PROCEDURA SELETTIVA PER POSTO DI PROFESSORE DI RUOLO DI SECONDA FASCIA SSD PHYS-04/A CODICE CONCORSO 2025PAE006

Curriculum vitae, list of publications and other documents characterising my teaching and research profile

Dr Federico Carollo
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Centre for Fluid and Complex Systems
Coventry University
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PERSONAL INFORMATION

Family name, Name: Carollo, Federico
Family status: married, 2 children
Researcher identifiers: Researcher-ID: ABE-6992-2021; ORCID: 0000-0002-6961-7143
Google Scholar: https://scholar.google.com/citations?user=Gzo4PZMAAAAJ&hl=en
Date of birth: September 6th 1985
Nationality: Italian

- ## EDUCATION

2013 – 2016 **PhD student** at the Department of Physics, University of Trieste (ITA) in the group of Prof. Fabio Benatti
PhD thesis: Quantum fluctuations and entanglement in mesoscopic systems
Award Date: 21/04/2016

2010 – 2012 **Physics student** at the University of Trieste (ITA)
Degree: Bachelor's degree (110/110 cum laude)
Thesis: Anderson localisation in the presence of temporal stochasticity

2007 – 2010 **Marine engineering student** at the University of Genoa (ITA)
Degree: Master's degree (110/110 cum laude)
Thesis: Dynamical analysis of a Co.G.A.S. plant for naval propulsion

2004 – 2007 **Marine engineering student** at the University of Genoa (ITA)
Degree: Bachelor's degree (108/110)
Thesis: Progetto di una nave da trasporto prodotti petrolchimici da 12380 TPL

- ## PROFESSIONAL EXPERIENCE

From 11/2024 **Associate Professor** – Centre for Fluid and Complex Systems, Coventry University (UK)

2020 – 2024 **Postdoctoral Research Fellow** at the Institut für Theoretische Physik – University of Tübingen (GER)

2016 – 2020 **Postdoctoral Research Fellow** in the Condensed Matter Theory group – University of Nottingham (UK)

- ## HABILITATION

2025 *Abilitazione Scientifica Nazionale alle funzioni di **professore universitario di prima fascia** nel Settore Concorsuale 02/B2 Fisica Teorica della Materia* (Italian habilitation as full professor for the field 02/B2 Theoretical Condensed Matter Physics)

2025 *Abilitazione Scientifica Nazionale alle funzioni di **professore universitario di seconda fascia** nel Settore Concorsuale 02/B2 Fisica Teorica della Materia* (Italian habilitation as associate professor for the field 02/B2 Theoretical Condensed Matter Physics)

2025 *Abilitazione Scientifica Nazionale alle funzioni di **professore universitario di seconda fascia** nel Settore Concorsuale 02/A2 Fisica Teorica delle Interazioni Fondamentali* (Italian habilitation as associate professor for the field 02/A2 Physics of Fundamental Interactions)

- **SUPERVISION OF STUDENTS AND POSTDOCTORAL FELLOWS**

Sept. 2025 –	Supervision (first supervisor) of **PhD student** (Liv Hammer) – Coventry University
Sept. 2025 –	Supervision (second supervisor) of **PhD student** (Mya Andrews) – Coventry University
Nov. 2024 –	Supervision (second supervisor) of **PhD student** (Uddhav Sen) – Coventry University
2022 – 2025	Supervision (first supervisor) of **PhD student** (Paulo J. Paulino) working on my project selected for funding within Eliteprogram für Postdocs of the Baden-Württemberg Stiftung – University of Tübingen (GER). **Thesis:** Nonequilibrium thermodynamics and large deviations in open quantum systems, (Magna cum laude)
Since 2020	Co-supervision of the research work of **junior post-doctoral fellows** (Buonaiuto, Cabot, Mazza, Gillman, Perfetto) and **PhD students** (Boneberg, Carnazza, Cech, Martins, Mattes) – University of Tübingen (GER)
2016 – 2020	Co-supervision of two **PhD students** (Vasiloiu and Fiorelli) – University of Nottingham (UK)
2024	Currently supervised **Master students** Moritz Eissler (Active quantum matter), Olivier Wieczorek (Quantum fluctuations across absorbing-state phase transitions), Paul Haffner (Cavity-atom systems with multi-level atoms and few bosonic modes) – University of Tübingen (GER)
2025	Supervision of **Bachelor student** Jan-Erik Fitzner. Thesis: "Exploring critical behavior in the quantum contact process using autoencoder-based clustering" – University of Tübingen (GER)
2024	Supervision of **Bachelor student** Paul Haffner. Thesis: "Nonequilibrium phase diagram of an atom-cavity system with three-level atoms" – University of Tübingen (GER)
2024	Supervision of **Master student** Robert Mattes. Thesis: "Emergent mean-field dynamics in open quantum systems with long-range interactions" – University of Tübingen (GER)
2024	Supervision of **Bachelor student** Oliver Wieczorek. Thesis: "Large deviations in systems with absorbing states" – University of Tübingen (GER)
2023	Supervision of **Master student** Giovanni Cemin. Thesis: "Inferring interpretable dynamical generators of local quantum observables from projective measurements through machine learning" – University of Tübingen (GER)
2023	Supervision of **Master student** Marcel Cech. Thesis: "Quantum simulation of biased open-system dynamics" – University of Tübingen (GER)
2022	Supervision of **Master student** Mario Boneberg. Thesis: "Quantum fluctuations and correlations in open quantum Dicke models" – University of Tübingen (GER)
2022	Supervision of **Master student** Markus Gnann. Thesis: "Quantum contact process with Z_2 symmetry" – University of Tübingen (GER)
2015	Supervision of **Master student** Jacopo Surace. Thesis: "Entangling two harmonic chains through a common bath" – University of Trieste (ITA)

2023 Supervision of **Bachelor student** Filip Bojko. Thesis: "Simulating absorbing phase transitions with quantum generalized Domany-Kinzel automata" – University of Tübingen (GER)

2023 Supervision of **Bachelor student** Moritz Eissler. Thesis: "Entanglement spreading in diffusive quantum trajectories of noninteracting fermionic chains" – University of Tübingen (GER)

2023 Supervision of **Bachelor student** Robert Mattes. Thesis: "Time-crystal phase transition and quantum correlations in a driven-dissipative spin-boson model" – University of Tübingen (GER)

2022 Supervision of **Bachelor student** Leah Muhle. Thesis: "Analysing quantum trajectories near a time-crystal phase transition using collision models" – University of Tübingen (GER)

2022 Supervision of **Bachelor student** Simon Kochsiek. Thesis: "The quantum Mpemba effect in simple spin systems" – University of Tübingen (GER)

- **TEACHING ACTIVITIES**

2026 **Lecturer** for the course "Quantum communication and quantum information" – Coventry University (UK). [The course starts in January 2026]

2025 **Lecturer** for the course "Further calculus and complex analysis" – Coventry University (UK).

2022 – 2023 **Lecturer** for the course "Large deviation approach to non-equilibrium systems" – University of Tübingen (GER). [This course was proposed and fully designed by me.]

2021 **Tutor** for the course "Classical field theory" held by Dr. Beatriz Olmos – University of Tübingen (GER)

2020 – 2021 **Lecturer** for the course "Large deviation approach to non-equilibrium physics" – University of Tübingen (GER). [This course was proposed and fully designed by me.]

2020 **Tutor** for the course "Theory of quantum information" held by Prof. Daniel Braun – University of Tübingen (GER)

Since 2020 **Supervisor** of several student seminars for different courses, including "The theory of open quantum Systems" and "Many-body quantum optics – University of Tübingen (GER)

2015 **Lecturer** at the 51st Winter School of Theoretical Physics: "Irreversible dynamics: nonlinear, nonlocal and non-Markovian manifestations" – Ladek Zdroj (POL)

- **REVIEWING ACTIVITIES**

Journals Reviewer for: Nature Physics, Nature Communications, Physical Review X, Physical Review Letters, Physical Review X Quantum, Physical Review A/B/E, Physical Review Research, Quantum, New Journal of Physics, Journal of Physics A: Mathematical and Theoretical, Europhysics Letters, Scipost Physics, Journal of Statistical Mechanics: Theory and Experiments, Journal of high energy Physics, Chaos: An Interdisciplinary Journal of Nonlinear Science

Grants — Reviewer for: ERC Starting Grant, Swiss National Science Foundation, ETH Zürich Grants, FWF Austrian Science Fund

- **PARTICIPATION IN RESEARCH UNITS**

Member of the DFG Research Unit FOR 5413: "Long-range interacting quantum spin systems out of equilibrium: Experiment, Theory and Mathematics" with Andergassen, Braun, Fortágh, Gross, Lesanovsky, Lubich, Olmos, Petrosyan, Slama, Teufel

Collaborator of the DFG Research Unit FOR 5522: "Quantum thermalization, localization, and constrained dynamics with interacting ultracold atoms" with Aidelsburger, Banuls, Bloch, Gross, Heidrich-Meisner, Heyl, Kehrein, Lesanovsky, Moessner, Pollmann, Zeiher

- **FUNDING, AWARDS AND RECOGNITIONS**

2025 — Project co-lead for EPSRC opportunity "Access to high performance computing facilities" (granted 10M CPU-hours)

2025 — Included in the Standford University and Elsevier's Top 2% Scientists list (ranking that identifies scholars who are top-cited in their respective fields)

2024 — Included in the Standford University and Elsevier's Top 2% Scientists list (ranking that identifies scholars who are top-cited in their respective fields)

2023 — Co-Principal Investigator of the project "Collective quantum phenomena in dissipative systems – towards time-crystal applications in sensing and metrology" funded under the QuantERA Call 2023 scheme. Total funding: ~ 1.000.000 €

2023 — Central contributor to conceiving and writing of the project "Kinetically constrained dynamics in quantum gases" submitted within the Research Unit FOR 5522 "Quantum thermalization, localization, and constrained dynamics with interacting ultracold atoms" funded by the **Deutsche Forschungsgemeinschaft** (GER). Funding for the proposed project 295.700 € (Total funding ~ 4.000.000 €)

2022 — Central contributor to conceiving and writing of the project "Absorbing state phase transitions in long-range interacting quantum spin systems" submitted within the Research Unit FOR 5413 "Long-range interacting quantum spin systems out of equilibrium: Experiment, Theory and Mathematics" funded by the **Deutsche Forschungsgemeinschaft** (GER) [Active participation to the interview with the evaluation panel]. Funding for the proposed project 309.500 € (Total funding ~ 4.000.000 €)

2021 — Principal investigator for the project "Quantum machines fueled by nonequilibrium phases of matter" funded by the **Baden-Württemberg Stiftung** within the program "**Eliteprogramm für Postdocs of the Baden-Württemberg Stiftung**" (GER). Funding for the proposed project 130.000 €

2020 - 2021 — **Teach@Tübingen Fellowship** at the University of Tübingen (GER). Awarded on a competitive university-wide call for research and teaching on topics proposed by the applicant. Funding for the proposed research and teaching project 30.000 €

2013 – 2016 — PhD Scholarship (36.000 €) "Theoretical and experimental physics on themes of the INFN". Awarded by the **National Institute of Nuclear Physics** (ITA)

2008 – 2009 — **Pretto-Cassanello Foundation Scholarship**. To students with highest marks (ITA)

- **WORKSHOPS, PUBLIC ENGAGEMENT AND PRESS**

Feb. 2026 Currently organising the second edition of the "Quantum Coventry Workshop: Many-body systems, non-equilibrium dynamics and quantum computing". The event will take place on the 23rd and 24th of February (for a list of speakers see https://www.statphys-coventry.org/home/events)

Apr–Jun 2025 Co-organiser and facilitator of three skill-development workshops "CovenDRI" for early-career researchers in theoretical physics and applied mathematics. Themes of the workshops are: *Developing independence as a researcher*; *Managing a research group; Applying for funding*

Feb. 2025 Organisation of "Quantum Coventry Workshop: Many-body systems, non-equilibrium dynamics and quantum computing" (see webpage https://iop.eventsair.com/qwc2025/ for details). Two-day event with 45 attendees, 11 invited speakers plus 5 contributed speakers and poster session

Feb. 2025 Press release from Coventry University on the work "Thermodynamics of coupled time crystals with an application to energy storage" [Quantum Sci. Technol. 11, 015003 (2026)] https://www.coventry.ac.uk/news/2025/coventry-university-time-crystals-quantum-batteries/

Jan. 2025 Letter on continuous sensing with time crystals [PRL 132, 050801 (2024)] selected for Physical Review Letters collection of the year 2024

Jan. 2025 Visit to Whoberley Hall Primary School (Coventry, UK) to talk about "working in science" and basic physics ideas

Nov. 2024 Article appeared on New Scientist on my manuscript "Thermodynamics of coupled time crystals with an application to energy storage" [Quantum Sci. Technol. 11, 015003 (2026)] https://www.newscientist.com/article/2456433-quantum-time-crystals-could-be-used-to-store-energy/

Aug. 2024 Podcast discussion for the series "The Quantum Feedback Loop" hosted by James Myers. The podcast title is "Dr. Federico Carollo on the intriguing present and future potential of time crystals" (https://rss.com/podcasts/quantum-feedback/1668392/)

2023 Article appeared on the New Scientist on my manuscript "Rydberg-ion flywheel for quantum work storage", Phys. Rev. A 108, L050201 (2023) https://www.newscientist.com/article/2399060-quantum-flywheel-could-be-fashioned-from-super-sized-charged-atoms/

2020 Article on the work "Building continuous time crystals from rare events", Phys. Rev. Lett. 125, 160601 (2020), in collaboration with researchers from Granada. https://canal.ugr.es/noticia/cientificos-de-la-ugr-logran-crear-cristales-de-tiempo-un-nuevo-estado-de-la-materia-empleando-un-superordenador/

PRE-PRINTS

[92] *"Adiabatically driven dissipative many-body quantum spin systems"*
P. J. Paulino, S. Teufel, Federico Carollo, I. Lesanovsky
arXiv:2509.12075

[91] *"Revealing emergent many-body phenomena by analyzing large-scale space-time records of monitored quantum systems"*
M. Cech, C. De Fazio, M. Cea, M. C. Bañuls, I. Lesanovsky, Federico Carollo
arXiv:2507.00944

[90] *"Quantum enhanced parameter estimation with monitored quantum nonequilibrium systems using inefficient photo detection"*
A. Cabot, Federico Carollo, I. Lesanovsky
arXiv:2503.21753

PEER-REVIEWED PUBLICATIONS

[89] *"Designing open spin-boson models for enabling quantum enhanced sensing through classical measurements"*
R. Mattes, A. Cabot, Federico Carollo, I. Lesanovsky
Physical Review Letters 135, 230402 (2025)

[88] *"Thermodynamics of coupled time crystals with an application to energy storage"*
P. J. Paulino, A. Cabot, G. De Chiara, M. Antezza, I. Lesanovsky, Federico Carollo
Quantum Science and Technology 11, 015003 (2026)

[87] *"Generation of entanglement and non-stationary states via competing coherent and incoherent bosonic hopping"*
P. Solanki, A. Cabot, M. Brunelli, Federico Carollo, C. Bruder, I. Lesanovsky
Physical Review A 112, L030601 (2025)

[86] *"Space-time correlations in monitored kinetically constrained discrete-time quantum dynamics"*
M. Cech, M. Cea, M. C. Bañuls, I. Lesanovsky, Federico Carollo
Physical Review Letters 134, 230403 (2025)

[85] *"Stochastic resetting in discrete-time quantum dynamics: steady states and correlations in few-qubit systems"*
S. Wald, L. H. Yao, T. Platini, C. Hooley, Federico Carollo
Quantum 9, 1742 (2025)

[84] *"Nonlinear classification capability of quantum neural networks due to emergent quantum metastability"*
M. Boneberg, Federico Carollo, I. Lesanovsky
Physical Review A 111, 062405 (2025)

[83] *"Long-range interacting systems are locally non-interacting"*
R. Mattes, I. Lesanovsky, Federico Carollo
Physical Review Letters 134, 070402 (2025)

[82] *"Unraveling-induced entanglement phase transition in diffusive trajectories of continuously monitored noninteracting fermionic systems"*
M. Eissler, I. Lesanovsky, Federico Carollo
Physical Review A 111, 022205 (2025)

[81] *"Quasiperiodic Floquet-Gibbs states in Rydberg atomic systems"*
W. S. Martins, Federico Carollo, K. Brandner, I. Lesanovsky
Physical Review A 111, L010202 (2025) [Letter]

[80] *"Exploiting nonequilibrium phase transitions and strong symmetries for continuous measurement of collective observables"*
A. Cabot, Federico Carollo, I. Lesanovsky
Physical Review A 110, L060601 (2024) [Letter]

[79] *"Machine learning of reduced quantum channels on noisy intermediate-scale quantum devices"*
G. Cemin, M. Cech, E. Weiss, S. Soltan, D. Braun, I. Lesanovsky, Federico Carollo
Physical Review A 110, 052418 (2024)

[78] *"Applicability of mean-field theory for time-dependent open quantum systems with infinite-range interactions"*
Federico Carollo, I. Lesanovsky
Physical Review Letters 133, 150401 (2024)

[77] *"Machine learning stochastic differential equations for the evolution of order parameters of classical many-body systems in and out of equilibrium"*
F. Carnazza, Federico Carollo, S. Andergassen, G. Martius, M. Klopotek, I. Lesanovsky
Machine Learning: Science and Technology 5, 045002 (2024)

[76] *"Stochastic thermodynamics at the quantum-classical boundary: A self-consistent framework based on adiabatic-response theory"*
J. Eglinton, Federico Carollo, I. Lesanovsky, K. Brandner
Quantum 8, 1486 (2024)

[75] *"Emergence of subharmonics in a microwave driven dissipative Rydberg gas"*
Z.-K. Liu, K.- H. Sun, A. Cabot, Federico Carollo, J. Zhang, Z.-Y. Zhang, L.-H. Zhang, B. Liu, T.-Y. Han, Q. Li, Y. Ma, H.-C. Chen, I. Lesanovsky, D.-S. Ding, B.-S. Shi
Physical Review Research 6, L032069 (2024) [Letter]

[74] *"Large deviation full counting statistics in adiabatic open quantum dynamics"*
P. J. Paulino, I. Lesanovsky, Federico Carollo
Physical Review Letters 132, 260402 (2024)

[73] *"Quantum thermodynamics of boundary time-crystals"*
Federico Carollo, I. Lesanovsky, M. Antezza, G. De Chiara
Quantum Science and Technology 9, 035024 (2024)

[72] *"Universal and nonuniversal probability laws in Markovian open quantum dynamics subject to generalized reset processes"*
Federico Carollo, I. Lesanovsky, J. P. Garrahan
Physical Review E 109, 044129 (2024)

[71] *"Inferring interpretable dynamical generators of local quantum observables from projective measurements through machine learning"*
G. Cemin, F. Carnazza, S. Andergassen, G. Martius, Federico Carollo, I. Lesanovsky
Physical Review Applied 21, L041001 (2024) [Letter]

[70] *"Numerical simulations of long-range open quantum many-body dynamics with tree tensor networks"*
D. Sulz, C. Lubich, G. Ceruti, I. Lesanovsky, Federico Carollo
Physical Review A 109, 022420 (2024)

[69] *"Continuous sensing and parameter estimation with the boundary time-crystal"*
A. Cabot, Federico Carollo, I. Lesanovsky
Physical Review Letters 132, 050801 (2024)

[68] *"A quantum fluctuation description of charge qubits"*
F. Benatti, Federico Carollo, R. Floreanini, H. Narnhofer, F. Valiera
New Journal of Physics 26, 013057 (2024)

[67] *"Entangled time-crystal phase in an open quantum light-matter system"*
R. Mattes, I. Lesanovsky, Federico Carollo
Physical Review A 108, 062216 (2023)

[66] *"Quantum reaction-limited reaction-diffusion dynamics of annihilation processes"*
G. Perfetto, Federico Carollo, J. Garrahan, I. Lesanovsky
Physical Review E 108, 064104 (2023)

[65] *"Non-Gaussian dynamics of quantum fluctuations and mean-field limit in open quantum central spin systems"*
Federico Carollo
Physical Review Letters 131, 227102 (2023)

[64] *"Rydberg-ion flywheel for quantum work storage"*
W. S. Martins, Federico Carollo, W. Li, K. Brandner, I. Lesanovsky
Physical Review A 108, L050201 (2023) [Letter]

[63] *"Quantum trajectories of dissipative time-crystals"*
A. Cabot, L. S. Muhle, Federico Carollo, I. Lesanovsky
Physical Review A 108, L041303 (2023) [Letter]

[62] *"Thermodynamics of quantum trajectories on a quantum computer"*
M. Cech, I. Lesanovsky, Federico Carollo
Physical Review Letters 131, 120401 (2023)

[61] *"Logarithmic negativity in out-of-equilibrium open free-fermion chains: An exactly solvable case"*
V. Alba, Federico Carollo
Scipost Physics 15, 124 (2023)

[60] *"Dissipative quantum many-body dynamics in (1+1)D quantum cellular automata and quantum neural networks"*
M. Boneberg, Federico Carollo, I. Lesanovsky
New Journal of Physics 25, 093020 (2023)

[59] *"Nonequilibrium thermodynamics and power generation in open quantum optomechanical systems"*
P. J. Paulino, I. Lesanovsky, Federico Carollo
Physical Review A 108, 023516 (2023)

[58] *"Mean-field dynamics of open quantum systems with collective operator-valued rates: validity and application"*
E. Fiorelli, M. Müller, I. Lesanovsky, Federico Carollo
New Journal of Physics 25, 083010 (2023)

[57] *"Reaction-Limited Quantum Reaction-Diffusion Dynamics"*
G. Perfetto, Federico Carollo, J. P. Garrahan, I. Lesanovsky
Physical Review Letters 130, 210402 (2023) Editors' Suggestion

[56] *"Collective atom-cavity coupling and nonlinear dynamics with atoms with multilevel ground states"*

E. Suarez, Federico Carollo, I. Lesanovsky, B. Olmos, Ph. W. Courteille, S. Slama
Physical Review A 107, 023714 (2023) Editors' Suggestion

[55] *"Using (1+1)D quantum cellular automata for exploring collective effects in large scale quantum neural networks"*
E. Gillman, Federico Carollo, I. Lesanovsky
Physical Review E 107, L022102 (2023) [Letter]

[54] *"Entangled multiplets and spreading of quantum correlations in a continuously monitored tight-binding chain"*
Federico Carollo, V. Alba
Physical Review B 106, L220304 (2022) [Letter]

[53] *"Many-body radiative decay in strongly interacting Rydberg ensembles"*
C. Nill, K. Brandner, B. Olmos, Federico Carollo, I. Lesanovsky
Physical Review Letters 129, 243202 (2022)

[52] *"Emergent quantum correlations and collective behavior in non-interacting quantum systems subject to stochastic resetting"*
M. Magoni, Federico Carollo, G. Perfetto, I. Lesanovsky
Physical Review A 106, 052210 (2022)

[51] *"Metastable discrete time-crystal resonances in a dissipative central spin system"*
A. Cabot, Federico Carollo, I. Lesanovsky
Physical Review B 106, 134311 (2022)

[50] *"Anderson and many-body localization in the presence of spatially correlated classical noise"*
S. Marcantoni, Federico Carollo, F. M. Gambetta, I. Lesanovsky, U. Schneider, J. P. Garrahan
Physical Review B 106, 134211 (2022)

[49] *"Signatures of a quantum stabilized fluctuating phase and critical dynamics in a kinetically constrained open many-body system with two absorbing states"*
Federico Carollo, M. Gnann, G. Perfetto, I. Lesanovsky
Physical Review B 106, 094315 (2022)

[48] *"Asynchronism and nonequilibrium phase transitions in (1+1)-dimensional quantum cellular automata"*
E. Gillman, Federico Carollo, I. Lesanovsky
Physical Review E 106, L032103 (2022) [Letter]

[47] *"Thermodynamics of quantum-jump trajectories of open quantum systems subject to stochastic resetting"*
G. Perfetto, Federico Carollo, I. Lesanovsky
SciPost Physics 13, 079 (2022)

[46] *"Inferring Markovian quantum master equations of few-body observables in interacting spin chains"*
F. Carnazza, Federico Carollo, D. Zietlow, S. Andergassen, G. Martius, I. Lesanovsky
New Journal of Physics 24, 073033 (2022)

[45] *"Quantum fluctuations and correlations in open quantum Dicke models"*

M. Boneberg, I. Lesanovsky, Federico Carollo
Physical Review A 106, 012212 (2022)

[44] *"Accelerating the approach of dissipative quantum spin systems towards stationarity through global spin rotations"*
S. Kochsiek, Federico Carollo, I. Lesanovsky
Physical Review A 106, 012207 (2022)

[43] *"Exact solution of a boundary time-crystal phase transition: time-translation symmetry breaking and non-Markovian dynamics of correlations"*
Federico Carollo, I. Lesanovsky
Physical Review A 105, L040202 (2022) [Letter]

[42] *"Dissipative quasiparticle picture for quadratic Markovian open quantum systems"*
Federico Carollo, V. Alba
Physical Review B 105, 144305 (2022)

[41] *"Nonequilibrium dark space phase transition"*
Federico Carollo, I. Lesanovsky
Physical Review Letters 128, 040603 (2022)

[40] *"Hydrodynamics of quantum entropies in Ising chains with linear dissipation"*
V. Alba, Federico Carollo
Journal of Physics A: Mathematical and Theoretical 55, 074002 (2022)

[39] *"Noninteracting fermionic systems with localized dissipation: Exact results in the hydrodynamic limit"*
V. Alba, Federico Carollo
Physical Review B 105, 054303 (2022) Editors' Suggestion

[38] *"Quantum and classical temporal correlations in (1+1)D quantum cellular automata"*
E. Gillman, Federico Carollo, I. Lesanovsky
Physical Review Letters 127, 230502 (2021)

[37] *"Designing nonequilibrium states of quantum matter through stochastic resetting"*
G. Perfetto, Federico Carollo, M. Magoni, I. Lesanovsky
Physical Review B 104, L180302 (2021) [Letter]

[36] *"Dynamical phases and quantum correlations in an emitter-waveguide system with feedback"*
G. Buonaiuto, Federico Carollo, B. Olmos, I. Lesanovsky
Physical Review Letters 127, 133601 (2021)

[35] *"Microscopic biasing of discrete-time quantum trajectories"*
D. Cilluffo, G. Buonaiuto, I. Lesanovsky, A. Carollo, S. Lorenzo, G. Massimo Palma, F. Ciccarello, Federico Carollo
Quantum Science and Technology 6, 045011 (2021)

[34] *"Exponentially accelerated approach to stationarity in Markovian open quantum systems through the Mpemba effect"*
Federico Carollo, A. Lasanta, I. Lesanovsky
Physical Review Letters 127, 060401 (2021)

[33] *"Large deviations at level 2.5 for Markovian open quantum systems: quantum jumps and quantum state diffusion"*
Federico Carollo, J. P. Garrahan, R. L. Jack
Journal of Statistical Physics 184, 13 (2021)

[32] *"Exactness of mean-field equations for open Dicke models with an application to pattern retrieval dynamics"*
Federico Carollo, I. Lesanovsky
Physical Review Letters 126, 230601 (2021)

[31] *"Numerical simulation of quantum nonequilibrium phase transitions without finite size effects"*
E. Gillman, Federico Carollo, I. Lesanovsky
Physical Review A 103, L040201 (2021) [Letter]

[30] *"Machine learning time-local generators of open quantum dynamics"*
P.P. Mazza. D. Zietlow, Federico Carollo, S. Andergassen, G. Martius, I. Lesanovsky
Physical Review Research 3, 023084 (2021) Editors' Suggestion

[29] *"Spreading of correlations in Markovian open quantum systems"*
V. Alba, Federico Carollo
Physical Review B 103, L020302 (2021) [Letter] Editors' Suggestion

[28] *"Nonequilibrium many-body quantum engine driven by time-translation symmetry breaking"*
Federico Carollo, K. Brandner, I. Lesanovsky
Physical Review Letters 125, 240602 (2020)

[27] *"Building continuous time crystals from rare events"*
R. Hurtado-Gutiérrez, Federico Carollo, C. Pérez-Espigares, P. I. Hurtado
Physical Review Letters 125, 160601 (2020)

[26] *"Entanglement statistics in Markovian open quantum systems: a matter of mutation and selection"*
Federico Carollo, C. Pérez-Espigares
Physical Review E 102, 030104 (2020) Rapid Communication

[25] *"Nonequilibrium phase transitions in (1+1)-dimensional quantum cellular automata with controllable quantum correlations"*
E. Gillman, Federico Carollo, I. Lesanovsky
Physical Review Letters **125**, 100403 (2020)

[24] *"Signatures of associative memory behavior in a multi-mode spin-boson model"*
E. Fiorelli, M. Marcuzzi, P. Rotondo, Federico Carollo, I. Lesanovsky
Physical Review Letters 125, 070604 (2020)

[23] *"Nonequilibrium quantum many-body Rydberg atom engine"*
Federico Carollo, F. M. Gambetta, K. Brandner, J. P. Garrahan, I. Lesanovsky
Physical Review Letters 124, 170602 (2020)

[22] *"Trajectory phase transitions in noninteracting spin systems"*
L. M. Vasiloiu, T. H. E. Oakes, Federico Carollo, J. P. Garrahan

Physical Review E 101, 042115 (2020) Editors' Suggestion

[21] *"Witnessing nonclassicality through large deviations in quantum optics"*
D. Cilluffo, G. Buonaiuto, S. Lorenzo, G. Massimo Palma, F. Ciccarello, Federico Carollo, I. Lesanovsky
Physical Review Research 2, 023078 (2020)

[20] *"Dynamics of strongly coupled disordered dissipative spin-boson systems"*
E. Fiorelli, P. Rotondo, Federico Carollo, M. Marcuzzi, I. Lesanovsky
Physical Review Research 2, 013198 (2020)

[19] *"Classical stochastic discrete time crystals"*
F. M. Gambetta, Federico Carollo, A. Lazarides, I. Lesanovsky, J. P. Garrahan
Physical Review E 100, 060105 (2019) Rapid Communication

[18] *"Numerical simulation of critical dissipative non-equilibrium quantum systems with an absorbing state"*
E. Gillman, Federico Carollo, I. Lesanovsky
New Journal of Physics 21, 093064 (2019)

[17] *"Critical behavior of the quantum contact process in one dimension"*
Federico Carollo, E. Gillman, H. Weimer, I. Lesanovsky
Physical Review Letters 123, 100604 (2019)

[16] *"Strong zero modes in a class of generalized Ising spin ladders with plaquette interactions"*
L. M. Vasiloiu, Federico Carollo, M. Marcuzzi, J. P. Garrahan
Physical Review B 100, 024309 (2019)

[15] *"Unraveling the large deviation statistics of Markovian open quantum systems"*
Federico Carollo, R. L. Jack, J. P. Garrahan
Physical Review Letters 122, 130605 (2019)

[14] *"Discrete time crystals in the absence of manifest symmetries or disorder in open quantum systems"*
F. M. Gambetta, Federico Carollo, M. Marcuzzi, J. P. Garrahan, I. Lesanovsky
Physical Review Letters 122, 015701 (2019)

[13] *"Dynamical criticality in open systems: nonperturbative physics, microscopic origin, and direct observation"*
C. Pérez-Espigares, Federico Carollo, J. P. Garrahan, P. I. Hurtado
Physical Review E 98, 060102 (2018) Rapid Communication

[12*] *"Quantum spin chain dissipative mean-field dynamics"*
F. Benatti, Federico Carollo, R. Floreanini, H. Narnhofer
Journal of Physics A: Mathematical and Theoretical 51, 325001 (2018)

[11] *"Enhancing correlation times for edge spins through dissipation"*
L. M. Vasiloiu, Federico Carollo, J. P. Garrahan
Physical Review B 98, 094308 (2018)

[10] *"Current Fluctuations in boundary-driven quantum spin chains"*
Federico Carollo, J. P. Garrahan, I. Lesanovsky

Physical Review B 98, 094301 (2018)

[9] *"Making rare events typical in Markovian open quantum systems"*
Federico Carollo, J. P. Garrahan, I. Lesanovsky, C. Pérez-Espigares
Physical Review A 98, 010103 (2018) Rapid Communication

[8] "*Fluctuating hydrodynamics, current fluctuations, and hyperuniformity in boundary-driven open quantum chains"*
Federico Carollo, J. P. Garrahan, I. Lesanovsky, C. Pérez-Espigares
Physical Review E 96, 052118 (2017)

[7*] "*Quantum fluctuations in mesoscopic systems"*
F. Benatti, Federico Carollo, R. Floreanini, H. Narnhofer
Journal of Physics A: Mathematical and Theoretical 50, 423001 (2017)

[6] *"Long-lived mesoscopic entanglement between two damped infinite harmonic chains"*
F. Benatti, Federico Carollo, R. Floreanini, J. Surace
Journal of Statistical Physics 168, 620 (2017)

[5*] "*Non-Markovian mesoscopic dissipative dynamics of open quantum spin chains"*
F. Benatti, Federico Carollo, R. Floreanini, H. Narnhofer
Physics Letters A 380, 381 (2016)

[4*] "*Dissipative entanglement of quantum spin fluctuations"*
F. Benatti, Federico Carollo, R. Floreanini
Journal of Mathematical Physics 57, 062208 (2016)

[3*] "*Dissipative dynamics of quantum fluctuations"*
F. Benatti, Federico Carollo, R. Floreanini
Annalen der Physik 527, 639 (2015)

[2*] "*Environment induced entanglement in many-body mesoscopic systems"*
F. Benatti, Federico Carollo, R. Floreanini
Physics Letters A 378, 1700 (2014)

[1] *"A non-Markovian dissipative Maryland model"*
F. Benatti, Federico Carollo
Open Systems & Information Dynamics 20, 1340001 (2013)

*Authors appear in alphabetical order. The paper is based on my first-hand original Ph.D. research.

PUBLICATIONS IN ENGINEERING

[2-ME] *"Dynamic simulation of a COGAS ship propulsion plant"*
G. Benvenuto, D. Bertetta, U. Campora, Federico Carollo
Conference Paper: NAV International Conference on Ship and Shipping Research 2012 (216369)

[1-ME] *"COGAS plant as possible future alternative to the diesel engine for the propulsion of large ships"*
G. Benvenuto, D. Bertetta, Federico Carollo, U. Campora,
Conference Paper: Sustainable Maritime Transportation and Exploitation of Sea Resources – Proceedings of the 14th Internation Congress of the International Maritime Association of the Mediterranean, IMAM 2011 pp. 603-613 (2012)

LIST OF SCIENTIFIC TALKS AND SEMINARS

- Invited Speaker: ***Mean-field dynamics of long-range interacting open quantum systems,*** 6th Nottingham Workshop on Quantum Non-Equilibrium Dynamics. Open Quantum Systems: Learning, Control and Thermodynamics – Nottingham/UK 24-26/09/2025

- Invited Lecturer: ***Mean-field and quantum fluctuations dynamics in long-range interacting open quantum systems,*** Summer School on Quantum Matter out of Equilibrium – Granada/Spain 1-5/09/2025

- Invited Seminar: ***Unveiling emergent phenomena in "digital" quantum trajectories,*** TCM Seminars – University of Cambridge/UK 24/07/2025

- Invited Seminar: ***Non-equilibrium phase transitions in open quantum systems: Universality, simulation, and "advantage",*** Phasecraft Ltd (Quantum start-up company) – Bristol/UK 16/05/2025

- Invited Seminar: ***Biasing open dynamics and exploring many-body effects in "digital" quantum trajectories through a thermodynamic approach,*** Birmingham Theory Seminars – University of Birmingham/UK 20/03/2025

- Invited Seminar: ***Thermodynamic approach to digital quantum trajectories,*** Physics Theory Group Seminars – University of Warwick/UK 14/03/2025

- Seminar: ***A thermodynamic framework for exploring and controlling quantum trajectories on quantum computers,*** French-German Doctoral College and L4 Seminar – 10/03/2025

- Contributed Talk: ***Absorbing state phase transitions in long-range interacting quantum spin systems,*** 2nd Retreat DFG Research Unit 5413 – Kloster Heiligkreuztal/Germany 22-23/02/2024

- Contributed Talk: ***Spreading of correlations in open quantum systems,*** Collaborative Workshop on transport – Max Planck Institut für Quantenoptik Garching/Germany 17-18/01/2024

- Invited Seminar: ***Absorbing state phase transitions in open quantum systems and quantum cellular automata,*** 5th QuCoLiMa Talks – University of Mainz/Germany 05/12/2023

- Invited Talk: ***Biasing open quantum dynamics on quantum computers,*** 5th Nottingham Workshop on Quantum Non-Equilibrium Dynamics "Emergent and collective phenomena, thermodynamics and fluctuations: From fundamentals to the next generation of quantum devices" – University of Nottingham/UK 13-15/11/2023

- Invited Talk: ***Quantum machine learning with open quantum systems,*** Workshop "NISQ computing without variational algorithms" – HQS Quantum Simulations GmbH, Germany 7-9/11/2023

- Invited Talk: ***Absorbing state phase transitions in quantum cellular automata,*** Workshop "Tensor Networks for Constrained Systems – Kavli Institute of Nanoscience, TU Delft/NL 16-18/10/2023

- Contributed Talk: ***Thermodynamics of quantum trajectories on a quantum computer,*** 15th Italian Quantum Information Science Conference – University of Trieste/IT 18-22/09/2023

- Invited Talk: ***Numerical simulation of open quantum many-body dynamics with tensor networks: absorbing-state phase transitions and long-range interactions,*** Dynamical low-rank approximation: New horizons – EPF Lausanne/CH 22-24/05/2023

- Contributed Talk: ***Absorbing state phase transitions in long-range interacting quantum spin systems,*** 1st Retreat DFG Research Unit 5413 – Kloster Heiligkreuztal/Germany 15-16/02/2023

- Invited Talk: ***Nonequilibrium phase transitions in open quantum systems with absorbing states,*** JSPS London Symposium – University of Nottingham/UK 12-15/12/2022

- Contributed Talk: ***Absorbing state phase transitions in long-range interacting quantum spin systems,*** Kick-off meeting DFG Research Unit 5413 – University of Tübingen/Germany 07/10/2022

- Poster: ***Exponentially accelerated approach to stationarity in Markovian open quantum systems,*** Quantum many-body physics in the presence of an environment – CY Cergy Paris Université /France 7-9/06/2022

- Invited Talk: ***Accelerating the approach towards stationarity in Markovian open quantum systems through the Mpemba effect,*** 12th Nottingham Symposium on Qunatum Systems Nottigham/UK 04/2022

- Contributed Talk: ***Nonequilibrium time-crystal quantum engine***, DPG Spring Meeting Erlangen/Germany 03/2022

- Seminar: ***Nonequilibrium many-body quantum engines,*** University of Tübingen/Germany 06/2021

- Invited Talk: ***Nonequilibrium many-body quantum engine driven by time-translation symmetry breaking***, 11th Nottingham Symposium on Quantum Systems, Nottingham/UK (04/2021)

- Seminar: ***Mpemba effect in Markovian open quantum systems***, University of Granada/Spain 04/2021

- Seminar: ***Nonequilibrium pattern-recognition phase transition in open quantum multimode Dicke models***, MPI for the Science of Light – Erlangen/Germany 16/02/2021

- Seminar: ***Non-equilibrium absorbing state phase transition in open quantum spin chains,*** University of Granada/Spain (03/2019)

- Invited Talk: ***Current fluctuations in boundary-driven quantum spin chains,*** Transport in Strongly Correlated Quantum Systems Conference, Natal/Brazil (07/2018)

- Contributed Talk: ***Current fluctuations in boundary-driven quantum spin chains,*** Conference on Non-equilibrium Systems "CONES 2018", London/UK (06/2018)

- Seminar: ***Current Fluctuations in boundary-driven quantum spin-chains,*** University of

Trieste/Italy 03/2018

- Seminar: ***Quantum entanglement in mesoscopic systems,*** Jagiellonian University, Kraków/Poland 30/05/2016

- Poster: ***Macroscopic Entanglement,*** WE-Heraeus Seminar, Bad Honnef/Germany 17-23/01/2016

- Seminar: ***Non-Markovian many-body dynamics,*** Analysis, Math-Phys, and Quantum, SISSA, Trieste/Italy 05/11/2015

- Seminar: ***Non-Markovian mean-field dissipative dynamics,*** University Roma Tre/Italy 03/11/2015

- Contributed Talk: ***Mean-field dissipative dynamics in infinite quantum systems,*** 8th Italian Quantum Information Science Conference, Monopoli/Italy 10-12/09/2015

- Invited Lecturer: ***Quantum fluctuations and mesoscopic dissipative dynamics,*** 51st Winter School of Theoretical Physics, Ladek Zdroj/Poland 08-14/02/2015

- Contributed Talk: ***Environment induced entanglement in mesoscopic systems,*** 8th Mini-Symposium "On Entanglement" University of Vienna/Austria 10/12/2014

- Contributed Talk: ***Environment induced entanglement in mesoscopic systems,*** Quantum Roundabout Nottingham/UK 29/06/2014-02/07/2014

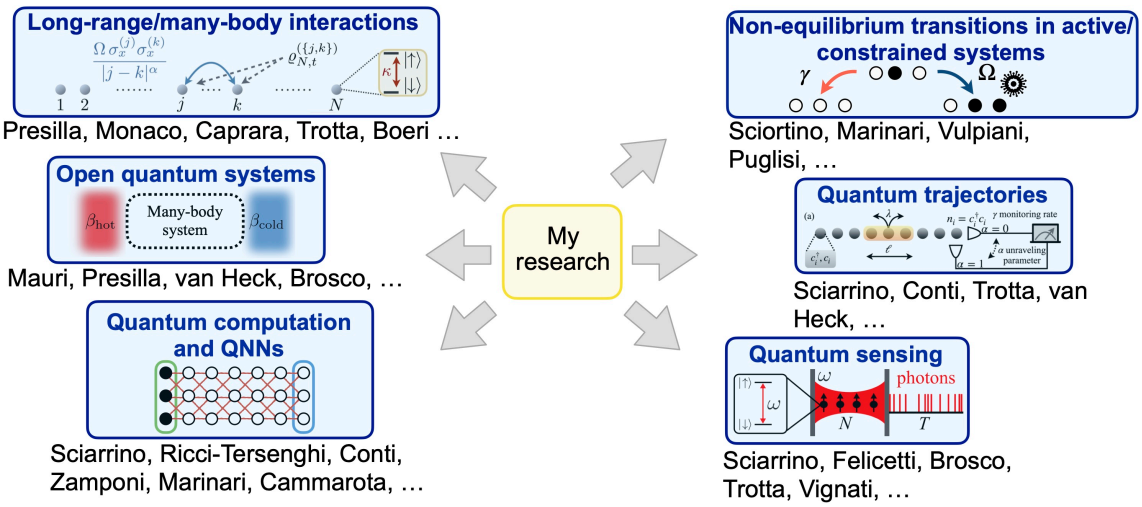
- Contributed Talk: ***Fluctuations algebra and mesoscopic entanglement***, Current Problems in Theoretical Physics, Vietri sul Mare/Italy 11-13/04/2014

Track record, current research, and future research in Rome

My research focuses on the characterisation and control of non-equilibrium behaviour in many-body quantum systems, **bridging quantum condensed matter, quantum information, quantum optics, and statistical physics**. My background ranges from mathematical aspects of open quantum systems to advanced numerical methods for simulating their dynamics. My goal is to develop new theoretical frameworks and computational tools to **uncover novel non-equilibrium many-body quantum phenomena and exploit them for quantum computation, quantum simulation and sensing tasks**. This research is not only at the frontier of fundamental science but also holds promise for impactful technologies, including quantum sensing and information setups.

My **research interests** (summarised in the figure below) demonstrate that **I am an excellent fit for the associate professorship available at the University of Rome La Sapienza** and that my **background complements existing strengths currently present in Rome.**

I further have a **strong network of collaborators**, and I am actively involved in **two major Research Units (FOR 5413 and FOR 5522) funded by the German Research Foundation (DFG)**. These initiatives bring together international leaders in the field of quantum non-equilibrium physics and quantum simulation. Additionally, I am a **collaborator of the quantum company Phasecraft Ltd**, with which I am working on the **quantum simulation of open quantum systems**. I believe it is important to note that, to the best of my knowledge, **none of my collaborators currently have partnerships with institutions in Rome**. This presents a great opportunity for the *quantum group* at La Sapienza to extend its network and immediately engage with, and benefit from, these well-established and successful initiatives which are fully aligned with the topics of this call.



Research interests. *The figure summarises the main research directions that I am currently pursuing, and that I intend to prioritise in the future. Beneath each box, I list a few examples of researchers in Rome (both at La Sapienza and at CNR) with whom it would be natural to discuss and collaborate on these topics. This list is by no means exhaustive, and I expect numerous other collaborations to occur. (Considering the large number of people in the department of physics at La Sapienza, it is simply not feasible to capture every potential partnership.)*

In what follows, I present a sample of my past achievements and outline ongoing and future research directions (connected to the topics highlighted in the figure above) that build on them. The numbers refer to articles in my list of publications.

__**Long-range interacting quantum many-body systems.**__ A central part of my research concerns the exploration of emergent correlations in long-range interacting quantum systems, including light-

matter platforms and collective spin models. Traditional approaches describe these systems in the thermodynamic limit via macroscopic sample-average observables. While such observables provide useful order parameters (e.g. in ensembles of atoms), this perspective tends to suppress genuinely quantum features, yielding effectively classical descriptions.
However, both experiments and theory now establish that many-body systems can exhibit nontrivial **mesoscopic (collective) quantum correlations** even when their macroscopic behaviour appears classical. This raises a fundamental theoretical challenge: identifying the correct degrees of freedom at the **boundary between microscopic and macroscopic physics.**

To address this challenge, I have extensively developed a formalism based on **quantum fluctuation operators** [7,12], which quantify fluctuations of collective observables around their macroscopic average. Under suitable assumptions, these operators satisfy a bosonic algebra emerging through **quantum central limit theorems**. They thus serve as *mesoscopic probes* capable of capturing entanglement and quantum correlations that persist in the thermodynamic limit. Using this framework, I have:

- rigorously characterised dissipative generation of collective entanglement [4,45,67];
- resolved long-standing questions on the interplay between mean-field behaviour and mesoscopic quantum correlations [12,32,36,65];
- established the relevance of fluctuation operators in central spin models, revealing new connections between condensed matter/NMR physics and quantum fluctuations [65].

This line of research provides a powerful and general methodology for understanding emergent quantum behaviour in large systems. My plan is to build on this work to study correlations in **experimentally relevant light-matter interacting systems, cold-atom settings and many-body boson systems** [36,45,67]. Moreover, long-range interacting quantum systems are highly relevant for superconductivity, providing a concrete basis for collaboration with Prof. van Heck and Prof. Boeri on superconducting phenomenology in open quantum settings. A further potential collaboration is with the group of Prof. Trotta, as central spin models provide an effective description of quantum dots, and the theoretical tools I have developed may prove valuable for advancing their analysis. This research strand has also the potential to open collaborations with mathematicians in Rome.

<u>**Thermodynamics of quantum trajectories and dynamical fluctuations.**</u> A second major theme of my research is the development of statistical-mechanics frameworks for **continuously monitored quantum systems**. In modern quantum-optics and/or cavity-QED experiments, photon emissions provide detailed time-resolved information about the system evolution. Understanding these time records is crucial for identifying **dynamical phases, critical behaviour**, and signatures of **complex many-body dynamics.**
I have made significant contributions to the thermodynamics of quantum trajectories, a large-deviation formalism treating trajectories as microstates of a fictitious equilibrium system. This framework introduces dynamical analogues of free energies, entropies, and susceptibilities and provides a **unified language for describing dynamical phases in driven-dissipative systems** [15,33]. My research has shown that this approach is not merely conceptual:

- I have used it to design open dynamics with on-demand photon-emission statistics [9,35,62];
- I have implemented proof-of-principle realisations of these protocols [62];
- I have further shown how this approach opens a new lens on many-body dynamics by revealing phase-transition behaviour at the level of quantum trajectories [86,91].

These results open new routes for engineering non-equilibrium behaviour in driven atomic gases, quantum optical systems, and hybrid light-matter setups. In the future, I indent to advance this programme by exploring monitored many-body systems as a natural platform for realising tuneable dynamical phases. I will investigate how continuous measurement and feedback drive new types of critical behaviour in many-body systems. This includes identifying new universality classes, studying dynamical symmetry breaking, and exploiting measurement-induced transitions in quantum information processing and sensing.

I expect this research programme to foster concrete collaborations with experimental groups in Rome. In particular, the theoretical tools I develop are directly applicable to the analysis of sampling experiments in integrated photonics platforms, creating a natural avenue for collaboration with Prof. Sciarrino on the control and tailoring of photonic output states. For instance, this may lead to the engineering of quantum states of light for sensing purposes and to the implementation of optimal measurement schemes to extract quantum information. In addition, trajectory-based methods and their analysis are highly relevant to quantum Ising machines currently investigated by the group of Prof. Conti, providing a strong basis for collaboration. The thermodynamics of trajectories can also be used to analyse non-classicality of light in quantum-optics setups, as I have shown in Ref. [21], which may also lead to additional collaborations with Prof. Trotta.

Non-equilibrium phase transitions and application to quantum sensing and technology. A consistent theme across my work is the exploration and characterisation of non-equilibrium phases and collective behaviour in many-body systems. My contributions range from **identifying new non-equilibrium universality classes** [17,25,41,57] to exploring their **technological potential**.
Of particular interest are also limit-cycle phases and time-crystalline behaviour in driven-dissipative settings [14,43]. I have shown that these phases of matter (which are purely dynamical) can be used to construct novel quantum engines operating without external periodic driving [28,59]. This represents a fundamentally new paradigm for quantum machines, potentially useful in optomechanical platforms or nanoscale devices.
Moreover, I have demonstrated that limit-cycle phases offer powerful resources for **quantum-enhanced sensing**, enabling continuous parameter estimation beyond classical limits with realistic measurement schemes [69,89,90]. This provides a direct **bridge between theory and experiment**, creating opportunities for collaborative projects.

Building directly on my recent work, I am developing sensing protocols that exploit dynamical transitions, trajectory fluctuations, and time-crystalline behaviour. In the future, I am planning to explore the role of strong and weak symmetries in open quantum systems for sensing applications. These ideas offer a distinctive and timely **link between quantum condensed matter theory and quantum information**.

This research connects naturally to experimental groups in Rome, as well as to researchers specialising in statistical physics and soft/active matter. Notably, indeed, many interesting models and powerful approaches in quantum non-equilibrium physics have been inspired by classical ones [17,41,48,86,91]. I anticipate that this line of research will also lead to collaborations with experts in quantum sensing, such as Dr Felicetti and Dr Brosco at CNR.

Exact results and numerical methods for open quantum (many-body) systems. I also maintain a strong interest in **rigorous mathematical analysis and computational approaches** to quantum many-body systems. From an analytical perspective, I have derived several **theorems establishing the exactness of mean-field approximations** in open quantum systems with long-range interactions, including spin-boson and cavity-QED models [12,32,58,65,78,83]. These results clarify the structure of collective correlations and enable the efficient exploration of experimentally relevant regimes.

On the computational side, I have developed **tensor-network methods for open systems**, including applications to **constrained dynamics** and entirely **new types of non-equilibrium phase transitions** [17,41,48,70]. I am currently developing tree-tensor-network approaches capable of efficiently capturing long-range quantum correlations in higher-dimensional and complex systems.

I will expand my work on tensor networks and analytical methods for open systems, aiming to provide tools for understanding/simulating large-scale monitored quantum matter and long-range interacting systems. This creates strong opportunities for collaboration with mathematical physicists in Rome (e.g. Prof. Presilla and Prof. Monaco). This body of numerical and analytical work will also generally create links with theorists (e.g. Prof. van Heck, Prof. Mauri, Prof. Marinari, Prof. Ricci-Tersenghi and others) and experimentalists (e.g. Prof. Conti and Prof. Trotta). These methods can indeed be adapted to describe a variety of different frameworks, both quantum and classical ones, including the emergence of equilibrium phase transitions in disordered systems and the dynamics of non-equilibrium classical stochastic processes.

<u>From machine-learning effective dynamics to quantum cellular automata and quantum neural networks.</u> A major challenge in many-body physics is identifying **effective dynamical equations for many-body subsystems**, especially far from equilibrium. In collaboration with the Machine Learning Cluster in Tübingen, I have developed interpretable **neural-network approaches** to infer open quantum dynamics directly from data [30]. These methods identify stochastic evolution equations for order parameters, reconstruct non-equilibrium free-energy landscapes, and successfully predict critical exponents [77]. They are robust to finite statistics [71], apply to discrete-time dynamics [79], and are thus suited for analysing experimental datasets or characterising noisy quantum devices.

In parallel, I have initiated a programme on **quantum neural networks** (QNNs), showing that effective nonlinearities, crucial for tasks such as classification, can arise from many-body effects near dynamical phase transitions [55,84]. This provides a mechanism for **quantum-enhanced information processing** and links conceptual insights from non-equilibrium physics to quantum machine learning.

These ideas have strong potential to generate future collaborations in Rome, particularly with experts in machine learning and statistical physics (e.g. Prof. Cammarota, Prof. Ricci-Tersenghi, Prof. Zamponi, Prof. Marinari). In addition, several concepts that I have developed are directly applicable to integrated photonics platforms, opening the door to interactions with Prof. Sciarrino, who is investigating the practical realisation of quantum neural networks.
Furthermore, I have demonstrated that quantum neural networks [84], as well as certain types of open quantum systems [32,58], can perform data classification and pattern recognition tasks, effectively functioning like Hopfield neural networks. This behaviour closely resembles dynamics in quantum Ising machines, highlighting promising opportunities of collaboration with Prof. Trotta.

<u>Research funding and opportunities.</u> My ambition is to establish a strong, internationally recognised research group at the University of Rome La Sapienza by securing competitive external funding. I plan to apply for national funding opportunities in Italy and to establish European Consortia, e.g. applying for QuantERA calls together with my collaborators. I will also work towards attracting outstanding international talents by supporting candidates in obtaining prestigious fellowships, such as Marie Skłodowska-Curie Actions or Chinese Scholarship Council fellowships, to come to Rome. Furthermore, next year, I am planning to apply for an ERC Consolidator Grant, which aligns perfectly with the timing and objectives of this appointment.

Throughout my academic career, I have taught and supervised students at various levels across three European countries: Italy, the UK, and Germany. This international experience equipped me with a broad perspective on teaching and supervision practices, enabling me to develop a coherent and effective approach to both. As highlighted in my CV, I have experience in **tutoring exercise classes**, such as “Theory of quantum information”, “Classical field theory”, as well as in **designing and delivering lecture courses** from scratch.

I am fully aware of the **teaching needs** of a department or university, and I am always willing to **contribute wherever my expertise is most useful**. At the same time, there are several courses that I would be particularly keen to offer at both Master’s and PhD levels. My teaching interests, illustrated by a few examples of potential courses provided below, span quantum many-body physics and quantum information, including the **theory of open quantum systems**, **mathematical aspects of systems with infinitely many degrees of freedom**, and numerical methods such as tensor networks for **simulating many-body quantum dynamics**. These topics are central to the training of theoretical physicists working on non-equilibrium quantum systems and quantum information.

I am also interested in designing and delivering more **“hands-on” courses**, from which I believe the students would benefit greatly. One example would be a course on **practical quantum computing**, in which, after a brief theoretical introduction, students would **directly implement and test quantum circuits** using platforms, such as the IBM Quantum framework, which are accessible online and have built-in classical simulators. This approach would allow them to acquire practical skills, understand the limitations of current hardware (such as coherence times and gate fidelities) and become proficient with state-of-the-art tools. This training would be particularly valuable for students who do not plan to pursue an academic career but are interested in **opportunities offered by quantum start-up companies**. Similar practice-oriented courses could also be developed in areas such as machine learning or numerical simulations (see last example below), which are also relevant beyond academia.

<u>Teaching concept</u>

In order to deliver engaging academic courses and retain student interest, I meticulously prepare my lectures and consider the best ways to present concepts and derivations, incorporating real-world examples. I provide detailed lecture notes to help students to follow along and reinforce learning.
However, preparation alone is not sufficient and **active student engagement is crucial**. From the first lecture, I strive to establish a **direct connection with students**, encouraging their participation. I am committed to creating an **inclusive and diverse learning environment**, where students feel valued, heard and comfortable, regardless of their background and character. When questions arise, I **facilitate a class-wide discussion** rather than simply providing answers, promoting peer learning and a classroom atmosphere where different perspectives are respected and encouraged. **Regularly looking for comments and feedback** allows me to gauge the class dynamics and student progress.

Course structure and delivery

Regarding the courses, I believe in clearly outlining from the outset their content, together with their **immediate importance** and their **long-term relevance also outside academia**. It is equally important to set clear expectations for both students and me.
To aid comprehension of complex concepts, I introduce topics gradually, starting with basic examples, conveying core ideas, and progressively moving to more advanced theories. As a theoretical physicist, I like my students to make **connections between different topics and fields**, to **articulate difficult concepts** and to develop and explain derivations with both **physical intuition and mathematical rigour**. I also like to show them various approaches to a same problem and to show how each of them offers a unique perspective.

To maintain student focus, I start by **recapping the previous lecture** and **outlining the objectives** for the current one. I conclude each lecture with a **three-sentence summary of the key points discussed**. These practices have been **well-received by students**.

Assignments and evaluation
Students should always be aware of what is expected from them in terms of assignments and examinations. I provide homework and exercises well in advance to help students manage their semester workload efficiently. My evaluations are clear and transparent, emphasising both strengths and areas for improvements.

Adaptive teaching approach
Beyond covering core material, I like to offer students some choice in the course's direction. For example, I may present a few topics for upcoming lectures and let the students decide based on their preference. This approach allows me to adapt the course to the interest of the class and to incorporate emerging topics in current research.

<u>Supervision concept</u>
With a broad experience in supervising students across different levels and different countries, I see supervision as a key role in **developing independent, critical, and creative researchers**. In my view, the primary goal of supervision is not only to guide students toward concrete scientific results, but also to foster critical thinking, problem-solving skills, and intellectual independence. These abilities are most effectively developed when students are encouraged, from an early stage, to actively engage with challenging problems under expert guidance.
I place strong emphasis on **clear scientific communication and critical self-reflection**. Students are encouraged to explain their work to peers, to consider their results within a broader context, and to openly discuss encountered challenges. This approach improves both the quality of the research and the effectiveness of supervision. I maintain an **open-door policy** and create a **supportive environment** in which students feel comfortable experimenting and asking questions. After an initial phase in which I teach students the necessary background, I gradually encourage them to take the lead in their projects, providing guidance without micromanaging their work. Whenever possible, I assign research problems of real interest, which **often lead to publications** and give students **experience in scientific writing** and collaboration.

Finally, I expose students to different methodological approaches and support them in choosing those best aligned with their interests and strengths. Thanks to my background spanning several theoretical and numerical methods, I can help students obtaining different perspectives on the same problem, **stimulating flexibility and creativity** in their research.

Example course 1: Large deviation approach to non-equilibrium physics

<u>Abstract:</u>
The aim of this course is to introduce the fundamental concepts that are at the basis of the theory of large deviations as applied to the statistical mechanics of non-equilibrium physical systems. In most cases, the time evolution of non-equilibrium physical systems is governed by an underlying stochastic process. Therefore, a description of the dynamics "on average" is often insufficient to capture the essential dynamical features of the system.

To illustrate this point, consider an atom system emitting photons towards a detector. Knowledge of the average photon-emission rate alone does not reveal whether emissions occur uniformly in time or in a highly intermittent manner. More generally, average descriptions neglect rare events and fluctuations, which play a crucial role in non-equilibrium dynamics. Although certain fluctuations may occur with low probability, understanding and characterising their structure is of fundamental importance. Such an analysis can reveal non-trivial dynamical features and even novel dynamical phases, including regimes characterised by highly ordered photon emissions or exceptionally efficient transport regimes.

In this course, we will explore how large deviation theory can be applied to non-equilibrium systems to derive large deviation rate functionals that describe the statistical properties of dynamical fluctuations. These functionals, which play a role analogous to free-energy and entropy in equilibrium statistical mechanics, can signal the presence of dynamical phase transitions or critical phenomena in the space of stochastic trajectories. Moreover, the formalism gives access to the detailed dynamical properties of rare fluctuations and allows one to identify the optimal stochastic process for which an atypical outcome of some observable becomes the typical behaviour.

Although the course is primarily focused on non-equilibrium physics, the methods and concepts introduced are of much broader relevance, with applications extending to fields such as economics and finance. Students will therefore acquire foundational tools that are widely used in contemporary scientific research and that also have direct relevance in non-academic and industrial contexts.

Example course 2: Dissipative dynamics of quantum systems

Abstract:

The aim of this course is to introduce the formalism used to describe non-unitary quantum dynamics together with the key ideas underlying the derivation of quantum master equations. We will also discuss how quantum master equations provide an effective description of the average dynamics of quantum systems whose evolution can also be represented by stochastic Schrödinger equations. This arises for instance in continuously monitored quantum systems, such as those encountered in photon-counting and homodyne-detection experiments. In many models in quantum optics and atomic physics, it is essential to account for the fact that realistic physical implementations are subject to dissipative processes and noise-induced mixing. In such situations, the standard Schrödinger equation, which describes the deterministic evolution of isolated quantum systems, is no longer adequate, and one must instead employ non-unitary dynamical descriptions often formulated in terms of (Markovian) quantum dynamical semigroups.

The course adopts an axiomatic approach to open quantum dynamics, discussing the fundamental properties that a dynamical map must satisfy to represent a physically admissible quantum evolution. In addition, we will present a derivation of Markovian dissipative dynamics from first principles, by considering the interaction of a quantum system with a thermal bath consisting of an infinite number of bosonic degrees of freedom. Finally, we will introduce the basic ideas behind quantum trajectories and stochastic Schrödinger dynamics.

The theory of open quantum systems plays a central role in several areas of modern physics. It is crucial for the study of non-equilibrium phenomena, both in genuinely dissipative settings and in unitary quantum quenches. In the latter case, attention is focused on a reduced set of degrees of freedom of an underlying many-body system, for which thermalisation and equilibration phenomena, reminiscent of those found in dissipative dynamics, can emerge.

Example course 3: Numerical simulation of (open) quantum many-body dynamics

Abstract:

Understanding the non-equilibrium properties of many-body quantum systems is notoriously challenging due to the exponential growth of resources required to represent their quantum state. This growth rapidly exceeds the capabilities of classical computational methods. To overcome this limitation, matrix product states have become a cornerstone of modern numerical approaches to the simulation of quantum many-body systems, particularly in one spatial dimension.

This course begins with an overview of exact numerical diagonalisation techniques for the simulation of both closed and open quantum many-body systems, highlighting their rapid breakdown as system size increases. We then introduce the theoretical framework and practical implementation of matrix-product-state methods. A central component of the course is the time-evolving block-decimation algorithm, which will be employed to study ground-state and thermal-state properties of equilibrium systems as well as Lindblad dynamics and quantum trajectories in open quantum systems.

Throughout the course, equal emphasis is placed on conceptual understanding and hands-on computational implementation. By the end of the course, students will have acquired practical experience with tensor-network techniques and will be well equipped to apply matrix-product-state methods to a wide range of problems in condensed matter physics, quantum information, and out-of-equilibrium dynamics.