Junior Meeting 2026

Titles and Abstracts

Talks

Cristina Caraci: Euclidean Quantum Field Theory as Limit of Interacting Inhomogeneous Bose Gases

Abstract: Euclidean (quantum) field theories have been extensively studied in the mathematical literature since the sixties, motivated by high-energy physics and statistical mechanics. Formally, they can be described by Gibbs measures associated with Euclidean action functionals over spaces of distributions. In the latest years it has been shown how such theories emerge as high-density limit of interacting Bose gases at positive temperature, giving a rigorous derivation from a realistic microscopic model of statistical mechanics. In this talk, I will present a result providing the derivation of such a field theory, in other words of the invariant Gibbs measure, with a quartic local interaction in two dimensions as a limit of an inhomogeneous interacting Bose gas.

Luca Damian: Random Phase Approximation in Quantum Many-Body Systems

Abstract: The Random Phase Approximation (RPA) is a widely used method to describe collective excitations and correlations in interacting fermionic quantum many-body systems. In this talk, I will introduce the basic ideas behind the RPA and discuss its connection to Bogoliubov theory. We will also briefly discuss the problem of the fermionic polaron, and how to use RPA to tackle it.

Daniele Ferretti: Zero-Range Interactions for Three-Dimensional Bosons – A Class of Model Hamiltonians

Abstract: We recall the known results for the construction of zero-range Hamiltonians, with particular focus on the three-dimensional bosonic case. As a matter of fact, the definition of pairwise point interactions for bosons leads to Hamiltonians that are unbounded from below in three dimensions. This lack of energetic stability is known in the physics literature as the Thomas effect and must be understood as a no-go theorem: in three dimensions, bosons can interact via zero-range forces only by means of many-body interactions.

The highly non-trivial question is how to identify the models that are more closely related to physical systems. In recent years, some developments have occurred in this direction.

We shall discuss how to construct a particular class of zero-range Hamiltonians describing Bose gases in three dimensions, and we present such a class in the language of Dirichlet forms, first introduced as a point-interaction-generating theory by Albeverio et al. in 1977.

Yoann Le Hénaff: Numerical Bogoliubov approximation for bosonic many-body quantum systems

Abstract: We discuss an algorithm for the numerical solution of the time-dependent Schrödinger equation for $N \gg 1$ bosons interacting via a two-body interaction potential in the mean-field scaling regime. Unlike existing numerical algorithms for quantum dynamics, the proposed algorithm has a computational complexity that is independent of the number N of particles. It is based on an ansatz for the wave function inspired by the Bogoliubov theory, which is an asymptotic theory for large N.

Hailun Lu: Lieb–Robinson Ideas and Quantitative Mean-Field Approximation for Bose Gases

Abstract: The microscopic Schrödinger dynamics of an N-boson system becomes increasingly difficult to analyze directly as the number of particles grows, motivating the search for effective one-body descriptions. In this talk, I discuss a route from many-body dynamics to effective nonlinear equations based on controlling the growth of correlations. I first recall the idea behind Lieb–Robinson bounds and explain how an analogous correlation estimate for observables acting on disjoint particle sets can be combined with the BBGKY hierarchy to obtain quantitative convergence of reduced density matrices for bounded interactions. I then turn to delta-type interactions, where the interaction becomes singular, and explain how truncation of the potential, regularization of the initial data, and error control allow one to extend the argument beyond the bounded case under additional assumptions. The focus is on the main proof strategy and on what correlation growth reveals about the accuracy of effective dynamics for Bose gases.

Lukas Reichmann: Dynamics of Two-Dimensional Bose Gases in the Focusing Case

Abstract: Consider the dynamics of a two-dimensional Bose gas with interactions of the form $N^{2\beta-1}w(N^{\beta}\cdot)$ for $0 < \beta < \infty$ or $N^{-1}e^{2N^{\kappa}}w(e^{N^{\kappa}}\cdot)$ for $0 < \kappa < 1/4$. The interaction may have a small attractive part. I will talk about how to prove a norm approximation for the dynamics according to Bogoliubov's prediction if the initial data is localised.

Kai Schmidt-Brauns: Do Locality Principles Survive Long-Range Interactions? Ground State Stability in Quantum Spin Systems

Abstract: Quantum Spin Systems (QSS) with long-range interactions provide a natural framework for modelling experimentally relevant quantum platforms (e.g. trapped ions). In quantum information processing, it is essential to control error propagation and the stability of measurement tasks, which are both related to the concept of a computational task's well-posedness. Known stability results primarily address Gibbs states or short-range systems, in which stability can be derived from a deeper locality principle. This principle relates three distinct notions of locality, namely Local Perturbations Perturb Locally, Local Indistinguishability, and Decay of Correlations. In contrast, these locality relations and their implications for stability remain poorly understood for ground states of long-range systems.

In this talk, I will introduce these foundational notions and the established techniques for short-range stability. I will then present to what extent these locality relations may be extended to the long-range, ground state regime, including partial implications and a refined stability result.

Elias Theil: Unitary-equivariant and permutation-invariant quantum channels

Abstract: The two classical algorithms of majority vote and copying information are mainstay tools in modern information processing, and they share two important symmetries. First, they are invariant under permuting the inputs or outputs, and second, any relabelling of the input is equivalent to a corresponding relabelling of the output.

In this talk, I will present the quantum analogue of permutation-invariant and unitary-equivariant quantum channels, which contain the quantum versions of majority vote and copying, that is purity amplification and approximate cloning. I will give a mathematical description of these channels that helps solve optimization problems with the corresponding permutation and unitary symmetries. Finally, I will explain how the aforementioned channels fit into the larger concept of spectrum transformations, where we want to change the spectrum of some input state into a different spectrum while keeping the eigenbasis.

Yaojun Wang: Relative compactness of the maximizing sequences for the k-plane transform

Abstract: In this talk, we will talk about the quasiextremizers for the k-plane transform in $\mathbb{R}^d$, which is also called the Radon transform when $k = d - 1$, and the X-ray transform when $k = 1$. In particular, we will show that every indicator quasiextremizer can be suitably approximated by 1_B, where B is an ellipsoid. Using this, we prove that every maximizing sequence for the k-plane transform is relatively compact, which is only known for $k = d - 1$ before.

Pitch Talks

Lukas Junge: Bose-Einstein condensation: An invitation

Abstract: Bose–Einstein condensation is a remarkable quantum phenomenon in which a macroscopic number of bosons occupy the same one-particle state. In this pitch talk, I will introduce the basic idea of Bose–Einstein condensation and explain how it emerges from the quantum statistics of indistinguishable particles. I will discuss how condensation can be characterized mathematically and briefly outline some of the challenges involved in establishing it rigorously for interacting Bose gases.

Jakob Oldenburg: Time-dependent density functional theory: an introduction to its mathematical foundations

Abstract: Assume you want to calculate some property of a large molecule. In principle, it is clear what you should do: solve the corresponding Schrödinger equation. However, if there are more than a few electrons, approaching this problem by discretizing the wave function is not feasible due to the exponential growth of the computational cost with the number of electrons N. Hence, other methods are necessary. A particularly successful one in applications both in chemistry and in physics is density functional theory (DFT) in which one describes the system via the density of electrons, which avoids the curse of dimensionality as it is a function of 3 rather than $3N$ coordinates. The price to pay for that is that all quantities now have to be expressed in terms of the density; it is not immediately clear when this is even possible and in practice it requires careful approximations.

In this session, we introduce the mathematical foundations of (time-dependent) DFT. We discuss how the intractable interacting problem is replaced by a non-interacting so called Kohn–Sham system with the same density. A key question here is why the density determines the system. This relies on a 1-1 correspondence between external potentials and densities. We conclude by sketching a recent result obtained together with Asbjørn Bækgaard Lauritsen and Mathieu Lewin establishing this correspondence in the time-dependent case under suitable assumptions.

Louis Paletta: Unconditional Quantum Advantage with Noisy Planar Architectures

Abstract: We consider quantum devices restricted to local operations in 2D and subject to local stochastic noise below a constant threshold. We show that such circuits are computationally more powerful than AC^0-circuits, i.e., noise-free, geometrically-unconstrained constant-depth classical circuits with unbounded fan-in AND, OR and NOT gates.

To this end, we exhibit a computational problem with the following properties: (i) Any instance of the problem is correctly solved with high probability by a certain geometrically 2D-local quantum circuit even if the latter is imperfectly implemented, but (ii) any polynomial-size AC^0-circuit fails to solve certain instances of the problem with constant probability.

To our knowledge, this is the first complexity-theoretic separation which applies to planar quantum devices, incorporates noise-resilience and is unconditional, i.e., does not rely on complexity-theoretic assumptions. This brings the experimental demonstration of an unconditional quantum advantage closer to experimental realities.

Dominik Sulz: From Image Compression to Quantum Dynamics – An Introduction to Tensor Networks

Abstract: Take a photo, throw away most of the information it contains, and you can still recognise it. Image compression works because real images are far simpler than the huge space of all possible pixel arrangements. Quantum many-body systems face the same problem on a much larger scale. Storing the state of just 40 interacting spins already takes around 18 terabytes, and every additional spin doubles that. This "curse of dimensionality" makes solving the time-dependent Schrödinger equation one of the hardest tasks in scientific computing. Yet the states nature actually produces are, much like real images, far simpler than the space they live in.

Tensor networks turn this observation into a method. In this session, we start with compressing a picture and step by step arrive at simulating quantum dynamics, using mainly pictures over formulas. Along the way, we'll see why these methods work so well and where they reach their limits.