Symposium Correlated Quantum Matter – From Cold Atoms to the Solid State (SYCQ)

Silke Bühler-Paschen
TU Wien
Wiedner Hauptstraße 8-10
1040 Wien, Austria
silke.buehler-paschen@tuwien.ac.at

Philipp Hauke
University of Trento
Via Sommarive 14
38123 Povo TN, Italy
philipp.hauke@unitn.it

Elke Scheer
University of Konstanz
Universitaetsstrasse 10
78464 Konstanz, Germany
elke.scheer@uni.kn

Correlated quantum matter displays some of the most intriguing phenomena - from strange metallicity and quantum spin liquid behavior to topological order - that escape our understanding. Massive or long-range entanglement might be a common characteristic of the underlying states but the verification is challenging, in particular in condensed matter systems. New approaches inspired by quantum information have the potential to boost progress. This symposium will bring together experts from the fields of ultracold atoms, mesoscopic systems, and quantum materials, to stimulate cross-talk between the communities, generate new ideas, and contribute to establishing a new field at the junction between correlated matter and quantum information.

Overview of Invited Talks and Sessions

(Lecture hall ZHG008)

Invited Talks

SYCQ 1.1	Tue	10:45–11:15	ZHG008	**New synthetic quantum systems with ultracold fermions in optical lattices** — •Leonardo Fallani
SYCQ 1.2	Tue	11:15–11:45	ZHG008	**Realization of Andreev-molecules** — •Szabolcs Csonka
SYCQ 1.3	Tue	11:45–12:15	ZHG008	**Giant transverse magnetic fluctuations at high fields in UTe_2** — •Kimberly Modic, Valeska Zambra, Amit Nathwani, Brad Ramshaw
SYCQ 1.4	Tue	12:15–12:45	ZHG008	**Emerging platforms to answer basic theoretical questions about correlated quantum matter** — •Joel Moore

Sessions

SYCQ 1.1–1.4	Tue	10:45–12:45	ZHG008	**Correlated Quantum Matter – From Cold Atoms to the Solid State**

SYCQ 1: Correlated Quantum Matter – From Cold Atoms to the Solid State

Time: Tuesday 10:45–12:45 Location: ZHG008

Invited Talk SYCQ 1.1 Tue 10:45 ZHG008
New synthetic quantum systems with ultracold fermions in optical lattices — •Leonardo Fallani — Università degli Studi di Firenze, Sesto Fiorentino, Italy

Ultracold atoms trapped in optical lattices provide a powerful technological platform for studying solid-state phenomena with ample tunability of the system parameters. In this quantum-simulation perspective, it is possible to control the atomic state to provide direct realizations of microscopic models and achieve "extreme" states of matter with no counterpart in conventional materials. I will discuss some recent developments in this field that are opened by the coherent manipulation of internal states in strongly interacting 173Yb fermions.

I will discuss the realization of multi-component SU(N) Fermi-Hubbard systems, where a coherent laser coupling between internal states can induce a controlled breaking of the global interaction symmetry and lead to a flavour-selective Mott localization, in connection with the physics arising in strongly correlated materials from the coupling of different orbitals.

I will also discuss recent experiments where we have measured Hall transport in interacting synthetic ladders, where the laser coupling implements the action of a strong external magnetic field on effectively charged particles. I will show a strong dependence of the Hall response upon changing atom-atom interactions and discuss the direct measurement of Hall voltages and resistances, which provide a direct connection between cold-atom quantum simulators and the measurement of electric-like quantities in solid-state systems.

Invited Talk SYCQ 1.2 Tue 11:15 ZHG008
Realization of Andreev-molecules — •Szabolcs Csonka — MTA-BME Superconducting Nanoelectronics Momentum Research Group, Department of Physics, Budapest University of Technology and Economics

Understanding the spectrum of individual atoms set the start of quantum mechanics 100 years ago and the learnt new concepts helped to understand more complex quantum systems like molecules, solids or superconductors. Present technologies allow us to realize artificial atoms and try to couple them one-by-one to create synthetic state-of-matters. In this talk I will present special molecules, so called Andreev-molecules, which are built up from artificial atoms coupled by superconductors. We will explain the basic properties of an artificial atom coupled to a superconductor; describe the role of crossed Andreev-reflection when more atoms are coupled. Finaly we will present experimental realization of two types of Andreev-molecule: the analog of H_2 and H_2O molecule. The polymerization of such superconducting molecules into a 1D chain is an exciting direction, which holds the promise to realize a topological superconducting system, the Kitaev-chain.

Invited Talk SYCQ 1.3 Tue 11:45 ZHG008
Giant transverse magnetic fluctuations at high fields in UTe_2 — •Kimberly Modic[1], Valeska Zambra[1], Amit Nathwani[1], and Brad Ramshaw[2] — [1]Institute of Science and Technology Austria, 3400 Klosterneuburg, Austria — [2]Cornell University, Ithaca, NY USA

Superconductors offer a rare glimpse into quantum mechanics at a macroscopic scale, making them powerful candidates for next-generation quantum technologies. While most superconducting qubits still rely on conventional materials like aluminum, a new class of unconventional superconductors-featuring exotic properties such as time-reversal symmetry breaking and nodal gaps-could enable new functionalities in quantum devices. Among these, UTe_2 stands out for its extraordinary behavior: it regains its superconducting state at ultra-high magnetic fields above 40 tesla, after initially being suppressed around 10 tesla–a phenomenon known as re-entrant superconductivity. One proposed explanation involves transverse fluctuations of a ferromagnetic order parameter. Yet, UTe_2 shows no clear signs of ferromagnetic order or strong fluctuations in standard magnetization measurements. To probe deeper, we developed a new technique to measure the transverse magnetic susceptibility in pulsed magnetic fields up to 60 tesla. In a manner reminiscent of the transverse field Ising model, large external magnetic fields applied along the b-axis lead to a huge increase in the transverse susceptibility–over 30 times greater than the longitudinal response. These findings suggest that the highly-unusual, magnetic field-enhanced superconductivity of UTe_2 is closely linked to this anisotropic magnetic response.

Invited Talk SYCQ 1.4 Tue 12:15 ZHG008
Emerging platforms to answer basic theoretical questions about correlated quantum matter — •Joel Moore — University of California, Berkeley — Lawrence Berkeley National Laboratory

New insights into correlated quantum materials have been achieved using a variety of experimental platforms and computational approaches that did not exist a few years ago. This talk begins with the example of the quantum Heisenberg chain and its unusual spin superdiffusion at high temperatures, which following initial theoretical predictions has now been observed in neutron scattering off crystals (2021), quantum emulators of ultracold atoms (2022), and gate-based superconducting quantum computers (2023-2024). One can ask more generally which problems in quantum materials are likely to be amenable to new approaches and which are likely to remain challenging at least in the near term. Using examples drawn from different materials classes, particularly spin systems and two-dimensional electronic materials, a guess at the possible sequence of progress in this area is presented.