A 5: Ultracold Matter II – Bosons (joint session Q/A)

Time: Monday 17:00–19:00 Location: P 2

A 5.1 Mon 17:00 P 2

In-situ cooling of bosonic Mott insulators via reservoir engineering — •Michele Miotto, Francesco Petiziol, and André Eckardt — Institut für Physik und Astronomie, Technische Universität Berlin

The preparation of pristine Mott insulator (MI) states of ultracold atoms in optical lattices is a crucial resource for a wide range of quantum simulation experiments. Although these systems offer remarkable controllability, small fractions of excitations inevitably emerge during lattice loading, which can significantly affect experimental quality. This limitation highlights the need for new in-situ cooling techniques to purify imperfect MIs. In this work, we theoretically propose and analyze a reservoir-engineering scheme aimed at mitigating such excitations. Specifically, we investigate whether a portion of a two-dimensional lattice can act as an engineered bath for a smaller subsystem hosting the MI. Focusing on a bosonic MI at unit density, confined to a one-dimensional strip and characterized by doublon-holon impurities, we use numerical simulations to test whether tuning the bath parameters can induce irreversible absorption of these excitations, thereby stabilizing the MI toward a uniform density profile.

A 5.2 Mon 17:15 P 2

Weakly interacting Bose gases in the canonical ensemble — •Jonata Santos[1], Axel Pelster[2], and Arnaldo Gammal[1] — [1]Universidade de São Paulo, Brazil — [2]University of Kaiserslautern-Landau, Germany

Based on the canonical description of a non-interacting Bose gas [1] we work out how both thermodynamic and statistical properties change perturbatively with respect to weak two-particle interactions. Up to first order we obtain a recursion formula for the canonical partition function, which consists of the same Feynman diagrams as the grand-canonical description [2] but with different Feynman rules. Resumming this recursion formula for the canonical partition function allows then to characterize the statistics of the ground-state occupancy by its respective cumulants. We demonstrate the applicability of this approach by analyzing a dilute Bose gas with contact interaction in a box trap. And we compare the results obtained by both periodic and Dirichlet boundary conditions in view of their relevance for current experiments with atomic gases, where the box trap is implemented, for instance, with digital mirror devices. [1] K. Glaum, H. Kleinert, and A. Pelster, Phys. Rev. A 06304 (2007). [2] A. Pelster and K. Glaum, Phys. Stat. Sol. B 237, 72 (2003).

A 5.3 Mon 17:30 P 2

Dipolar supersolids in toroidal traps — •Paul Uerlings[1], Fiona Hellstern[1], Kevin Ng[1], Michael Wischert[1], Tim Jerglotz[1], Koushik Mukerjee[2], Malte Schubert[2], Stephan Welte[1,3], Ralf Klemt[1], Stephanie Reimann[2], and Tilman Pfau[1,3] — [1]5. Physikalisches Institut and Center for Integrated Quantum Science and Technology IQST, Universität Stuttgart — [2]Division of Mathematical Physics and NanoLund, LTH, Lund University — [3]CZS Center QPhoton

Supersolids formed from a dipolar BEC exhibit a spontaneous, periodic density modulation while maintaining the frictionless flow of a superfluid. This unique behavior results from breaking both the global U(1) gauge symmetry and the continuous translational symmetry, leading to three types of collective excitations: the first- and second-sound branches, along with amplitude (Higgs) modes. In harmonic traps, these Higgs-like excitations hybridize with other modes, making them difficult to observe experimentally. In this study, we theoretically investigate the excitation spectrum of a dipolar quantum gas of Dysprosium atoms confined in a toroidal trap. Our results reveal decoupled sound and amplitude-like modes. This allows us to study the time evolution and dispersion of a localized Higgs-like quasiparticle excitation. The quadratic dispersion of this quasiparticle, together with the periodic density modulation, leads to (fractional) revivals, similar to those observed in the optical Talbot effect. We also present our experimental work towards observing these excitations in-situ.

A 5.4 Mon 17:45 P 2

Dynamic behaviour of density correlations across the chaotic phase for interacting bosons — •Óscar Dueñas Sánchez[1,2] and Alberto Rodríguez[1,2] — [1]Departamento de Física Fundamental, Universidad de Salamanca, E-37008 Salamanca, Spain — [2]Instituto Universitario de Física Fundamental y Matemáticas (IUFFyM), Universidad de Salamanca, E-37008 Salamanca, Spain

We study the dynamical manifestation of the chaotic phase in the time-dependent propagation of experimentally relevant two-particle correlations for one-dimensional interacting bosons. In particular, we show that the onset of chaos reshapes the correlation profiles, alters the propagation front and velocity, and modifies both the decay of the first correlation maximum and the long-time saturation values. These observables provide a detailed characterization of correlation transport beyond standard light-cone pictures. We further relate these findings to the emergence of a diffusive regime in the correlation propagation previously observed in Ref. [1], quantified through a suitably defined correlation transport distance.

[1] O. Dueñas, D. Peña and A. Rodríguez, Phys. Rev. Research 7, L012031 (2025)

A 5.5 Mon 18:00 P 2

How to seed ergodic dynamics of interacting bosons under conditions of many-body quantum chaos — Lukas Pausch[1,2], Edoardo G. Carnio[3,4], Andreas Buchleitner[3,4], and •Alberto Rodríguez[5,6] — [1]Institut de Physique Nucléaire, Atomique et de Spectroscopie, CESAM, Université de Liège, B-4000 Liège, Belgium — [2]Present address: German Aerospace Center, Institute of Quantum Technologies, D-89081 Ulm, Germany — [3]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Straße 3, D-79104 Freiburg, Germany — [4]EUCOR Centre for Quantum Science and Quantum Computing, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Straße 3, D-79104 Freiburg, Germany — [5]Departamento de Física Fundamental, Universidad de Salamanca, E-37008 Salamanca, Spain — [6]Instituto Universitario de Física Fundamental y Matemáticas (IUFFyM), Universidad de Salamanca, E-37008 Salamanca, Spain

We demonstrate how the initial state of ultracold atoms in an optical lattice controls the emergence of ergodic dynamics as the underlying spectral structure is tuned into the quantum chaotic regime. Distinct initial states' chaos threshold values in terms of tunneling as compared to interaction strength are identified, as well as dynamical signatures of the chaos transition, on the level of experimentally accessible observables and time scales [1].

[1] L. Pausch, E. G. Carnio, A. Buchleitner, A. Rodríguez, Rep. Prog. Phys. 88(5), 057602 (2025).

A 5.6 Mon 18:15 P 2

Vortex nucleation studied through spatially-resolved velocity fields — •Elinor Kath, Jelte Duchene, Hanyi Jang, Helmut Strobel, and Markus K. Oberthaler — Kirchhoff-Institut für Physik, Universität Heidelberg

We developed a method to measure spatially resolved superfluid velocity fields from a single experimental realisation. This technique grants direct access to dynamical properties that remain hidden in density images, like phase gradients, transport mechanisms, and turbulent flow patterns.

The nucleation of vortices is associated with a rise in incompressible kinetic energy, drawn from the kinetic energy's compressible, phononic part. By extracting velocity fields we obtain the full kinetic energy and separate its compressible (phononic) and incompressible (vortical) components. This allows us to study the conversion of compressible to incompressible energy during vortex nucleation.

We create a vortex gas by strongly distorting the condensate's phase and density. We track the appearance of vortices in time through density depletions, the curl of the velocity field, and the evolving energy balance, making a first step towards the study of how quantized vortices first form in quantum fluids, how turbulence initiates, how different excitations redistribute energy.

A 5.7 Mon 18:30 P 2

Observation of sine-Gordon solitons in a spinor Bose-Einstein condensate — Yannick Deller, Alexander Schmutz, Raphael Schäfer, •Alexander Flamm, Florian Schmitt, Ido Siovitz, Thomas Gasenzer, Helmut Strobel, and Markus Oberthaler — Kirchhoff-Institut für Physik, Universität Heidelberg, Heidelberg, Germany

Sine-Gordon solitons are a paradigmatic solution of the integrable sine-Gordon model. Utilizing a robust and reproducible local spinor phase imprinting scheme, we are able to produce sine-Gordon solitons in a quasi one-dimensional spin-1 BEC. We report on their time evolution while tuning their velocity by using the effective quadratic Zeeman shift, and therefore observe the characteristic collision behavior of the integrable sine-Gordon model. These results confirm that spinor BECs are a highly controllable experimental platform for studying the dynamics of the sine-Gordon model and its generalizations.

A 5.8 Mon 18:45 P 2

Single Realization Spatially Resolved Velocity Reconstruction for a 2D BEC — •Jelte Duchene, Elinor Kath, Hanyi Jang, Helmut Strobel, and Markus Oberthaler — Kirchhoff-Institut für Physik, Universität Heidelberg

We present a method to extract both the velocity field and density of a 2D Bose-Einstein condensate (BEC) from single realizations. The method is based on Bragg spectroscopy extended to two dimensions, where two pairs counter propagating laser pulses with frequencies ω and $\omega + \delta$ are incident on the atomic cloud and resonant with atoms according to their initial velocity. By imaging the scattered atoms after a short time of flight and modelling the Bragg beams as coupled two-level systems, we can reconstruct the spatially resolved velocity along the beam direction. A second pair of Bragg beams along a different axis allows us to extract the full 2D velocity field. Short Bragg pulses with a broad bandwidth address a broad band of velocities to enable the reconstruction of the full velocity field from a single realization of the BEC. We characterize the method by measuring the velocity profile of a single vortex and collective excitation of the system. This technique opens a path toward single-shot studies of 2D superfluid dynamics like the propagation of excitations, quantum turbulence, and vortex dynamics.