Nicolò Defenu – Curriculum Vitae

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Date of Birth	19^{th} May 1988	**Office Phone**	+41 44 633 78 75
Nationality	Italian	**Institute Email**	ndefenu@phys.ethz.ch
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Education

11/2010 BSc with honors - Sapienza University of Rome, Roma

110/110 cum laude - 28/30 Average
Third Year Project - Second Quantization with application to phonon propagation.
Advisor: M. Testa

10/2012 MSc with honors - Sapienza University of Rome, Roma

110/110 cum laude - 29/30 Average
Final Year Project -Overhauser method for pair correlation function calculation applied to density functional theory.
Advisor: J. Lorenzana

18/10/2016 PhD with honors - International School for Advanced Studies (SISSA), Trieste

PhD cum laude (Maximum degree in the Italian System)
PhD Thesis -Application of Functional Renormalization Group Approach to spin systems and long range models.
Advisors: S. Ruffo, A. Trombettoni and A. Codello

01/2022 Italian National Scientific Habilitation:

Theoretical condensed matter physics
II Level.

01/2022 Italian National Scientific Habilitation:

Theoretical physics of fundamental interactions
II Level.

Past Positions

Dec 2016 Institute for Theoretical Physics (ITP), Philosophenweg, 19 - 69120 Heidelberg, Germany
Four years Post-Doc position in the group of Prof. Dr. Tilman Enss.

Present Position

Mar 2020 Institute for Theoretical Physics, ETH Zürich, Wolfgang-Pauli-Str. 27, 8093, Zürich, Switzerland
Three years Post-Doc position in the group of Prof. Dr. Gian Michele Graf.

Institutional Responsability

2013-2015 Webmaster of the theoretical condensed matter group, SISSA, Italy.

2018-2019 Member of the Young Researchers Board in the Structures Excellence Cluster, Heidelberg.

2018-2020 Seminar Organisation at the Institute for theoretical physics, Heidelberg University.

Approved Research Project

2018-2019 Individual research fellow: 2019-Individual research fellow of the Young Investigator Training Program.
"Functional Renormalization Group Methods in Quantum and Statistical Physics".'
Amount: 3'000€, **Role**: Principal Investigator

2020-2022 Exploratory Project of Structures Excellence Cluster, Heidelberg.
"Universality on Network Structures from Quantum Dynamics to Big Data."
Amount: 150'000€, **Role**: Principal Investigator

2022-2024 Exploratory Project of Structures Excellence Cluster, Heidelberg.
"Critical behavior of epidemic models on distinct network topologies and applications to the study of brain disease."
Amount: 150'000€, **Role**: Co-Principal Investigator

Supervision of graduate students and post-doctoral fellows

2019-2020 Master Student: Marvin Syed, M. Sc. Heidelberg University, Germany
Thesis Title: *"Dynamical Quantum Phase Transitions in the Spherical Model."*

2019-2020 Master Student: Alberto Giuseppe Catalano, M. Sc. Heidelberg University, Germany
Thesis Title: *"Renormalization group approach to the solution of integrals and Schrödinger eigenvalues equations"*

2020-2021 Master Student: Pascal Schweizer, M. Sc. ETH, Zurich
Thesis Title: *"Quantum Criticality and the Spherical Model on a Graph."*

2020-2021 Master Student: Benjamin Liégeois, M. Sc. ETH, Zurich
Thesis Title: *"A functional RG approach to PT-symmetric models."*

2020-2021 Master Student: Ka Rin Sim, M. Sc. ETH, Zurich
Thesis Title: *"Quantum quenches in Hermitian and non-Hermitian systems."*

2018-2022 PhD Student: Guido Giachetti, Ph. D. SISSA, Trieste
PhD Project: *"Topological phase transition with long-range interactions."*

2021-Pres. PhD Student: Andrea Solfanelli, Ph. D. SISSA, Trieste
PhD Project: *"Quantum thermodynamics of long-range systems."*

2021-Pres. PhD Student: Ka Rin Sim, Ph. D ETH, Zurich
PhD Project: *"Kibble-Zurek mechanism in non-Hermitian systems."*

2022-Pres. PhD Student: Benjamin Liégeois, Ph. D. ETH, Zurich
PhD Project: *"Strongly interacting non-Hermitian systems."*

2020-Pres. Post-Doc Fellow: Giacomo Bighin Heidelberg University, Germany.
Post-Doc Project: *"Universality on Network Structures from Quantum Dynamics to Big Data."*

Teaching experience

2017-2020 Teaching Assistant at Heidelberg University, Germany.
Graduate Course: *"Advanced Condensed Matter Theory."*
Graduate Course: *"Condensed Matter Theory."*
Bachelor Course: *" Seminar on Statistical Physics."*
Graduate Course: *"Theoretical Statistical Physics."*
Bachelor Course: *"Seminar on Nonlinear Systems"*

2018 Guest lecturer at University of Massachussets, Boston, USA.
Bachelor Course: *"Thermodynamics and Statistical Mechanis"*

2019-2021 Head Teaching Assistant at Heidelberg University, Germany.
Graduate Course: *"Theoretical Statistical Physics."*

2019-2020 Lecturer of the Stat. Phys. sector at SISSA, Italy.
Graduate Course: *"Functional Renormalization Group."*

2020-2022 Co-Instructor for seminar courses at ETH Zürich, Switzerland.
Graduate Course: *"Proseminar on Renormalization Group."*
Graduate Course: *"Proseminar in Theoretical Physics."*
Graduate Course: *"Solitons and Instantons in Condensed Matter."*

2021 Lecturer at the domestic graduate school, Mainz University, Germany.
Course: *"Statistical mechanics and dynamics of long-range quantum spin systems."*

2022 Tutor at the Spring College in the Physics of Complex Systems, ICTP, Italy.
Course: *"Statistical mechanics of long-range interacting systems*

Memberships in Panels, Boards / Individual Scientific Reviewing Activities

2018-2019 Member of the Young Researchers Panel in the Structures Excellence Cluster, Heidelberg.

2018-2019 Invited Referee for multiple journals:
PRA, PRB, PRE, PRL, J. Stat. Mech, Eur. Phys. J. C, Comm. Phys. (Nature), Sci-Post.

Active memberships in scientific societies, fellowships in renowned academies

2016-2022 External Member of SISSA (Trieste), Italy.

2016-2022 External Member of the CNR Istituto officina dei materiali (Trieste), Italy.

2018-2022 Member of the Collaborative Research Centre 1225 at the University of Heidelberg, Germany.
Title: *"ISOQUANT: Isolated quantum systems and universality in extreme conditions"*

2018-2020 Member of the Structures Excellence Cluster at the University of Heidelberg, Germany.
Title: *"STRUCTURES: A unifying approach to emergent phenomena in the physical world, mathematics, and complex data.*

2019-2021 The CNR/MTA Italy-Hungar Joint Project CNR Istituto officina dei materiali (Trieste), Italy.
Title: *"Strongly interacting systems in confined geometries"*

2020-2022 External Member of Excellence Cluster at the University of Heidelberg, Germany.
Title: *"STRUCTURES: A unifying approach to emergent phenomena in the physical world, mathematics, and complex data.*

2020-2022 Member of the National Centre of Competence in Research, Switzerland.
Title: *"The mathematics of Physics (SwissMAP)"*

Organization of conferences

07/2021 "1st Workshop on Low Dimensional Quantum Many Body Systems."
Location: Internationales Wissenschaftsforum Heidelberg, Germany.

07/2022 "Out-of-equilibrium and collective dynamics of quantum many-body systems."
Location: The Pauli Center for Theoretical Studies, Zurich, Switzerland.

09/2023 "Out-of-equilibrium dynamics and quantum information of many-body systems with long-range interactions." (Pre-Approved)
Kavli Institute for Theoretical Physics, Santa Barbara, California.

Major Scientific Achievements

- **Critical behaviour of quantum long range $O(N)$ ferromagnets.** [*Phys. Rev.* B, **96**, 104432 (2017)]
  In presence of long range interactions the traditional quantum to classical correspondence is spoiled and the universal behaviour at the quantum critical point of an $O(N)$ ferromagnet in dimension d is not equal to the one of its classical equivalent in dimension $d+1$. I devised a generalisation of my early PhD studies to address the quantum critical behaviour of long range ferromagnetic models, leading to the current best estimates for the critical exponents of these systems. These results are fundamental to the interpretation of atomic molecular and optics experiment, which can simulate long-range quantum spin Hamiltonians. I developed the idea and carried on the calculation and interpreted the results.
- **Universal dynamical scaling in fully connected models.** [Phys. Rev. Lett. **121**, 240403 (2018)]
  The problem of universal dynamical scaling for fully connected models at slow drives has been source of enormous interest among the cold atom community, since the introduction of cavity QED and trapped ion platforms. Still, no ultimate answer had emerged for this problem due to the difficulty for numerical technique to access the scaling region and to the failure of traditional Kibble-Zurek scaling. I recognised the analogy of this problem with the one of a single Boson mode and I was able to derive an analytical solution, interpreting all the previous numerical evidences found in the literature. Moreover, I exactly proved that fully connected systems are non-adiabatic for any form of quasi static drives and derived their universal scaling corrections [Comm. Phys. **4**, 150 (2021)].
- **Quantum Anomalies in two dimensional fermi gases.** [Science **365**, 268 (2019)]
  As a member of the ISOQUANT collaboration, it was part of my project to interact with experimental groups. The comparison between the real space imaging of a two dimensional cold atom cloud and the measurement of its momentum distribution was devised by myself, with the scope of identifying the corrections generated by the breaking of scale invariance due to quantum fluctuations. The experimental group of Prof. S. Jochim performed the measurement, leading to the first evidence of quantum anomaly in the dynamical evolution of fermi gases.
- **Topological phase transitions in high order correlations.** [*Phys. Rev. Lett.* **123**, 100601 (2019)]
  Coupling multiple 2D magnetic layers shall not generate any additional continuous critical point with respect to the case of the single isolated layer. While we confirmed this expectation for second order phase transitions, we discovered a novel topological phase in the scaling of multi-body correlations for two coupled magnetic layers, each displaying Berezinksii-Kosterlitz-Thouless scaling. This novel form of scaling scenario was theoretically depicted by myself, thanks to *ad-hoc* devised self-consistent method, and used to justify the numerical observations made by G. Bighin. Our result paves the way to the understanding of topological scaling and defect unbinding in a wide range of exotic 2D materials, possibly including High-T_c superconductors, where the layered structure has a fundamental impact on criticality.
- **Discrete spectrum of long-range quantum systems.** [*Proc. Nat. Acad. Sci.* **118** e2101785118 (2021)]
  The linear dynamics of closed quantum systems produces well-known difficulties in the definition of quantum chaos. This leads to several issues in the theoretical justification of the equilibration and thermalization dynamics observed in closed experimental systems. In the case of large harmonic baths these issues are partially resolved due to the continuous nature of the spectrum, which produces divergent Poincaré recurrence times. As noticed already by Boltzmann in his early investigations on classical systems, the divergence of Poincaré recurrence times in the large size limit reconciles the deterministic description of quantum/classical systems with the ergodic hypothesis of statistical mechanics. I was able to prove that such a scenario does not apply to long-range systems, where the microscopic components interact via a power-law two body potential of the form $V(r) \sim 1/r^{\alpha}$, with $\alpha < d$ where d is the dimension of the system. The spectrum of these systems remains discrete up to the thermodynamic limit, in contradiction with the textbook description of infinitely extended systems, leading to finite Poincaré recurrence times also for large size systems. This leads to the emergence of long-lived quasi-stationary states (QSSs) after a sudden quench of the Hamiltonian internal parameters. These states present a macroscopic lifetime, which increases with the system size. Despite their ubiquity in the context of long-range interacting systems, the fundamental mechanism at the root of their existence had remained unknown until the picture I derived in Ref. [*Proc. Nat. Acad. Sci.* **118** e2101785118 (2021)].