Dr Bruno Bertini

Date of Birth: 10/12/1988
Place of Birth: Piombino, Province of Livorno, Italy
Citizenship: Italian
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Research Career

- **Postdoctoral Fellow** at the **University of Ljubljana** — **2017 - Present**
  Supervisor: *Prof. Tomaž Prosen*
- **Postdoctoral Fellow** at **SISSA**, Trieste — **2015 - 2017**
  Supervisor: *Prof. Pasquale Calabrese*

Education

- **D. Phil Student** at the **University of Oxford** — **2012 - 2015**
  Supervisor: *Prof. Fabian Essler*
  Degree: *D.Phil (PhD) in Theoretical Physics*
- **Allievo (Student)** at **Scuola Normale Superiore di Pisa** — **2010 - 2012**
  Degree: *Diploma di Licenza in Fisica*
  Grade: *70/70 cum laude*
- **Master Student** at the **University of Pisa** — **2010 - 2012**
  Supervisors: *Prof. Pasquale Calabrese, Prof. Mihail Mintchev*
  Degree: *Laurea Magistrale in Fisica Teorica (Master's Degree in Theoretical Physics)*
  Grade: *110/110 cum laude*
- **Undergraduate Student** at the **University of Pisa** — **2007 - 2010**
  Supervisor: *Prof. Enore Guadagnini*
  Degree: *Laurea Triennale in Fisica (Bachelor's Degree in Physics)*
  Grade: *110/110 cum laude*

Awards

- **Marie Skłodowska-Curie Actions Seal of Excellence** — **2019**
  (Quality label awarded to all proposals submitted to the MSCA Individual Fellowships Call that scored above 85% (mine was 90.4%) but could not be funded from the call budget)
- **Invited Lecturer at the school SFT 2019** — **2019**
  Postgraduate school on subjects related to Statistical Physics held yearly at the Galileo Galilei Institute in Florence
- **Selected at the entrance exam of Scuola Normale Superiore di Pisa** — **2010**
  (Highly competitive exam that gives access to additional lectures, exclusion from tuition fees, free accommodation and meals for the entire duration of the undergraduate studies)

Research Topics

- Non-Equilibrium Dynamics in Quantum Many-Body Systems
- Integrable Systems (Quantum Spin Chains and Integrable Quantum Field Theories)
- Weakly Non-Integrable Systems and Prethermalization
- Entanglement in Many-Body Systems
- Many-Body Quantum Chaos

Technical Skills

- ☐ Analytical Expertise:
  Bethe Ansatz Techniques (Coordinate, Algebraic, and Thermodynamic Bethe Ansatz), Integrable Scattering Matrices, Form Factor Approaches, Bosonization, Quantum Field Theory, Transfer Matrix Approaches, Equation-of-Motion Techniques, Free Fermion Techniques.
- ☐ Numerical Expertise:
  C/C++ computational tools, Mathematica, Matlab.

Teaching

- ☐ **Lecturer** at the **GGI**, Florence **2019**
  Course: *Transport in closed one-dimensional systems*
  (Part of the PhD school SFT 2019 – Lectures on Statistical Field Theories)
  Course Length: *6 hours*
- ☐ **Lecturer** at the **University of Ljubljana** **2019**
  Course: *Selected Topics in Theoretical Physics*
  (Part of a course teaching selected topics in theoretical physics to PhD students of all physics areas)
  Course Length: *6 hours*
- ☐ **Problem Class Tutor** at the **University of Oxford** **2013**
  Course: *C6 Theoretical Physics*
  (Theoretical physics for master students of the final year)
  Course Length: *1 Term*

Recent Professional Activities

- ☐ **Referee**
  APS Journals: *Phys. Rev. Lett., Phys. Rev. X, Phys. Rev. A, Phys. Rev. B., Phys. Rev. E*
  IOP Journals: *J. Stat. Mech.*
  Springer Journals: *JHEP*
  SciPost Journals: *SciPost Physics*
- ☐ **Organiser**
  Trieste-Ljubljana meeting (meeting of the statistical physics groups of SISSA, ICTP, and University of Ljubljana held three times a year)

References

Prof. Fabian H. L. Essler fabian.essler@physics.ox.ac.uk
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Publication List

Overview. I authored **21** papers (20 of them have been published/accepted for publication in peer reviewed journals while one is under review). These include **1** paper published in Physical Review X and **5** letters published in Physical Review Letters. My other articles appear in Physical Review B (5), Journal of Statistical Mechanics (7), Journal of Physics A (1), and SciPost Physics (1).

Citations. So far I have obtained **766** citations. My h-index is currently **15**, while my i10-index is **16** (source Google Scholar). The number of citations of each paper according to Google Scholar is reported by the bold number in brackets.

[21] **B. Bertini**, L. Piroli, and M. Kormos, *Transport in the sine-Gordon field theory: from generalized hydrodynamics to semiclassics*, arXiv:1904.02696 (2019) [Phys. Rev. B, in print].

[20] **B. Bertini**, P. Kos, and T. Prosen, *Exact Correlation Functions for Dual-Unitary Lattice Models in 1+1 Dimensions*, arXiv:1904.02140 (2019).

[19] V. Alba, **B. Bertini**, and M. Fagotti, *Entanglement evolution and generalised hydrodynamics: interacting integrable systems*, SciPost Phys. **7**, 005 (2019). **(1)**

[18] **B. Bertini**, P. Kos, and T. Prosen, *Entanglement spreading in a minimal model of maximal many-body quantum chaos*, Phys. Rev. X **9**, 021033 (2019). **(4)**

[17] M. Mestyán, **B. Bertini**, L. Piroli, and P. Calabrese, *Spin-charge separation effects in the low-temperature transport of 1D Fermi gases*, Phys. Rev. B **99**, 014305 (2019). **(6)**

[16] **B. Bertini**, M. Fagotti, L. Piroli, and P. Calabrese, *Entanglement evolution and generalised hydrodynamics: noninteracting systems*, J. Phys. A: Math. Theor. **51**, 39LT01 (2018). **(22)**

[15] **B. Bertini**, P. Kos, T. Prosen, *Exact Spectral Form Factor in a Minimal Model of Many-Body Quantum Chaos*, Phys. Rev. Lett. **121**, 264101 (2018). **(15)** [**Selected for a commentary in *Journal Club for Condensed Matter Physics***]

[14] **B. Bertini**, E. Tartaglia, and P. Calabrese, *Entanglement and diagonal entropies after a quench with no pair structure*, J. Stat. Mech. (2018) 063104. **(14)**

[13] **B. Bertini** and L. Piroli, *Low-Temperature Transport in Out-of-Equilibrium XXZ Chains*, J. Stat. Mech. (2018) 033104. **(21)**

[12] **B. Bertini**, L. Piroli, and P. Calabrese, *Universal broadening of the light cone in low-temperature transport*, Phys. Rev. Lett. **120**, 176801 (2018). **(19)**

[11] **B. Bertini**, E. Tartaglia, and P. Calabrese, *Quantum Quench in the Infinitely Repulsive Hubbard Model: The Stationary State*, J. Stat. Mech. (2017) 103107. **(15)**

[10] L. Piroli, J. De Nardis, M. Collura, **B. Bertini**, and M. Fagotti, *Transport in out-of-equilibrium XXZ chains: non-ballistic behavior and correlation functions*, Phys. Rev. B **96**, 115124 (2017). **(68)**

[9] M. Mestyán, **B. Bertini**, L. Piroli, and P. Calabrese, *Exact solution for the quench dynamics of a nested integrable system*, J. Stat. Mech. (2017) 083103. **(39)**

[8] **B. Bertini**, *Approximate light cone effects in a non-relativistic quantum field theory after a local quench*, Phys. Rev. B **95**, 075153 (2017). **(17)**

[7] **B. Bertini**, F.H.L. Essler, S. Groha, N.J. Robinson, *Thermalization and light cones in a model with weak integrability breaking*, Phys. Rev. B **94**, 245117 (2016). **(35)**

[6] **B. Bertini**, M. Collura, J. De Nardis, and M. Fagotti, *Transport in Out-of-Equilibrium XXZ Chains: Exact Profiles of Charges and Currents*, Phys. Rev. Lett. **117**, 207201 (2016). **(175)** [**Selected for a Viewpoint in *Physics***]

[5] **B. Bertini** AND M. FAGOTTI, *Determination of the Nonequilibrium Steady State Emerging from a Defect*, Phys. Rev. Lett. **117**, 130402 (2016). **(42)**

[4] **B. Bertini**, L. PIROLI, P. CALABRESE, *Quantum quenches in the sinh-Gordon model: steady state and one point correlation functions*, J. Stat. Mech. (2016) 063102. **(45)**

[3] **B. Bertini**, F.H.L. ESSLER, S. GROHA, N.J. ROBINSON, *Prethermalization and Thermalization in Models with Weak Integrability Breaking*, Phys. Rev. Lett. **115**, 180601 (2015). **(97)**

[2] **B. Bertini** AND M. FAGOTTI, *Pre-Relaxation in Weakly Interacting Models*, J. Stat. Mech. (2015) P07012. **(46)**

[1] **B. Bertini**, D. SCHURICHT, F.H.L ESSLER, *Quantum Quench in the Sine-Gordon Model*, J. Stat. Mech. (2014) P10035. **(84)**

Recent Invited Talks (since 2017)

- ☐ *Dual-unitary quantum circuits*
  Event: Invited seminar, Ecole Normale Superiéure of Paris, France
  Date: June 2019
- ☐ *Exact Spectral Form Factor and Entanglement Spreading*
  Event: Young Researches Meeting in Integrable Systems, University Cergy-Pontoise, France
  Date: June 2019
- ☐ *Dual-unitary quantum circuits*
  Event: Emergent Hydrodynamics in Low Dimensional Quantum Systems, IIP Natal, Brazil
  Date: May 2019
- ☐ *Exact Spectral Form Factor and Entanglement Spreading in a Minimal Model of Many-Body Quantum Chaos*
  Event: Condensed Matter Theory Seminar, Budapest University of Technology and Economics, Hungary
  Date: March 2019
- ☐ *Transport in Closed Integrable Systems*
  Event: Condensed Matter Theory Seminar, University of Pisa, Italy
  Date: February 2019
- ☐ *Exact Spectral Form Factor and Entanglement Spreading in a Minimal Model of Many-Body Quantum Chaos*
  Event: Christmas Symposium of Physicists, Maribor, Slovenia
  Date: December 2018
- ☐ *Exact Spectral Form Factor in a Minimal Model of Many-Body Quantum Chaos*
  Event: The Forum, University of Oxford, UK
  Date: October 2018
- ☐ *Exact Spectral Form Factor in a Minimal Model of Many-Body Quantum Chaos*
  Event: Non-equilibrium behaviour of isolated classical and quantum systems, SISSA Trieste, Italy
  Date: September 2018
- ☐ *Transport in Closed One-Dimensional Systems: Integrable Models and Universality at Low Temperatures*
  Event: Transport in strongly correlated quantum systems, IIP Natal, Brazil
  Date: August 2018
- ☐ *Transport in Closed One-Dimensional Systems: Integrable Models and Universality at Low Temperatures*
  Event: Quantum Paths, ESI Vienna, Austria
  Date: April 2018
- ☐ *Transport in Closed One-Dimensional Systems: Integrable Models and Universality at Low Temperatures*
  Event: Nonequilibrium Phenomena in Quantum Systems, Krvavec, Slovenia
  Date: December 2017
- ☐ *Transport in Closed One-Dimensional Systems: Integrable Models and Universality at Low Temperatures*
  Event: Condensed Matter Theory Seminar, University of Amsterdam
  Date: December 2017
- ☐ *Transport in Integrable Spin Chains and Beyond*
  Event: Wonders of Broken Integrability, Simons Center for Geometry and Physics, Stony Brook, USA
  Date: October 2017
- ☐ *Transport in out-of-equilibrium spin chains*
  Event: DPG meeting, Dresden, Germany
  Date: March 2017
- ☐ *Transport in out-of-equilibrium spin chains*
  Event: Condensed Matter Theory Seminar, City, University of London
  Date: March 2017
- ☐ *Transport in out-of-equilibrium spin chains*
  Event: Condensed Matter Theory Seminar, University of Ljubljana
  Date: January 2017

Research Statement

My research interests lie on the field of out-of-equilibrium quantum statistical mechanics. In particular, my main goal is to obtain a full microscopic description of relaxation processes in isolated quantum many-body systems.

Achieving a microscopic description of relaxation mechanisms is one of the most enduring research themes in theoretical physics and engages scientists since the days of Boltzmann. Nonetheless, the fundamental mechanisms allowing isolated systems to relax have not yet been found, and relaxation processes are typically explained by employing ergodicity arguments, which give no information on the time-scales, or are essentially accepted as an additional law of nature. Even if these points of view are sufficient for many practical purposes a solution of the conceptual problem remains highly desirable and quantum mechanics offers the cleanest framework to perform this investigation.

Strong pressure towards more accurate theoretical investigations of relaxation in isolated quantum systems was provided by the recent progress in experimental and computational techniques. Indeed, while in the past experiments were conducted on "real" solids and were unable to observe unitary dynamics due to unavoidable decoherence and dissipation effects, recent breakthroughs in experimental techniques led to the realisation of "synthetic" quantum many-body systems composed of cold atomic gases in optical lattices. These systems can display coherent unitary evolution on large time scales, providing the perfect experimental framework for a thorough analysis of relaxation mechanisms. At the same time, novel numerical techniques to simulate quantum many-body dynamics became available, giving a reliable touchstone to compare with theoretical predictions. These two facts stimulated a renaissance of theoretical investigations aiming for an analytical characterisation of relaxation mechanisms.

During the course of my research I investigated several aspects of this problem. Specifically, my interests can be divided in three main strands. The first concerns the study of isolated, homogeneous (i.e. translational invariant), many-body systems after the switch of a sudden homogeneous perturbation (homogeneous quantum-quench). This represents the minimal non-trivial setting for studying non-equilibrium dynamics and allows for substantial quantitative understanding. In particular, the best-understood case is that integrable systems, a special class of many-body systems (non-trivial in one dimension) characterised by the presence of an extensive number of local conservation laws. In this context I computed time evolution and stationary values of relevant observables in interacting integrable systems (both lattice models and quantum field theories) [1, 4, 9, 11], using a combination of form-factor expansions and Bethe ansatz techniques. I studied the spreading of entanglement in interacting integrable models and in free systems prepared in exotic initial states [14], where the standard quasiparticle picture for the entanglement spreading has to be modified. Finally I investigated the dynamics of weakly non-integrable systems [2, 3, 7], observing a crossover from integrable to non-integrable dynamics similar to those described by the celebrated Kolmogorov-Arnold-Moser theory in few-particle classical systems. In particular in Ref. [3] we presented the first theoretical modelisation of this phenomenon, known as prethermalization, in a finite-dimensional system.

The second strand of my research concerns the study of non-equilibrium dynamics of isolated quantum many-body systems that are not invariant under translations, namely they are inhomogeneous. This setting is closer to the experimental setups and generates a much richer phenomenology. For instance, it allows one to observe transport phenomena. My most recognised work in this context, Ref. [6], concerns the study of transport in integrable systems. The theory that I contributed to develop, now known as "generalized hydrodynamics", is currently receiving considerable attention from the scientific community. It is a subject of international conferences (see, e.g., here) and of commentaries in popular science journals (see e.g. J. Dubail, Physics **9**, 153 (2016); R. Berkowitz, Physics Today, 3rd of April 2019). Together with my works on the development of the theory (see also Refs. [5] and [10]), I also also contributed in extending it to study the entanglement spreading [16, 19], and I found explicit solutions in free cases [5, 7] and in interacting cases via asymptotic expansions [12, 13, 21]. The latter have been used to find novel physical effects [12] and to compare generalized hydrodynamics with existing approximate analytical approaches, such as the semiclassical approach of Sachdev and collaborators [21].

Finally, the third strand of my research concerns the study of relaxation mechanisms from a different perspective. Instead of considering strongly constrained systems like the integrable ones, one looks for the opposite case of minimally structured models. These models generically oversimplify some of the features of real many-body systems (such as closed dynamics) in order to make the problem tractable, but, nonetheless, they exhibit several generic behaviours, e.g., in the spreading of entanglement and in the time-evolution of out of time order correlations. My most important contribution in this area has been the identification of a class of periodically driven quantum many-body systems (with local interactions) for which we could determine some properties exactly even in absence of integrability, for instance we computed dynamical correlations [20], spectral statistics [15], and entanglement dynamics [18]. In particular, in Ref. [15] we rigorously proved the emergence of Random-Matrix-Theory-like spectral statistics in a locally interacting spin chain, giving the first analytical demonstration of many-body quantum chaos. To the best of my knowledge, this class of systems, called “dual-unitary” quantum circuits, is the first and currently the only known class with these properties.