitzpatrick, and A. A. Houck, Hyperbolic lattices in circuit quantum electrodynamics, Nature 571, 45—50 (2019).
[2] J. Maciejko and S. Rayan, Hyperbolic band theory, Sci. Adv. 7, abe9170 (2021); J. Maciejko and S. Rayan, Automorphic Bloch theorem for hyperbolic lattices, Proc. Natl. Acad. Sci. U.S.A. 119, e2116869119 (2022).
[3] P. M. Lenggenhager, A. Stegmaier, L. K. Upreti, T. Hofmann, T. Helbig, A. Vollhardt, M. Greiter, C. H. Lee, S. Imhof, H. Brand, T. Kießling, I. Boettcher, T. Neupert, T. Thomale, and T. Bzdušek, Simulating hyperbolic space on a circuit board, Nat. Commun. 13, 4373 (2022).
[4] D. M. Urwyler, P. M. Lenggenhager, I. Boettcher, R. Thomale, T. Neupert, and T. Bzdušek, Hyperbolic topological band insulators, arXiv:2203.07292 (2022).
[5] T. Bzdušek and J. Maciejko, Flat bands and band touching from real-space topology in hyperbolic lattices, arXiv: 2205.11571 (2022).

Mixed state quantum random walk and the entanglement phase transition

Christian Carisch (ETHZ)

Inhomogeneous nonequilibrium DMFT with kernel memory truncation

Jiyu Chen (University of Fribourg)

We introduce the formalism of the nonequilibrium cluster DMFT for inhomogeneous systems. With this scheme, we study a realistic multi-layer material 1T-TaS$_2$ and benchmark the reliability of a recently proposed memory truncation method of the Kadanoff-Baym equations (KBE).

GW+EDMFT investigation of $Pr_{1-x}Sr_xNiO_2$ under pressure

Viktor Christiansson (University of Fribourg)

Motivated by the recent experimental observation of a large pressure effect on T_c in $Pr_{1-x}Sr_xNiO_2$, we study the electronic properties of this compound as a function of pressure for x=0 and 0.2 doping using self-consistent *GW*+EDMFT. Our results demonstrate a non-trivial interplay between physical pressure and chemical doping in this material, and small but systematic changes with increasing pressure. The pressure dependent changes in the electronic structure of the undoped compound suggest an increasingly single-band-like behavior in the high-pressure regime, while a qualitatively different behavior is found in the doped system. We also point out that fluctuations in the orbital occupations and spin states are not consistent with a single-band picture, and that at least a two-band model is necessary to reproduce the full result. This multi-orbital nature manifests itself most clearly in the doped compound.

From chiral squeezing to nonlinear topology in optomechanics

Javier del Pino (ETHZ)

Synthetic gauge fields can be harnessed to engineer unconventional transport and localise bosonic states by breaking time-reversal symmetry and mimicking electrons' behaviour in electromagnetic fields. Optomechanical systems address optically mechanical modes via modulated radiation pressure, enabling spring constant tuning and strong mechanical interactions that imprint nonreciprocal Peierls phases – akin to the Aharonov-Bohm effect for electrons [1].

Here we demonstrate how optomechanical cavities unlock synthetic magnetic fields for many-mode oscillator networks, offering a route toward acoustic chirality and non-Hermitian topological states [2]. These ideas are tested within state-of-the-art nanobeam photonic crystals that support localised optical resonances coupled to multiple coherent mechanical overtones. Phase control of intensity-modulated driving in a single cavity then unlocks a versatile, optically-tunable nanomechanical network featuring arbitrary-range interactions that span a synthetic dimension (Fig. 1a). Our study analyses the emergence of chiral phononic propagation in single mechanical loops with nonreciprocal Aharonov-Bohm (AB) link phases. In addition, we demonstrate the interplay of AB interference and gain by inducing parametric interactions through radiation pressure, through control of non-Hermitian physics, including exceptional points and non-reciprocal phononic amplification (Fig. 1b). We finally overview our efforts [3] in exploiting optomechanical nonlinearities, natural in our systems, to control bifurcations into self-oscillating phases via nonreciprocal control phases.

Our findings open new prospects for bosonic transport and non-Hermitian topological phases for mechanical modes at the nanoscale. They ultimately illustrate the potential of optomechanical systems toward quantum chiral acoustic networks and strongly nonlinear systems with broken Hermiticity and time-reversal symmetry.

[1] Mathew J. P.* , del Pino, J.* , Verhagen E. (2020). Synthetic gauge fields for phonon transport in a nano-optomechanical system (*equal contribution) - [Nature Nanotechnology volume 15, pages 198 - 202]
[2] del Pino, J.*, Slim, Jesse J.* and Verhagen, E. (2021). Non-Hermitian chiral phononics through optomechanically-induced squeezing. (*equal contribution) [Nature volume 606, pages 82–87 (2022)]
[3] Košata, Jan*, del Pino, J.*, Heugel, Toni L. and Zilberberg, Oded (2022). HarmonicBalance.jl: a Julia suite for interacting nonlinear dynamics. (*equal contribution) [SciPost Phys. Codebases 6 (2022)]

Magnetic Flux Response of Non-Hermitian Topological Phases

Michael Denner (University of Zurich)

We derive the response of non-Hermitian topological phases with intrinsic point gap topology to localized magnetic flux insertions. In two spatial dimensions, we identify the necessary and sufficient conditions for a flux skin effect that localizes an extensive number of in-gap modes at a flux core. In three dimensions, we furthermore establish the existence of: a flux spectral jump, where flux tube insertion fills up the entire point gap only at a single parallel crystal momentum; a higher-order flux skin effect, which occurs at the ends of flux tubes in presence of pseudo-inversion symmetry; and a flux Majorana mode that represents a spectrally isolated mid-gap state in the complex energy plane. We uniquely associate each non-Hermitian symmetry class with intrinsic point gap topology with one of these cases or a trivial flux response, and discuss possible experimental realizations.

Linear Flavor-Wave Analysis of SU(4)-Symmetric Tetramer Model

Nobuo Furukawa (Aoyama Gakuin University)

Spin-dimer materials such as $TlCuCl_3$ are prototypical examples for studying interesting phases of matter and quantum phase transitions, e.g., non-magnetic state to a canted Néel phase under magnetic fields. In the area of cold atomic and optical systems, which have high controllability as for the geometry of lattice, the strength of interaction between atoms, etc. Recently, a great deal of effort is being made to realize higher-symmetric quantum many-body systems to find novel physical properties. For example, alkaline-earth(-like) fermionic atoms are closed-shell in the ground state, and the nuclear spin I provides 2I + 1 states, e.g., I = 5/2 for ^{173}Yb. In principle, with these atomic species we can prepare ideal SU($N \leq 2I + 1$)-symmetric systems because the interatomic interaction does not depend on the nuclear spin to a great approximation.
In this work, we consider a natural extension of the physics of spin-dimer materials under strong magnetic field to SU(4)-symmetric systems. We study the quantum magnetism of the SU(4) Mott insulator in an optical tetramerized superlattice, in which atoms with four nuclear-spin components (named “u”, “d”, “c”, and “s”) strongly interact with each other, by using the SU(4) Heisenberg model. More specifically, we investigate quantum phases induced by the external field by which the population of {u, d} tends to increase while {c, s} components are disfavored. Using an extended linear flavor-wave theory (LFWT) based on four-site plaquettes, we observe quantum phase transitions from fully antisymmetrized tetramer-singlet state (SU(4)-singlet state) to resonating-valence-bond (RVB) state on each tetramer, connected by an intermediate mixed phase between these two phases. We also report excitation spectra of these phases using LFWT calculations.

This work has been done by in collaboration with Yuki Miyazaki(1), Giacomo Marmorini(1,2) and Daisuke Yamamoto(2). (1) Aoyama Gakuin University (2) Nihon University.

Strong pinning transition with arbitrary defect potentials

Filippo Gaggioli (ETHZ)

Dissipation-free current transport in type II superconductors requires vortices, the topological defects of the superfluid, to be pinned by defects in the underlying material. The pinning capacity of a defect is quantified by the Labusch parameter $\kappa \sim f_p/\xi C$, measuring the pinning force f_p relative to the elasticity C of the vortex lattice, with ξ denoting the coherence length (or vortex core size) of the superconductor. The critical value κ = 1 separates weak from strong pinning, with a strong defect at κ > 1 able to pin a vortex on its own. The onset of strong pinning at κ = 1+ exhibits a striking correspondence to the physics of a critical point terminating a thermodynamic first-order transition, with the Labusch parameter κ replacing the scaled temperature T/T_c. So far, this transition has been studied for isotropic defect potentials, resulting in a critical exponent μ = 2 for the onset of the strong pinning force density $F_{pin} \sim n_p f_p(\xi/a_0)2(\kappa-1)^{\mu}$, with n_p denoting the density of defects and a0 the intervortex distance. This result is owed to the special rotational symmetry of the defect producing a finite trapping area Strap ~ ξ^2 at the strong-pinning onset. The behavior changes dramatically when studying anisotropic defects with no special symmetries: the strong pinning then originates out of isolated points with length scales growing as ξ(κ – 1)1/2, resulting in a different force exponent μ = 5/2. Our analysis of the strong pinning onset for arbitrary defect potentials makes heavy use of the Hessian matrix describing the curvature of the pinning potential and leads us to interesting geometrical structures: the strong pinning onset is characterized by the appearance of unstable areas of elliptical shape whose boundaries mark the locations where vortices jump. The associated locations of asymptotic vortex positions define areas of bistable vortex states; these bistable regions assume the shape of a crescent with boundaries that correspond to the spinodal lines in a first-order transition and cusps corresponding to critical end- points. Both, unstable and bistable areas grow with κ > 1 and join up into larger domains; for a uniaxially anisotropic defect, they merge into the ring-shaped areas previously encountered for isotropic defects. Finally, we extend the analysis to the case of a random two-dimensional pinning landscape (or short, pinscape) and discuss the topological properties of unstable and bistable regions as expressed through the Euler characteristic.

Creep effects on the Campbell response in type II superconductors

Vadim Geshkenbein (ETHZ)

Applying the strong pinning formalism to the mixed state of a type-II superconductor, we study the effect of thermal fluctuations (or creep) on the penetration of an ac magnetic field as quantified by the so-called Campbell length λ_C. Within strong pinning theory, vortices get pinned by individual defects, with the jumps in the pinning energy and force between bistable pinned and free states quantifying the pinning process. We find that the evolution of the Campbell length $\lambda_C(t)$ as a function of time t is the result of two competing effects, the change in the force jumps and a change in the trapping area of vortices; the latter describes the area around the defect where a nearby vortex gets and remains trapped. Contrary to naive expectation, we find that during the decay of the critical state in a zero-field cooled (ZFC) experiment, the Campbell length is usually nonmonotonic, first decreasing with time t and then increasing for long waiting times. Field cooled (FC) experiments exhibit hysteretic effects in λ_C; relaxation then turns out to be predominantly monotonic, but its magnitude and direction depend on the specific phase of the cooling-heating cycle. Furthermore, when approaching equilibrium, the Campbell length relaxes to a finite value, different from the persistent current, which vanishes at long waiting times t, e.g., above the irreversibility line. Finally, measuring the Campbell length for different states, zero-field cooled, field cooled, and relaxed, as a function of different waiting times t and temperatures T , allows to spectroscopyse the pinning potential of the defects.

Floquet ground state in periodically-driven many-body quantum systems

Tatsuhiko Ikeda (ISSP)

Emergent U(1) symmetry in non-particle-conserving 1D models

Zakaria Jouini (EPFL)

Motivated by recent investigations of Rydberg atom chains, we explore the properties of Luttinger liquid phases that emerge in 1D models with a non-conserved number of particles. We consider a chain of spinless fermion where particles are created three by three on adjacent sites. Despite being irrelevant in the RG sense, the perturbation still affects the observables due to its breaking of U(1) symmetry. In the framework of the flow equation approach, we present an intuitive picture that accounts for additional terms in the correlations which cannot be captured by standard bosonization mapping. The obtained results provide insight into the properties of the floating phase in the Z_3 - symmetric model of hard-core bosons that was introduced as a dual description of the commensurate melting of period-3 density waves.

Quantum Optics with Giant Artificial Atoms

Johannes Knörzer (ETHZ)

Superconducting circuits coupled to acoustic waveguides have extended the range of phenomena that can be experimentally studied using tools from quantum optics. In particular giant artificial atoms permit the investigation of systems in which the electric dipole approximation breaks down and pronounced non-Markovian effects become important. While previous studies of giant atoms focused on the realm of the rotating-wave approximation, in [1] we go beyond this and perform a numerically exact analysis of giant atoms strongly coupled to their environment, in regimes where counterrotating terms cannot be neglected. To achieve this, we use a Lanczos transformation to cast the field Hamiltonian into the form of a one-dimensional chain and employ matrix-product state simulations. This approach yields access to a wide range of system-bath observables and to previously unexplored parameter regimes, and is of independent interest for the simulation of strongly coupled systems.

[1] D. Noachtar, J. Knörzer, and R. H. Jonsson, Non-perturbative treatment of giant atoms using chain transformations, Phys. Rev. A 106, 013702 (2022).

Marginal quenches and drives in Tomonaga-Luttinger liquids

Bastien Lapierre (University of Zurich)

In this talk I will discuss the physics of Tomonaga-Luttinger liquids (TLLs) thrown out-of-equilibrium by marginal deformations, i.e., interaction modulations. I will show that the quench dynamics starting from generic initial states exhibit rich physics, with periodic exact zeros in the Loschmidt echo time evolution. I will then discuss the Floquet dynamics of TLLs and show how the su(1,1) structure of the periodic drive can be used to derive the stroboscopic time evolution of various physical observables, which is dictated by an exactly derived stability diagram. Finally using the tools developed previously, I will show that the Renyi divergence between two TLLs can be non-perturbatively obtained as a quench in Euclidean space-time.

Tunable tachyon mass in PT-broken massive Thirring

Benjamin Liegeois (ETHZ)

We investigate the possibility of phase transition and influence of effective gauge fields in a non-Hermitian PT-symmetric generalization of the two-dimensional massive Thirring model with particular focus on the PT-broken sector of the model. For this purpose, the functional renormalization-group is employed. The method predicts a new phase displaying a relevant imaginary mass, corresponding to monstronic excitations displaying exponentially growing amplitudes for timelike intervals and tachyonic (Lieb-Robison-bound breaking, oscillatory) excitations for spacelike intervals. Furthermore, since the phase manifests itself as an unconventional attractive spinodial fixed point, which is expected not to be reached in finite real-life systems, we predict that the effective renormalized mass reached can be tuned through the microscopic parameters of the model. While our results further predict a dramatic change in the renormalization group flows in the presence of an effective gauge field, the robustness of the new phase is nevertheless shown to hold contrary to the celebrated BKT transition occurring in the PT-unbroken sector. The effective gauge-field is further predicted to provide an additional way to tune the renormalized mass, and therefore the growth/oscillation rate of the corresponding excitations.

Ab initio calculations of electrical magnetochiral anisotropy with Wannier interpolation

Xiaoxiong Liu (University of Zurich)

sign with handedness. An example is electrical magnetochiral anisotropy (eMChA), a linear change in the resistivity of chiral conductors in a magnetic field. A strong eMChA was recently reported in p doped tellurium [1,2]. Motivated by these works, we have developed an ab initio methodology for evaluating the eMChA response of chiral crystals. We use the semiclassical Berry-Boltzmann formalism within the constant relaxation-time approximation to express the Ohmic current at order $E^2 \times B$ in terms of the band energies, Berry curvature, and intrinsic orbital moment of the Bloch states, which we then evaluate numerically using Wannier interpolation. We report preliminary results for tellurium as a function of temperature and doping concentration, and compare with experiment.

[1] G. Rikken and N. Avarvari, Phys. Rev. B 99, 245153 (2019).
[2] F. Calavalle et al. Nat. Mater. 21, 526 (2022).

A homodyne detection scheme for the measurement of quantum geometry and topological invariants

Markus Lysne (University of Fribourg)

We apply a quantum optical measurement scheme - homodyne detection - to the study of geometrical and topological quantities of condensed matter systems. By a hybrid set-up involving a 2D material placed within a cavity coupled to input and output ports, we perform correlation measurements on the electric field generated by the cavity light-matter interaction. By different polarizations of the intracavity field, we are able to measure all components of the quantum geometric tensor, $Q_{\mu\nu}$, for constant energy contours in the Brillouin zone. Applying recent results involving the metric-curvature correspondence, we use the measured quantum metric in order to describe the topological phase of the material at hand. As an interesting application, we consider a minimal model for twisted bilayer graphene at the magic angle, and discuss the feasibility of extracting the Euler number.

Anomalous magneto-transport at low-density in a quasi 1d conductor

Giacomo Morpurgo (University of Geneva)

Among the various 2D magnetic semiconductors that have been recently discovered and investigated, CrSBr has shown unexpected transport properties under field-effect doping. In particular, the absence of Hall effect and a large anisotropy of the conductivity indicate quasi- 1D behavior and possibly strong disorder [1]. Here, we study the field- and temperature- dependent longitudinal and transverse conductivities in a 2D anisotropic tight-binding model ($t_\perp \leq t_\|$), where the dissipation is described by a local (i.e., momentum-independent) self- energy Σ. Using the Kubo formalism, we calculate numerically the conductivity tensor up to second order in the field. This model allows one to describe the crossover from a regime of coherent anisotropic transport when $\Sigma < t_\perp$ to a quasi-1D regime with incoherent transport along one direction when $t_\perp < \Sigma < t_\|$. Furthermore, it allows us to explore a low-density regime that has not been much studied so far, where the chemical potential lies below the band and, when $k_B T < \Sigma$, the metallicity stems from spectral-weight broadening due to the self-energy rather than thermal excitation of carriers.

[1] W. Fan et al., Adv. Mater. 2022, 2109759 (2022)

Ultrafast control of spin-orbital separation probed with time-resolved RIXS

Aaron Müller (ETHZ – PHYS)

Quasi-one-dimensional systems exhibit many-body effects elusive in higher dimensions. A prime example is spin-orbital separation, which has been measured by resonant inelastic X-ray scattering (RIXS) in Sr_2CuO_3. Here, we theoretically analyze the time-resolved RIXS spectrum of Sr_2CuO_3 under the action of a time-dependent electric field. We show that the external field can reversibly modify the parameters in the effective *t–J* model used to describe spinon and orbiton dynamics in the material. For strong driving amplitudes, we find that the spectrum changes qualitatively as a result of reversing the relative spinon to orbiton velocity. The analysis shows that in general, the spin-orbital dynamics in Mott insulators in combination with time-resolved RIXS should provide a suitable platform to explore the reversible control of many-body physics in the solid with strong laser fields.

Effect of eletrostatic interaction on domain structures of thin film hexagonal manganites

Aaron Müller (ETHZ – MATL)

Signature of two-triplet bound states condensation in the INS spectrum of $SrCu_2 (BO_3)_2$ at high magnetic field

Mithilesh Nayak (EPFL)

Inelastic Neutron Scattering experiments have been conducted on $SrCu_2 (BO_3)_2$ in high external magnetic field up to 26 T. The INS energy transfer shows a rich set of excitations whose energies and spectral intensities have been measured as a function of magnetic field. The dynamics of the underlying Shastry-Sutherland model with Dzyaloshinskii–Moriya interactions has been simulated with Time-dependent Variational Principle and the numerical dynamical structure factor agrees qualitatively with the experiments. The ground state develops a uniform magnetization that increases linearly with the magnetic field in the regime 20-26 T. Our numerics indicate that this is due to the condensation of S=2, S_z=2 bound state of triplets [1, 2] and not to the condensation of single triplets. These bound states eventually crystallize to give the known structure of the magnetization plateau at 1/8 beyond 26 T [3]. Our analysis considers two possible scenarios, (a) single triplet condensation, (b) bound state condensation, and it compares the Shastry-Sutherland model's excitations on the respective states with the numerical estimates. A component-wise analysis shows that the series of energies at which excitations occur are only consistently explained by the condensation of bound states.

[1] T. Momoi and K. Totsuka, Magnetization plateaus of the Shastry-Sutherland model for $SrCu_2(BO_3)_2$: Spin-density wave, supersolid, and bound states, Phys. Rev B, 62, 15067(2000)
[2] H. Nojiri, H. Kageyama, Y. Ueda and M. Motokawa, ESR Study on the Excited State Energy Spectrum of $SrCu_2(BO_3)_2$ –A Central Role of Multiple-Triplet Bound States, J. Phys. Soc. Jpn. 72, pp. 3243-3253 (2003)
[3] P. Corboz and F. Mila, Crystals of Bound States in the Magnetization Plateaus of the Shastry Sutherland Model, Phys. Rev. Lett. 112, 147203 (2014)

Identifying the Huse-Fisher universality class of the three-state chiral Potts model

Samuel Nyckees (EPFL)

Using the corner-transfer matrix renormalization group approach, we revisit the three-state chiral Potts model on the square lattice, a model proposed in the eighties to describe commensurate-incommensurate transitions at surfaces, and with direct relevance to recent experiments on chains of Rydberg atoms. This model was suggested by Huse and Fisher to have a chiral transition in the vicinity of the Potts point, a possibility that turned out to be very difficult to definitely establish or refute numerically. Our results confirm that the transition changes character at a Lifshitz point that separates a line of Pokrovsky-Talapov transition far enough from the Potts point from a line of direct continuous order-disorder transition close to it. Thanks to the accuracy of the numerical results, we have been able to base the analysis entirely on effective exponents to deal with the crossovers that have hampered previous numerical investigations. The emerging picture is that of a new universality class with exponents that do not change between the Potts point and the Lifshitz point, and that are consistent with those of a self-dual version of the model, namely correlation lengths exponents $\nu_x = 2/3$ in the direction of the asymmetry and $\nu_y = 1$ perpendicular to it, an incommensurability exponent $\beta = 2/3$, a specific heat exponent that keeps the value $\alpha = 1/3$ of the three-state Potts model, and a dynamical exponent $z = 3/2$. These results are in excellent agreement with experimental results obtained on reconstructed surfaces in the nineties, and shed light on recent Kibble-Zurek experiments on the period-3 phase of chains of Rydberg atoms.

Weak ergodicity breaking in Hubbard, *t-J-U* and related models

Kiryl Pakrouski (ETHZ)

Many-body scars are states that do not obey the eigenstate thermalization hypothesis and thus lead to weak ergodicity breaking. Time evolution starting from a mix of such states exhibits "revivals" - the system returns to the exact initial state after equal periods of time. It has been shown [arXiv:2007.00845] that three families of highly symmetric states are many-body scars for any spin-1/2 fermionic Hamiltonian of the form H_0+OT, where T is a generator of an appropriate Lie group. One of these families consists of the well-known eta-pairing states while all such states have advantages for storing and processing quantum information. We show that a number of well-known coupling terms, such as the Hubbard and the Heisenberg interactions, and the Hamiltonians containing them (including topological ones), are of the required form and support these states as scars without fine-tuning. To facilitate possible experimental implementations, we discuss the conditions for the low-energy subspace of these models to be comprised solely of scars. We expand this framework to the non-Hermitian open systems and demonstrate that for them the scar subspace continues to undergo coherent time evolution and exhibit "revivals".

Based on: arXiv:2106.10300 and arXiv:2007.00845.

Quasiparticle conductance oscillations and snake states in domain walls of a chiral p-wave superconductor

Tudor Pahomi (ETHZ)

In a nonuniform perpendicular magnetic field, classical charged particles exhibit open, meandering, snake-like trajectories, for instance at the boundary between two regions with opposite field directions. We present in this poster the analogous quantum snake states expected to appear in inhomogeneous chiral p-wave superconductors. At the domain wall separating two superconducting phases with opposite chiralities, we prove such localized in-gap modes originate from the overlapping Andreev bound states belonging to the respective domains and sharing the propagation direction. Consequently, their properties depend on certain features of the effective Josephson junction whose control might be experimentally feasible, for example, the inter-domain tunneling strength or the relative global superconducting phase. The periodic spatial structure of the snake states is found to play a particularly important role in the transport of Bogoliubov quasiparticles. We explain the oscillations of the quasiparticle (energy) transmission probability are owed to a commensurability condition of the snake-state period and thus represent a hallmark of the chiral domain wall.

Electron slush and Mott criticality in TMD moirés

Louk Rademaker (University of Geneva)

Though the recent revolution in moiré materials started with the discovery of correlated insulators and superconductivity in twisted bilayer graphene, I will argue that much strong electron correlations are present in bilayers of transition-metal dichalcogenides (TMDs). I will introduce the origins of flat bands in TMD moirés, including surprising ARPES results on twisted bilayer WSe_2. Moving on to heterobilayers, I will discuss theoretical results on the exotic phases one might expect in the regime of Wigner-Mott phases, including the possibility of an amorphous conducting electron “slush”. Finally, the TMD bilayers realize the unique opportunity to study continuous Mott metal-insulator transitions. I will compare results between TMDs, organic compounds and dilute 2DEGs to set the stage for a theoretical pursuit of Mott criticality.

Non-thermal superconducting order in multi-orbital systems

Sujay Ray (University of Fribourg)

Non-thermal order in out of equilibrium systems has recently become an active field. There have been predictions of eta pairing in the photo-doped single band Hubbard model and enhanced triplet pairing in a two orbital Hubbard model. We study the photo-doped two orbital Hubbard model using nonequilibrium dynamical mean field simulation to search for non-thermal orders. Our calculations show that, at half filling, there is an emerging eta pairing in case of complete population inversion in the lower and upper Hubbard bands. The population inversion corresponds to the creation of triplons and singlons in the half filled two orbital Hubbard model. The triplon-singlon subspace can be studied by a generalized Schrieffer-Wolff transformation which projects out the doublon states. Our analytical study indicates that, unlike in the single band model, there are potential instabilities to magnetic, orbital and charge ordering along with eta pairing, leading to a rich phase diagram in the triplon-singlon subspace of the multi orbital systems.

Quantum phases in small spin J_1-J_2 chains

Aman Sharma (EPFL)

As Mermin-Wagner theorem indicates there is no order possible for a one-dimensional chain with Heisenberg interactions due to very high quantum fluctuations. In such cases, Quantum spin liquid is obtained, which as the name suggests has no long range order, on the other hand this phase is interesting because there exists a long range entanglement, and the system is described by, what was first suggested by Phil Anderson, Valence Bond state (VBS). In a VBS spin-1/2s which are present on each site form singlet entangled pairs with the spin-1/2s present on the other sites. It is to be remembered that entanglement obeys what is known as monogamy, that is, once a spin-1/2 is paired with one of the spin-1/2s on another site it cannot be paired with any other spin-1/2. Also, this picture works even for the higher spins because each spin can be thought to be composed of spin-1/2s, this is true because the spin at the metal ions fundamentally arise from the orbital picture of the filling of electrons, with each unpaired spin in the d or f orbital of a transition metal ion, or rare earth metal ion respectively providing an overall spin to the ion. However, VBS picture only fails in the way that the VBS ground states are non-orthogonal, the problem is solved though using projector methods. The rotational symmetry (SU(2)) possessed by the QSL state, due to the lack of ordering, can be broken if we activate next nearest neighbor coupling, or that is also a way of realising the spin ladder, so that in the system we have nearest neighbor AFM couplings with J_1 strength and next nearest neighbor AFM couplings with J_2 strength. Adding J_2 coupling causes frustration in the system, however, if J_2 is large enough it causes a Quantum phase transition into an ordered phase. We have found in our simulations performed by DMRG techniques if we keep increasing J_2 the system traverses through several phases, namely, starting from Heisenberg critical phase, it goes into a dimerised phase, then again into the critical phase with no long range order but at the same time no fixed q vector of the classical helical phase of the J_1-J_2 model. J_1-J_2 model studied for smaller spins is particularly interesting because they show higher quantum behavior which cannot be expected by studying the classical model. Spin-1/2 is fully quantum mechanical, but spins like 3/2 or 5/2 still have reminiscents of the quantum behavior .In my poster presentation, I would like to discuss about these different quantum phases in J_1-J_2 model for various small spin chains.

Strain modulation effects on the topological properties of a chiral *p*-wave superconductor

Yuto Shibata (ETHZ)

Motivated by recent developments in sample fabrication techniques, we study strain modulation effects on electronic structures of a two-dimensional single-band chiral *p*-wave superconductor within the BCS mean-field scheme. We employ a lattice model and solve the Bogolyubov-de Gennes equations numerically. Implementing strain modulations through spatially varying hopping matrix elements, we observe the appearance of spontaneous supercurrents due to the resulting spatial modulation of order parameter amplitudes. Moreover, we show from analyses of spectral functions and local Chern markers that sufficiently strong strain modulation induces the formation of topologically distinct domains within the system and, thus, chiral edge modes at their boundaries [2].

[1] M. D. Bachmann *et al.*, Science 366, 221 (2019).
[2] Y. Shibata and M. Sigrist arXiv:2205.13918.

Quantum quench in non-Hermitian systems

Karin Sim (ETHZ)

Non-Hermiticity leads to non-unitary evolution and possibly complex energy eigenvalues. We employ a consistent framework to address these issues by considering the non-trivial dynamics of the Hilbert space metric. Our study of a linearly-quenched non-Hermitian system reveals defect freezing in the adiabatic limit, and that no Kibble-Zurek scaling regime exists in our model. In particular, we compare this to the approach of simply normalising quantities by the norm of the time-evolved state. We find that the normalisation approach fails to capture the essential physics of defect freezing and the correct symmetry of physical observables.

Kondo physics in structured mesoscopic impurities

Lidia Stocker (ETHZ)

The characterisation of strongly-correlated effects in quantum impurity systems (QIS) is particularly challenging due to the infinite size of the environment and the inability of local correlators to capture the build-up of long-ranged
entanglement in the system. Here, we devise an entanglement-based observable – the purity of the impurity – as a witness for the formation of strong correlations. In combination with the Numerical Renormalisation Group (NRG) and Variational Matrix Product States (VMPS) method for QIS, we showcase the utility of our scheme when exactly solving (i) all-electronic dots–cavity and (ii) graphene quantum dots devices. In (i), we identify how the conducting dot-lead Kondo singlet is quenched by an insulating intra-impurity singlet formation. In (iii), we identify SU(2), SU(4) dot-leads Kondo effects, and valley-valley intradot singlet formation. With the generalisation of the NRG-VMPS method to out-of-equilibrium scenarios, we advance an extensive framework for the study of many-body effects in QIS.

Isospin phase transitions and superconductivity in Bernal bilayer and rhombohedral trilayer graphene

Andras Szabo (ETHZ)

Of the zoo of graphene-based layered systems, my presentation touches on Bernal bilayer and rhombohedral trilayer graphene, where the low-energy continuum theory is described by four-fold (valley and spin) degenerate gapless electronic bands, exhibiting quadratic and cubic band touching, respectively. Recent experiments shed light on a cascade of degeneracy lifting phase transitions in both systems, when subjected to chemical doping and external electric displacement field. I propose a simple explanation for these isospin phase transitions, based on the interplay between the experimentally tunable chemical doping and electric field, and interaction induced competing phases. Besides the emergent metallic phases, these systems also give rise to multiple distinct superconducting orders. I propose that the prominent pairing arising proximal to a spin-polarized half-metal (with valley degeneracy) is spin-triplet f-wave in nature, which I support via a leading-order renormalization group calculation. Moreover, I argue that the valley- and spin-polarized quarter-metal phase in graphene-like systems is conducive for pair-density-wave ordering, which is yet to be observed. The spatial and momentum space properties of this exotic pairing will also be highlighted.

Modelling magnetic order in the multiferroic hexagonal manganites

Tara Tosic (ETHZ)

Multiferroic hexagonal manganites (R-MnO_3) are prototype systems for studying highly frustrated magnetism, the suppressed order giving rise to exotic phases such as spin liquids or extended critical regimes in this family of materials. However, their exact magnetic ground state varies with no obvious trend from compound to compound. Despite conclusive experimental measurements of their magnetic orders, the theory leading to a distinct magnetic symmetry is to date unclear. Using a combination of symmetry analysis, first-principles density functional theory and phenomenological modelling, we explore a zone-boudary breathing mode (K1) and show it sits at the junction between magnetic and structural changes. We propose a phase diagram to describe the magnetic structure as a function of the anisotropy and exchange interactions. This in turn allows us to explain the dependence of the magnetic ground state on the identity of the rare-earth ion and on the K1 mode. By controlling structural changes within zone-boundary modes through external stimuli, modes such as K1 could act as knobs that effectively tune the magnetic ground state.

Hidden magnetic octupoles and second-order magnetoelectric effect

Andrea Urru (ETHZ)

We discuss how magnetic octupoles provide a basis for interpreting the second-order magnetoelectric effect, in which a bilinear electric field induces a linear magnetization, or the product of magnetic and electric fields induces a polarization. Magnetic octupoles are the next order terms, beyond the well-established magnetoelectric multipoles responsible for the linear magnetoelectric effect, in the multipole expansion of a non-uniform magnetization density, $\mathbf{m}(\mathbf{r})$. They are represented by the rank-3 tensor

$$\mathcal{M}_{ijk} = \int \mu_i(\mathbf{r}) r_j r_k d^3\mathbf{r}$$

, which we begin by decomposing into its irreducible spherical components. We then use Cr_2O_3 as a case study and show that, in addition to the linear magnetoelectric effect caused by its magnetoelectric multipoles, it has a hidden second-order local magnetic response caused by the anti-ferroic ordering of its magnetic octupoles.

Symmetry breaking and spectral structure of the interacting Hatano-Nelson model

Songbo Zhang (University of Zurich)

We study the Hatano-Nelson model, i.e., a one-dimensional non-Hermitian chain of spinless fermions with nearest-neighbor nonreciprocal hopping, in the presence of repulsive nearest-neighbor interactions. At half-filling, we find two transitions, as the interaction strength increases. The first transition is marked by an exceptional point between the first and the second excited state in a finite-size system and is a first-order symmetry-breaking transition into a charge density wave regime. Persistent currents characteristic of the Hatano-Nelson model abruptly vanish at the transition. The second transition happens at a critical interaction strength that scales with the system size and can thus only be observed in finite-size systems. It is characterized by a collapse of all energy eigen-values onto the real axis. We further show that in a strong interaction regime, but away from half-filling, the many-body spectrum shows point gaps with nontrivial winding numbers, akin to the topological properties of the single-particle spectrum of the Hatano-Nelson chain. Our results contribute to an understanding of fermionic many-body systems with non-Hermitian Hamiltonians.

Electron Optics in an Inverted-Band pn Junction

Yuhao Zhao (ETHZ)

Electron optics offers a promising condensed matter platform for manipulating and guiding electron beams with high efficiency and robustness. This field commonly relies on the spatial confinement of the electrons into 1D channels. Recently, electron optics using 2D Dirac materials were proposed, such as graphene-based transistors. In this work, we demonstrate the potential for electron optics applications using a band-inverted system resulting from particle-hole hybridization. We develop the theory of the interface scattering in the inverted-band \$pn\$ junction using a scattering matrix approach and provide a comprehensive protocol for constructing electron optic components, such as focusing lens, bifurcating lens, polarizers, and mirrors. The feasibility of the experimental realization under disorder and finite temperate is confirmed using numeric simulations.