# Book of Abstracts

Recent Advances in Many-Particle Systems

February 9–11, 2026 • University of Pisa

# Abstracts

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## 1: TBA

*Riccardo Adami*
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## 2: Exchange Interactions and Cuprate Superconductivity

*Jean-Bernard Bru*
Basque Center for Applied Mathematics and UPV/EHU Bilbao

In this talk, we will explain the effect of quantum interactions exchanging different types of particles. We will consider a system made of two fermions and one boson, in order to study the effect of such an off-diagonal interaction term. We will in particular show the existence of exponentially localized dressed bound fermion pairs. We will give particular attention to the regime of very large on-site (Hubbard) repulsions, because this situation is relevant for cuprate superconductors. Indeed, in the meantime, we will explain the high- temperature superconductivity of cuprates and apply our model to such physical systems.

## 3: On the point spectrum of Dirac Hamiltonians via new relativistic viral identities.

*Lucrezia Cossetti*

UPV/EHU Bilbao

Originally developed to understand characterising properties related to dispersive phenomena, in the last decades viral-type identities obtained through the so-called method of multipliers have been recognized as a powerful tool in Spectral Theory, in particular in connection with proofs of absence of point spectrum for a wide class of operators. When the method of multiplier

applied to the toy model given by the self-adjoint Schrödinger operator

$$H = -\Delta + V,$$

one obtains the non-relativistic viral identity

$$2\langle \psi, -\Delta \psi \rangle = \langle \psi, x \cdot \nabla V \psi \rangle,$$

Valid for any $\psi$ solution of the eigenvalue problem $H\psi = \lambda\psi$, with $\lambda \in R$.

This identity immediately yields sufficient conditions for the absence of such solutions: the most natural one being the repulsivity condition

$$x \cdot \nabla V \leq 0.$$

In the context of Dirac operators $H = H_D + V$, with $H_D = -I\alpha \cdot \nabla + m\beta$, the corresponding relativistic analogue of the viral identity reads

$$2\langle \psi, -I\alpha \cdot \nabla \psi \rangle = \langle \psi, x \cdot \nabla V \psi \rangle.$$

Unlike in the Schrödinger case, the term involving the kinetic part is no longer positive, and this lack of positivity prevents a direct derivation of conditions excluding the existence of eigenvalues.

In this seminar, we will show how to overcome this difficulty in two different ways. The first approach exploits the supersymmetric structure of the Dirac operator, reducing the analysis to a more involved Schrödinger-type operator. The second approach consists in introducing new virial identities based on a completely new development of the method of multipliers. These two strategies mirror to two recent works: the first in collaboration with N. Arrizabalaga and M. Morales, and the second, still in preparation, with L. Fanelli and F. Pizzichillo.

## 4: Effective dynamics of weakly interacting bosons at high density

*Daniele Ferretti*

GSSI - Gran Sasso Science Institute

We discuss the time evolution of weakly interacting Bose gases on a three-dimensional torus of arbitrary volume. The coupling constant is chosen to be the inverse of the density of the system, which is considered to be large (and independent of the particle number). We focus on a class of initial states endowed with a coherent structure exhibiting quasi-complete Bose-Einstein condensation. For each fixed time in a finite interval, we prove the convergence of the one-particle reduced density matrix towards the projection onto the normalized order parameter describing the condensate – evolving according to the Hartree equation – in the iterated limit where the volume (and therefore the particle number), and subsequently the density go to infinity.

## 5: Small-mass data scattering for mass-subcritical NLS with combined non-linearities

*Luigi Forcella*

University of Pisa

We consider the NLS equation with combined power-type nonlinearities in the mass-subcritical regime, where a focusing leading term is perturbed by a lower order defocusing term, and we prove small data scattering. The proof relies on the pseudo-conformal transformation in conjunction with a general variational argument used to obtain the positivity of certain modified energies. The smallness assumption is only on the mass of the initial datum, and not on the whole $\Sigma$-norm. This is a joint work with J. Bellazzini and V. Georgiev.

## 6: Random purification channel and random Stinespring superchannel

*Filippo Girardi*

Scuola Normale Superiore

The recently introduced random purification channel, which converts $n$ copies of an arbitrary mixed quantum state into $n$ copies of the same uniformly random purification, has emerged as a powerful tool in quantum information theory. We give a remarkably simple construction of this channel, making its known properties — and several new ones — immediately transparent. We also introduce a channel-level analogue, which we call the random Stinespring superchannel. This consists in a procedure to transform $n$ parallel queries of an arbitrary quantum channel into $n$ parallel queries of the same uniformly random Stinespring isometry, via universal encoding and decoding operations that are efficiently implementable. Throughout the presentation, we are going to discuss some surprising applications in quantum learning theory and quantum Shannon theory.

## 7: $\Phi_2^4$ Theory limit of a many-body bosonic free energy

*Lucas Jougla*

Constructor University Bremen

We consider the quantum Gibbs state of an interacting Bose gas on the 2D torus. We set temperature, chemical potential and coupling constant in a regime where classical field theory gives leading order asymptotics. In the same limit, the repulsive interaction potential is set to be short-range: it converges to a Dirac delta function with a rate depending polynomially on the other scaling parameters. In this setting, the free-energy of the interacting Bose gas (counted relatively to the non-interacting one) converges to the free energy of the $\Phi_2^4$ non-linear Schrödinger-Gibbs measure, thereby revisiting recent results and streamlining proofs thereof. The approach combines the variational method of Lewin-Nam-Rougerie to connect, with controled error, the quantum free energy to a classical Hartree-Gibbs one with smeared non-linearity. The convergence of the latter to the $\Phi_2^4$ free energy then follows from arguments of Fröhlich-Knowles-Schlein-Sohinger. This derivation parallels recent results of Nam-Zhu-Zhu.

This talk is based on a joint work with Nicolas Rougerie.

## 8: Modified scattering dynamics in the Vlasov-Poisson equation near an attractive point mass

*Bernhard Kepka*

University of Zurich

The long-time behaviour of solutions to the Vlasov-Poisson equation has been a topic of interest for many years. A particular situation which has been studied recently concerns solutions with a repulsive point charge. In this work, we consider the corresponding case of an attractive point mass. We study perturbations of the point mass with radial symmetry, i.e. a gas of particles, for instance, stars in a galaxy, surrounding a central mass. Our study is based on action-angle variables in order to simplify the linearised dynamics which is given by the standard Kepler problem. Assuming that the initial distribution of the gas is localised on hyperbolic trajectories according to the linearised dynamics, we prove that the long-time behaviour is given by a modified scattering dynamics.

This is joint work with Klaus Widmayer.

## 9: Recent results on Bose–Einstein condensation in random environments

*Joachim Kerner*

University of Hagen

In this talk we discuss recent developments and results regarding Bose–Einstein con- densation (BEC) in random environments. For the most part, we are concerned with a random system

originally considered by Kac and Luttinger in 1973. Due to the complexity of the underlying random one-particle model, the nature of the BEC in the non-interacting Kac-Luttinger model was understood only recently. In this talk, our goal will be to un- derstand the impact of repulsive two-particle interactions on condensation. This talk is based on joint work with C. Boccato (Pisa), M. Pechmann (Tennessee), and W. Spitzer (Hagen).

## 10: A mathematical analysis of Dynamical Mean-Field Theory

*Alfred Kirsch*

Technische Universität München

Dynamical Mean-Field Theory (DMFT) is a post Hartree-Fock method designed for strongly correlated fermionic systems such as lattice quantum systems. From the perspective of statistical physics, it can be seen as a quantum analog of the mean-field approach to Ising models. Despite its widespread use in condensed matter physics, very little is known about the mathematical properties of this approximation. In this talk, I will present the first proof of the existence of solution(s) to the DMFT equations, within the simple setting of the single-site, translation-invariant, paramagnetic IPT solver applied to the Fermi-Hubbard model. The main ingredient of our proof is based on a reformulation of the DMFT equations in the space of probability measures, the latter being possible after a mathematically rigorous definition of the quantities of interest (Green's function, self-energy and hybridization function).

## 11: Non-perturbative Renormalization Group and Euclidean formalism

*Vieri Mastropietro*

University of Rome La Sapienza

Quantum field theory and statistical mechanics allow predictions in spectacular agreement with experiments, but they are often based on perturbative methods. The Renormalization Group and the Euclidean formalism provide a non-perturbative and rigorous formulation using a probabilistic approach. I will describe some recent results on the anomalous gyromagnetic moment of the electron, the non-renormalization of anomalies and transport coefficients, and the universality of critical indices, in which physical quantities are expressed in terms of convergent series.

## 12: Fermions in a magnetic fields: derivation of Hartree-Fock dynamics and semiclassical commutators

*Ngoc Nhi Nguyen*

University of Lille

In this talk, we will discuss some recent results on the effective dynamical properties for inter-

acting fermionic systems in a magnetic field, in the mean-field regime. This is a joint work with Niels Benedikter (Milan), Chiara Boccato (Pise) and Domenico Monaco (Rome).

## 13: Vortex Dynamics in binary mixtures of Bose-Einstein Condensates

*Enrico Ortu*

Turin Polytechnic

Collective excitations in interacting many-body systems often display an effective particle-like behavior, whose dynamics is influenced by nonlinear interaction effects and the role of boundaries. This is the case, for example, of quantum vortices, topological excitations that arise in superfluid mediums of bosonic and fermionic nature which surprisingly behave as particles or dipoles in the low-temperature limit. In this contribution, we investigate the scattering dynamics of massive vortex dipoles emerging in binary mixtures of Bose–Einstein condensates, highlighting the role of the confining geometry.

We show that the interaction of a vortex dipole with an obstacle gives rise to two distinct scattering regimes, a "fly-by" and a "go-around" process, whose transition can be explained and predicted in terms of the deflection angle as a function of the impact parameter. This is performed via an analytical approach based on the point-like model in the plane geometry. Furthermore, we show the emergence of an on-average massless dynamics whenever the nonlinear interactions with the obstacle become negligible, allowing to restore full integrability within these asymptotic regimes.

Finally, we benchmark the effective point-like description against numerical simulations of two coupled Gross–Pitaevskii equations, demonstrating quantitative agreement and clarifying the domain of validity of the reduced model. Our results provide insight into the emergence of effective particle dynamics in strongly nonlinear many-body systems and into the role of confinement and interactions in vortex scattering processes.

## 14: Subcriticality at High Temperatures in Lattice System

*Lorenzo Pettinari*

University of Trento

Lattice spin systems describe quantum particles whose positions are confined to the vertices of a graph, so that only their internal degrees of freedom contribute to the dynamics. In this talk, I will present new sufficient conditions for identifying a high-temperature regime in which the system exhibits subcritical behaviour. These conditions are formulated in terms of the uniqueness of Kubo–Martin–Schwinger (KMS) states and rely on a non-commutative analogue of the Kirkwood–Salzburg equations, combined with a novel decomposition of local observables. In contrast to standard approaches, our results are uniform in the single-site Hilbert space dimension and require only a bound on the inverse critical temperature that depends on the

natural $C^0$-norm of the interaction potentials. I will also discuss the strengths and limitations of this method, as well as potential extensions to systems with infinite-dimensional single-site Hilbert spaces. (Joint work with N. Drago and C. F. J. van de Ven. Based on arXiv:2511.12651 and Commun. Math. Phys. 406, 163 (2025).)

## 15: Random Euclidean Matching for Exponentially Decaying densities

*Francesca Pieroni*

University of Rome La Sapienza

The Random Matching problem is the problem of finding the best matching between two n-tuples of independent random variables identically distributed on $R^d$, where the term "best" refers to a cost function provided by the euclidean distance. In this talk we introduce the problem, we focus on the recent developments on the topic and then on the case of points distributed in $R^d$ according to a probability distribution with an exponentially decaying tail.

## 16: $\mathbb{Z}^2$ lattice gauge theory coupled to fermionic matter

*Marcello Porta*

Sissa Trieste

I will discuss a model for fermions on a two-dimensional square lattice, minimally coupled to a $\mathbb{Z}^2$-valued dynamical gauge field, living on the bonds of the lattice. As observed numerically, this system displays a rich phase diagram, depending on the model parameters. In particular, at half-filling, the model at low temperature exhibits a semimetallic phase, in which the low-energy charge excitations are effectively described by 2+1 dimensional massless Dirac fermions. I will discuss the rigorous proof of this fact, building on Lieb's seminal work about the solution of the $\pi$-flux phase conjecture. In presence of a staggered mass term, the ground state of the gauge theory turns out to be four-fold degenerate, and separated by the rest of the spectrum by a gap. In particular, it supports anyonic excitations, equivalent to the ones of the toric code. The proofs are based on reflection positivity, chessboard estimates, fermionic cluster expansion and Hastings' quasi-adiabatic flow. Based on collaborations with Sven Bachmann (UBC Vancouver) and Leonardo Goller (SISSA).

## 17: Long-time validity of Bogoliubov theory

*Simone Rademacher*

University of Munich

We consider the Bogoliubov approximation for the many-body quantum dynamics of weakly interacting Bose gases and establish a uniform-in-time validity of Bogoliubov theory. The proof relies on a detailed analysis of the dispersive behavior of the symplectic Bogoliubov dynamics,

which allows for a rigorous derivation of the Bogoliubov theory as an effective description of quantum fluctuations around the Bose-Einstein condensate on all time scales. This is joint work with Phan Thanh Nam and Avy Soffer.

## 18: On the Efimov effect for four particles in two dimensions

*Jonathan Rau*

Karlsruhe Institut of Technology

The Efimov effect describes how three particles in three dimensions, interacting via short-range potentials, can form infinitely many bound states. Predicted by Efimov in 1970, it was established rigorously by Yafaev in 1974. In 1991 Tamura gave a fully variational proof of the effect.

For systems with short-range interactions involving an arbitrary number of particles in arbitrary dimensions, it is known that no analogous effect occurs, except possibly for four particles in two dimensions. Assuming that solely three-particle subsystems can interact, we show that such four-particle systems in two dimensions indeed possess an infinite discrete spectrum. The underlying mechanism is an effective long-range interaction generated by quantum tunneling in terms of zero-energy solutions in four dimensions, which binds the system at large distances.

Our proof extends Tamura's variational construction to four dimensions to capture the relevant tunneling behavior. Combined with a Born–Oppenheimer–type separation of internal degrees of freedom, this yields a fully variational demonstration of an Efimov-type effect.

## 19: Peierls instability and Kekulé distortion in graphene

*Thaddeus Roussigné*

Paris Dauphine - CEREMADE

In this talk, I would like to present recent work in condensed matter with David Gontier and Eric Séré, where we investigate a conventional tight-binding model for graphene. In this model, distortion of the honeycomb lattice is allowed, but penalized by a quadratic energy. We prove that the optimal 3-periodic lattice configuration has Kekulé O-type symmetry, and that for a sufficiently small elasticity parameter, the minimizer is not translation-invariant. Conversely, we prove that for a large elasticity parameter the translation-invariant configuration is the unique minimizer. (The preprint is available at https://arxiv.org/abs/2510.24230)

## 20: The 1D periodic Schrödinger equation with concentrated nonlinearity

*Andrew Rout*

Politecnico di Milano

The Schrödinger equation with concentrated nonlinearity is an effective model for a quantum gas with an impurity. Its nonlinearity consists of a Dirac delta multiplied by the standard power-type nonlinearity. In this talk, I will discuss some aspects of its well-posedness on a circle for regular initial conditions. The proof is based on exploiting the Volterra integral equation structure that arises from the concentrated nature of the nonlinearity. Based on joint work with Jinyeop Lee (University of Basel).

## 21: Quantization of complex projective spaces

*Blazej Ruba*
University of Warsaw

Complex projective spaces serve as classical phase spaces for bosonic systems with a fixed number of particles. They are also coadjoint orbits of unitary groups whose geometric quantization produces the symmetric tensor representations. I will present a semiclassical expansion of operator products on these spaces, described by a star product, with error estimates that are sharp in both the required regularity of symbols and the optimal constants. The proof combines techniques based on positivity – positivity-preserving transformations, operator inequalities, majorization – with Lie-theoretic input made available by the high symmetry of the setting.

## 22: The Lee-Huang-Yang formula for hard sphere bosons: an upper bound

*Benjamin Schlein*
University of Zurich

In the last years, there has been substantial progress in the rigorous justification of the Lee-Huang-Yang prediction for the ground state energy per unit volume of dilute Bose gases. While lower bounds have been derived for very general repulsive interactions, so far the upper bound has only been proven for square integrable potentials. In this talk, I am going to present a new upper bound for the ground state energy, completing the derivation of the Lee-Huang-Yang formula for dilute hard spheres. This is a joint work with G. Basti, M. Brooks, S. Cenatiempo and A. Olgiati.

## 23: Fractional Quantum Hall States: Infinite Matrix Product Representation and its Implications

*Severin Schraven*
Technical University of Munich

We present a novel matrix product representation of the Laughlin and related fractional quantum Hall wavefunctions based on a rigorous version of the correlators of a chiral quantum field theory. This representation enables the quantitative control of the coefficients of the Laughlin

wavefunction times an arbitrary monomial symmetric polynomial when expanded in a Slater determinant or permanent basis. It renders the properties, such as factorization and the renewal structure, inherent in such fractional quantum Hall wavefunctions transparent. We prove bounds on the correlators of the chiral quantum field theory and utilize this representation to demonstrate the exponential decay of connected correlations and a gap in the entanglement spectrum on a thin cylinder.

## 24: Conspiracy of Potential Wells and Absence of Efimov Effect in Dimension Four

*Marvin R. Schulz*

University of Copenhagen

The Efimov effect is a surprising phenomenon for three particles in three-dimensional space: three particles interacting via short-range potentials can form infinitely many bound states with certain universality properties. The effect originates from quantum tunnelling of zero-energy solutions in an double-well potential. In this talk, I will explain why the analogous mechanism fails in four dimensions. We show that, although a quantum tunnelling effect for the double-well potential in four dimensions does exist—established by deriving lower bounds on the ground-state energy that match upper bounds previously obtained by Pinchover—the resulting binding force is too weak to generate an Efimov-type spectrum. As a consequence, we recover the known absence of Efimov effect for three particles in four-dimensional space through a purely variational argument.

## 25: On distances among Slater Determinant States and Determinantal Point Processes

*Dario Trevisan*

University of Pisa

In this talk, we will examine the role of determinantal processes in modeling the repulsion among points. We will discuss the connections between these stochastic processes and quantum mechanics, through the measurement of Slater determinant states, that reflect fermionic behavior. The goal is to establish novel quantitative bounds between these objects, exploiting these connections and measures such as trace/total variation and Wasserstein distances. Based on a joint work with C. Boccato and F. Pieroni (arXiv:2504.08971).

## 26: Smoothing effect for the scattering operator associated with 1-d NLS and generalized KdV

*Nicola Visciglia*

University of Pisa

In the first part of the seminar we recall the definition and main classical results about nonlinear scattering for solutions to 1-d NLS and gKdV. In the second part of the seminar we present new results about the structure of the scattering operator and some related smoothing properties. This is a joint work with N. Burq, H. Koch, N. Tzvetkov.