Q 68: Quantum Gases: Bosons V

Time: Friday 14:30–16:15 Location: B305

Q 68.1 Fri 14:30 B305

Integrating physical intuition into neural networks for potential reconstruction in ultracold atoms — •Miriam Büttner and Axel U. J. Lode — Institute of Physics, Albert-Ludwig University of Freiburg, Hermann-Herder-Strasse 3, 79104 Freiburg, Germany

Ever since the rise of interest in Bose-Einstein Condesates (BECs), the research field of interacting ultracold indistinguishable particles has expanded, both in its experimental realizations as well as in its theoretical descriptions.In this work, we present a physically motivated neural network architecture for the extraction of quantum observables from single-shot measurements of ultracold atoms. The focus of the work is put on the inclusion of physical intuition into such a network architecture. Our proposed architecture utilizes extended pre-processing that exploits the stochastic nature of the measurement results, given that the so called single-shot images consist of samples of the N-body density. As we are extracting an external potential from samples of a density, our loss function takes inspiration from the constrained-search approach to density functional theory. We thus demonstrate, that in a way similar to inverse density functional methods, a Bose-Einstein condensate*s external potential can be reconstructed.

Q 68.2 Fri 14:45 B305

An unsupervised deep learning algorithm for single-site reconstruction in quantum gas microscopes with short-spaced optical lattices — •Alexander Impertro[1,2], Julian Wienand[1,2], Sophie Häfele[1,2], Hendrik von Raven[1,2], Scott Hubele[1,2], Till Klostermann[1,2], Cesar Cabrera[1,2], Immanuel Bloch[1,2], and Monika Aidelsburger[1] — [1]Department of Physics, LMU München, and MCQST, 80799 Munich — [2]Max-Planck-Institut für Quantenoptik, 85748 Garching

In quantum gas microscopy experiments, reconstructing the site-resolved lattice occupation with high fidelity is essential for the accurate extraction of physical observables. For short interatomic separations and limited signal-to-noise ratio, this task becomes exponentially more challenging. Previous methods use only limited a-priori knowledge about the system at hand and rapidly decline in performance as the lattice spacing is decreased below the imaging resolution. Here, we present a novel algorithm based on deep convolutional neural networks to reconstruct the site-resolved lattice occupation in a regime, where the lattice constant is half the imaging resolution, with high fidelity. The network can be directly trained with experimental fluorescence images in an unsupervised manner. It is able to capture density-dependent effects due to its inherent nonlinearity and allows a fast reconstruction of large images. Additionally, we demonstrate two methods to benchmark the experimental reconstruction fidelity with data from our cesium quantum gas microscope, where we find promising results across all fillings.

Q 68.3 Fri 15:00 B305

Spectroscopy of xenon-helium mixtures for Bose-Einstein condensation of vacuum-ultraviolet photons — •Thilo vom Hövel, Eric Boltersdorf, Frank Vewinger, and Martin Weitz — Institut für Angewandte Physik, Universität Bonn, Wegelerstr. 8, D-53115 Bonn

Bose-Einstein condensation of visible spectral range photons is currently investigated in our and other groups using liquid dye solutions as thermalization media for photon gases in optical microcavities. We here propose an experimental approach to apply these principles for the construction of a coherent light source in the VUV (100 - 200nm), a wavelength regime for which it is difficult to construct lasers due to the high pump power needed to achieve population inversion in active media.

As dye solutions are not suitable for VUV operation, an alternative thermalization medium needs to be found, allowing for contact to the thermal environment by repeated absorption and re-emission of photons. Our candidate are dense heteronuclear xenon-helium mixtures with absorption and emission features around 147nm wavelength, provided by quasi-molecular states formed from the atomic xenon's $5p^6$ and $5p^5 6s$ states, respectively. We here report on recent spectroscopic investigations of such samples at high pressure, with particular emphasis on the spectral overlap between absorption and emission profiles. Further, results on the validity of the thermodynamic Kennard-Stepanov relation are presented, whose fulfillment is a prerequisite for the proposed approach.

Q 68.4 Fri 15:15 B305

How creating one additional well can generate Bose–Einstein condensation — •Mihály Máté[1,5], Örs Legeza[1], Rolf Schilling[2], Mason Yousif[3], and Christian Schilling[3,4] — [1]Wigner Research Centre for Physics, Budapest, Hungary — [2]Institut für Physik, Johannes Gutenberg-Universität, Mainz, Germany — [3]Clarendon Laboratory, University of Oxford, Oxford, United Kingdom — [4]Department of Physics, Arnold Sommerfeld Center for Theoretical Physics, Ludwig-Maximilians-Universität, München, Germany — [5]Department of Mathematics, Technical University of Munich, Germany

We propose and study a model for N hard-core bosons which allows for the interpolation between one- and high-dimensional behavior by variation of just a single external control parameter s/t. It consists of a ring-lattice of d sites with a hopping rate t and an extra site at its center. Increasing the hopping rate s between the central site and the ring sites induces a transition from the regime with a quasi-condensed number N_0 of bosons proportional to $\sqrt{N}$ to complete condensation with $N_0 \simeq N$. In the limit $s/t \to 0, d \to \infty$ the low-lying excitations follow from an effective ring-Hamiltonian. An excitation gap makes the condensate robust against thermal fluctuations at low temperatures. These findings are supported and extended by large scale density matrix renormalization group computations. We show that ultracold bosonic atoms in a Mexican-hat-like potential represent an experimental realization allowing one to observe the transition from quasi to complete condensation by creating a well at the hat's center.

Q 68.5 Fri 15:30 B305

Wilsonian Renormalization in the Symmetry-Broken Polar Phase of a Spin-1 Bose Gas — •Niklas Rasch[1], Aleksandr N. Mikheev[1,2], and Thomas Gasenzer[1,2] — [1]Kirchhoff-Institut für Physik, Universität Heidelberg, Im Neuenheimer Feld 227, Germany — [2]Institut für Theoretische Physik, Universität Heidelberg, Philosophenweg 16, Germany

Wilsonian renormalization group theory is applied in a 1-loop perturbative expansion to the spin-1 Bose gas both in the thermal and in the symmetry-broken polar phase. For the latter, the symmetry is broken explicitly and flow equations including the renormalization of the condensate density are computed. A scheme is established for investigating the flow equations in a cut-off independent manner at fixed particle density. We observe the emergence of anomalous scaling in the chemical potential which relates to a flow towards the quasi-relativistic phononic regime. To restore convergent flow equations, we explicitly include wave-function renormalization of the first order time derivative and adapt the rescaling scheme. This yields convergent, cut-off independent predictions for all couplings. We are able to qualitatively describe the gas close to criticality, e.g. the shift of the critical temperature, and quantitatively predict low-temperature observables, e.g. condensate depletion.

Q 68.6 Fri 15:45 B305

Quantum walk of two composite bosons — •Pedro Weiler, Mama Kabir Njoya Mforifoum, Gabriel Dufour, and Andreas Buchleitner — Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg i.Br.

Many-body interference plays a key role in the dynamics of identical particles. In this contribution we discuss the quantum walk of two identical composite bosons on a 1D lattice. We consider composites made up of either two fermions or two bosons bound by contact interactions. Depending on the quantum statistics of the composite bosons' constituents, we observe different dynamical behaviours arising from an interplay of interaction and exchange processes.

Q 68.7 Fri 16:00 B305

Pairing of 2D electromagnetic bosons under spin-orbit coupling and transverse magnetic field — •Sergueï Andreev — Albert-Ludwigs-Universität Freiburg, D-79104 Freiburg

Exciton-polaritons in 2D semiconductors are electromagnetic bosons characterized by massive dispersion, polarization (spin) and pairwise interactions produced by the Coulomb forces between the constituent electrons and holes. Two bosons with opposite spins may form a bound state (biexciton). The bosons experience effective momentum-dependent magnetic fields due to the electron-hole exchange interaction and longitudinal-transverse splitting of the photon modes. These effective fields couple the spin-singlet biexciton to the continua in the triplet scattering channels. In this talk we shall discuss the ensuing phenomena for monolayer and bilayer semiconductors placed into an external transverse magnetic field (Faraday geometry). We predict biexcitonic halos possessing synthetic angular momenta $L_z = \pm 2\hbar$ [1] and dissociation of a biexciton Bose-Einstein condensate into a superfluid current of excitons upon increasing the density. We point out affinity of these phenomena to the polarized exciton superstripe emerging at zero transverse magnetic field in the equilibrium many-body phase diagram of dipolar excitons in bilayers at sufficiently large inter-layer distances, where the biexciton becomes weakly bound [2].

References:

[1] S. V. Andreev, Phys. Rev. B 106, 155157 (2022)
[2] S. V. Andreev, Phys. Rev. B 103, 184503 (2021)