Marco Falconi — Curriculum Vitæ

Contact Details

Politecnico di Milano
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Full Name Marco Falconi

Birth date October 5, 1983

Birth place Faenza (RA), Italy

Nationality Italian

Academic Appointments

- **Politecnico di Milano**
  - Associate Professor — *November 2023 - Present*
  - Senior Researcher — *April 2021 - October 2023*
- **Università di Roma Tre**
  - Researcher — *September 2019 - March 2021*
- **Fachbereich Mathematik – Universität Tübingen**
  - Postdoc — *January 2018 - August 2019*
- **Institut für Mathematik – Universität Zürich**
  - Postdoc — *April 2017 - December 2017*
- **Dipartimento di Matematica e Fisica — Università di Roma Tre**
  - Cond-math postdoc — *April 2016 - March 2017*
- **Institut für Analysis, Dynamik und Modellierung — Universität Stuttgart**
  - Research assistant — *October 2015 - March 2016*
- **Centre Henri Lebesgue — Université de Rennes I**
  - Centre Henri Lebesgue postdoc — *January 2014 - September 2015*
- **Dipartimento di Matematica — Università di Bologna**
  - Postdoc — *June 2012 - December 2013*

Education

Alma Mater Studiorum — Università di Bologna, Bologna (Italy)

Dottorato (Ph.D.) in Mathematics. **January 2009 - May 2012**

- Defense: June 8, 2012
- Dissertation: Classical limit of the Nelson model
- Advisor: Prof. Giorgio Velo
- Committee: Prof. Piero D'Ancona, Prof. Alberto Parmeggiani, Prof. Marco Peloso

Laurea Specialistica (M.Sc.), Theoretical Physics **2005 - 2007**

- Grade: 110/110 *cum Laude*
- Dissertation: On the regularization of phase-space path integral in curved manifolds
- Advisor: Prof. Fiorenzo Bastianelli

Laurea Triennale (B.Sc.), Physics **2002 - 2005**

- Grade: 110/110 *cum Laude*
- Dissertation: Sulla nozione di distinguibilità e degenerazione (in Italian)
- Advisor: Prof. Loris Ferrari

Teaching Experience

Politecnico di Milano

Scuola di Ingegneria Civile, Ambientale e Territoriale.

- *Geometria* (Lecturer: 3h lect. per week).
  Winter Term, A.y. 2021-2022

Scuola di Ingegneria Civile, Ambientale e Territoriale.

- *Mathematical Physics* (Lecturer: 4h lect. per week).
  Winter Term, A.y. 2021-2022

Università di Roma Tre

Dipartimento di Ingegneria, Corso di Laurea in Ing. e Tecnologie per il Mare.

- *Analisi I* (Lecturer: 4h lect. per week).
  Winter Term, A.y. 2020-2021

Dipartimento di Scienze, Corso di Laurea in Geologia.

- *Matematica* (Lecturer: 2h lect. per week).
  Winter Term, A.y. 2020-2021

Dipartimento di Matematica e Fisica, Corsi di Laurea in Fisica e Matematica.

- *Complementi di Meccanica – Mod. A* (Lecturer: 4h lect. per week).
  Summer Term, A.y. 2019-2020

Dipartimento di Scienze, Corso di Laurea in Ottica.

- *Istituzioni di Matematica – Mod. A* (Lecturer: 6h lect. + 2h ex. cl. per week). **Winter Term, A.y. 2019-2020**

Universität Tübingen

Fachbereich Mathematik, Master program in Mathematical Physics.

- *Advanced Semiclassical Analysis* (Lecturer: 2h lect. per week).
  Winter Term, A.y. 2018-2019

Universität Tübingen

Fachbereich Mathematik, Master program in Mathematical Physics.

- *Non-Linear Dispersive Partial Differential Equations* (Lecturer: 4h lect. + 2h ex.cl. per week). **Summer Term, A.y. 2017-2018, 2018-2019**

Universität Zürich

Institut für Mathematik.

- *Analysis I* (Teaching Assistant: 2h ex.cl. per week).
  Winter Term, A.y. 2017-2018

Università La Sapienza

Minicorso (Short course for Ph.D. students).

- *An introduction to semiclassical analysis in infinite dimensions, and its applications to mean and quantum field theories.* **November 2016**

Universität Stuttgart

Fachbereich Mathematik.

- *Analysis I* (Teaching Assistant: 2h ex.cl. per week).
  Winter Term, A.y. 2015-2016

IRMAR — Université de Rennes I

Cours doctoral (Ph.D. Course—given in french).

- *Relations de commutation canoniques: représentations en systèmes fini ou infini-dimensionnels.* **January-February 2015**

Alma Mater Studiorum — Università di Bologna

Faculty of Architecture, Teaching Assistant/Member of the Examination Committee. **2009-2013**

- *Istituzioni di Matematica*, CdL Architettura e Processo Edilizio (Elements of Mathematics).
- *Istituzioni di Matematiche I e II*, Cdl Architettura (Elements of Mathematics I and II).

Facoltà di Ingegneria, CdL in Ingegneria Informatica.

- *Analisi Matematica per l'Ingegneria Informatica* (Teaching Assistant). **Winter Term, A.y. 2010-2011**

Funding

- **INdAM Intensive Period 2022** **€ 30k**

  Funding for the organization of an intensive research trimester in Politecnico di Milano, co-organized with M. Correggi. **March-May 2022**

- **Progetto Giovani GNFM 2020** **€ 4k**

  Young researchers program of the Italian Group of Mathematical Physics. Investigators: G. Basti, M. Falconi (PI), D. Fermi, and D. Ferretti. **2021-2022**

- **Progetto Giovani GNFM 2017** **€ 4k**

  Young researchers program of the Italian Group of Mathematical Physics. Investigators: R. Carlone (PI), M. Falconi, D. Fermi, and M. Olivieri. **2017-2018**

Fields of Interest

Infinite Dimensional Microlocal and Semiclassical Analysis; Mathematical Methods of Quantum Physics; Nonlinear Partial Differential Equations; Measure theory and integration in infinite dimensional vector spaces:

- Wigner measures and Egorov-type Theorems in infinite dimensions
- Quasi-Classical Systems
- Renormalization in Quantum Field Theory
- Lattice Quantum ElectroDynamics
- Open Quantum Systems
- Rigorous derivation of effective theories in solid state and optical physics
- Scattering theory for linear and nonlinear evolution systems
- Pointless topology and measure theory in infinite dimensional vector spaces

Publications

Convergence of states for polaron models in the classical limit (with A. Olgiati, N. Rougerie) **Preprint (2023)**
2311.05940

Abstract: We consider the quasi-classical limit of Nelson-type regularized polaron models describing a particle interacting with a quantized bosonic field. We break translation-invariance by adding an attractive external potential decaying at infinity, acting on the particle. In the strong coupling limit where the field behaves classically we prove that the model's energy quasi-minimizers strongly converge to ground states of the limiting Pekar-like non-linear model. This holds for arbitrarily small external attractive potentials, hence this binding is fully due to the interaction with the bosonic field. We use a new approach to the construction of quasi-classical measures to revisit

energy convergence, and a localization method in a concentration-compactness type argument to obtain convergence of states.

Ground State Properties in the Quasi-Classical Regime (with M. Correggi, M. Olivieri) **Anal. PDE 16(8), 1745–1798 (2023)**
2007.09442
10.2140/apde.2023.16.1745

Abstract: We study the ground state energy and ground states of systems coupling non- relativistic quantum particles and force-carrying Bose fields, such as radiation, in the quasi-classical approximation. The latter is very useful whenever the force-carrying field has a very large number of excitations, and thus behaves in a semiclassical way, while the non-relativistic particles, on the other hand, retain their microscopic features. We prove that the ground state energy of the fully microscopic model converges to the one of a nonlinear quasi-classical functional depending on both the particles' wave function and the classical configuration of the field. Equivalently, this energy can be interpreted as the lowest energy of a Pekar-like functional with an effective nonlinear interaction for the particles only. If the particles are confined, the ground state of the microscopic system converges as well, to a probability measure concentrated on the set of minimizers of the quasi-classical energy.

Renormalized Bogoliubov Theory for the Nelson Model (with J. Lampart, N. Leopold, D. Mitrouskas) **Preprint (2023)**
2305.06722

Abstract: We consider the time evolution of the renormalized Nelson model, which describes N bosons linearly coupled to a quantized scalar field, in the mean-field limit of many particles $N \gg 1$ with coupling constant proportional to $N^{-1/2}$. First, we show that initial states exhibiting Bose-Einstein condensation for the particles and approximating a coherent state for the quantum field retain their structure under the many-body time evolution. Concretely, the dynamics of the reduced densities are approximated by solutions of two coupled PDEs, the Schrödinger-Klein-Gordon equations. Second, we construct a renormalized Bogoliubov evolution that describes the quantum fluctuations around the Schrödinger-Klein-Gordon equations. This evolution is used to extend the approximation of the evolved many-body state to the full norm topology. In summary, we provide a comprehensive analysis of the Nelson model that reveals the role of renormalization in the mean-field Bogoliubov theory.

Quasi-Classical Dynamics (with M. Correggi, M. Olivieri)
J. Eur. Mat. Soc. (JEMS) 25(2), 731–783 (2023)
1909.13313
10.4171/JEMS/1197

Abstract: We study quantum particles in interaction with a force-carrying field, in the quasi-classical limit. This limit is characterized by the field having a very large number of excitations (it is therefore macroscopic), while the particles retain their quantum nature. We prove that the interacting microscopic dynamics converges, in the quasi-classical limit, to an effective dynamics where the field acts as a classical environment that drives the quantum particles.

Semiclassical analysis of quantum asymptotic fields in the Yukawa theory (with Z. ammari, M. Olivieri) **J. Differential Equations 357, 236–274 (2023)**
2111.03352
10.1016/j.jde.2023.01.037

Abstract: In this article, we study the asymptotic fields of the Yukawa particle-field model of quantum physics, in the semiclassical regime $\hbar \to 0$, with an interaction subject to an ultraviolet cutoff. We show that the transition amplitudes between final (respectively initial) states converge towards explicit quantities involving the outgoing (respectively incoming) wave operators of the nonlinear Schrödinger-Klein-Gordon (S-KG) equation. Thus, we rigorously link the scattering theory of the Yukawa model to that of the Schrödinger-Klein-Gordon equation. Moreover, we prove that the asymptotic vacuum states of the Yukawa model have a phase space concentration property around classical radiationless solutions. Under further assumptions, we show that the S-KG energy admits a unique minimizer modulo symmetries and identify exactly the semiclassical measure of Yukawa ground states. Some additional consequences of asymptotic completeness are also discussed, and some further open questions are raised.

Derivation of the Maxwell-Schrödinger equations: A note on the infrared sector of the radiation field (with N. Leopold) **J. Math. Phys. 64, 011901 (2023)**
2203.16368
10.1063/5.0093786

Abstract: We slightly extend prior results about the derivation of the Maxwell-Schrödinger equations from the bosonic Pauli-Fierz Hamiltonian. More concretely, we show that the findings from Leopold and Pickl [SIAM J. Math. Anal. 52(5), 4900-4936 (2020)] about the coherence of the quantized electromagnetic field also hold for soft photons with small energies. This is achieved with the help of an estimate from Ammari et al. [arXiv:2202.05015 (2022)], which proves that the domain of the number of photon operator is invariant during the time evolution generated by the Pauli-Fierz Hamiltonian.

Bogoliubov Dynamics and Higher-order Corrections for the Regularized Nelson Model (with N. Leopold, D. Mitrouskas, S. Petrat)
Rev. Math. Phys. 33, 2350006 (2023)
2110.00458
10.1142/S0129055X2350006X

Abstract: We study the time evolution of the Nelson model in a mean-field limit in which N non-relativistic bosons weakly couple (w.r.t. the particle number) to a positive or zero mass quantized scalar field. Our main result is the derivation of the Bogoliubov dynamics and higher-order corrections. More precisely, we prove the convergence of the approximate wave function to the many-body wave function in norm, with a convergence rate proportional to the number of corrections taken into account in the approximation. We prove an analogous result for the unitary propagator. As an application, we derive a simple system of PDEs describing the time evolution of the first- and second-order approximation to the one-particle reduced density matrices of the particles and the quantum field, respectively.

Entanglement Hamiltonians - from field theory, to lattice models and experiments (with M. Dalmonte, V. Eisler, B. Vermersch)
Ann. Phys. (Berlin) 534(11), 202200064 (2022)
2202.05045
10.1002/andp.202200064

Abstract: We review results about entanglement (or modular) Hamiltonians of quantum many-body systems in field theory and statistical mechanics models, as well as recent applications in the context of quantum information and quantum simulation.

Towards a derivation of Classical ElectroDynamics of charges and fields from QED (with Z. Ammari, F. Hiroshima)
Preprint (2022)
2202.05015

Abstract: The purpose of this article is twofold:

- On one hand, we rigorously derive the Newton-Maxwell equation in the Coulomb gauge from first principles of quantum electrodynamics in agreement with the formal Bohr's correspondence principle of quantum mechanics.
- On the other hand, we establish the global well-posedness of the Newton-Maxwell system on energy-spaces under weak assumptions on the charge distribution.

Both results improve the state of the art, and are obtained by incorporating semiclassical and measure theoretical techniques. One of the novelties is the use of quantum propagation properties in order to build global solutions of the Newton-Maxwell equation.

Microscopic derivation of time-dependent point interactions (with R. Carlone, M. Correggi, M. Olivieri) **SIAM J. Math. Anal. 53(4), 4657-4691 (2021)**
1904.11012
10.1137/20M1381344

Abstract: We study the dynamics of the three-dimensional Fröhlich polaron - a quantum particle coupled to a bosonic field - in the quasi-classical regime, *i.e.*, when the field is very intense and the corresponding degrees of freedom can be treated semiclassically. We prove that in such a regime the effective dynamics for the quantum particles is approximated by the one generated by a time-dependent point interaction, *i.e.*, a singular time-dependent perturbation of the Laplacian supported in a point. As a byproduct, we also show that the unitary dynamics of a time-dependent point interaction can be approximated in strong operator topology by the one generated by time-dependent Schrödinger operators with suitably rescaled regular potentials.

The dilute Fermi gas via Bogoliubov theory (with E.L. Giacomelli, C. Hainzl, M. Porta) **Ann. Henri Poincaré 22(7), 2283-2353 (2021)**
2006.00491
10.1007/s00023-021-01031-6

Abstract: We study the ground state properties of interacting Fermi gases in the dilute regime, in three dimensions. We compute the ground state energy of the system, for positive interaction potentials. We recover a well-known expression for the ground state energy at second order in the particle density, which depends on the interaction potential only via its scattering length. The first proof of this result has been given by Lieb, Seiringer and Solovej. In this paper we give a new derivation of this formula, using a different method; it is inspired by Bogoliubov theory, and it makes use of the almost-bosonic nature of the low-energy excitations of the systems. With respect to previous work, our result applies to a more regular class of interaction potentials, but it comes with improved error estimates on the ground state energy asymptotics in the density.

Some rigorous aspects of fragmented condensation (with D. Dimonte, A. Olgiati)
Nonlinearity 34(1), 1-32 (2021)
1809.03586
10.1088/1361-6544/abb451

Abstract: In this paper we discuss some aspects of fragmented condensation from a mathematical perspective. Inspired by techniques of pseudodifferential calculus and semiclassical analysis in Bosonic Quantum Field Theory, we propose a simple way of identifying fragmentation, and we analyze the effects of pair interaction on finite fragmented states. In particular, we focus on the persistence of finite fragmented condensation when the gap between the degenerate ground state and the excited states of the corresponding non-interacting system is very large.

Magnetic Schrödinger Operators as the Quasi-Classical Limit of Pauli-Fierz-type Models (with M. Correggi, M. Olivieri) **J. Spectr. Theory 9(4), 1287-1325 (2019)**
1711.07413
10.4171/JST/277

Abstract: We study the quasi-classical limit of the Pauli-Fierz model: the system is composed of finitely many non-relativistic charged particles interacting with a bosonic radiation field. We trace out the degrees of freedom of the field, and consider the classical limit of the latter. We prove that the partial trace of the full Hamiltonian converges, in resolvent sense, to an effective Schrödinger operator with magnetic field and a corrective electric potential that depends on the field configuration. Furthermore, we prove the convergence of the ground state energy of the microscopic system to the infimum over all possible classical field configurations of the ground state energy of the effective Schrödinger operator.

Cylindrical Wigner measures **Doc. Math. 23, 1677-1756 (2018)**
1605.04778
10.4171/DM/658

Abstract: In this paper we study the semiclassical behavior of quantum states acting on the C*-algebra of canonical commutation relations, from a general perspective. The aim is to provide a unified and flexible approach to the semiclassical analysis of bosonic systems. We also give a detailed overview of possible applications of this approach to mathematical problems of both axiomatic relativistic quantum field theories and nonrelativistic many body systems. If the theory has infinitely many degrees of freedom, the set of Wigner measures, *i.e.* the classical counterpart of the set of quantum states, coincides with the set of all cylindrical measures acting on the algebraic dual of the space of test functions for the field, and this reveals a very rich semiclassical structure compared to the finite-dimensional case. We characterize the cylindrical Wigner measures and the *a priori* properties they inherit from the corresponding quantum states.

Concentration of cylindrical Wigner measures
Commun. Contemp. Math. 20(5) 1750055 (2018)
1704.07676
10.1142/S0219199717500559

Abstract: In this brief note we aim to characterize the cylindrical Wigner measures associated to regular quantum states in the Weyl C*-algebra of canonical commutation relations. In particular, we provide conditions, at the quantum level, sufficient to prove the concentration of all the corresponding cylindrical Wigner measures as Radon measures on suitable topological vector spaces. The analysis is motivated by variational and dynamical problems in the semiclassical study of bosonic quantum field theories.

Effective Potentials Generated by Field Interaction in the Quasi-Classical Limit (with M. Correggi) **Ann. Henri Poincaré 19(1), 189-235 (2018)**
1701.01317
10.1007/s00023-017-0612-z

Abstract: In this work we study the partial dynamics of particles linearly coupled with a quantized radiation field, in the *quasi-classical limit*. We prove that, as the field alone becomes macroscopic and the corresponding degrees of freedom are traced out, the effective Hamiltonian of the particles converges in resolvent sense to a self-adjoint Schrödinger operator that contains an additional external potential induced by the field configuration. The explicit form of such potential can be described exactly using techniques from semiclassical analysis. For specific (coherent) field configurations, it is possible to obtain trapping potentials. Finally, we prove convergence of the ground state energy of the full system to a suitable effective variational problem involving the classical state of the field: the original ground state energy converges to the infimum of the ground state energy of the quasi-classical Hamiltonian of the particles, over all (classical) field configurations with finite energy.

Scattering theory for Lindblad master equations (with J. Faupin, J. Fröhlich, B. Schubnel) **Comm. Math. Phys. 350(3), 1185–1218 (2017)**
1602.04045
10.1007/s00220-016-2737-1

Abstract: In this work we study the scattering theory for evolution semigroups of Lindblad type, on the ideal $\mathcal{I}_1(\mathcal{H})$ of trace class operators on a Hilbert space $\mathcal{H}$. The semigroups of Lindblad type are C_0-semigroups that map the convex cone $\mathcal{I}_1(\mathcal{H})_+ \subset \mathcal{I}_1(\mathcal{H})$ of positive elements into itself, preserving the trace. They are used to describe open quantum systems in the Markovian regime. We discuss the regularity assumptions on the non unitary part of the semigroup generator, sufficient to prove existence of the wave operators and the asymptotic completeness of the theory. We also introduce the modified wave operators useful to describe physical systems in which particles can be captured by the target during the scattering process. An important ingredient in our analysis is the scattering theory for dissipative operators in Hilbert spaces.

Bohr's correspondence principle for the renormalized Nelson model (with Z. Ammari) **SIAM J. Math. Anal. 49(6), 5031-5095 (2017)**
1602.03212
10.1137/17M1117598

Abstract: Egorov-type theorems characterize the evolution of semiclassical Wigner measures corresponding to quantum states that are evolved by means of a unitary dynamics. To the quantum linear evolution there corresponds, in the semiclassical limit, the pushforward of the Wigner measure by means of the (nonlinear) classical Hamiltonian flow associated to the system. For quantum field theories, proving such type of results provides some serious technical challenges, due to the necessity of performing, at the quantum level, renormalization procedures in order to define the dynamics non-perturbatively. In addition, these procedures may in principle modify the classical dynamics that is obtained in the limit. In this work we prove an Egorov-type theorem for an important model of nonrelativistic quantum field theory widely used in condensed matter physics: the Nelson model. We make crucial use of a family of symplectomorphisms in the classical phase space, that allow to put the classical system of Schrödinger-Klein-Gordon equations in a "normal form" suitable for quantization, providing at the same time a bridge between the undressed and dressed dynamics of the system.

On the rate of convergence for the mean field approximation of Bosonic many-body quantum dynamics (with Z. Ammari, B. Pawilowski)
Commun. Math. Sci. 14(5), 1417-1442 (2016)
1411.6284
10.4310/CMS.2016.v14.n5.a9

Abstract: In recent years, the derivation of effective mean field dynamical theories from underlying microscopic theories has been a subject of great interest for both the communities of mathematical physics and analysis. In this work, we study the time propagation of the rate of convergence for the reduced density matrices corresponding to generic states in bosonic non-relativistic systems. We prove that the initial-time rate of convergence is preserved by the evolution of the system if it is at most of order $1/n$ (where n is the number of particles in the system). For initial rates of order $o(1/n)$, the time evolution reduces the rate to order $1/n$. This result holds, provided the interaction potential between particles is sufficiently regular, for a very wide class of initial microscopic configurations, and shows that the initial coherent structure *is not a priori necessary* to obtain an

optimal rate of convergence. We also verify through numerical analysis that $O(1/n)$ is indeed the optimal rate of convergence, both for initial microscopic states with coherent structure ("mean-field states") and for a class of more entangled states ("twin Fock states").

Self-Adjointness criterion for operators in Fock spaces

Math. Phys. Anal. Geom. 18(1) (2015)

1405.6570

10.1007/s11040-015-9173-x

Abstract: In this work we discuss a self-adjointness criterion for densely defined symmetric operators in Fock spaces. The criterion applies to polynomials in the creation and annihilation operators, whose "non-diagonal" part (the part with a different number of creation and annihilation operators) is at most of order two. The advantage of this method is that it does not require neither positivity of the operator, nor that one part of it is a small perturbation of the other. Therefore it can be applied also in situations where the aforementioned conditions are not satisfied. Some applications are discussed; of particular interest is the one to Pauli-Fierz type operators.

Wigner measures approach to the classical limit of the Nelson model: Convergence of dynamics and ground state energy (with Z. Ammari)

J. Stat. Phys. 157(2), 330-364 (2014)

1403.2327

10.1007/s10955-014-1079-7

Abstract: In this work we derive a Schrödinger-Klein-Gordon dynamical system as the classical limit of a microscopic model of non-relativistic bosonic particles in regularized interaction with a scalar bosonic field. Microscopic states evolved in time converge to the push-forward through the S-KG flow of probability measures concentrated in the energy space (Wigner measures). In addition, the ground state energy of the microscopic model converges, when the density of non-relativistic particles is fixed, to the infimum of the S-KG energy functional.

Global Solution of the Electromagnetic Field-Particle System of Equations

J. Math. Phys. 55, 101502 (2014)

1311.1675

10.1063/1.4897211

Abstract: The Newton-Maxwell system describes the nonlinear coupled dynamics of charges (with extended charge distribution) in interaction with the electromagnetic field. We study the global well-posedness of the corresponding Cauchy problem, both in homogeneous Sobolev spaces with negative index, and in non-homogeneous Sobolev spaces with positive index (for the electromagnetic field). The static part of Maxwell's equations act as a constraint on the initial data, and it is satisfied at any time if satisfied at the initial time. The local well-posedness is extended to any time using energy-type estimates, assuming suitable regularity of the particles' charge distribution.

Mean field limit of bosonic systems in partially factorized states and their linear combinations **ArXiv e-Print (2013)**

1305.5699

Abstract: We study the mean field limit of marginal densities in a system of non-relativistic bosons with pair interaction, corresponding to linear combinations of either coherent or (partially) factorized states. Such marginals converge, in the Hilbert-Schmidt norm, to linear combinations of projectors onto solutions of the Hartree equation corresponding to each initial condition.

Classical limit of the Nelson model with cut off

J. Math. Phys. 54, 012303 (2013)

1205.4367

10.1063/1.4775716

Abstract: In this work we study the classical limit of the Nelson model with cut off, in the regime where both numbers of non-relativistic particles and field excitations are infinitely large. We prove convergence of the expectation value of canonical quantum observables to the solution of the corresponding classical equations, and we characterize the two-parameter evolution group of quantum fluctuations. The expectation values are calculated with respect to coherent and factorized states both for the particles and the scalar field. The choice of factorized states for the scalar field

yields a somewhat unexpected quantum residue in the classical limit. It takes the form of an average over all classical solutions corresponding to initial data that differ by a phase.

Mode Regularization for N = 1,2 SUSY Sigma Model (with R. Bonezzi)
J. High Energy Phys. 10 (2008) 019
0807.2276
10.1088/1126-6708/2008/10/019

Abstract: Worldline $N=1$ and $N=2$ supersymmetric sigma models in curved background are useful to describe spin one-half and spin one particles coupled to external gravity, respectively. It is well known that worldline path integrals in curved space require regularization: we present here the mode-regularization for these models, finding in particular the corresponding counterterms, both in the case of flat and curved indices for worldline fermions. For $N=1$, using curved indices we find a contribution to the counterterm from the fermions that cancels the contribution of the bosons, leading to a vanishing total counterterm and thus preserving the covariance and supersymmetry of the classical action. Conversely in the case of $N=2$ supersymmetries we obtain a non-covariant counterterm with both curved and flat indices. This work completes the analysis of the known regularization schemes for $N=1,2$ nonlinear sigma models in one dimension.

Proceedings

Quasi-Classical Spin-Boson Models (with M. Correggi, M. Merkli)
***Quantum Mathematics Vol. I*, Springer INdAM Series (2023)**

2110.00458

Abstract: In this short note we study Spin-Boson Models from the Quasi-Classical standpoint. In the Quasi-Classical limit, the field becomes macroscopic while the particles it interacts with, they remain quantum. As a result, the field becomes a classical environment that drives the particle system with an explicit effective dynamics.

Semiclassical Analysis in Infinite Dimensions: Wigner Measures
Bruno Pini Mathematical Analysis Seminar (2016)
10.6092/issn.2240-2829/6686

Abstract: We review some aspects of semiclassical analysis for systems whose phase space is of arbitrary (possibly infinite) dimension. An emphasis will be put on a general derivation of the so-called Wigner classical measures as the limit of states in a non-commutative algebra of quantum observables.

Supervised Students

PhD Students

- **Marco Olivieri, La Sapienza Università di Roma.**
  Quasi-Classical Limits of Particle-Field Quantum Systems. **2016-2019**
  Co-supervised with M. Correggi

Master Students

- **Alessandro Chessari, Politecnico di Milano and ENS Lyon.**
  Ongoing project on Many-Body Spectroscopy. **2021-2023**
  Co-supervised with M. Filippone

Organization

Research Periods & Schools

- **Hausdorff Summer School.**
  Recent Advances in Quantum and Statistical Mechanics. **June 26-30, 2023.**
  Co-organized with C. Brennecke, S. Cenatiempo
- **INdAM Intensive Period @PoliMi.**
  INdAM Quantum Meetings (IQM22). **March-May 2022**
  Co-organized with M. Correggi

Conferences & Workshops

- **Workshop @UniMi.**
  Quantum Before Christmas. **December 2021**
  Co-organized with D. Bambusi, N. Benedikter, C. Boccato, M. Correggi, V. Mastropietro

Seminars

- **Seminars @UniMi/PoliMi/Insubria.**
  Itinerant Quantum Math Meetings (IQMM). **2021-Present**
  Co-organized with N. Benedikter, C. Boccato, C. Cacciapuoti
- **Mathematical Challenges in Quantum Mechanics.**
  MCQM Seminar. **2021-Present**
  Co-organized with C. Cacciapuoti, R. Carlone, S. Cenatiempo, E.L. Giacomelli, D. Monaco, M. Olivieri

Latest Oral Communications

Hausdorff Center for Mathematics, Bonn (Germany)
- *Renormalization at any order of lattice infrared QED_4* **January 26th, 2023**
  Probability Seminar

Università di Milano, Milano (Italy)
- *Renormalization at any order of lattice infrared QED_4* **January 9th, 2023**
  Mathematical Quantum Matter

Tohoku University, Sendai (Japan)
- *A Quantum detour: regularizing classical electrodynamics by means of QED*
  November 28th, 2022
  Mathematical Challenges in Quantum Mechanics (online)

Centro Culturale Don Orione Artigianelli, Venezia (Italy)
- *A Quantum detour: regularizing classical electrodynamics by means of QED*
  August 26th, 2022
  Quantissima in the Serenissima IV

GNFM, Montecatini (Italy)
- *Quantum-driven classical trajectories in electrodynamics* **May 6th, 2022**
  Assemblea Scientifica GNFM 2022

GSSI+Università dell'Aquila, L'Aquila (Italy)
- *Variational Problems in Quasi-Classical Systems* **December 14th, 2020**
  SMAQ Seminar (online)

Universität Basel, Basel (Switzerland)
- *Variational Problems in Quasi-Classical Systems* **November 4th, 2020**
  Seminar Analysis and Mathematical Physics (online)

Jacobs University, Bremen (Germany)
- *Quasi-Classical Dynamics* **October 1st, 2020**
  Nonlinear Dynamics in Quantum Mechanics (online)

Università di Roma Tre, Roma (Italy)
- *Ground State Energy of Interacting Fermions at Low Density* **October 1st, 2020**
  Seminario di Fisica Matematica

Università La Sapienza, Roma (Italy)
- *Operatori d'onda e stati legati di un campo semiclassico in interazione con un gas di Bose* **November 20th, 2019**
  Seminario di Fisica Matematica

Institut Fourier, Grenoble (France)
- *Rigorous derivation of three-dimensional, time-dependent point interactions*
  Séminaire d'analyse **October 7th, 2019**

Università di Pavia, Pavia (Italy)
- *Limiti Quasi-Classici in Meccanica Quantistica* **September 2nd, 2019**
  XXI Congresso U.M.I.

Universität Tübingen, Tübingen (Germany)
- *Microscopic Derivation of Point Interactions* **July 5th, 2019**
  Tübingen-Zürich Meeting in Mathematical Physics

Institut Henri Poincaré, Paris (France)
- *Quasi-Classical Dynamics* **April 8th, 2019**
  Séminaire tournant "Spectral Problems in Mathematical Physics"

GSSI, L'Aquila (Italy)
- *Semi and Quasi-Classical approximation of ground state energy for bosonic systems* **November 29th, 2018**
  Gran Sasso Quantum Meetings @GSSI: from Many Particle Systems to Quantum Fluids.

DISMA, Politecnico di Torino, Torino (Italy)
- *Derivation of Ionization Models from Particle-Field Microscopic Interactions.*
  Trails in Quantum Mechanics and Surroundings 2018 **September 27th, 2018**

Palazzone della Scuola Normale Superiore, Cortona (Italy)
- *Semiclassical Analysis in AQFT* **June 7th, 2018**
  AQFT: Where Operator Algebras Meet Microlocal Analysis

IRMAR, Rennes (France)
- *State-valued measures, integration of observable-valued functions, and applications to the study of coupled physical systems* **April 12th, 2018**
  Séminaire EDP

Université de Lorraine, Metz (France)
- *Mesures de Wigner cylindriques* **March 8th, 2018**
  Séminaire LieGA

BCAM, Bilbao (Spain)
- *Magnetic Laplacians as the Quasi-Classical Limit of Microscopic Models of Pauli-Fierz Type* **November 7th, 2017**
  BCAM Scientific Seminar

Università La Sapienza, Roma (Italy)
- *Semiclassical properties of physical states* **October 25th, 2017**
  Seminario di Fisica Matematica

SwissMAP, Grindelwald (Switzerland)
- *Cylindrical Wigner Measures in Bosonic systems* **September 13th, 2017**
  4th SwissMAP General Meeting

LAGA, Université Paris 13, Paris (France)
- *Cylindrical Wigner Measures in Bosonic systems* **July 5th, 2017**
  Champ moyen quantique et problèmes liés

Research Visits

Short Term Recent visits (inviting host in brackets)

- *LMU München (Jonas Lampart)* **January 8th-14th, 2020**
- *LPMMC CNRS Grenoble (Nicolas Rougerie)* **October 7th-11th, 2019**
- *IRMAR Rennes (Zied Ammari)* **February 8th-20th, 2019**
- *Università La Sapienza, Roma (Michele Correggi)* **September 17rd-23th, 2018**

- *IRMAR Rennes (Zied Ammari)* **April 10th-15th, 2018**
- *Université de Lorraine (Sébastien Breteaux)* **March 7th-9th, 2018**
- *BCAM, Bilbao (Jean-Bernard Bru)* **November 6th-9th, 2017**
- *Università La Sapienza, Roma (Michele Correggi)* **October 23rd-27th, 2017**
- *SISSA Trieste (Alessandro Michelangeli)* **October 16th-20th, 2017**
- *IRMAR Rennes (Zied Ammari)* **March 13th-17th, 2017**

Participation in Committees

Member of the Selection Committee for a W3 Professor Position in Mathematics for the Natural Sciences.

Fachbereich Mathematik, Universität Tübingen **2019**

Reviewing Activity

Reviewer for peer-reviewed journals and books

SIAM Journal on Mathematical Analysis; Communications in Mathematical Physics; Journal of Functional Analysis; Milan Journal of Mathematics; Reviews in Mathematical Physics; Mathematical Physics, Analysis and Geometry; Journal of Mathematical Physics; New Journal of Physics; Journal of Physics A: Mathematical and Theoretical; Physica Scripta; Foundations of Physics; Springer Mathematics and Statistics book division.

Reviewer for the American Mathematical Society (MathSciNet Reviews)

Qualifications

Professore di I Fascia

Abilitazione Scientifica Nazionale alle funzioni di Professore di I fascia
SC *01/A4* – SSD *MAT/07* **2023-2034**
Ministero dell'Università e della Ricerca

Professore di II Fascia

Abilitazione Scientifica Nazionale alle funzioni di Professore di II fascia
SC *01/A4* – SSD *MAT/07* **2020-2031**
Ministero dell'Università e della Ricerca

Affiliations

ERC project UniCoSM **2019-2020**

FIR project Cond-Math **2016**

Graduiertenkolleg 1838 **2015-2016**

Laboratoire d'Excellence Centre Henri Lebesgue **2014-2015**

Société Mathématique de France (SMF) **2014-Present**

European Mathematical Society (EMS) **2015-Present**

American Mathematical Society (AMS) **2016-Present**

International Association of Mathematical Physics (IAMP) **2014-Present**

Gruppo Nazionale di Fisica Matematica (GNFM) **2017-2018, 2020-Present**

Honors, Awards, Fellowships

Postdoc Fellowships

Twentyfour months, Universität Tübingen **January 2018 - December 2019**
Postdoc fellowship

Nine months, Universität Zürich **April - December 2017**
Postdoc fellowship

Twelve months, Università di Roma Tre — **April 2016 - March 2017**
Assegno di Ricerca --- FIR project Cond-Math

Six months, Universität Stuttgart — **October 2015 - March 2016**
Postdoc fellowship

Twelve months, Centre Henri Lebesgue — **October 2014 - September 2015**
Centre Henri Lebesgue fellowship
Programme "Investissements d'avenir" --- ANR-11-LABX-0020-01

Nine months, Centre Henri Lebesgue — **January - September 2014**
Centre Henri Lebesgue fellowship
Programme "Investissements d'avenir" --- ANR-11-LABX-0020-01

Ph.D. Grant

Three years, Università di Bologna — **2009, 2010, 2011**

Language skills

Italian — Mother Tongue

English — Fluent

French — Very good knowledge

Spanish — Basic knowledge

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