Q 38: Ultra-cold Plasmas and Rydberg Systems I (joint session A/Q)

Time: Wednesday 14:30–16:30 Location: F303

Q 38.1 Wed 14:30 F303

Topological phases of Rydberg spin excitations in a honeycomb lattice induced by density-dependent Peierls phases — •Simon Ohler[1], Maximilian Kiefer-Emmanouilidis[1,2], and Michael Fleischhauer[1] — [1]University of Kaiserslautern-Landau, D-67663 Kaiserslautern, Germany — [2]German Research Centre for Artificial Intelligence, D-67663 Kaiserslautern, Germany

We show that the nonlinear transport of bosonic excitations in a honeycomb lattice of spin-orbit coupled Rydberg atoms gives rise to disordered quantum phases which are topological and candidates for spin liquids. As demonstrated in [Lienhard *et al.* Phys. Rev. X, **10**, 021031 (2020)] the spin-orbit coupling breaks time-reversal and chiral symmetries and leads to a density-dependent complex hopping of the hard-core bosons or equivalently to complex XY spin interactions. Using exact diagonalization (ED) we investigate the phase diagram resulting from the competition between density-dependent and direct transport. In mean-field there is a transition from a quasi-condensate to a 120°-phase when the complex hopping exceeds the direct one. In the full model a new phase with a finite spin gap emerges close to the mean-field critical point due to quantum fluctuations induced by the density-dependence of the hopping. We show that this phase is a genuine disordered one. It has a large spin chirality and a many-body Chern number $C = 1$, which is robust to disorder. ED simulations of small lattices point to a non-degenerate ground state and thus to a bosonic integer-quantum Hall (BIQH) phase, protected by $U(1)$ symmetry.

Q 38.2 Wed 14:45 F303

Self-Organized Criticality and Griffith's Effects — •Daniel Brady and Michael Fleischhauer — University of Kaiserslautern - Landau, Kaiserslautern, Germany

Rydberg atoms interact strongly over very large distances leading to effects such as blockade and facilitation. Using Monte-Carlo simulations of an optically driven Rydberg many body gas in the facilitation regime, we analyse the effects of disorder on the facilitation dynamics of the system. In the absence of disorder, realised e.g. by the thermal motion of the atoms, the system exhibits a phase transition between an active and an absorbing phase. The presence of an additional slow decay results in self-organized criticality.

In the low temperature limit, dynamics in the gas are entirely determined on a local scale giving rise to a heterogeneous, disordered Griffiths phase. Here, the facilitation dynamics are constrained to clusters where inter-atom distances equal the facilitation distance. The structure of these clusters can be mapped to an Erdos-Renyi graph. We numerically investigate the dynamics and improve an existing Langevin equation to this regime.

Furthermore, since the network structure changes slower than the internal facilitation dynamics in this regime, spatial correlations appear between atoms. We investigate these utilizing a two atom toy model.

Q 38.3 Wed 15:00 F303

Deexcitation of Rydberg atoms in the neutrino mass experiment KATRIN using THz radiation* — •Shivani Ramachandran — Bergische Universität Wuppertal (BUW)

The key requirement for the KArlsruhe TRItium Neutrino experiment (KATRIN) in measuring the effective electron anti-neutrino mass with a sensitivity of 200 meV at 90% (C.L.)is, minimal background. In order to achieve that and eliminate some known contributors, several background suppression methods have already been implemented. Presently the most prominent contribution to the background in the measured signal is electrons produced by the thermal ionization of Rydberg atoms. They originate due to the sputtering of ^{210}Pb from inherent radioactivity from the walls of the KATRIN main spectrometer. A plausible method is using THz and microwave radiation (method developed by ASACUSA CERN) which can lead to a reduced lifetime of Rydberg atoms and allow for dedicated stimulated de-excitation. The influence of THz light source in the main spectrometer along with the state and spatial evolution of the Rydberg atoms is presented via simulations. Different species of atoms are sputtered which can lead to two-electron excited states, ultralong-range Rydberg atoms, etc, such possibilities are discussed. The influence of magnetic fields on the emission of ionization electrons is also investigated to understand the background model better.

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Q 38.4 Wed 15:15 F303

A linear response protocol to probe aging in a disordered Rydberg quantum spin system — •Moritz Hornung, Eduard Braun, Dillen Lee, Titus Franz, Sebastian Geier, Gerhard Zürn, and Matthias Weidemüller — Physikalisches Institut, Heidelberg University, Germany

In spite of many years of research, the question of whether or not the spin glass transition in disordered Heisenberg spin systems is a true phase transition is still open for debate. Of late, emerging platforms for quantum simulation greatly increase the accessibility of these systems and thus provide further insight into the topic. Already, anomalously slow dynamics that are characteristic for spin glasses have been observed on a platform consisting of Rydberg atoms, where the spin degree of freedom is encoded within highly excited electronic states.

To extend on these findings, we propose an experimental sequence based on slow ramps of the external field. This allows for the initialization of low energy states, which correspond to the low effective temperatures needed in order to observe a spin glass transition. We then introduce a small perturbation of the external field to measure the linear response depending on the speed of the initialization ramp. Finally, the platform is used to probe whether aging, rejuvenation and memory effects as observed in open spin glasses exist in a similar fashion for isolated quantum spin systems. The experimental results are complemented with numerical simulations based on exact diagonalization of a small system.

Q 38.5 Wed 15:30 F303

Analysing crosstalk with the digital twin of a Rydberg atom QPU — •Alice Pagano[1,2,3], Daniel Jaschke[1,2,3], Sebastian Weber[4], and Simone Montangero[1,2,3] — [1]Institute for Complex Quantum Systems, Ulm University — [2]Dipartimento di Fisica e Astronomia "G. Galilei" & Padua Quantum Technologies Research Center, Università degli Studi di Padova — [3]INFN, Sezione di Padova — [4]Institute for Theoretical Physics III and Center for Integrated Quantum Science and Technology, Stuttgart University

Decoherence and crosstalk are two adversaries when aiming to parallelize a quantum algorithm: on the one hand, the execution of gates in parallel reduces decoherence due to a shorter runtime, but on the other hand, parallel gates in close proximity are vulnerable to crosstalk. This challenge is visible in Rydberg atom quantum computers where atoms experience strong van der Waals interactions decaying with distance. We demonstrate how the preparation of a 64-qubit GHZ state is affected by crosstalk in the closed system with the help of a tensor network digital twin of a Rydberg atom QPU. Then, we compare the error from crosstalk to the decoherence effects proving the necessity to parallelize algorithms.

Q 38.6 Wed 15:45 F303

Probing the presence of phase transitions in disordered quantum spin systems — •Eduard Jürgen Braun, Moritz Hornung, Titus Franz, Dillen Lee, Sebastian Geier, Gerhard Zürn, and Matthias Weidemüller — Physikalisches Institut, Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg

Closed many-body quantum systems out of equilibrium can show interesting behaviour without classical counterpart, where many-body localization and discrete time crystals are among the most prominent examples. Some theories also predict a spin-glass to paramagnet quantum phase transition within a many-body localized phase. Inspired by these predictions, in this talk we are going to present our latest results to probe a possible quantum phase transition in a disordered spin system.

To experimentally study the existence of a phase transition we will use our quantum simulation platform based on a frozen Rydberg gas in order to probe nonequilibrium properties of Heisenberg XXZ spin models. By choice of an appropriate combination of Rydberg states, different symmetry classes, like the Heisenberg XX, XXZ and Ising models can be realized. For these interacting systems, we have found glassy dynamics and a non-thermalizing regime hinting towards the presence of a localized phase.

Q 38.7 Wed 16:00 F303

Spatially and temporally resolved wavepacket dynamics of an ion-Rydberg system by means of a high-resolution ion microscope — •Herrera-Sancho OA, Berngruber Moritz, Anasuri Viraatt SV, Conrad R, Yi-Quan Zou, Zuber Nicolas, Meinert Florian, Löw Robert, and Pfau Tilman — 5. Physikalisches Institut and Center for Integrated Quantum Science and Technology, Universität Stuttgart, 70569 Stuttgart, Germany

The superb control along with the manipulation of ultracold temperature species have permitted access to explore interactions in ensembles of neutral atoms. When these complex systems are excited to Rydberg states, and are very close, consequently induces a blockade effect. The latter has opened the door in order to address many questions and give rise to explore, for example, trimers with multiple correlated systems, ultracold ionic impurities, individual ion-atom collisions and to probe quantum macroscopicity. In this direction, we focus on the direct spatially and temporally resolved S-state wavepacket dynamics of an ion-Rydberg system using our advanced high-resolution ion microscope. By employing a single cold Rb+ ion which facilitates the excitation of a Rydberg atom over thirty micrometers distances, the experimental findings provide evidence to indicate the shape of the wavepacket dynamics in the polarization C4 potential of the ion-Rydberg interaction. These results are compared with the theoretical predictions where it is examined the effect of the adiabatic transition from the S-states with no bound states into the steep section corresponding to non-adiabatic of the high-l states.

Q 38.8 Wed 16:15 F303

Chiral Rydberg States of Laser Cooled Atoms — •Stefan Aull[1], Steffen Giesen[2], Peter Zahariev[1,3], Robert Berger[2], and Kilian Singer[1] — [1]Experimentalphysik 1, Universität Kassel, Heinrich-Plett-Str. 40, 34132 Kassel — [2]Fb. 15 - Chemie, Hans-Meerwein-Straße 4, 35032 Marburg — [3]Institute of Solid State Physics, Bulgarian Academy of Sciences, 72, Tzarigradsko Chaussee, 1784 Sofia, Bulgaria

We propose a protocol for the preparation of chiral Rydberg states. It has been shown theoretically that using a suitable superposition of hydrogen wavefunctions, it is possible to construct an electron density and probability current distribution that has chiral nature [1]. Following a well established procedure for circular Rydberg state generation and subsequent manipulation with taylored radio frequency pulses under the influence of electric and magnetic fields, the necessary superposition of hydrogen-like states with correspondingly adjusted phases can be prepared. Enantio-sensitive detection using photo-ionization with circularly polarized light is under theoretical and experimental development. The results are aimed to be used for chiral discrimination [2] of molecules.

[1] A. F. Ordonez and O. Smirnova, Propensity rules in photoelectron circular dichroism in chiral molecules. I. Chiral hydrogen, Phys. Rev. A, vol. 99, no. 4, p. 43416

[2] S. Y. Buhmann et al., Quantum sensing protocol for motionally chiral Rydberg atoms, New Journal of Physics, vol. 23, no. 8, Art. no. 8, Aug. 2021