Q 43: Ultracold Matter (Bosons) III (joint session Q/A)

Time: Wednesday 14:30–16:30 Location: WP-HS

Q 43.1 Wed 14:30 WP-HS

Out of equilibrium superfluid density evolution of dipolar Bose-Einstein condensate in ramped up disorder — •Rodrigo P A Lima[1,2], Milan Radonjić[3,4], and Axel Pelster[5] — [1]Universidad de Castilla-La Mancha, Spain — [2]Universidade Federal de Alagoas, Brazil — [3]Universität Hamburg, Germany — [4]University of Belgrade, Serbia — [5]Rheinland-Pfälzische Technische Universität Kaiserslautern-Landau, Germany

We study the evolution of the superfluid density of an ultracold Bose gas in a ramped-up weak random potential. The bosons are assumed to interact not only through an isotropic short-range contact interaction [1], but also through an anisotropic long-range dipole-dipole interaction. We determine the disorder ensemble averaged components of the superfluid density parallel and perpendicular to the dipole direction. In particular, we discuss how their reversible and irreversible contributions depend on both the dipolar interaction strength and the ramp-up time.

[1] M. Radonjić and A. Pelster, SciPost Phys. **10**, 008 (2021).

Q 43.2 Wed 14:45 WP-HS

Coupled Higgs-Goldstone dynamics in the Bose-Hubbard model — •Thomas Hauschild[1], Ulli Pohl[1], Sayak Ray[1], and Johann Kroha[1,2] — [1]Physikalisches Institut, Universität Bonn, Nussallee 12, 53115 Bonn, Germany — [2]School of Physics and Astronomy, University of St. Andrews, North Haugh, St. Andrews KY16 9SS, United Kingdom

The realization of a Mott-superfluid transition in the Bose-Hubbard model using ultracold bosons in an optical lattice led to exploring many aspects of non-equilibrium physics over the past decade. These include collective excitations of the Bose-Einstein condensate near the Mott transition. We investigate the dynamics of these Higgs and Goldstone modes beyond the harmonic approximation using the field theory approach [1]. The coupling of the modes is analogous to the one in a Bosonic Josephson junction [2], and, thus, can possibly yield phase space dynamics like in a mathematical pendulum. In the long wavelength limit, we obtain the equations of motion for the coupled condensate amplitude and phase modes. In particular, we investigate the transition from a low-amplitude oscillation with spontaneously broken, localized phase to a running-phase mode.

[1] K. Sengupta, N. Dupuis, Phys. Rev. A, **71**, 033629 (2005).

[2] A. Smerzi, S. Fantoni, S. Giovanazzi, S. R. Shenoy, Phys. Rev. Lett, **79**, 4950 (1997).

Q 43.3 Wed 15:00 WP-HS

Chaotic phase of the tilted Bose-Hubbard model — Pilar Martín Clavero[1] 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 present an energy-resolved map of the many-body chaotic phase of the tilted Bose-Hubbard model at unit filling as a function of the tilt F, interaction strength U and tunneling energy J. Our results are based on the analysis of spectral statistics and of eigenvector structure via generalized fractal dimensions. While quantum chaos intuitively disappears for sufficiently large tilts, we demonstrate that a non-vanishing finite tilt can enlarge the extension of the ergodic region, as compared to the $F = 0$ case [1]. We furthermore characterize the chaotic regime in U-F space around the energy of the Fock state with homogeneous density, typically used in experimental studies.

[1] P. M. Clavero, “Chaotic Phase of the Bose-Hubbard Hamiltonian in an external static field”. BSc Thesis. Universidad de Salamanca (2024).

Q 43.4 Wed 15:15 WP-HS

Propagation of two-particle 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 by means of a conveniently defined two-particle correlation transport distance ℓ. Our results show that the chaotic phase induces the emergence of an effective diffusive regime in the asymptotic temporal growth of ℓ, characterized by an interaction dependent diffusion coefficient, which we estimate [1]. We investigate the origin of such behaviour by analysing the spatial and temporal evolution of two-particle correlations, where we see a clear correspondence between a general change in their profile and the emergence of the diffusive regime.

[1] O. Dueñas, D. Peña and A. Rodríguez, arXiv:2410.10571

Q 43.5 Wed 15:30 WP-HS

Suppression of Floquet Heating in a Driven Bose-Hubbard Chain via Bath-Engineering — •Lorenz Wanckel and André Eckardt — Technische Universität Berlin, Institut für Theoretische Physik, 10623 Berlin, Germany

Floquet engineering is a crucial control technique in ultracold quantum gas experiments, enabling the creation of effective Hamiltonians with properties that are otherwise difficult to achieve, such as topological nontrivial band structures. However, in isolated systems, these effective descriptions break down at long times due to Floquet heating and the stabilization by dissipation into a bath is generally an open question, as is the asymptotic state of driven dissipative systems. We investigate a driven Bose-Hubbard model and attempt to mitigate heating through weak dissipative coupling to a bath. We assess heating effects by analyzing the population of the ground state of the effective Hamiltonian in the asymptotic state, obtained from the Born-Markov master equation. Our analysis identifies two sources of heating and demonstrates how to choose parameters to effectively suppress heating.

Q 43.6 Wed 15:45 WP-HS

Anomalous non-thermal fixed point in a quasi-2d dipolar Bose gas — •Niklas Rasch[1], Wyatt Kirkby[1,2], Lauriane Chomaz[2], and Thomas Gasenzer[1,3] — [1]Kirchhoff-Institut für Physik, Universität Heidelberg, Im Neuenheimer Feld 227 — [2]Physikalisches Institut, Universität Heidelberg, Im Neuenheimer Feld 226 — [3]Institut für Theoretische Physik, Universität Heidelberg, Philosophenweg 16

This work focuses on anomalous non-thermal fixed-points (NTFP) in the temporal evolution of a 2d dipolar Bose gas, exhibiting slow, subdiffusive coarsening characterized by algebraic growth of a characteristic length scale $L(t) \sim t^{\beta}$ with $\beta \ll 1/2$. Sampling from various initial vortex configurations, we evolve the Bose gas using the semi-classical truncated-Wigner approach. For a highly dilute gas, anomalous scaling prevails, with an exponent $\beta \sim 1/5$, for various dipolar strengths and tilting angles. For late times or strong dissipation we observe the transition into diffusive scaling with $\beta = 1/2$. In the quantum regime, realised for typical experimental parameters, we also find anomalously slow scaling, albeit with more fluctuations than in the classical limit. Within a quasi-2d setting, we analyze the dependence of the scaling exponents on the anisotropic and long-range nature of the dipolar interaction. Further, we investigate the role of vortex (anti-)clustering and find both strong clustering as well as anti-clustering throughout the anomalous scaling regime. Our results support the universal nature of the anomalous NTFP and hint towards three-vortex collisions as the primary source for the subdiffusive coarsening.

Q 43.7 Wed 16:00 WP-HS

Conformal symmetry as a resource for improved parameter estimation in the nonlinear Schrödinger equation — David B. Reinhardt[1], Dean Lee[2], •Wolfgang P. Schleich[3,4], and Matthias Meister[1] — [1]German Aerospace Center (DLR), Institute of Quantum Technologies, Ulm, Germany — [2]Facility for Rare Isotope Beams and Department of Physics and Astronomy, Michigan State University, USA — [3]Institut für Quantenphysik and Center for Integrated Quantum Science and Technology (IQST), Universität Ulm, Germany — [4]Hagler Institute for Advanced Study at Texas A&M University, USA

The conformal symmetry of the non-linear Schrödinger equation (NLSE) unifies the stationary and time-dependent travelling-wave solutions of the one-dimensional cubic-quintic NLSE, the cubic NLSE and LSE. Any two systems that are classified by the same single number called the cross-ratio are related by this symmetry [1]. Here, we show that the symmetry serves as a powerful resource in parameter estimation from noisy empirical data, significantly enhancing results through the application of an optimization afterburner that exploits the conformal symmetry with random transformation coefficients. The conformal afterburner optimization finds the true global minimum more reliably compared with a standard fitting approach with randomized initial guesses. The new method demonstrates that group transformations can enhance the performance of search algorithm and therefore has far reaching practical applications for nonlinear physical systems. [1] Reinhardt et al., arXiv:2306.17720 (2023)

Q 43.8 Wed 16:15 WP-HS

Gapless Hartree-Fock-Bogoliubov Theory for Bose-Bose Droplets — •Alexander Wolf[1,2], Maxim Efremov[2], and Axel Pelster[3] — [1]Institute of Quantum Physics and Center for Integrated Quantum Science and Technology (IQ$^{\mathrm{ST}}$), Ulm University, Ulm, Germany — [2]German Aerospace Center (DLR), Institute of Quantum Technologies, Ulm, Germany — [3]Department of Physics and Research Center OPTIMAS, Rheinland-Pfälzische Technische Universität Kaiserslautern-Landau, Kaiserslautern, Germany

By generalizing the gapless Hartree-Fock-Bogoliubov theory for one component [1] to a Bose-Bose mixture, we develop a quantum droplet theory that unifies existing approaches. In addition to the condensate densities and depletions, both intra- and interspecies exchange as well as anomalous correlations are considered as variational parameters. The latter two require taking into account that two atoms in a Bose-Einstein condensate do not scatter in vacuum but inside a medium that dresses the collisions. We solve the resulting set of algebraic self-consistency equations at zero temperature for the special case of two identical components. Surprisingly, the equilibrium densities of the quantum droplets obtained with our approach perfectly agree with the results of quantum Monte-Carlo simulations [2] for all interspecies interactions with one minor discrepancy.

[1] N. P. Proukakis *et al.*, Phys. Rev. A **58**, 2435 (1998).
[2] V. Cikojević *et al.*, Phys. Rev. A **99**, 023618 (2019).