TT 80: Correlated Electrons: Poster

Time: Thursday 15:00–18:00 Location: Poster E

TT 80.1 Thu 15:00 Poster E

Synthesis and Characterisation of Chemically tuned $CeRh_2As_2$ — •Sushma Lakshmi Ravi Sankar, Seunghyun Khim, Arushi Yadav, and Lea Richter — Max Planck Institute of Chemical Physics of Solids, Dresden

$CeRh_2As_2$ is an intriguing Kondo-lattice system which demonstrates novel phase diagrams involving superconductivity and an unknown ordered state. The unique multiple superconducting phases are suggested to be given by a combination of local inversion symmetry breaking and a localized nature of the Ce-4f electrons. Furthermore, the emergence of superconductivity within an ordered phase, suggested to be the quadrupole density wave state, remains to be understood regarding its nature and proposes a complex role of the Ce-4f electrons. To reach a deeper understanding of this pristine system, a doping study could be a promising experimental approach. Substituting the As site with the isovalent P is expected to decrease the lattice constants while doping the Ce atom with La would effectively modify electronic structures by introducing hole carriers. Here, we will report on preliminary works on single-crystal growth of P- and La-doped $CeRh_2As_2$. We utilized the Bi-flux method, previously used for growing the pristine crystal. Our characterization including crystal structures and basic properties such as resistivity, magnetization, and specific heat will be presented in order to find systematic changes in physical parameters.

TT 80.2 Thu 15:00 Poster E

Growth and characterisation of $PrCo_2P_2$ and $NdCo_2P_2$ single crystals — •Benjamin Helmer, Fabian Fiedler, Kristin Kliemt, and Cornelius Krellner — Physikalisches Institut, Goethe-Universität Frankfurt, 60438 Frankfurt am Main, Germany

Recently, long-lived spin waves in the THz regime were discovered in the metallic antiferromagnet $CeCo_2P_2$ [1], resulting from an intricate interplay of structural and magnetic degrees of freedom in this compound. Therefore it is of current interest to investigate similar compounds in the $LnCo_2P_2$ series. Here, we present the crystal growth of (Pr,Nd)Co_2P_2 in tin flux, using temperatures of up to 1400°C and a vertical temperature gradient, and the corresponding structural and physical characterization.

The structural characterization is performed by powder x-ray diffractometry, energy-dispersive x-ray spectroscopy and Laue diffraction. Magnetic properties of these systems, arising from the combination of the 4f-moments of $(Pr,Nd)^{3+}$-ions and the 3d-moments of Co^{3+}, are investigated by measurements of magnetization and heat capacity.

[1] G. Poelchen *et al.*, Nat. Commun. **14**, 5422 (2023)

TT 80.3 Thu 15:00 Poster E

Electron Spin Resonance of Eu on triangular layers in EuT_2P_2 (T=Mn, Zn, Cd). — •Jörg Sichelschmidt[1], Pierre Chailloleau[1], Sarah Krebber[2], Asmaa El Mard[2], Kristin Kliemt[2], and Cornelius Krellner[2] — [1]Max-Planck-Insitut für Chemische Physik fester Stoffe, 01187 Dresden — [2]Physikalisches Institut, Goethe-Universität Frankfurt, 60438 Frankfurt

Eu-based 122 systems in the trigonal $CaAl_2Si_2$ structure haven proven to show unusual transport properties such as anomalous Hall effect or colossal magnetoresistance, in the vicinity of an antiferromagnetically ordered state [1,2]. We investigated the electron spin resonance (ESR) of Eu^{2+} in EuT_2P_2 (T=Mn, Zn, Cd) single crystals. The temperature dependencies of ESR linewidth and resonance shift show a similar behaviour when approaching the Eu-ordered state – a divergence towards T_N, indicating the growing importance of magnetic correlations and the build-up of internal magnetic fields.

[1] S. Krebber et al. Phys. Rev. B **108**, 045116 (2023).
[2] X. Cao et al., Phys. Rev. Res. **4**, 023100 (2022).

TT 80.4 Thu 15:00 Poster E

Magnetism, heat capacity and electronic structure of $EuCd_2P_2$ in view of its colossal magnetoresistance — •Sarah Krebber[1], Dmitry Usachov[2], Charu Garg[1], Marvin Kopp[1], Jens Müller[1], Denis Vyalikh[3], Cornelius Krellner[1], and Kristin Kliemt[1] — [1]Physikalisches Institut, Goethe Universität Frankfurt, Germany — [2]Donostia International Physics Center (DIPC), 20018 Donostia-San Sebastian, Spain — [3]Iberasque, Basque Foundation for Science, Bilbao, Spain

Materials showing a colossal magnetoresistance (CMR) effect have been studied extensively over the last decades as they potentially form the materials basis for future applications. Recently, Eu-based 122 compounds in the trigonal $CaAl_2Si_2$ structure type have been shown to be promising candidates to study this CMR effect in antiferromagnetically ordered materials, where the underlying mechanism is still under investigation [1-3]. Recent studies propose the formation of ferromagnetic clusters to be the cause for these unusal transport properties in $EuCd_2P_2$ [2]. Here we present a detailed study of the magnetic properties of $EuCd_2P_2$ in connction with its heat capacity and electrical resistivity particulary in the view of its colossal magnetoresistance. Furthermore, we report on its electronic structure by ARPES measurements accompanied by DFT calculations.

[1] Z.C.Wang et al., Adv. Mater. 33, 2005755 (2021).
[2] V.Sunko et al., Phys. Rev. B 107, 144404 (2023).
[3] S.Krebber et al., Phys. Rev. B 108, 045116 (2023).

TT 80.5 Thu 15:00 Poster E

Unveiling novel interactions: hybridization variations in mixed-valent TmSe under negative pressure — •Chul Hee Min[1,2], Simon Müller[3], Michael Heber[4], Lenart Dudy[5], Woojae Choi[6], Yong Seung Kwon[6], Hendrik Bentmann[1], Friedrich Reinert[2], and Kai Rossnagel[2,4] — [1]FYI, NTNU, Norway — [2]IEAP, CAU Kiel, Germany — [3]EP7, Uni. Würzburg, Germany — [4]DESY, Germany — [5]SOLEIL, France — [6]DGIST, South Korea

In the 1980s, a range of interactions associated with the localized 4f states in rare earth compounds were contemplated, but the extent of their influence on physical properties remained unclear. Consequently, in most instances, these interactions were overlooked, and the standard Anderson model was commonly employed for such compounds. However, our recent investigations have uncovered spectroscopic evidence of a hitherto unrecognized interaction in the mixed-valent TmSe, particularly when subjected to negative pressure (the substitution of Se with Te). Our photoemission results reveal a distinct behavior: the 4f peak, previously considered singular, actually comprises two peaks that progressively separate with increasing the lattice parameter. Moreover, we demonstrate a correlated variation in the hybridization between the 4f states and other states. Consequently, our findings highlight a variable interaction that evolves with lattice expansion, with the bonding character transitioning from 5d to the cation p states. This discovery underscores the necessity of incorporating at least one additional hybridization into the Anderson model to effectively capture the mixed-valent characteristics.

TT 80.6 Thu 15:00 Poster E

Single crystal growth and characterization of $EuMn_2Si_2$ and $EuMn_2Ge_2$ — •Janina Strahl, Marwa Hussein Abdelhakam Abouelela, Kristin Kliemt, and Cornelius Krellner — Institute of Physics, Goethe-University, Frankfurt (Main), Germany

$EuMn_2Si_2$ exhibits a thermally driven valence transition at around 530 K of the europium ions above room temperature from Eu^{3+} at low temperatures to $Eu^{\sim 2.5+}$ at high temperatures [1]. The isoelectronic and isostructural substitution of silicon with germanium leads to a stabilization of the divalent state of Eu in $EuMn_2Ge_2$ without Eu ordering down to 1.5 K [1]. Both rare earth intermetallic 122 compounds crystallize in the tetragonal $ThCr_2Si_2$ structure type and show antiferromagnetic ordering of the manganese sublattices above room temperature. In literature [1,2] additional spin-reorientation transitions in polycrystalline samples at low temperatures were observed. In this contribution, we present the single crystal growth of these compounds and the results of our structural, chemical and magnetic characterization.

[1] M. Hofmann et al., Phys. Rev. B 69, 174432 (2004)
[2] I. Nowik et al., Phys. Rev. B 55, 3033 (1997)

TT 80.7 Thu 15:00 Poster E

Effect of substitutions and disorder on the valence transition in $YbIn_{1-x}(Ag/Au)_xCu_4$ single crystals — •Michelle Ocker, Bereket Ghebretinsae, Jan Niklas Zimmermann, Bernd Wolf, Kristin Kliemt, Michael Lang, and Cornelius Krellner — Physikalisches Institut, Goethe Universität Frankfurt, 60438 Frankfurt/Main, German

$YbInCu_4$ is one of the rare cases which exhibits a 1^{st}-order valence transition at ambient pressure as a function of temperature around $T_v = 42$ K [1]. The first-order valence transition line is terminated at a second-order critical endpoint (CEP) [2] where strong fluctuations together with strong coupling effects can be expected. In order to identify these effects and to study them in more detail, single crystalline samples were prepared in In-Cu flux [3]. To tune the material to a point close to the CEP in the valence cross-over region single crystals substituted with silver and gold were prepared. To fine-tune the substituted samples measurements under He-gas pressure were performed. We report on the single crystal growth with different substitution levels and different initial compositions. We present the results of our structural, chemical and physical characterization for the various samples. We show the elastic constant $c_L(T, p)$ and discuss the behaviour of the magneto-elastic coupling constant near the CEP.
[1] I. Felner et al., Physical Review B 35, (1987) 6956.
[2] Y. Onuki et al., J. Phys. Soc. Japan 89, (2020) 102001.
[3] J. L. Sarrao et al., Physical Review B 54, (1996) 12207.

TT 80.8 Thu 15:00 Poster E

Electric Field Gradient influenced by Rare Earth Elements in *R*AlSi Weyl Semimetals — •Tillmann Weinhold[1], Hank Wu[2], Rajib Sarkar[1], Vadim Grinenko[3], Fazel Tafti[4], Stephen Blundell[2], and Hans-Henning Klauss[1] — [1]TU Dresden, Germany — [2]University of Oxford, Great Britain — [3]Shanghai JiaoTong University, China — [4]Boston College, MA, USA

Weyl semimetals exhibit topologically non-trivial band-structures with Weyl nodes that can host massless fermionic quasiparticles (Weyl fermions). These can give rise to exotic electronic properties such as anomalous Hall effect and a chiral anomaly in the transverse magnetoresistance.

We used NMR and μSR experiments to gain information about local static and dynamic magnetic properties of RAlSi (R = {La, Ce, Nd}). Surprisingly, we observe an Electric Field Gradient (EFG) at the *Al* position, which is dependent on the rare earth element present in the compound. The EFG is most pronounced for NdAlSi and vanishes for LaAlSi.

TT 80.9 Thu 15:00 Poster E

Heat capacity and magnetization studies of the kagome intermetallic compound YbCr6Ge6 — •Kilian Srowik[1], Laura T. Corredor[1], Bernd Büchner[1,2], Sabine Wurmehl[1], and Vitaliy Romaka[1] — [1]Leibniz Institute for Solid State and Materials Science Dresden (IFW Dresden), 01069 Dresden, Germany — [2]Institut für Festkörper- und Materialphysik, Technische Universität Dresden, 01062, Dresden, Germany

Intermetallic compounds, with their mixed bonding character show a wide variety of physical properties, particularly electric and magnetic phenomena. Between them, compounds with rare-earth elements and transition metals owe their varied properties to the relationship between the localized f electrons of the rare-earth elements and the itinerant d electrons of the transition elements. Examples include the kagome metal candidate YCr6Ge6, incommensurate antiferromagnetism and successive spin reorientation in YMn6Ge6 and YbFe6Ge6, and the recent heavy fermion system YbV6Sn6. In this work, a newly synthesized YbCr6Ge6 bearing hexagonal MgFe6Ge6 structure, consisting of a triangular ytterbium sublattice and a kagome chromium sublattice, is investigated. Here, we report on heat capacity and magnetization measurements of this new compound at low temperatures and high magnetic fields. Contrary to most of its RECr6Ge6 sister compounds, a clear antiferromagnetic transition around 4 K is observed. Our results are discussed in the light of structural data.

TT 80.10 Thu 15:00 Poster E

$Ce_2Ir_3Ga_5$: A new locally non-centrosymmetric heavy fermion system — •Arushi Arushi, Raul Cardoso-Gil, and Christoph Geibel — Max Planck Institute for Chemical Physics of Solids, 01187 Dresden, Germany

Recently, a new type of unconventional superconductivity with a field-induced transition between two different superconducting (SC) states was discovered in the heavy fermion system $CeRh_2As_2$. This unusual SC state was proposed to be based on specific symmetries of the underlying structure, i.e., a globally centrosymmetric layered structure, but where the Ce-layers themselves lack inversion symmetry. This new type of SC state has attracted strong interest, prompting the search for further heavy fermion systems crystallizing in structures with appropriate symmetries. Here, I will present the discovery and the study of a new Ce-based heavy fermion system with a globally centrosymmetric structure but without inversion symmetry on the Ce-site, $Ce_2Ir_3Ga_5$. A single crystal X-ray diffraction study revealed an orthorhombic $U_2Co_3Si_5$ type structure. Resistivity, specific heat, and magnetization measurements indicate a moderate-heavy fermion behavior with a Kondo energy scale of the order of 40 K. Most experimental results suggest the absence of magnetic order, but a tiny anomaly in the specific heat opens the possibility for a very weak, itinerant type of ordering.

TT 80.11 Thu 15:00 Poster E

Phase diagram study of the Falicov-Kimball Model on the two-dimensional Kagome lattice — •Ammar Nejati[1] and Younes Javanmard[2] — [1]Jülich Centre for Neutron Science (JCNS) — [2]Leibniz Universität Hannover

The Falicov-Kimball Model (FKM) is a relatively simple model of coupled quantum and classic degrees of freedom, in the middle of the spectrum between the Hubbard and the Anderson models.

A number of studies have revealed its rich phase diagram in two-dimensional lattices, e.g. square and triangular lattices [1,2].

In a square lattice with half-filling, depending on the interaction strength and temperature, FKM exhibits a rich variety of phases: At sufficiently low temperatures, there is a charge density wave (CDW) phase; at high temperatures and weak interactions, a weakly localized phase appears which becomes an Anderson-localized phase in the thermodynamic limit; at high temperatures and strong interactions, a Mott insulating phase emerges [1]. In addition, there are two other phases called 'quantum liquid' and 'classical liquid' in triangular lattices and away from halffilling at sufficiently low temperatures and weak interactions [2]. We set up a Monte Carlo algorithm for the two-dimensional FKM away from the half-filling regime on a kagome lattice to study this model's rich phase diagram, and to extend the previous studies regarding the consequences of geometry on the emegent quantum phases and the corresponding phase transitions.
[1] Phys. Rev. Lett. 117, 146601
[2] Phys. Rev. Lett. 122, 197601

TT 80.12 Thu 15:00 Poster E

Specific heat and magnetocaloric effect measurements as probe of field-induced states in the Cobalt based honeycomb compound $BaCo_2(AsO_4)_2$ — •Sebastian Erdmann[1], Prashanta Mukharjee[1], Philipp Gegenwart[1], and Alexander A. Tsirlin[2] — [1]Experimentalphysik VI, Universität Augsburg, Germany — [2]Felix Bloch Institute for Solid State Physics, Universität Leipzig, Germany

In recent years the honeycomb Kitaev model has attracted much interest, because it can be analytically solved and displays a quantum spin liquid (QSL) state. Realization of the Kitaev interaction requires spin-orbit magnetic moments. Thus, mainly 4d and 5d honeycomb materials, like α-$RuCl_3$ and Na_2IrO_3 were studied in this context. However, recently the $3d^7$ Cobalt based honeycomb compounds such as $BaCo_2(AsO_4)_2$, $Na_2Co_2TeO_6$, and $Na_3Co_2SbO_6$ were predicted as suitable alternatives. Although the Kitaev interaction may be weaker in these materials due to the weaker spin-orbit coupling, it was theoretical predicted, that the QSL state might be more accessible because of the easy suppression of the antiferromagnetic Heisenberg coupling. Among these materials $BaCo_2(AsO_4)_2$ is a suitable candidate as it is free from structural imperfections and has a low critical field required to tune from the ordered to the paramagnetic state. We report specific heat and magnetic Grüneisen parameter measurements on $BaCo_2(AsO_4)_2$ down to the millikelvin range and study the details of the *H-T* phase diagram. Several field-induced anomalies are observed, whose origin will be discussed.

TT 80.13 Thu 15:00 Poster E

Coherent and screening properties of Dirac electrons — •Max Fischer[1], Arianna Poli[2], Niklas Wagner[1], Alessandro Toschi[3], Sergio Ciuchi[2], and Giorgio Sangiovanni[1] — [1]Universität Würzburg, Würzburg, Germany — [2]Università dell'Aquila, Coppito-L'Aquila, Italy — [3]TU Wien, Vienna, Austria

We investigate the quasi-particle transport properties of a model describing interacting Dirac and Weyl semimetals in the presence of local Hubbard repulsion U, where we explicitly include a deviation from the linearity of the energy-momentum dispersion through an intermediate-energy scale Λ.

In particular we analyze the screening processes affecting the lo-

cal moments in such correlated Dirac semimetals and compare their physics to corresponding Anderson impurity models.

TT 80.14 Thu 15:00 Poster E

Chiral quantum phase transition in moiré Dirac materials — •Ana García-Page[1] and Laura Classen[1,2] — [1]Max Planck Institute for Solid State Research, D-70569 Stuttgart, Germany — [2]Department of Physics, Technical University of Munich, D-85748 Garching, Germany

Strong enough interactions induce a semimetal-to-insulator transition in Dirac materials, which can be viewed as the solid-state analogue of the chiral phase transition in quantum chromodynamics. Moiré Dirac materials such as twisted bilayer graphene offer a new opportunity to study this transition because they facilitate tuning the effective interaction via a twist angle. Motivated by this, we explore the quantum phase transition of a 2D Dirac material which spontaneously develops a gap that breaks an Ising symmetry. We model it via an effective Gross-Neveu-Yukawa theory and employ the functional renormalisation group method to map out the phase diagram. We analyse the quantum critical behavior at the transition and investigate the effect of a chemical potential which introduces a finite charge density.

TT 80.15 Thu 15:00 Poster E

Perturbative approach to the quantum phase transition in the Dicke-Ising chain — •Jonas Leibig, Anja Langheld, Max Hörmann, and Kai Phillip Schmidt — Department Physik, Staudtstraße 7, Friedrich-Alexander Universität Erlangen-Nürnberg, D-91058 Erlangen, Germany

For the first time, we calculate high-order series expansions of the Dicke-Ising chain in the strong-coupling limit. We achieve this by applying a conditional displacement transformation and mapping to a self-consistent matter problem. We improve former results [1, 2] and are now able to derive the exact series results in the thermodynamic limit. We solve the self-consistent equations up to order 20 for ground-state energy and magnetization and analyze the phase diagram.

We examine ferromagnetic and antiferromagnetic Ising interactions, including the Dicke model and quantized transverse-field Ising chain as limiting cases. For ferromagnetic interactions, a second-order quantum phase transition occurs up to J = 0.5h from the Dicke limit and a first-order transition until J = 2h from the other limit. In the range between 0.5h and 2h, distinguishing between a first- and second-order phase transition is challenging. Quantum Monte Carlo simulations support the series approach, particularly for antiferromagnetic Ising interactions.

[1] J. Rohn et al., Phys. Rev. Res. 2, 023131 (2020)
[2] Y. Zhang et al., Sci Rep 4, 4083 (2014)

TT 80.16 Thu 15:00 Poster E

Spin-orbit coupled states arising in the half-filled t_{2g} shell — •Marco Schönleber and Maria Daghofer — Insitut für Funktionelle Materie und Quantentechnologien, Universität Stuttgart

Strongly correlated and spin-orbit coupled t_{2g} systems have been extensively investigated. By coupling orbital and spin angular momentum into one quantity, spin-orbit coupling (SOC) tends to reduce orbital degeneracy, e.g. for the widely studied case of one hole in the t_{2g} shell. However, the opposite has to be expected at half filling. Without spin-orbit coupling, all orbitals are half filled, no orbital degree of freedom is left and coupling to the lattice can be expected to be small. At dominant spin-orbit coupling, in contrast, one of the j=3/2 states is empty and the system couples to the lattice. We investigate this issue. One finding is that the low-energy manifold evolves smoothly from the four S=3/2 states in the absence of SOC to the four j=3/2 states with dominant SOC. These four states are always separated from other states by a robust gap. We then discuss a relevant superexchange mechanism to assess the interplay between spin-orbit coupling and coupling to the lattice.

TT 80.17 Thu 15:00 Poster E

Emergence of magnetism by structural engineering in a spin-orbit coupled oxide — •Ji Soo Lim[1], Martin Kamp[1], Merit Spring[1], Axel Lubk[2], Johannes Schultz[2], Ivan Soldatov[2], Rudolf Schäfer[2], Amar Fakhredine[3], Carmine Autieri[3], Fadi Choueikani[4], Philippe Ohresser[4], Bernd Büchner[2], Giorgio Sangiovanni[1], Michael Sing[1], and Ralph Claessen[1] — [1]Physikalisches Institut and Würzburg-Dresden Cluster of Excellence ct.qmat, Würzburg, Germany — [2]Leibniz Institute for Solid State and Materials Research and Würzburg-Dresden Cluster of Excellence ct.qmat, Dresden, Germany — [3]Institute of Physics, Polish Academy of Sciences, Poland — [4]Synchrotron SOLEIL, Ormes les Merisiers, Saint-Aubin, BP 48, Gif-sur-Yvette, France

Iridates exhibit an interesting emergent phenomena due to the interplay of short-range Coulomb interaction, spin-orbit coupling and crystal-field. Here, we manipulate the structural properties of SrIrO3 films by using SrTiO3 (111) substrates. A spontaneous twinned superstructure with a periodicity of 3 unit cells (uc) and unexpected magnetism is found. The interfaces between the 3 uc stacks are distinguished by face-sharing octahedra. We observe two transitons at about 30 and 7 K, linked to magnetism. Below 30 K, the anomalous Hall effect appears, with hysteresis loops below 7 K. X-ray circular magnetic dichroism and magneto-optic Kerr effect microscopy prove the emergence of magnetism below 30 K. Calculations indicate a different electronic band structure due to face-sharing octahedra and two-dimensional ferromagnetism of the interfaces.

TT 80.18 Thu 15:00 Poster E

$TlYbSe_2$ a new member of the $J = 1/2$ triangular lattice Yb delafossite family: from spin liquid to field - induced magnetic order — T. Fujii[1], M. Pillaca[3], F. Bärtl[2], J. Sichelschmidt[1], S. Luther[2], E. Häussler[3], H. Yasuoka[1], J. Wosnitza[2], H. Kühne[2], Th. Doert[3], and •M. Baenitz[1] — [1]Max Planck Institute for Chemical Physics of Solids, Dresden — [2]Hochfeld-Magnetlabor Dresden, HZDR — [3]Faculty of Chemistry and Food Chemistry, TU Dresden

$TlYbSe_2$ is a new member of the Yb delafossite family [1], which differs strongly from the previous alkali metal Yb delafossites. It is characterized by a much larger saturation field (about 25 T) and a higher transition temperature (about 2 K) of the ordered state. As for the other Yb delafossites, long ranged magnetic order is absent down to low temperatures in zero field. We report detailed macroscopic and microscopic measurements as a function of magnetic field and temperature on polycrystalline samples. Besides bulk methods such as magnetization and specific heat, spectroscopic methods such as ESR and NMR are applied.

[1] B. Schmidt, J. Sichelschmidt, K. M. Ranjith, Th. Doert, and M. Baenitz, Phys. Rev. B 103, 214445 (2021).

TT 80.19 Thu 15:00 Poster E

Magnetic dilution of a frustrated triangular-lattice spin system — •S. Luther[1], F. Bärtl[1,2], E. Häussler[3], T. Doert[3], J. Sichelschmidt[4], T. Kotte[1], J. Wosnitza[1,2], M. Baenitz[4], and H. Kühne[1] — [1]Hochfeld-Magnetlabor Dresden, HZDR — [2]Institut für Festkörper- und Materialphysik, TU Dresden — [3]Fakultät für Chemie und Lebensmittelchemie, TU Dresden — [4]MPI-CPfS, Dresden

Among the Yb-based triangular-lattice antiferromagnets, the delafossite $NaYbS_2$ is one of the candidates for realizing a quantum-spin-liquid (QSL) ground state. The magnetic phase diagram was probed by several experimental methods. The proposed QSL ground state of $NaYbS_2$ is suppressed at fields of several tesla, and long-range order with various spin configurations is manifested. As a next step, we investigated possible changes to this phenomenology by diluting the magnetic lattice of $NaYbS_2$ by means of Lu substitution. We synthesized a series of $NaYb_{1-x}Lu_xS_2$ single crystals, with $0 \leq x \leq 1$, and characterized these crystals by various probes, where the ESR spectroscopy data reveal a systematic reduction of the Weiss temperature as x is increased [1]. Further, we present recent specific-heat, magnetization and NMR measurements for samples with $x = 0.2$, which reveal a reduction of the transition temperature to the field-induced long-range magnetic order. An unchanged enhancement of the nuclear spin-lattice relaxation rate $1/T_1$ at low fields and temperatures indicates the stability of the putative QSL ground state against small levels of magnetic dilution.

[1] E. Häußler et al., Phys. Rev. Mater. **6**, 046201 (2022)

TT 80.20 Thu 15:00 Poster E

Quantum Phase Transitions of Kitaev's Toric Code on a Honeycomb lattice — •Viktor Kott, Matthias Mühlhauser, and Kai Phillip Schmidt — FAU, Erlangen-Nürnberg, Deutschland

We investigate the robustness of the topological phase of Kitaev's toric code in a uniform magnetic field on the honeycomb lattice through perturbative linked cluster expansions using a hypergraph decomposition. This approach allows us to correctly account for the non-trivial mutual exchange statistics of elementary anyonic excitations. By extracting the ground-state energy and excitation energies of the topo-

logical phase, we can determine the quantum phase transitions out of this topologically ordered state. In contrast to the conventional toric code on a square lattice, the ground-state phase diagram is dependent on the magnetic field's sign, which distinguishes between unfrustrated and frustrated parameter regimes. Consequently, this leads to distinct quantum-critical properties and a richer phase diagram.

TT 80.21 Thu 15:00 Poster E

Linear and non-linear response of the extended Kitaev model in a magnetic field — •Olesia Krupnitska — Institute for Theoretical Physics, Technical University Braunschweig, D-38106 Braunschweig, Germany — Institute for Condensed Matter Physics, National Academy of Sciences of Ukraine, 1 Svientsitskii Street, Lviv, 79011, Ukraine

Investigation of elementary excitations of the generalized Kitaev model plays an important role for understanding the dynamic properties of its solid-state realization. In the present study, we consider linear and non-linear response of the extended Kitaev model induced by an external magnetic field. Linear and non-linear response susceptibilities will be calculated within the Majorana mean-field approach. We discuss how the obtained results can be used for the interpretation of the experimental study of Kitaev-like compounds.

TT 80.22 Thu 15:00 Poster E

Kondo screening in Kitaev-type spin-orbitals liquids — •Christos Kourris and Matthias Vojta — Institut für Theoretische Physik, TU Dresden, Dresden, Germany

In systems of itinerant fermions interacting with local moments, the competition between Kondo screening and various types of symmetry breaking and topological order can give rise to rich phenomenology. The existence and type of screening depend crucially on the low-energy properties of the host system. Here we use suitable mean-field schemes to study situations where a single Kondo impurity is coupled to a Kitaev-type spin-orbital liquid, whose excitations are itinerant Majorana fermions.

TT 80.23 Thu 15:00 Poster E

Thermodynamic and magnetic characterization of the 3D magnetically frustrated langbeinite material $Tl_2Mn_2(SO_4)_3$ — •Alexander Bäder[1], Lucas Berger[1], Ladislav Bohatý[2], Petra Becker-Bohatý[2], Oliver Breunig[1], and Thomas Lorenz[1] — [1]II. Physikalisches Institut, Universität zu Köln — [2]Institut für Kristallographie, Universität zu Köln

According to theory, a 3D antiferromagnetic Heisenberg model with strong geometric frustration can be realized on the so-called trillium lattice [1]. Magnetic trillium lattices can be found in cubic materials of the low-symmetry space group $P2_13$, which is realized by several members of the langbeinite family, but up to now the magnetic properties of such materials have been hardly explored. In a recent study, signatures of a field-driven quantum spin-liquid behavior have been reported for the langbeinite material $K_2Ni_2(SO_4)_3$ with S=1 Ni^{2+} ions on a trillium lattice [2]. Here, we report the thermodynamic and magnetic characterization of the analogous $Tl_2Mn_2(SO_4)_3$ langbeinite with S=5/2 Mn^{2+} ions. From specific heat, magnetocaloric-effect, and magnetization measurements we derive a B–T phase diagram, indicating the presence of at least 3 magnetic phases below a temperature of about 1.5 K. The low ordering temperature in combination with a large field of 15 T to reach magnetic saturation indicates pronounced magnetic frustration.

This work was supported through CRC1238 (projects A02 and B01).
[1] J. Hopkinson, Phys. Rev. B **74**, 224441 (2006)
[2] I. Živković *et al.*, Phys Rev. Lett. **127**, 157204 (2021)

TT 80.24 Thu 15:00 Poster E

Evidence for low temperature magnetic ordering in triangular $YbBO_3$ — •Marvin Klinger[1], Prachi Telang[1], Tim Treu[1], Anna Moser[1], Ramesh Nath[2], Surya Mohanty[2], Gediminas Simutis[3], Anton Jesche[1], and Philipp Gegenwart[1] — [1]EP VI, Center for Electronic Correlations and Magnetism, Institute of Physics, University of Augsburg — [2]School of Physics, Indian Institute of Science Education and Research Thiruvananthapuram — [3]Laboratory for Neutron and Muon Instrumentation, Paul Scherrer Institut

The triangular magnet $YbBO_3$ attracted considerable attention as a quantum spin liquid candidate material with absent magnetic long-range order as well as spin freezing down to 20 mK in muon spin rotation (μSR) experiments [1]. In the course of investigating the suitability of this material for millikelvin adiabatic demagnetization refrigeration, we prepared a phase pure $YbBO_3$ powder, mixed it with fine silver powder for optimizing thermal contact and pressed pellets for standardized ADR performance test in the PPMS, similar as in [2]. The heat capacity, determined from the warming curve, indicates a clear and sharp magnetic phase transition at 400 mK, also confirmed by μSR on the same pellet. This indicates that silver is required to bind the grains together for thermal contact, otherwise the sample temperature could be significantly increased leading to wrong conclusions.

Work supported by the German Research Foundation through project 514162746 (GE 1640/11-1).
[1] K. Somesh et al., Phys. Rev. B 107, 064421 (2023).
[2] A. Jesche et al., Phys. Rev. B 107, 104402 (2023).

TT 80.25 Thu 15:00 Poster E

How to: Mean-field calculations with long-range interactions — •Jan Alexander Koziol[1], Giovanna Morigi[2], and Kai Phillip Schmidt[1] — [1]Department of Physics, Staudtstraße 7, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Germany — [2]Theoretical Physics, Saarland University, Campus E2.6, D-66123 Saarbrücken, Germany

We introduce an approach to set up mean-field calculations for lattice models with long-range interactions. The basic idea of our method is to perform mean-field calculations on all possible unit cells up to a given extend. The long-range interaction is treated without truncation using resummed couplings. One further advantage of the method we present is that all phases with ordering vectors fitting on any of the considered unit cells can be detected within out framework. We describe in detail the underlying theoretical ideas behind the method, the technicalities on how to implement the unit cell generation, and several results we obtained for spin-1/2 degrees of freedom and bosons on the two-dimensional square and triangular lattice.

TT 80.26 Thu 15:00 Poster E

Continuous similarity transformation for Antiferromagnetic Heisenberg model on a honeycomb lattice — •Dag-Björn Hering[1], Matthias R. Walther[2], Kai P. Schmidt[2], and Götz S. Uhrig[1] — [1]Technische Universität Dortmund, Department of Physics, Condensed Matter Theory, Otto-Hahn-Str. 4, 44227 Dortmund — [2]Friedrich-Alexander-Universität Erlangen-Nürnberg, Institut für Theoretische Physik I, Staudtstraße 7, 91058 Erlangen

In [1,2] Sala et al. showed that YbCl3 realizes the antiferromagnetic spin 1/2 Heisenberg model on the honeycomb lattice by comparing neutron scattering results with linear and self-consistent spin wave theory. However, deviations of the experimental data to the spin wave theory results occurred, namely an anomaly in the one-magnon dispersion at the K-point and in features of the the two-magnon continuum. This suggests that a treatment beyond self-consistent spin wave theory is needed. Continuous similarity transformations (CSTs) quantitively reproduced neutron scattering results for the antiferromagnetic Heisenberg model on a square lattice [3,4,5], where 1/S expansions were not sufficient for quantitative results. Here, we apply to the (CSTs) spin 1/2 Heisenberg model on the honeycomb lattice. The CST flow equations are truncated in momentum space by the scaling dimension d so that all contributions with $d \leq 2$ are taken into account. The resulting quartic magnon-conserving effective Hamiltonian is analyzed in the zero-, one-, and two-magnon sector.
[1] Nat. Commun. 12, 171 (2021)
[2] Commun. Phys. 6, 234 (2023)
[3] Rev. Lett. 115, 207202 (2015)
[4] SciPost Phys. 4, 001 (2018)
[5] Phys. Rev. Res. , 013132 (2023)

TT 80.27 Thu 15:00 Poster E

Thermodynamic properties of the triangular lattice XXZ model — •Alexander Schwenke and Wolfram Brenig — Institute for Theoretical Physics, Technical University Braunschweig, D-38106 Braunschweig, Germany

Motivated by its rich ground-state phase diagram, we investigate the triangular lattice XXZ model as a prime example to benchmark the numerical linked cluster expansion (NLCE) as a method for the study of geometrically frustrated quantum magnets. We employ a single-site representation in order to evaluate thermodynamic properties in a finite magnetic field $\vec{B}$. To this end we present results for the internal energy, the specific heat, the magnetization, and the magnetic susceptibility for clusters of sizes up to $\sim \mathcal{O}(11)$ sites. Supplementing these

calculations with exact diagonalization results, we discuss various cuts in the $J - \vec{B}$ plane.

TT 80.28 Thu 15:00 Poster E

Significant suppression of the lattice softening close to the QCP in $CoNb_2O_6$ — •Andreas Hauspurg[1,2], S. Zherlitsyn[1], K. Matsuura[3], T.-H. Arima[4], and J. Wosnitza[1,2] — [1]Hochfeld-Magnetlabor Dresden, HZDR, Germany — [2]Institut für Festkörper- und Materialphysik, TU Dresden, Germany — [3]RIKEN Center for Emergent Matter Science, Japan — [4]Department of Advanced Materials Science, University of Tokyo, Japan

$CoNb_2O_6$ is a model system for the spin-$\frac{1}{2}$ one-dimensional transverse field Ising model and shows a quantum critical point (QCP) at 4.75 T for $H \parallel b$. Neutron-diffraction experiments have revealed a set of discrete collective spin modes in $CoNb_2O_6$, which follow the long-sought E8 symmetry at the QCP. This proposition is supported by investigations with THz spectroscopy and NMR, which suggest that a one-dimensional QCP might lie within the 3D ordered phase [1, 2, 3].

We studied $CoNb_2O_6$ by means of the ultrasound pulsed-echo technique and investigated the in field magnetoelastic properties down to lowest temperatures of 0.3 K. In our contribution we present and discuss a significant suppression of the elastic softening related to the QCP. We studied this behavior to much lower temperatures than done before [4].

[1] Coldea *et al.*, Science 327, 177 (2010).
[2] Amelin *et al.*, Phys. Rev. B 102, 104431 (2020).
[3] Kinross *et al.*, Phys. Rev. X 4, 031008 (2014).
[4] Matsuura *et al.*, Phys. Rev. Lett. 124, 127205 (2020).

TT 80.29 Thu 15:00 Poster E

Unconventional magnetic excitation in novel frustrated spin-1/2 triangular antiferromagnets — •Fanjun Xu[1,2], Nazmul Islam[1], and Bella Lake[1,2] — [1]Helmholtz-Zentrum Berlin, DE — [2]Technische Universität Berlin, DE

In frustrated magnets, many exotic quantum phenomena can appear as a consequence of the competing interaction. One of the most celebrated examples is the highly degenerated ground state of unsatisfied spins on the triangular lattice antiferromagnet (TLAF). Theoretical studies suggest spin-1/2 TLAF develops long-range magnetic order at the ground state, combined with broadened and renormalized downward magnon excitations.

Surprisingly, a recent inelastic neutron scattering experiment on the spin-1/2 TLAF $Ba_3CoSb_2O_9$ reveals unconventional multiband higher energy excitations. To clarify whether this unconventional higher energy excitation continuum is universal for spin-1/2 triangular antiferromagnets or not, an inelastic neutron scattering experiment on high-quality polycrystalline $Ba_3CoNb_2O_9$ and $Ba_3CoTa_2O_9$ was performed.

In this poster, the magnetic excitations of the novel spin-1/2 TLAF $Ba_3CoNb_2O_9$ and $Ba_3CoTa_2O_9$ will be presented. The strong quantum fluctuations of the effective S-1/2 cobalt moments are evident by the higher energy continuum qualitatively observed in both compounds. The single-magnon scattering will be discussed in detail with a Heisenberg model.

TT 80.30 Thu 15:00 Poster E

Crystal growth and investigation of metallic kagome magnet $GdMn_6Ge_6$ — •Katharina M. Zoch, Kristin Kliemt, and Cornelius Krellner — Physikalisches Institut, Goethe-Universität Frankfurt, 60438 Frankfurt am Main, Germany

Metallic kagome systems show topologically nontrivial magnetic and electronic structures with the AT_6X_6-compounds counting as one of the prototypes of this material class [1]. The unique magnetism and interesting band structure makes them an ideal family to tune exotic magnetic and topological states using external parameters. So far, most work is based on polycrystalline samples, especially for the AMn_6Ge_6 (A = lanthanide) compounds. The typical self-flux crystal growth is challenging and has only been successfully performed for compounds with AMn_6Ge_6 (A = Tb-Lu) [2]. Here, we present the growth of $GdMn_6Ge_6$ crystals using a self-flux method as well as their chemical and physical characterization.

[1] N. J. Ghimire et al., Sci. Adv. 6, eabe2680 (2020)
[2] H. Zhou et al., Phys. Rev. Materials 7, 024404 (2023)

TT 80.31 Thu 15:00 Poster E

Optical conductivity of the kagome magnets FeSn and Fe_3Sn_2: search for Weyl cone and flat band excitations — •Jihaan Ebad-Allah[1,2], Fabian Meggle[1], Raphael Borkenhagen[1], Lilian Prodan[3], Vladimir Tsurkan[3], Felix Schilberth[3], István Kézsmárki[3], and Christine Kuntscher[1] — [1]Experimentalphysik II, Universität Augsburg, 86159 Augsburg, Germany — [2]Department of Physics, University of Tanta, 31527 Tanta, Egypt — [3]Experimentalphysik V, Center for Electronic Correlations and Magnetism, Institute for Physics, Universität Augsburg, D-86135 Augsburg, Germany

Magnetic materials with kagome-lattice arrangement have recently attracted considerable interest due to their remarkable electronic and magnetic properties such as topological Weyl semimetal state, topological superconductivity, and anomalous Hall effect. Kagome magnets FeSn and Fe_3Sn_2 belong to this material class, where theoretical calculations predict the existence of flat bands, nodal points, and helical nodal-lines in the vicinity of the Fermi energy, which motivated us to search for their fingerprints in the optical conductivity. Thus, we performed temperature-dependent reflectivity measurements on single crystals of both compounds. Our results reveal a similar profile of the optical conductivity spectrum for both materials, namely, intraband contributions at low energy, a dip below 0.16 eV, and a pronounced absorption band at around 0.4 eV followed by an increase of σ_1 towards higher energies. We relate the observed excitations to possible transitions between electronic bands predicted by theoretical calculations.

TT 80.32 Thu 15:00 Poster E

Magnetic phase diagram of the frustrated kagome system clinoatacamite — •Aaron Schulze[1], Carolin Kastner[1], Leonie Heinze[1], Dirk Menzel[1], Manfred Reehuis[2], Ralf Feyerherm[2], Kirrily Rule[3], Anja Wolter[4], and Stefan Süllow[1] — [1]IPKM, TU Braunschweig, Germany — [2]HZB, Berlin, Germany — [3]ANSTO, Australia — [4]IFW, Dresden, Germany

The natural mineral clinoatacamite ($Cu_2Cl(OH)_3$) has been discussed as geometrically frustrated magnet. The Cu^{2+} ions form a system of kagome layers with an antiferromagnetic in-plane coupling. This type of geometrical frustration leads to exotic quantum states at low temperatures. Here, we present an extensive study using single crystalline material that reveal a complex magnetic phase diagram of the material at low temperatures.

The measurements of the specific heat, magnetic susceptibility and magnetization as well as neutron scattering experiments indicate the existence of several magnetic phases. It is known that the uppermost magnetic phase has an ordering temperature of 18.1 K. The microscopic details of this phase are unknown. The lowest temperature phase exhibits signs of canted antiferromagnetism. Several exotic intermediate phases, whose microscopic behaviour is unclear, exist between these phases. From our data we construct the magnetic phase diagram for magnetic fields parallel and perpendicular to the kagome planes.

TT 80.33 Thu 15:00 Poster E

μm-beam LEED study of the charge density wave in the kagome metal CsV_3Sb_5 — •Lukas Jehn[1], Felix Kurtz[1], Alp Akbiyik[1], Gevin von Witte[2], Amir Haghighirad[3], Dong Chen[4], Chandra Shekhar[4], Hannes Böckmann[1], Matthieu Le Tacon[3], Claudia Felser[4], and Claus Ropers[1,5] — [1]Max Planck Institute for Multidisciplinary Sciences, D-37077 Göttingen — [2]Department of Information Technology and Electrical Engineering, ETH Zürich, CH-8093 Zürich — [3]Institute for Quantum Materials and Technologies, KIT, D-76344 Eggenstein-Leopoldshafen — [4]Max Planck Institute for Chemical Physics of Solids, D-01187 Dresden — [5]4th Physical Institute, University of Göttingen, D-37077 Göttingen

The discovery of the novel kagome metal CsV_3Sb_5 [1] sparked broad interest due to the coexistence of a charge density wave (CDW) phase and possible unconventional superconductivity [2]. We used low-energy electron diffraction (LEED) with a μm-sized electron beam [3] to study the structural CDW phase transition. We recorded high-quality backscattering diffraction patterns in ultrahigh vacuum from multiple cleaved samples. Surprisingly, we did not find superstructure reflexes at intensity levels predicted from dynamic LEED calculations based on the lattice distortion in the bulk. Therefore, we conclude that the periodic lattice distortion accompanying the CDW in CsV_3Sb_5 is less pronounced at surfaces than in the bulk.

[1] B. R. Ortiz et al., Phys. Rev. Mater. 3, 094407 (2019)
[2] B. R. Ortiz et al., Phys. Rev. Lett. 125, 247002 (2020)
[3] G. Storeck et al., Struct. Dyn. 4, 044024 (2017)

TT 80.34 Thu 15:00 Poster E

NMR of the Ising-type spin chain $BaCo_2V_2O_8$ at pulsed mag-

netic fields — D. Opherden[1], Z. Wang[2], Y. Ihara[3], K. Matsui[4], T. Kotte[1], S. Yamamoto[1], J. Wosnitza[1], S. Luther[1], T. Lorenz[5], and •H. Kühne[1] — [1]HLD-HZDR, Dresden — [2]Department of Physics, TU Dortmund — [3]Department of Physics, Hokkaido University — [4]Institute for Solid State Physics, Tokio — [5]Institute of Physics II, University of Cologne

NMR measurements at pulsed magnetic fields have been developed at dedicated large-scale research facilities for some time and are becoming increasingly available for user experiments. We will present our new results on the Ising-type spin-chain system $BaCo_2V_2O_8$, which hosts a quantum critical point at 40 T for magnetic fields applied transverse to the Ising axis. We studied $BaCo_2V_2O_8$ using ^{51}V NMR with pulsed magnetic fields up to about 60 T. The resulting NMR spectra probe the local uniform magnetization up to and across the regime of the quantum critical point. In the saturated regime, the field-induced suppression of electronic-moment fluctuations enables the detection of otherwise undetectable ^{59}Co NMR spectra, providing complementary insight into the field-driven polarization process of the Co^{2+} moments.

TT 80.35 Thu 15:00 Poster E

Charge-Density wave in a two-band model of infinite-layer nickelates — •Tharathep Plienbumrung[1], Maria Daghofer[1], Jean-Baptiste Morée[2], and Andrzej Oleś[3] — [1]Institute for Functional Matter and Quantum Technologies, University of Stuttgart, Stuttgart, Germany — [2]Waseda Research Institute for Science and Engineering, Waseda University, Tokyo, Japan — [3]Institute for Theoretical Physics, Jangiellonian University, Krakow, Poland

Recent measurements on infinite-layer (IL) nickelate compounds have found a charge-ordered state in the undoped compound as well as, short-range magnetic behavior. These measurements highlight the significant role of the rare-earth orbitals on nickelate compound, and the importance of nonlocal correlations in studying IL nickelate. Here, we study the two-band model of IL nickelate, including intersite Coulomb interaction, at quarter-filling on cubic lattice. We employ variational cluster approach (VCA) to study the spin and charge properties of the model at thermodynamics limit. The short-range correlations within cluster size are solved exactly while the long-range interactions beyond the cluster are included via mean-field approximation. We show that the intersite Coulomb interactions are substantial, creating the interplay between the spin and charge fluctuations in the IL nickelate. Furthermore, we explore the effect of doping on the charge and magnetic properties of the model. The single-particle spectral functions of the model at different doping level will be presented.

TT 80.36 Thu 15:00 Poster E

Transport properties and magnetization of $Sr_4Ru_3O_{10}$ — •Lara Pätzold[1], Zahra Ghazinezhad[1], Agustinus A. Nugroho[2], Markus Braden[1], and Thomas Lorenz[1] — [1]II. Physikalisches Institut, Universität zu Köln, Germany — [2]Bandung Institute of Technology, Indonesia

The layered transition metal oxide $Sr_4Ru_3O_{10}$ is a member of the Ruddlesden-Popper series and crystallizes in an orthorhombic structure. It is a ferromagnetic metal with $T_c \approx 105$ K and an additional metamagnetic transition at 50 K, where a deeper understanding of the magnetism is still missing. We present a study of single crystals of $Sr_4Ru_3O_{10}$ in terms of magnetization and electrical transport properties. We measured in-plane and out-of-plane magnetization and also investigated a possible anisotropy in the ab plane. Additionally we measured longitudinal ρ_{xx} and Hall resistivity ρ_{xy} with the magnetic field applied in the c direction. We observe a normal and anomalous Hall effect, whereby the latter shows a non-monotonic temperature dependence. In addition, the magnetoresistance changes sign at low temperatures. Analogous behavior of ρ_{xx} and ρ_{xy} is seen in the sister compound $SrRuO_3$, which in addition shows a anomalous spin dynamics [1]. All of these observations are associated to Weyl points in the bandstructure [2].

Funded by the DFG via CRC 1238 Projects A02, B01 and B04

[1] K. Jenni et al., Phys Rev Lett. **123**, 017202 (2019)
[2] K. Takiguchi et al., Nat. Commun. **11**, 4969 (2020)

TT 80.37 Thu 15:00 Poster E

Experimental signatures of gate tunable superconductivity in Al/STO heterostructures — •Jaydean Schmidt, Matthias Kronseder, Nicola Paradiso, and Christoph Strunk — Department of Exp. and Appl. Physics, University of Regensburg (Germany)

We demonstrate the effect of strong electric fields on aluminum (Al) thin films epitaxially grown on strontium titanite (STO) substrates. As a quantum paraelectric, STO has a large dielectric constant ($\varepsilon \approx 7000$), causing strong charge accumulation at the interface. STO based heterostructures have gained significant attention in the context of interface superconductivity [1]. The growth of certain metals onto STO induces the formation of oxygen vacancies in STO, acting as double electron donors in the highly conductive interface layer.

By applying an external electric field, we obtain a hole density of the combined Al/STO system $n \approx 2$ - $7\times10^{20}/m^2$. These values are similar to Al films ($\approx 10^{21}/m^2$) but much higher than the values measured for LAO/STO interface 2DEGs ($\approx 10^{18}/m^2$), indicating a charge flow dominated by Al charge carriers. Furthermore, both $T_c(n)$ and $B_c(T,n)$ are gate tunable, up to 15% and 50%, respectively. We found that $T_c \approx 0.92$ - 1.06 K is much lower compared to isolated thin Al films (≈ 1.4 K) yet higher than in STO. The system thus behaves like a bilayer of two superconductors with different gap that forms one proximity coupled system. It is surprising that the hybrid film remains gate tunable, despite the high carrier density of Al.

[1] N. Reyen et. al, Science, **317**, 1196 (2007)

TT 80.38 Thu 15:00 Poster E

High-pressure study of CDW in 2H-$TaSe_2$ — •Yuliia Tymoshenko[1], Amir-Abbas Haghighirad[1], Tom Lacmann[1], Alsu Ivashko[1], Gaston Garbarino[2], Luigi Paolasini[2], and Frank Weber[1] — [1]Institute for Quantum Materials and Technologies, Karlsruhe Institute of Technology, 76021 Karlsruhe, Germany — [2]European Synchrotron Radiation Facility, 71 avenue des Martyrs, CS 40220, Grenoble 38043, France

The study of charge density wave (CDW) materials is one of the most intriguing areas of modern solid state physics, since CDW often appears close to superconductivity (SC). The relationship between these phenomena, whether it be cooperation, competition, or simply coexistence, has been a subject of long-standing controversy. 2H-$TaSe_2$, a prototypical transition metal dichalcogenide (TMD) in which CDW and SC are intertwined, serves as a promising material to shed light on the interplay of both cooperative electron phenomena. Here we present our recent high-pressure x-ray diffraction (XRD) and spectroscopy (IXS) measurements showing a full suppression of the CDW by pressure, revealing a quantum critical point (QCP). The data shows a close connection between the QCP and the emegnent superconducting phase.

TT 80.39 Thu 15:00 Poster E

Interplay between the coupled electronic and lattice orders in unconventional CDW systems $BaNi_2As_2$ studied by collective mode spectroscopy — •Chandra Vardhan Kotyada[1], Priyanka Yogi[1], Amon P. Lanz[1], Amrit R. Pokharel[1], Amir A. Haghighirad[2], Matthieu Le Tacon[2], and Jure Demsar[1] — [1]Institute of Physics, Johannes Gutenberg University Mainz, 55128 Mainz, Germany — [2]Institute for Quantum Materials and Technologies, KIT, 76344 Karlsruhe, Germany

Time-resolved reflectivity studies of in $BaNi_2As_2$, a non-magnetic analogue of the parent compound of a pnictide superconductor $BaFe_2As_2$, reveal the existence of several charge-density-wave (CDW) amplitude modes[1], as in prototype CDW systems[2]. Their temperature and excitation density dependence suggest the charge-order driven nematicity in $BaNi_2As_2$ and support the idea of orthorhombic-triclinic structural symmetry phase transition being mediated by the stabilization of the CDW order[1]. We extend our studies to cover a large range in P-substituted $BaNi_2(As_{1-x}P_x)_2$[3]. Beyond the triclinic critical point (x 0.07), where also six-fold enhancement of superconducting T_c is observed[3], only two strongly damped sub-THz amplitude modes are resolved. The fact that diffraction and spectroscopic data[3] imply the absence of orthorombic distortions in samples beyond x 0.07 suggests the changes in the collective mode spectrum may be linked to variation in nematicity.

[1] A.R. Pokharel et. al., Comm. Phys. 5, 141 (2022)
[2] K. Warawa et al., Phys. Rev. B 108, 045147 (2023)
[3] Y. Yao et al., Nat. Commun. 13, 4535 (2022)

TT 80.40 Thu 15:00 Poster E

Optical investigation of altering correlation strength driven phase transition in 2D correlated molecular conductors — •Savita Priya, Dieter Schweitzer, and Martin Dressel — 1. Physikalisches Institut, Universität Stuttgart, Germany

Two-dimensional molecular electron systems are considered model systems for studying low-dimensional physics; exhibiting interesting phase

diagrams with exotic charge and magnetic ordering phenomena, electronic correlations and coupling of the electron system with the underlying molecular and lattice system. The quasi-two-dimensional BEDT-TTF charge transfer salts can be tuned by chemical means, i.e. change of counter anion or partial atomic substitution in the organic layers, leading to a subtle modification of the coupling. Here we partialy substitute sulfur with selenium atoms in the organic framework of α-(BEDT-TTF)$_2$I$_3$, known for its metal-insulator phase transition at 135 K, forming α-(BEDT-STF)$_2$I$_3$ and α-(BEDT-TSF)$_2$I$_3$. We investigate changes in electronic behavior on the phase transition from the metallic to low temperature insulating phase in the substituted counterparts of α-(BEDT-TTF)$_2$I$_3$ (below 66 K for BEDT-STF and 40 K for BEDT-TSF). The chemical modification affects the molecular orbital overlap asymmetrically in BEDT-STF and symmetrically in BEDT-TSF. Our approach combines wide-ranged infrared spectroscopy with temperature variation (down to 12 K) to analyze changes in electronic response, focusing on order and temperature change of phase transition.

TT 80.41 Thu 15:00 Poster E

Unveiling the optical behavior of a doped molecular quantum spin liquid candidate — Savita Priya[1], Sudip Pal[1], Christian Prange[1], Hiromi Taniguchi[2], and •Martin Dressel[1] — [1]1. Physikalisches Institut, Universität Stuttgart, Germany — [2]Graduate School of Science and Engineering, Saitama University, Japan

Quantum spin liquid (QSL) materials, identified by antiferromagnetic spin arrangement in a triangular lattice, have attracted attention ever since it was theorized. Study of the experimentally challenging QSL state, described by absence of long-range magnetic order due to geometric frustration involves techniques such as thermodynamic methods and magnetic probes to elucidate the magnetic properties. Among molecular QSLs, the κ-phase BEDT-TTF salts are notably significant as their triangular lattice points consist of BEDT-TTF dimer, in contrast to the atomic arrangement in inorganic QSL candidates. Owing to the incommensurate interpenetrating sublattice structure, a quasi-two dimensional organic conductor, κ-(BEDT-TTF)$_4$Hg$_{2.89}$Br$_8$ has gained attention as a doped QSL candidate. The unconventional stoichiometry results in 11complexity and plausible inhomogeneity. It is interesting to compare the electronic properties with the isostructural QSL candidate, κ-(BEDT-TTF)$_2$Cu$_2$(CN)$_3$. Here we present the results of our detailed infrared investigations of the correlated electron system κ-(BEDT-TTF)$_4$Hg$_{2.89}$Br$_8$ in a wide temperature and spectral range revealing insights into charge dynamics, vibrational properties, subtle temperature-induced changes in the electronic behavior and the anisotropic optical response.

TT 80.42 Thu 15:00 Poster E

Unusual magnetic anisotropy of the near-room-temperature ferromagnet Fe$_4$GeTe$_2$ — Riju Pal[1,2,3], Joyal J. Abraham[1,2], Suchanda Mondal[4], Prabhat Mandal[3], Atindra Nath Pal[3], Bernd Büchner[1,2], Vladislav Kataev[1], and •Alexey Alfonsov[1] — [1]Leibniz IFW Dresden, 01069 Dresden, Germany — [2]TU Dresden, 01062 Dresden, Germany — [3]S. N. Bose National Centre for Basic Sciences, 700106 Kolkata, India — [4]Saha Institute of Nuclear Physics, 700064 Kolkata, India

The representative of the family of two-dimensional conducting materials with high ferromagnetic ordering temperature, the Fe_4GeTe_2 compound features a peculiar spin reorientation transition at $T_{SR} \sim 110$ K suggesting a non-trivial temperature evolution of the magnetic anisotropy (MA). Here, we report an electron spin resonance (ESR) study of MA in this compound. We found that above a characteristic temperature of $T_{shape} \sim 150$ K the total magnetic anisotropy is mostly given by the demagnetization effect. Below T_{shape} we observed the growth of the intrinsic magnetic anisotropy that counteracts the shape anisotropy, rendering the sample seemingly isotropic at T_{SR}. At all temperatures from 3 K up to 300 K the main contribution to the intrinsic magnetic anisotropy is found to be of an easy-axis type. Below another characteristic temperature $T_d \sim 50$ K the anisotropy becomes even more complex than a simple easy-axis type. The temperatures characteristic for the evolution of intrinsic magnetic anisotropy match those observed in transport measurements, suggesting an inherent coupling between magnetic and electronic degrees of freedom in Fe_4GeTe_2.

TT 80.43 Thu 15:00 Poster E

Multipartite entanglement in the spin-1 bilinear-biquadratic chain — •Malo Rouxel and Andreas Honecker — Laboratoire de Physique Théorique et Modélisation, CNRS UMR 8089, CY Cergy Paris Université, France

The spin-1 bilinear-biquadratic chain represents the most general model for an isotropic exchange interaction in a spin-1 chain. In this model, the Hamiltonian can be expressed as a function of θ:

$$H = \sum_i (\cos(\theta)(S_i S_{i+1}) + \sin(\theta)(S_i S_{i+1})^2).$$

The chain exhibits several phases depending on the value of θ: the Haldane phase, a dimerized phase, a ferromagnetic phase, and a gapless phase. We show that proper multipartite entanglement measures enable the differentiation of various behaviors of the ground state depending on θ, and thus the identification of the corresponding phases. This ground state is obtained by diagonalizing the Hamiltonian using the Lanczos algorithm and the divide-and-conquer eigenvalue algorithm. As the ground state can be degenerate, symmetries and conservation laws are also studied.

TT 80.44 Thu 15:00 Poster E

A Combinatorial Method for Calculating Moments of Many-Body Operators — •Elaheh Adibi and Erik Koch — Institute for Advanced Simulation, Forschungszentrum Jülich, 52425 Jülich, Germany

We introduce an approach for calculating the moments for many-electron systems defined as $\langle E^M \rangle = \mathrm{Tr}\, H^M$ where H denotes the Hamiltonian in second quantization. Working in a basis of Slater determinants, $|I\rangle$, matrix elements $\langle I|H^M|I\rangle$ can only be non-zero if the orbital indices of the creation operators are a permutation of those of the annihilation operators. Classifying all permutations in terms of cycles enables us to calculate $\sum_I \langle I|H^M|I\rangle$ for different classes of cycles which is proportional to a binomial involving the number of orbitals and electrons. This binomial is then simply multiplied by the appropriate Eulerian number, which determines the number of permutations of a cycle with a given number of ascents.

TT 80.45 Thu 15:00 Poster E

Efficient Spin-Structure Estimation through Flavor-Specific Twisted Boundary Conditions — •Benjamin Heinrich — Institut für funktionelle Materie und Quantentechnologie, Universität Stuttgart

The challenge of constrained cluster sizes arising from the escalating computational demand of exact diagonalization (ED) can be addressed by extending periodic with twisted boundary conditions. By employing flavor-specific twisted boundary conditions, wherein each spin gains a distinct phase during hopping, additional points in momentum space become accessible when computing the spin excitation spectrum. In this study, we explore the viability of this approach by applying it to the Hubbard model on one- and two-dimensional lattices. Our findings indicate that this method produces reliable results in scenarios where the pertinent physics is predominantly captured by a single quasiparticle (e.g., one magnon), even if the relevant magnetic order is incommensurate with the bare lattice. However, its reliability diminishes in more intricate situations (e.g., two spinons). For the former case, this methodology provides a valuable initial insight into excitation spectra with minimal computational demands and can be easily integrated into existing ED code.

TT 80.46 Thu 15:00 Poster E

Hypergraph Decompositions — •Matthias Mühlhauser and Kai Phillip Schmidt — Friedrich-Alexander-Universität Erlangen-Nürnberg

A crucial element of graph-based linked-cluster expansions is to identify structurally equivalent clusters. To this end the clusters are typically represented by graphs, where the vertices represent the sites and the edges represent the couplings between the sites. The structural equivalence of clusters corresponds to isomorphism of the respective graphs.

However, if (possibly oriented) many-site couplings exist such a graph representation is typically not obvious, whereas hypergraphs naturally capture this structure. Interestingly, it is known that hypergraphs can be unambigously represented by bipartite graphs. We exploit this representation to distinguish equivalence classes of clusters and set up linked-cluster expansions via full hypergraph decompositions [1].

[1] Phys. Rev. E 105, 064110

TT 80.47 Thu 15:00 Poster E

Accelerating nonequilibrium Green function simulations with embedding self-energies — •Jan-Philip Joost[1], Karsten Balzer[2], Hannes Ohldag[1], and Michael Bonitz[1] — [1]Kiel Uni-

versity, Institute for Theoretical Physics and Astrophysics, 24098 Kiel, Germany — [2]Computing Center of Kiel University, 24118 Kiel, Germany

Real-time nonequilibrium Green functions (NEGFs) have been very successfully used to simulate the dynamics of correlated many-particle systems far from equilibrium. However, NEGF simulations are computationally expensive since the effort scales cubically with the simulation duration. Recently, we introduced the G1-G2 scheme that allows for a dramatic reduction to time-linear scaling [1]. While previous applications focused on isolated systems, here we extend the G1-G2 scheme to open systems applying the NEGF-concept of an embedding selfenergy. We demonstrate how this concept can be transformed into a time linear system of equations and present results for the charge transfer between correlated 2D materials and an external ion [2].

[1] N. Schlünzen, J.-P. Joost and M. Bonitz, Phys. Rev. Lett. 124, 076601 (2020)
[2] K. Balzer, N. Schlünzen, H. Ohldag, J.-P. Joost, and M. Bonitz, Phys. Rev. B 107, 155141 (2023)

TT 80.48 Thu 15:00 Poster E

Green's functions of quantum impurity systems from MPS-based band Lanczos — •Coraline Letouzé[1], Guillaume Radtke[1], Benjamin Lenz[1], and Sebastian Paeckel[2] — [1]Sorbonne Université, Muséum National d'Histoire Naturelle, UMR CNRS 7590, Institut de Minéralogie, de Physique des Matériaux et de Cosmochimie, IMPMC, 75005 Paris, France — [2]Department of Physics, Arnold Sommerfeld Center for Theoretical Physics (ASC), Munich Center for Quantum Science and Technology (MCQST), Ludwig-Maximilians-Universität München, 80333 München, Germany

Quantum impurity models are important both on their own (see e.g. Kondo effect or quantum dots) and as solvers for embedding techniques such as the dynamical mean-field theory (DMFT). Accurately calculating the Green's functions of such interacting quantum many-body systems is still a challenging problem. To that aim, we implement the (band) Lanczos algorithm for matrix-product states (MPS). It allows us to compute real-frequency Green's functions by diagonalizing the Krylov projection of the Hamiltonian, while efficiently compressing the many-body wavefunctions. We present results for the 2D Hubbard model and DMFT-based impurity models of transition metal oxides.

TT 80.49 Thu 15:00 Poster E

The Orthonormalized Kernels Representation: a semi-analytic compression algorithm for imaginary axis Greens functions — •Andreas Hausoel[1,2], Max Fischer[3,2], Giorgio Sangiovanni[3,2], Jeroen van den Brink[1,2], and Oleg Janson[1,2] — [1]Institute for Theoretical Solid State Physics, Leibniz IFW Dresden, Helmholtzstr. 20, 01069 Dresden, Germany — [2]Würzburg-Dresden Cluster of Excellence Ct.qmat, Technische Universität Dresden, 01062, Dresden, Germany — [3]Institut für Theoretische Physik und Astrophysik, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany

Recently there were introduced two novel and exciting representations (= quantum mechanical basis sets) of Greens functions on the imaginary axis: the intermediate representation (IR) and the discrete Lehmann representation (DLR). They optimally compress the physical information (removing all the noise and redundant data) in two very different ways. However, both have a drawback, preventing them from becoming 'the' new basis for quantum mechanical calculations: the analytical form of the IR is not known, and the DLR is not orthonormal.

The Orthonormalized Kernels Representation (OKR) manages to cure their drawbacks and unite their advantages. However, this construction creates a severe problem at an entirely different place: nonlinear diagrammatic equations become intracable.

With our poster we explain this new perspective on the subject and put the manifold possibilities for further advance up for discussion.

TT 80.50 Thu 15:00 Poster E

Convergence behaviour of numerical linked-cluster expansions — •Harald Leiser, Max Hörmann, and Kai Phillip Schmidt — Department Physik, Staudtstraße 7, Friedrich-Alexander Universität Erlangen-Nürnberg, D-91058 Erlangen, Germany

An important step in understanding dynamical properties of quantum many-body systems is the investigation of one-particle properties in the thermodynamic limit. For a Hamiltonian $H = H_0 + xV$ we derive an effective block-diagonal Hamiltonian $H_{\text{eff}} = T^\dagger H T$ with the projective cluster-additive transformation [1]. We calculated numerical linked-cluster expansions (NLCEs) for the antiferromagnetic transverse-field Ising model on a chain, ladder, triangular stripe and a sawtooth chain and obtained $S = \log(T)$ and H_{eff}. Moreover, we compared the convergence of the NLCE for the models under study with regards to the used unit cell expansion. Especially for the saw-tooth chain, a comparison with an expansion into triangles showed better agreements with extrapolations of existing series expansion [2]. Apart from that, we expand the framework to obtain one-particle properties more efficiently. To be concrete, we use the information on S of a cluster expansion up to a cluster-size with N spins to calculate $\exp(-S)H\exp(S)$ in the thermodynamic limit and compare this with the usual NLCE up to the same cluster-size.

[1] M. Hörmann et al., SciPost Phys. 15 (2023) 097
[2] D. J. Priour et al., Phys. Rev. B 64 (2001) 134424

TT 80.51 Thu 15:00 Poster E

Actively moving domain in a driven ferrimagnet — •Reza Doostani, Achim Rosch, Dennis Hardt, and Nina del Ser — Institute for Theoretical Physics, University of Cologne, Germany

We investigate the behavior of a ferrimagnet driven by a weak oscillating staggered magnetic field. The undriven system can be described by Heisenberg energy term and magnetocrystalline anisotropy. Numerical and analytical studies of this classical spin model using Landau-Lifshitz-Gilbert equation show the existence of a rotational Goldstone mode. We Also study the long-range order of the system in presence of thermal fluctuation in one and three dimension. Further analysis can be done by inserting a domain wall into the system. Driving the system results in the movements of domain wall with speed v which interestingly is linear to the field amplitude. This claim is realized both analytically and numerically.

TT 80.52 Thu 15:00 Poster E

Transverse Ising model in curved 2D geometries — •Grigorios Makris[1], Ion Cosma Fulga[2,3], and Fabian Hassler[1] — [1]Institute for Quantum Information, RWTH Aachen University, Germany — [2]Institute for Theoretical Solid State Physics, IFW Dresden, Germany — [3]Würzburg-Dresden Cluster of Excellence ct.qmat, Dresden, Germany

The transverse field Ising model is a prime example of a quantum phase transition. The one dimensional model has been solved analytically as it maps to a free fermion system and rigorous results for its scaling properties have been obtained. The two dimensional model has been evaluated numerically in two dimensional flat space.

Here, we study the transverse field Ising model in a curved two dimensional geometry. We investigate the finite size effects near the infinite critical point and its scaling in the thermodynamic limit.

TT 80.53 Thu 15:00 Poster E

Understanding the supercritical phase of the Hubbard model with timescales of the local moment screening — •Léo Gaspard[1,2] and Jan M. Tomczak[2,3] — [1]Laboratoire de Chimie et Physique Quantiques, Université Toulouse III - Paul Sabatier, Toulouse, France — [2]Institut für Festkörperphysik, Technische Universität Wien, Wien, Austria — [3]King's College London, London, United Kingdom

A material's phase diagram typically indicates the types of realized long-range orders, corresponding to instabilities in static response functions. In correlated systems, however, key phenomena crucially depend on dynamical processes, too: In a Mott insulator, the electrons' spin moment fluctuates in time, while it is dynamically screened in Kondo systems. Here, we introduce a timescale "t_m" characteristic for the screening of the local spin moment and demonstrate that it fully characterizes the dynamical mean-field phase diagram of the Hubbard model: The retarded magnetic response delineates the Mott transition and provides a new perspective on its signatures in the supercritical region above. We show that "t_m" has knowledge of the Widom line and that it can be used to demarcate the Fermi liquid from the bad metal regime. Additionally, we identify a region with preformed local moments that we suggest to have a thermodynamic signature.

TT 80.54 Thu 15:00 Poster E

Dynamically generated quadrupole polarization using Floquet adiabatic evolution — •Gonzalo Camacho, Christoph Karrasch, and Roman Rausch — Technische Universität Braunschweig, Institut für Mathematische Physik, Mendelssohnstrasse 3, 38106 Braunschweig, Germany

We investigate the nonequilibrium dynamics of the S = 1 quantum spin chain subjected to a time-dependent external drive, where the driving frequency is adiabatically decreased as a function of time (Floquet adiabatic evolution). We show that, when driving the rhombic anisotropy term (known as the two-axis countertwisting in the context of squeezed spin states) of a Néel antiferromagnet, we can induce an overall enhancement in the quadrupole polarization, while at the same time suppressing the staggered magnetization order. The system evolves into a new state with a net quadrupole moment and antiferroquadrupolar correlations. This state remains stable at long times once the driving frequency is kept constant. On the other hand, we find that we cannot achieve a quadrupole polarization for the symmetry-protected Haldane phase, which remains robust against such driving.
[1] C. Camacho et al., Phys. Rev. Res. 5, 023015 (2023)

TT 80.55 Thu 15:00 Poster E

Formation and stability of Floquet-Bloch bands in a quasi-1D model of interacting spinless fermions. — •Manuel Buriks, Karun Gadge, and Salvatore R. Manmana — Institut für Theoretische Physik, Georg-August-Universität Göttingen, Deutschland

Motivated from the search of Floquet side bands (FBs) in experiments on different materials, we study the time evolution of periodically driven interacting spinless fermions on a quasi-1D system resembling a graphene stripe. Using matrix product states (MPS), we compute the time-evolution of the spectral function and study the formation and stability of FBs for different setups.

TT 80.56 Thu 15:00 Poster E

Relaxation dynamics in the one-dimensional Kondo lattice model — •Arturo Perez Romero and Fabian Heidrich-Meisner — Institut for Theoretical Physics, Georg-August-Universität Göttingen, D-37077 Göttingen, Germany

We study the real-time dynamics of optically excited electrons coupled in a paradigmatic model describing the coupling between localized and conduction electrons, the Kondo lattice model. In particular, we analyze the role of localized electrons interacting with a highly excited carrier at low density for an antiferromagnetic coupling ($J > 0$) via the time-dependent Lanczos method. We implement a ferromagnetic orden for the localized electrons and an opposite spin for the itinerant electron as our initial state. We perform an extensive analysis of the time evolution by calculating the spin-spin correlation between localized electrons and between delocalized and localized electrons and the electronic momentum distribution function. We discuss several dynamical properties, such as the magnetization transfer from the charge carrier to localized spins, the approach of the system to the steady state, and the transient dynamics by considering long and short time scales.

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TT 80.57 Thu 15:00 Poster E

Application of the TraSPI Method to Aharonov-Bohm Interferometers with Interacting Quantum Dots. — •Alexander Hahn, Jürgen König, and Fred Hucht — Theoretische Physik, Universität Duisburg-Essen and CENIDE, 47048 Duisburg, Germany

Utilizing the "Transfer-matrix Summation of Path Integrals" (TraSPI) approach[1], we extend the method's application to the study of quantum transport in an Aharonov-Bohm interferometer accommodating two quantum dots. Here, the usage of the TraSPI method allows for the calculation of the current influenced by the enclosed magnetic flux and on-site Coulomb interactions. The numerical accuracy and efficiency of the TraSPI method allow for a detailed exploration of the interplay between quantum coherence and dot interactions.
[1] S. Mundinar, A. Hahn, J. König, and A. Hucht, Phys. Rev. B **106**, 165427 (2022)

TT 80.58 Thu 15:00 Poster E

Exploring magnetic pairing mechanisms in the t-J model on mixed-dimensional ladder systems using high-order series expansion — •Jakob Heidweiler, Patrick Adelhardt, Paul Fadler, and Kai Phillip Schmidt — Friedrich-Alexander-Universität Erlangen-Nürnberg

For many years, the t-J model has been suggested as the basis upon which to discuss high-T superconducting systems. Over the last decades the t-J model has become a paradigmatic model to understand the physics of high-T_c superconductors in a minimal setting. Nevertheless, pinpointing the exact pairing mechanism in these systems has not been accomplished. In recent works on mixed-dimensional t-J ladders [1,2] a magnetic pairing mechanism between holes on opposite legs of the ladder has been suggested. Here we extend these investigations by applying perturbative continuous unitary transformations (pCUTs) about the isolated rung limit in the thermodynamic limit. We investigate the effective low-energy Hamiltonian with special attention towards the properties of the emergent bound states.
[1] H. Lange et al. arXiv:2309.13040
[2] H. Lange et al. arXiv:2309.15843

TT 80.59 Thu 15:00 Poster E

Cooperative effects in dense cold atomic gases including magnetic dipole interaction — •Nico Bassler[1,2], Ishan Varma[3], Marvin Proske[3], Patrick Windpassinger[3], Kai Phillip Schmidt[1], and Claudiu Genes[2,1] — [1]Department of Physics, Friedrich-Alexander Universität Erlangen-Nürnberg (FAU), D-91058 Erlangen, Germany — [2]Max Planck Institute for the Science of Light, D-91058 Erlangen, Germany — [3]Institut für Physik, Johannes Gutenberg-Universität Mainz, 55122 Mainz, Germany

We theoretically investigate cooperative effects in cold atomic gases exhibiting both electric and magnetic dipole-dipole interactions, such as occurring for example in clouds of dysprosium atoms. We distinguish between the quantum degenerate case, where we take a many-body physics approach, and the quantum non-degenerate case, where we use the formalism of open system dynamics. For quantum non-degenerate gases, we illustrate the emergence of tailorable spin models in the high-excitation limit. In the low-excitation limit, we provide analytical and numerical results detailing the effect of magnetic interactions on the directionality of scattered light and characterize sub- and superradiant effects. For quantum degenerate gases, we study the interplay between sub- and superradiance effects and the fermionic or bosonic quantum statistics nature of the ensemble.