Q 3: Quantum Gases: Bosons I

Time: Monday 14:00–16:00 Location: E 001

Q 3.1 Mo 14:00 E 001

Matter Wave Turbulence: Beyond Kinetic Scaling — •Boris Nowak, Christian Scheppach, and Thomas Gasenzer — Institut für Theoretische Physik, Ruprecht-Karls-Universität Heidelberg, Philosophenweg 16, 69120 Heidelberg

Turbulent scaling phenomena in an ultracold Bose gas far away from thermal equilibrium are studied theoretically. These phenomena are characterized in terms of universal scaling of correlation functions like the momentum distribution of particles. It is shown that certain scaling exponents derived within the Kolmogorov-Zakharov theory of wave turbulence are not necessarily found in the full dynamical theory considered here. Despite this, our results indicate that the Kolmogorov picture remains useful even in the strong turbulence regime at long wavelengths. Power-laws with anomalously large exponents recently found for the momentum dependence of the density in the long-wavelength limit could be experimentally accessible in ultracold atomic gases. Possible avenues to study such dynamical critical phenomena in experiments with ultracold gases are explored.

Q 3.2 Mo 14:15 E 001

Anderson Localization of Solitons — Krzysztof Sacha[1,2], •Cord A. Müller[2,3], Dominique Delande[2], and Jakub Zakrzewski[1] — [1]Uniwersytet Jagielloński, Kraków, Poland — [2]Laboratoire Kastler-Brossel, Paris, France — [3]Physikalisches Institut, Universität Bayreuth, Germany

At low temperature, a quasi-one-dimensional ensemble of atoms with an attractive interaction forms a bright soliton. When exposed to a weak and smooth external potential, the shape of the soliton is hardly modified, but its center-of-mass motion is affected. We show that in a spatially correlated disordered potential, the quantum motion of a bright soliton displays Anderson localization. The localization length can be much larger than the soliton size and could be observed experimentally.

[1] K. Sacha et al., PRL 103, 210402 (2009)

Q 3.3 Mo 14:30 E 001

Quasi-relativistic physics with ultra-cold gases — Julius Ruseckas[1], Gediminas Juzeliunas[1], Michael Merkl[2], Frank Zimmer[2], Patrik Öhberg[2], Markus Lindberg[3], Andreas Jacob[4], and •Luis Santos[4] — [1]Institute of Theoretical Physics and Astronomy of Vilnius University, A. Gostauto 12, Vilnius 01108, Lithuania — [2]School of Engineering and Physical Sciences, Heriot-Watt University, Edinburgh EH14 4AS, United Kingdom — [3]Department of Physics, Abo Akademi University, Abo FIN-20500, Finland — [4]Institute of Theoretical Physics, Leibniz University of Hannover, Appelstr. 2 D-30169, Hannover, Germany

Although cold gases are typically neutral, artificial electromagnetism may be induced by rotation, hopping-engineering in lattices and particular laser arrangements (as recently realized at NIST). We focus on the latter, discussing how spin-orbit coupling (SOC) may be induced in cold atoms, leading to a Dirac point and quasi-relativistic physics, in spite of the extremely low velocities. After discussing some quasi-relativistic consequences (as atomic Veselago super-lensing), we comment on the nonlinear properties of spinor condensates with SOC, which under proper conditions are described by a nonlinear Dirac equation, which present self-localized solutions, resembling chiral confinement in high-energy physics. We analyze 1D self-confined condensates, which present an intriguing sinusoidal dependence with the interaction strength. In addition, we show that the interplay between SOC and non-linearity may allow for self-localized condensates in 2D and 3D, which are fundamentally unstable in standard condensates.

Q 3.4 Mo 14:45 E 001

Process-chain approach to the Bose-Hubbard model — •Niklas Teichmann, Dennis Hinrichs, and Martin Holthaus — Institut für Physik, Carl von Ossietzky Universität, D-26111 Oldenburg, Germany

We carry out a perturbative analysis, of high order in the tunneling parameter, of the ground state of the homogeneous Bose-Hubbard model in the Mott insulator state[1]. This is done within a diagrammatic process-chain approach, derived from Kato's representation of the many-body perturbation series, which can be implemented numerically in a straightforward manner. We compute ground-state energies, atom-atom correlation functions, density-density correlations, and occupation number fluctuations, for one-, two-, and three-dimensional lattices with arbitrary integer filling. In addition, the process-chain approach is employed for calculating the boundary between the Mott insulator phase and the superfluid phase with very high accuracy. We find a surprising scaling relation, that maps critical hopping parameters for different filling factors onto each other [2].

[1] N. Teichmann, D. Hinrichs, M. Holthaus and A. Eckardt, Phys. Rev. B **79**, 224515 (2009).
[2] N. Teichmann and D. Hinrichs, EPJ B **71**, 219 (2009).

Q 3.5 Mo 15:00 E 001

Emergence of Levy distribution in many-body quantum systems — •Alexey V. Ponomarev, Sergey Denisov, and Peter Hanggi — Institute of Physics, University of Ausgburg, Germany

Levy distribution is known to describe a whole range of complex phenomena: classical chaotic transport, processes of subrecoil laser cooling, fluctuations of stock market indices, time series of single molecule blinking events, bursting activity of small neuronal networks, to name a few. The appearance of Levy distribution in a system output is a strong indicator of a long-range correlation "skeleton" which conducts system intrinsic dynamics.

Using two complimentary approaches, the canonical and the grand-canonical formalisms, we discovered that the momentum distribution of N strongly interacting (hard-core) bosons at finite temperatures confined on a one-dimensional optical lattice obeys the Levy distribution. The tunable Levy spline reproduces momentum distributions up to one recoil momentum. Our finding allows for calibration of complex quantum many-body states by using a unique scaling exponent.

[1] A. V. Ponomarev, S. Denisov and P. Hanggi, arXiv:0907.4328.

Q 3.6 Mo 15:15 E 001

Quantum Kinetic Theory of Superfluid Internal Convection — •Lukas Gilz and James R. Anglin — TU Kaiserslautern, Kaiserslautern, Germany

When a superfluid is heated locally one observes a superfluid current from colder to hotter regions, while the normal fluid flow is directed in the opposite direction. This 'internal convection' is modeled well by Landau's phenomenological two fluid model. We obtain a more fundamental description of internal convection by extending standard Quantum Kinetic Theory to include two reservoirs of different temperatures. We find that internal convection is caused by non-resonant scattering events that do not conserve momentum.

Q 3.7 Mo 15:30 E 001

Local and non-local relaxation of a 1D Bose gas with finite interactions — •Dominik Muth, Bernd Schmidt, and Michael Fleischhauer — Fachbereich Physik und Forschugszentrum OPTIMAS, Technische Universität Kaiserslautern

Simulating the dynamics of interacting quantum many-body systems is one of the computationally hardest problems in physics. One of the open questions is, whether integrable models, which have an infinite number of conserved quantities, relax (say, after a quench in the interaction strength) to a state that can be locally fully described by a grand canonical ensemble, defined only by temperature and chemical potential, or whether other quantities have to be taken into account in the Gibbs state. We investigate this question in the case of a 1D Bose gas with repulsive delta-type interactions, as found in recent experiments using ultra-cold gases. Dynamical simulations (employing a matrix-product-states description) of a quench yields both local and non-local correlations. They indicate, that indeed the stationary state for local quantities is identical to the grand canonical one. The same method is applied to the regime of strong attractive interactions. Here experiments have shown, that the system, instead of collapsing into the ground state, remains in a highly excited, metastable state. The properties and process of the formation of this so called super Tonks-Girardeau gas will be explored.

Q 3.8 Mo 15:45 E 001

Finding stationary states of the Gross-Pitaevskii equation: A numerical approach — •Parimah Kazemi — Universität Ulm, Institut für Quantenphysik, D-89069 Ulm, DE

The Gross-Pitaevskii equation is the starting point for studying many systems of Bose-Einstein condensates and superfluidity. In this work, we present a new method for the direct minimization of the Gross-Pitaevskii (GP) energy with or without rotation. The minimizers of the Gross-Pitaevskii energy correspond to stationary states. Our minimization is based on a gradient descent method using a new approach to enforce the normalization constraint. The new method is implemented in both finite difference and finite element in two and three dimensional settings and used to compute various complex configurations including those with vortices of rotating Bose-Einstein condensates. The new gradient method shows better numerical performances compared to classical gradient methods, especially when high rotation rates and complex trapping potential are considered