

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.

Yoann Le Henaff: 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 .

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.

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.

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.

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.

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.

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.

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.