<u>Curriculum Vitae</u>

<u>Roberto Franzosi</u>
Palazzina di Fisica
Department of Physical Science,
Earth and Environment
University of Siena
Via Roma, 56
I-53100 Siena (Italy)

Phone: +39 0577 23 2493
e-mail: roberto.franzosi@unisi.it

Personal webpage: https://sites.google.com/site/franzosiwp/
ORCID: https://orcid.org/0000-0001-7588-921X

Scopus July 2020
h-index: 17
documents by author: 57
total citations: 967

Personal Information
Birth date: October 13, 1968
Birthplace: Crema (CR)
Citizenship: Italy
Marital Status: Married
Children: Bianca Franzosi, born 24 May 2005, Miriam Franzosi, born 2 April 2007 and Nina Franzosi, born 1 August 2011
Military: Absolved May 1995 April 1996

Languages
Italian (native language), English (good), French (elementary)

Programs: Fortran, C, C++, Matlab, Mathematica, Maple.

Education

- *14/04/2021 AL 14/04/2030:* Italian National Scientific Qualification (ASN) *(art. 16, comma 1, Legge 240/10) Full Professor (Professore di Prima Fascia), S.C. 02/A2 – Theoretical Physics of Fundamental Interactions (Fisica Teorica delle Interazioni Fondamentali).*
- *09/09/2019 AL 09/09/2025:* Italian National Scientific Qualification (ASN) *(art. 16, comma 1, Legge 240/10) Associate Professor (Professore di Seconda Fascia), S.C. 01/A4 – Mathematical Physics (Fisica-Matematica).*
- *February 2019: French Qualification for "Professeur des universités" in the area* 30-"*Milieux dilués et optique"* (N. **19130188725**).
- *February 2019: French Qualification for "Professeur des universités" in the area 28-"Milieux denses et matériaux"* (N. **19128188725**).
- *February 2015: French Qualification for "Professeur des universités" in the area* 30-"*Milieux dilués et optique"* (N. **15130188725**).
- *February 2013: French Qualification for "Professeur des universités" in the area 28-"Milieux denses et matériaux"* (N. **13128188725**).
- *January 2009:* French Qualification for "Professeur des universités" in the area 30-"Milieux

dilués et optique” (N. **09130188725**).

●*February 2008:* French Qualification for “*Maître de conférences”* in the areas *29-“Constituants élémentaires”* (N. **08229188725**) and *30-“Milieux dilués et optique”* (N. **08230188725**).

●*September 2000:* Italian Abilitation a teacher of physics at the secondary schools.

●*11 February 1999:* University of Florence, ”Dottorato di Ricerca” in Physics,
Thesis Title: *Geometrical and Topological Aspects in the Study of Phase Transitions.*
Advisor: Prof. Marco Pettini, Université Aix-Marseille 2, France et INAF Florence, Italy.
Referees:
Prof M. Zannetti University de Salerno, Italy;
Prof. M. Salerno University de Salerno, Italy;
Prof. G. Soliani University de Lecce, Italy

●*16 Mars, 1995:* University of Pisa, Degree ”Diploma di Laurea” in Physics. Graduated Magna Cum Laude (110/110 cum laude),
Thesis Title: *Study of Gravity in (2+1) dimensions with Tessellation method*.
Advisor: Prof. Enore Guadagnini, University of Pisa, Italy.

Positions

● *October 2021 – Present*: researcher at term RTDB at Department of Physical Science, Earth and Environment - University of Siena – Via Roma, 56 - I-53100 Siena – Italy.

● *September 2013 – September 2021*: researcher at Institute of Optics - National Research Council (“INO-CNR”) UOS of Florence – Largo Enrico Fermi, 2 - I-50125 Firenze – Italy.

● *January 2011 – Present*: Member of QSTAR (Quantum Science and Technology in Arcetri) Largo Enrico Fermi, 2, I-50125 Firenze (Italy)

● *December 2011 – August 2013*: researcher at Institute for Complex Systems - National Research Council (“ISC-CNR”) UOS of Florence – Via Madonna del Piano, 10 - I-50019 Sesto Fiorentino – Italy

Research Interests

Statistical Mechanics: Geometro-Topological Approach to Phase-Transitions.

Classical and Quantum Dynamics: Generalized Coherent States, Time Dependent Variational Principle, *Bose-Einstein Condensates, Bose-Hubbard Model, Self-Trapping.*

Statistical Mechanics: Microcanonical Ensemble, Entropy, Negative Temperatures, Small Systems.

Statistical Mechanics: Complex Networks, Complexity Estimation.

Quantum Information: Fisher Information, Geometry of Quantum Systems, Fubini-Study metric, Entanglement Characterization.

Participation in Research Project

2017 The Project **Q-Clocks** (Cavity-Enhanced Quantum Optical Clocks) is one of the **26 excellent international proposals in the field of quantum technology research that quantERA** has recommended for funding. In this project I am the Principal Investigator for INO-CNR.

Before 2011 I have been involved in many research project by means of which I got money for my fellowship. Nevertheless I haven't had responsibilities as leader since in Italy this is not

possible with a term position.
In 2007 I have been awarded with the *Exchange Grant "Transport Properties in Bose-Einstein Condensates"* within the framework of the European Science Foundation activity entitled "Quantum Degenerate Dilute Systems"

Competitions
2011 I have won a national competition at CNR for a Permanent Researcher position to work at the Institute for Complex Systems of the National Research Council – Sesto Fiorentino - Florence Italy.
In 2008 I have applied for an Associate Professorship in Theoretical Condensed Matter Physics position (Ref. 211- 0175) at the Niels Bohr Institute and I have been considered "qualified for this position".

Professional Service
2020-present Topic Editor for: Entropy.
2018/19 Guest Editor for: Entropy - Special Issue "The Ubiquity of Entropy".
Editor for: Open Physics (formerly Central European Journal of Physics) (De Gruyter), section of *Statistical Physics*.
Referee for: Phys. Rev. B, Phys. Rev. E, Phys. Lett. A, Journal of Mat. Phys., Journal of Phys. A, Journal of Phys. B, New Journal of Phys, Central European Journal of Physics.

Institutional roles
- 2018- Presedent of the commission for a post-doctoral position (assegno di ricerca) CNR-INO (ASS/INO/018/2018/FI)
- 2018- Presedent of the commission for a post-doctoral position (assegno di ricerca) CNR-INO (ASS/INO/014/2018/FI)
- 2018- Presedent of the commission for a post-doctoral position (assegno di ricerca) CNR-INO (ASS/INO/008/2018/FI)
- 2014- Controrelatore tesi di laurea on *"Modelling weakly-interacting Bose gases via the stochastic Gross-Pitaeskii equation : Theoretical approach and numerical simulations", candidate* Donatello Gallucci – University of Siena – IT.
- 2013- Member of the commission for a post-doctoral position (assegno di ricerca) CNR-INO (BANDO ASS/INO/011/2013/FI)

Scientific Collaborations
- *2005 - 2013:* Prof. R. Livi, Dept. of Physics, University of Florence, Italy
- *2005 - 2013:* Prof. G-L. Oppo, Dept. of Physics, Strathclyde University, Glasgow UK
- *2002 - 2005:* Prof. E. Arimondo, Dept. of Physics, University of Pisa, Italy
- *1998 - present:* Prof. M. Pettini, Université Aix-Marseille 2, France
- *1999 - present:* Prof. V. Penna, Dept. of Physics, Polytechnic of Turin, Italy
- *1998 - 2001:* Prof. R. Gatto, Dept. of Physics, University of Geneva, Switzerland

References
- Prof. Roberto Livi, Dipartimento di Fisica, Università di Firenze, Via G. Sansone 1, I-50019 Sesto Fiorentino, Italy, tel. +39 055 5252332, e-mail: Roberto.Livi@fi.infn.it
- Prof. Ennio Arimondo, Dipartimento di Fisica, Università di Pisa, Largo B. Pontecorvo 3, I-56127 Pisa, Italy, tel. +39 050 2214115, e-mail: arimondo@df.unipi.it
- Prof. Dino Leporini, Dipartimento di Fisica, Università di Pisa, Largo B. Pontecorvo 3, I-56127 Pisa, Italy, tel. +39 050 2214237, e-mail: leporini@df.unipi.it
- Prof. Marco Pettini, Université Aix-Marseille2, France, e-mail: marco.pettini@gmail.com
- Prof. Mario Rasetti, Dipartimento di Fisica del Politecnico di Torino, Corso Duca degli

Abruzi 24, 10129 Torino, Italy, Tel. 011/564-7324 (6730), e-mail: rasetti@isi36a.isi.it
- Prof. Vittorio Penna, Dipartimento di Fisica del Politecnico di Torino, Corso Duca degli Abruzi 24, 10129 Torino, Italy, Tel. +39 011 564 7303, e-mail: vittorio.penna@polito.it

Teaching Experiences
- *2020-2021:* Teacher of Analytical Mechanics, at the physical sciences and earth department, University of Siena
- *2020-2021:* Teacher of Quantum Mechanics, at the physical sciences and earth department, University of Siena
- *2019-2020:* Teacher of Mathematical Methods for Physics, at the physical sciences and earth department, University of Siena
- *2019-2020:* Teacher of Analytical Mechanics, at the physical sciences and earth department, University of Siena
- *2019-2020:* Teacher of Quantum Mechanics, at the physical sciences and earth department, University of Siena
- *2018-2019:* Teacher of Analytical Mechanics, at the physical sciences and earth department, University of Siena
- *2018-2019:* Teacher of Mathematical Methods for Physics, at the physical sciences and earth department, University of Siena
- *2018-2019:* Teacher of Quantum Mechanics, at the physical sciences and earth department, University of Siena
- *2017-2018:* Teacher of Analytical Mechanics, at the physical sciences and earth department, University of Siena
- *2017-2018:* Teacher of Mathematical Methods for Physics, at the physical sciences and earth department, University of Siena
- *2017-2018:* Teacher of Quantum Mechanics, at the physical sciences and earth department, University of Siena
- *2016-2017:* Teacher of Analytical Mechanics, at the physical sciences and earth department, University of Siena
- *2016-2017:* Teacher of Mathematical Methods for Physics, at the physical sciences and earth department, University of Siena
- *2016-2017:* Teacher of Quantum Mechanics, at the physical sciences and earth department, University of Siena
- *2015-2016:* Teacher of Mathematical Methods for Physics, at the physical sciences and earth department, University of Siena
- *2015-2016:* Teacher of Quantum Mechanics, at the physical sciences and earth department, University of Siena
- *2014-2015:* Teacher of Quantum Mechanics, at the physical sciences and earth department, University of Siena
- *2013-2014:* Teacher of Quantum Mechanics, at the physical sciences and earth department, University of Siena
- *2012-2013:* Teacher of Quantum Mechanics, at the physical sciences and earth department, University of Siena
- *2010-2011:* Teacher of Physics at “Istituto Professionale Cennino Cennini”, Colle di Val d'Elsa (Siena)
- *2008-2009:* Teacher of Condensed Matter Physics, at the Chemical of Material Course, University of Siena
- *2003-2004, 2004-2005, 2006-2007, 2007-2008 and 2008-2009:* Undergraduate teaching assistant (tutor) of Classical Physics, at the Electrical and Chemical Engineering Courses, University of Pisa
- *2005-2006:* Undergraduate teaching assistant (tutor) of Classical Physics, at the

Electrical, Chemical and Biomedical Engineering Courses, University of Pisa

- *2006-2007:* Undergraduate teaching assistant (tutor) of Classical Physics, at the Informatic Engineering Course, University of Florence

Supervisor students

- *2019-2020:* **Thesis di laurea in fisica triennale** *Title "5-D Gravity. An interpretation of the cosmological constant", dott. Pietro Paolo Melella – 28 Aprile 2021*
- *2019-2020:* **Thesis di laurea in fisica triennale** *Title "Geometrical approach to the dynamics and the entanglement of a quantum system", dott. Alessio Batazzi – 28 Aprile 2021*
- *2018-2019:* **Thesis di laurea in fisica triennale** *Title "Effective model for the study of the dynamics of Rabi and Dicke models", dott. Antonio Santacesaria – 11 Giugno 2020*
- *2018-2019:* **Thesis di laurea in fisica triennale** *Title "Dynamics of Bose-Einstein condensates coupled in optical lattices", dott. Riccardo Ferretta – 28 Aprile 2020*
- *2018-2019:* **Thesis di laurea in fisica triennale** *Title "Characterization of entanglement properties in the Rabi and Dicke models", dott. Saverio Palazzi – 10 Dicembre 2019*
- *2018-2019:* **Thesis di laurea in fisica triennale** Title *"Entanglement and squeezing properties in coherent spin states", dott. Bianca Nardi – 16 Luglio 2019*
- *2017-2018:* **Thesis di laurea in fisica triennale** Title "Characterization of entanglement properties in multi-qubit states", dott. Denise Cocchiarella – 29 Aprile 2019
- *2016-2017:* **Thesis di laurea in fisica triennale** Title "Dynamics of interacting Bose-Einstein condensates", dott. Luigi Palimieri – 23 Aprile 2018
- *2016-2017:* **Thesis di laurea in fisica triennale** Title "Dynamics of photo-desorption (LIAD) of alkali atoms from porous glass", dott. Edoardo Ballini – 23 Aprile 2018
- *2016-2017:* **Thesis di laurea in fisica triennale** Title "Quantum estimation of entanglement properties in lattice spin systems", dott. Stefano Scali – 23 Aprile 2018
- *2014-2015:* **Thesis di laurea in fisica triennale** Title "Variational Approach to the Study of the Dynamics of Bosons on Lattices", dott. Jacopo Soldateschi – 24 Settembre 2015

Participation to Conferences

- *March 2000: "XIX Convegno di Fisica Teorica e Struttura della Materia",* Fai della Paganella, Italy*,* March 26-29 2000, **Poster**: *Spectrum Structure of Coupled Bose-Einstein Condensates*
- *June 2000: "Convegno informale di Fisica Teorica", Cortona, Italy,* May 31 – June.3 2000*,* **Seminar**: *Doublet structure of the energy spectrum of coupled Bose condensate*
- *June 2000: INFM Meeting,* Genova, Italy, June 12-16 2000, **Poster**: "*Struttura Spettrale di Condensati di Bose Interagenti"*
- *March 2001: "XX Convegno di Fisica Teorica e Struttura della Materia",* Fai della Paganella, Italy, March 25-28 2001, **Poster**:*Dynamics of Three Coupled Bose-Einstein Condensates: Integrable Sub-Dynamics, Self-Trapping Mechanisms and Chaos Onset*
- *May 2001:* dept. of physics ofl Polytechnic of Turin, Italy, **Seminar**: "*Dinamica di condensati di Bose-Einstein accoppiati: aspetti classici e quantistici dell'effetto di self-trapping"*
- *May 2001:* "VI Convegno nazionale di fisica statistica e dei sistemi complessi", 29-31 Maggio, 2001, Parma, Italy, **Seminar**: "*Quantum Dynamics of Coupled Bose-Einstein Condensates: Semi-classical and Quantum Self-Trapping Mechanism"*
- *June 2001:* dept. of physics of the University of Florence, **Seminar**: *"Dinamica di condensati di Bose-Einstein accoppiati: aspetti classici e quantistici nell'effetto di self-trapping"*
- *June 2001:* INFM Meeting, Roma, Italy, June 18-22 2001, **Poster**: "*Exact solutions of the*

Schroedinger problem for coupled Bose-Einstein condensates and self-trapping effect"

- *December 2001:* Workshop on Bose-Einstein Condensates, University of Salerno, Italy, December 19-20 2001, **Seminar**: *Three Coupled Bose-Einstein Condensates Dynamics: Collective modes, Self-Trapping populations and chaos onset*
- *March 2002: "XXI Convegno di Fisica Teorica e Struttura della Materia",* Fai della Paganella, Italy, March 21-24 2002, **Poster**: *Nonlinear Dynamics of Three Coupled Bose-Einstein Condensates*
- *June 2002:* "VII Convegno nazionale di fisica statistica e dei sistemi complessi", June 3-5 2002, University of Parma, Italy, **Seminar**: *Chaos Onset in the Dynamics of Three Coupled Bose-Einstein Condensates*
- *June 2002:* INFM Meeting, Fiera del Levante, Bari, Italy, June 24-28, 2002, **Poster**: *Dynamics of Three Coupled Bose-Einstein Condensates: Nonlinear Effects and Chaos Onset*
- *July 2002:* International Conference on Theoretical Physics, Paris, France, UNESCO, July 22-27 2002, **Poster 1**: *Quantum symmetry breaking in the dynamics of Bose-Einstein condensate arrays*; **Poster 2**: *Dynamics of Three Bose-Einstein Condensates with Symmetric Coupling: Instability Effects and Collective Modes*
- *October 2002:* Workshop: Nonlinear Dynamics in Classical and Quantum Mechanics, October 10-11 2002, Sammommé, Italy, **Seminar**:*Induction of excitations and symmetry breaking in the dynamics of Bose-Einstein condensate arrays*
- *March 2003:* XXII Convegno di Fisica Teorica e Struttura della Materia, Fai della Paganella, Italy, March 20-23 2003, **Poster**: *Superfluid and Mott regimes in the dynamics of interacting Bose-Einstein condensates*
- *April 2003:* Workshop: Nonlinear Dynamics and Chaos in Classical and Quantum Mechanics, April 14-15 2003, Sammommé, Italy, Seminar: *Classical and Quantum Aspects in the Dynamics of Coupled Bose-Einstein*
- *June 2003:* Second Internation Workshop Theory of Quatum Gases and Quantum Coherence, Levico, Italy, June 12-14 2003, **Poster 1**: *Interplay between classical and quantum regimes in the dynamics of interacting Bose-Einstein condensates*; **Poster 2**: *Spectral properties vs. mean-field dynamical modes of three coupled Bose-Einstein condensates*
- *June 2004:* dept of physics "E. Fermi", University of Pisa, Italy, **Seminar**: *Topological Approach to Phase Transitions*
- *September 2004:* 5th European Quantum Information Processing & Communication Workshop, Roma, Italy, September 20-22 2004, **Poster**: *Entanglement and quantum control of cold atoms in 1D optical lattices*
- *October-November 2005:* Congress: Theory of Quantum Gasses and Quantum Computation, Cortona, Italy, October 28-November 2 2005, **Poster**: *Transport properties of Bose-Einstein condensates in optical lattices*
- *September 2006: "*XXIV Convegno Fisica teorica e struttura della materia" Levico Terme, Italy, September 17-20 2006, **Poster**: *Self Localization of BECs in Optical Lattices induced by Boundary Dissipation*
  September 2006: Congress: Solitons and nonlinear phenomena in degenerate quantum gases, Cuenca, Spain, Sept. 27-30, 2006, **Seminar**: *Probing the dynamics of BECs in Optical Lattice via Boundary Dissipation*
- *April 2008:* Congress: Nonlinear phenomena in quantum degenerate gases Toledo Spain, April 1-4 2008, **Poster**: *Localized States of Bose-Einstein Condensates in Optical Lattices: Dynamical and Statistical Mechanical Properties*
- *July 2009:* 18th International Laser Physics Workshop Barcelona Spain, July 13-17 2009, **Poster**: *Localization of Bose-Einstein Condensates in Optical Lattices*
- *June 2012:* XVII CONVEGNO NAZIONALE DI FISICA STATISTICA E DEI

SISTEMI COMPLESSI, Parma (Italy), 20-22 June 2012, **Seminar**: *Stati localizzati e a temperature negative nell'equazione nonlineare di Schrödinger discretizzata.*

- *June 2017:* XXII CONVEGNO NAZIONALE DI FISICA STATISTICA E DEI SISTEMI COMPLESSI, Parma (Italy), 28-30 June 2017, Invited **Seminar**: *Microcanonical entropy: negative temperatures and finite systems.*
- *October 2018:* Assemblea del Gruppo Nazionale di Fisica Matematica, Montecatini (Italy), 4-6 October 2018, Invited **Seminar**: Microcanonical entropy: negative temperature and finite systems.
- *February 2020*: INFN Workshop IS Quantum February 6-7 2020 Bologna (Italy), **Seminar**: Entanglement measure for M-qudit Systems.
- *February* 2020: qqq Workshop in Milano February 18-21 2020 Milano (Italy), **Poster**: Entanglement measure for M-qudit Systems.
- June 2021: 1st Convegno della Società Italiana di Fisica Statistica, June 23-25 online, **Seminar**: Entanglement signature of the Superradiant Quantum Phase Transition.
- September 2021: 107th Congresso Nazionale della Società Italiana di Fisica, September 13-17 online, **Seminar**: Entanglement signature of the Superradiant Quantum Phase Transition.

List of publications

1. R. Franzosi and E. Guadagnini, ”Particle decays and space-time kinematics in (2 + 1) gravity”, *Nuclear Physics B* **450** (1995) 327-354

2. R. Franzosi and E. Guadagnini, ”Topology and classical geometry in (2 + 1) gravity”, *Class. Quantum Grav.* **13** (1996) 433-460

3. M. Cerruti-Sola, R. Franzosi and M. Pettini, ”Lyapunov exponents from geodesic spread in configuration space”, *Phys. Rev. E* **56** 4872 (1997)

4. R. Franzosi, M. Ghilardi and E. Guadagnini, ”Modular transformations and one-polygon tessellation”, *Phys. Lett. B* **418** (1998) 42-45

5. R. Franzosi, L. Casetti, L. Spinelli and M. Pettini,“Topological aspects of geometrical signatures of phase transitions”, *Phys. Rev. E* **60** R5009 (1999)

6. R. Franzosi, M. Pettini and L. Spinelli, “Topology and phase transitions: a paradigmatic evidence”, *Phys. Rev. Lett.* **84**, 2774 (2000)

7. R. Franzosi, R. Gatto, G. Pettini and M. Pettini, “Analytic Lyapunov exponents in a classical nonlinear field equation”, *Phys. Rev. E* **61** R3299 (2000)

8. R. Franzosi, V. Penna and R. Zecchina, “Quantum Dynamics of coupled Bosonic Wells within the Bose-Hubbard Picture”, *Int. Jour. of Mod. Phys. B* Vol. **14**, No. 9 (2000) 943-961

9. R. Franzosi and V. Penna, “Spectral Properties of Coupled Bose-Einstein Condensates”, *Phys. Rev. A* **63**, 043609-1 (2001)

10. R. Franzosi and V. Penna, “Self-trapping mechanisms in the dynamics of three coupled Bose-Einstein condensates”, *Phys. Rev. A* **65**, 013601-1 (2001)

11. R. Franzosi and V. Penna, “Spectral Properties and Self-Trapping Eﬀect in Coupled Bose-Einstein Condensates”, *Laser Physics*, Vol **12**, No.1, (2002), pp. 71-76

12. R. Franzosi and V. Penna, “Chaotic behavior, collective modes and self-trapping in the dynamics of three coupled Bose-Einstein condensates”, *Phys. Rev. E*, **67**, 046227 (2003)

13. P. Buonsante, R. Franzosi, and V. Penna,“Instability Eﬀects in the Dynamics of three Coupled Bosonic Wells”, *Laser Physics*, Vol **13**, No.4, (2003), p. 537-542

14. P. Buonsante, R. Franzosi, and V. Penna, “Dynamical Instability in a Trimeric Chain of Interacting Bose-Einstein Condensates”, *Phys. Rev. Lett.*, **90**, 050404 (2003)

15. R. Franzosi and M. Pettini, “Theorem on the Origin of Phase Transitions”, *Phys. Rev. Lett.* **92**, 60601 (2004)

16. P. Buonsante, R. Franzosi, and V. Penna, “Dynamics of twin-condensate configurations in an open chain of three Bose-Einstein condensates”, *Laser Physics*, Vol **14**, No.4, (2004), p. 556-564

17. P. Buonsante, R. Franzosi and V. Penna, “From the superfluid to the Mott regime and back: triggering a non-trivial dynamics in an array of coupled condensates”, *J. Phys. B*, **37**, (2004) s195-s203
18. P. Buonsante, R. Franzosi and V. Penna, “Persistence of mean-field features in the energy spectrum of small arrays of Bose-Einstein condensates”, *J. Phys. B*, **37**, (2004) s229-s238
19. R. Franzosi, B. Zambon, and E. Arimondo, “Nonadiabatic eﬀects in the dynamics of atoms confined in a cylindric time-orbiting-potential magnetic trap”, *Phys. Rev. A*, **70**, 053603 (2004)
20. M. Pettini, L. Casetti, M. Cerruti-Sola, R. Franzosi, E. G. D. Cohen, “Weak and strong chaos in FPU models and beyond”, Invited paper for the special issue of Chaos celebrating the 50th anniversary of the FPU article, *Chaos* **15**, 015106 (2005)
21. R. Franzosi, P. Poggi and M. Cerruti-Sola, “Lyapunov exponents from unstable periodic orbits”, *Phys. Rev. E* **71**, 036212 (2005)
22. R. Franzosi, M. Cristiani, C. Sias and E. Arimondo “Coherent transport of cold atoms in angle-tuned optical lattices”, *Phys. Rev. A* **74**, 013403 (2006)
23. R. Livi, R. Franzosi and G.-L. Oppo, “Selflocalization of Bose-Einstein condensates in optical lattices via boundary dissipation”, *Phys. Rev. Lett.* **97**, 060401 (2006)
24. R. Franzosi, R. Livi and G.-L. Oppo, “Probing the dynamics of Bose-Einstein condensates via boundary dissipation”, *Journal of Physics B* **40**, 1195 (2007)
25. R. Franzosi, M. Pettini and L. Spinelli, “Topology and Phase Transitions I. Preliminary Results”, *Nuclear Physics B* **782** (2007) 189-218
26. R. Franzosi and M. Pettini, “Topology and Phase Transitions II. Entropy and Topology”, *Nuclear Physics B* **782** (2007) 219-240
27. R. Franzosi, “Nonclassical dynamics of Bose-Einstein condensates in an optical lattice in the super-fluid regime”, *Phys. Rev. A* **75**, 053610 (2007)
28. M. Cerruti-Sola, G. Ciraolo, R. Franzosi and M. Pettini, “Riemannian geometry of Hamiltonian chaos: Hints for a general theory”, *Phys. Rev. E*, **78**, 046205 (2008)
29. P. Buonsante, R. Franzosi and V. Penna, “Control of unstable macroscopic oscillations in the dynamics of three coupled Bose condensates ”, *J. Phys. A: Math. Theor.* **42** (2009) 285307
30. B. Zambon and R. Franzosi, “Dynamics of atoms in a time orbiting potential trap: consequences of the classical description”, J. Phys. B **43** 085302 (2010).
31. R. Franzosi, S. M. Giampaolo and F. Illuminati, “Quantum localization and bound-state formation in Bose-Einstein condensates”, *Phys. Rev. A* **82**, 063620 (2010).
32. R. Franzosi, S. M. Giampaolo, F. Illuminati, R. Livi, G-L. Oppo, and A Politi, “Localization of Bose-Einstein condensates in optical lattice”, accepted for the publication in Central European Journal of Physics, Online First™, 18 May 2011**.**
33. R. Franzosi, “Microcanonical entropy and dynamical measure of temperature for systems with two first integrals”, J. Stat. Phys. (2011) 143: 824–830
34. R. Franzosi, R. Livi, G.-L. Oppo and A. Politi “Discrete Breathers in Bose-Einstein Condensates”, *Nonlinearity* 24 (2011) R89-R122
35. R. Franzosi “Geometric microcanonical thermodynamics for systems with first integrals”, *Phys. Rev. E*, **85**, R050101 (2012)
36. S. Iubini, R. Franzosi, R. Livi, G.-L. Oppo and A. Politi, “*Discrete breathers and negative-temperature states”,* New J. Phys. **15** (2013) 023032.
37. R. Franzosi and R. Vaia, “*Newton's cradle analogue with Bose–Einstein condensates”,* J. Phys. B, **47** 095303 (2014)
38. R. Franzosi and R. Vaia, “*Quantum Newton's Cradle with Bose-Einstein Condensates”,* 2Physics.com, Sunday, June 01, 2014,
http://www.2physics.com/2014/06/quantum-newtons-cradle-with-bose.html
39. Roberto Franzosi, Domenico Felice, Stefano Mancini, Marco Pettini, “*A geometric entropy detecting the Erdös-Rényi phase transition*”, EPL, **111** (2015) 20001.
40. I. Donato, M. Gori, M. Pettini, G. Petri, S. De Nigris, R. Franzosi and F. Vaccarino,

"Persistent homology analysis of phase transitions", *Phys. Rev. E,* **93**, 052138 (2016).
41. R. Franzosi, D. Felice, S. Mancini and M. Pettini, "Riemannian-geometric entropy for measuring network complexity", *Phys. Rev. E,* **93**, 062317 (2016).
42. P. Buonsante, R. Franzosi and A. Smerzi, "On the dispute between Boltzmann and Gibbs entropy", *Annals of Physics* **375** (2016) 414–434.
43. P. Buonsante, R. Franzosi and A. Smerzi, "Phase transitions at high energy vindicate negative microcanonical temperature", *Phys. Rev E* **95**, 052135 (2017).
44. D. Felice, R. Franzosi, S. Mancini and M. Pettini, "Catching homologies by geometric entropy", *Physica A* **491**, (2018) 666-677.
45. R. Franzosi, "Microcanonical entropy for classical systems", *Physica A* **494**, (2018) 302-307.
46. V. Penna, F. A. Raffa and R. Franzosi, "Algebraic properties and spectral collapse in nonlinear quantum Rabi models", *J. Phys. A: Math. Theor.* **51** (2018) 045301.
47. M. Gori, R. Franzosi and M. Pettini, "Topological origin of phase transitions in the absence of critical points of the energy landscape", *J. Stat. Mech.* **9** (2018) 093204.
48. G. Pettini, M. Gori, R. Franzosi, C. Clementi and M. Pettini**,** "On the origin of phase transitions in the absence of symmetry-breaking", *Physica A* **516**, (2019) 376-392.
49. R. Franzosi, "A microcanonical entropy correcting finite-size effects in small systems", *JSTAT* (2019) 083204.
50. S. Scali and R. Franzosi, "Entanglement estimation in non-optimal qubit states", *Annal of Physics* 411 (2019) 167995.
51. G. Bel-Hadj-Aissa, M. Gori, V. Penna, G. Pettini and R. Franzosi, "Geometrical Aspects in the Analysis of Microcanonical Phase-Transitions", *Entropy* **2020**, *22*, 380.
52. D. Cocchiarella, S. Scali, S. Ribisi, B. Nardi, G. Bel-Hadj-Aissa, and R. Franzosi, "Entanglement distance for arbitrary *M*-qudit hybrid systems", *Phys. Rev. A* **101**, 042129 (2020).
53. G. Bel-Hadj-Aissa, M. Gori, R. Franzosi and M. Pettini, "Geometrical and topological study of the Kosterlitz–Thouless phase transition in the XY model in two dimensions", *J. Stat. Mech.* (2021) 023206.
54. E. Faraji, R. Franzosi, S. Mancini and M. Pettini, "Transition between random and periodic electron currents on a DNA chain", *Int. J. Mol. Sci.* **2021**, *22*, 7361.
55. E. Faraji, R. Franzosi, S. Mancini and M. Pettini, "Energy transfer to the phonons of a macromolecule through light pumping", *Scientific Reports* (2021) 11:6591
56. A. Nourmandipour, A. Vafafard, A. Mortezapour and R. Franzosi, "Entanglement protection of classically driven qubits in a lossy cavity", *Scientific Reports* (2021) 11:16259.

Preprint

1. D. Cocchiarella, S. Scali, S. Ribisi, B. Nardi, G. Bel Hadj Aissa and R. Franzosi, "Entanglement distance for an arbitrary state of *M* qubits", arXiv:1908.03117.

Book Chapters

2. R. Livi, R. Franzosi and G.-L. Oppo, *Spontaneous Localization of Bose-Einstein Condensates in Optical Lattices with Boundary Dissipations,* in Laser and Bose-Einstein Condensation Physics, Editors: Man Mohan, Anil Kumar, Aranya B. Bhattacherjee, Anil Kumar Razdan, Narosa Publishing House, ISBN: 978-81-8487-064-0
3. M. Pettini, R. Franzosi and L. Spinelli, "*Topology and Phase Transitions: Towards a Proper Mathematical Definition of Finite N Transitions*", in Nucleus–Nucleus Collisions -Proceedings of the Conference "Bologna 2000: Structure of the Nucleus at the Dawn of the Century" *Bologna, Italy, 29 May – 3 June 2000,* WORLD SCIENTIFIC 2012, ISBN: 978-981-281-093-9

Not specialized press

- **Physics World** - the member magazine of the Institute of Physics, May 2, 2014 *"How to build a quantum Newton's cradle",* by Tushna Commissariat, reporter for *physicsworld.com,* article not specialized on my paper: R. Franzosi and R. Vaia, "*Newton's cradle analogue with Bose–Einstein condensates",* J. Phys. B, **47** 095303 (2014).
- **Elsevier Physics Twitter channel** - The paper "On the dispute between Boltzmann and Gibbs entropy" featured on the official Elsevier Physics Twitter channel: https://twitter.com/ElsevierPhysics/status/811122455679012864

Most relevant scientific contributions

General Relativity. I started my research activity in 1995 working on General Relativity. I have studied the dynamics of gravitating spinless particles, in (2+1) dimensions, within the framework of the 't Hooft's presentation of the three-dimensional space-time. The causal structure of the space-time, that is the universe, seen by a set of spinless gravitating particles, is obtained by describing the time-evolution of such system in terms of a two-dimensional space-like surface. The set of these Cauchy surfaces, which are parametrised by time, foliate the space-time. Within the 't Hooft's solution each surface, at fixed time, is taken to be piecewise flat and the corresponding tessellation is constructed by means of polygons. The presence of a point-like mass is pointed out by a conical singularity. Each polygon's edges moves at constant speed but when one of the lengths of the polygon's edges vanishes or when one of the corners hits an edge, one has a transition in which the structure of the tessellation of the spatial surface undergoes a local change. These changes are embodied in the 't Hooft's formalism. By using the 't Hooft representation, in paper **1.**, it has been described the decays of gravitating particles, and it has been derived the associated kinematic relations by discussing the effect of gravity on the structure of the energy-momentum conservation law. Moreover, it has been shown that the time-evolution of the momenta of a set of spinless particles, can be described in terms of a generalized space-time kinematics, based on a representation of the braid group.
In paper **2.** it has been illustrated how the non-trivial topology of universe can be described within the 't Hooft's formalism. In the case of a universe with spatial topology of torus it has been discussed the relation between 't Hooft's transitions and modular transformations. Moreover, it has been constructed the universal covering of space-time and it has been computed the Hubble's constant for an expanding universe.
In paper **4.** it has been studied the time evolution of a universe with the spatial topology a torus by means of a one-polygon tessellation with three-legs vertices. It has been considered the action of modular transformations on this solution, and it has been shown that the corresponding orbit is densely distributed inside the entire phase-space of the model.

Thermodynamic Phase Transitions. In my PhD Thesis I started considering the dynamical properties of Hamiltonian systems that - in the statistical mechanical canonical framework - undergo second order phase transitions. In the light of a differential-geometrical treatment of Hamiltonian dynamics, where the motions are seen as geodesics of suitable Riemannian manifolds, the "mechanical manifolds", as well as the constant energy hyper-surfaces of phase space, these systems are found to undergo peculiar geometric transformations that, in my Thesis, have been attributed to major topological changes at the transition point. These results are reported in paper **5.**, where certain geometric properties of sub-manifolds of configuration space have been numerically investigated for the classical φ^4 models in one and two dimensions, and where it has been shown that peculiar behaviours of these geometric quantities are found only in the two dimensional system, when the phase transformation does take place. To cope with the constructive study of topological properties of high dimensional manifolds is a hard task, nevertheless a substantial confirmation of the crucial role of configuration space topology in the occurrence of phase transitions has been given in my PhD Thesis through several intermediate steps culminating with the direct numerical computation of the Euler characteristic of the relevant manifolds, in presence and in the absence of phase transitions. These results are contained in paper [**6.**] that reports upon numerical computation of the Euler characteristic χ (which is a topological invariant) of the equipotential hyper-surfaces Σ_v of the configuration space of the classical φ^4 models in one and two dimensions. The pattern $\chi(\Sigma_v)$ versus v (potential energy) reveals that a major topology change in the family $\{\Sigma_v\}_v$ takes place in presence of a phase transition. This preliminary work together that one of paper [**15.**] have paved the way to proving a general theorem. In fact, more recently, I have been co-author of two papers, [**25.**] and [**26.**], where it has been given a proof of a general theorem about the necessity of a deep link between configuration space topology and the occurrence of thermodynamical phase transitions. These works enlighten of new light the problem of phase transitions, indeed the thermodynamic singularities that correspond to phase transformations, are found to necessarily stem from suitable changes in the topology of certain sub-manifolds of the configuration space. This is an independent an more fundamental mechanism with respect to the standard ones and it provides new tools and methods to tackle those transition phenomena that are presently at the forefront of the research.

Bose-Einstein Condensates Dynamics. In 2000 I started investigating the dynamics of interacting Bose-Einstein condensates by exploring the classical as well the quantum regime.
In the first regime, the dynamics of Bose-Einstein condensates in periodic potentials (optical lattices) is described by the Gross-Pitaevskii equation that, in the tight binding regime, is well approximated by a discrete non-linear Schroedinger equation. On the other hand, the quantum dynamics of such systems is described by a Bose-Hubbard model. Initially, I have investigated the classical dynamics of two interacting Bose-Einstein condensates (dimer). In spite of the integrable character of this system's dynamics, due to non-linearity, its equations of motion admit pretty interesting and unexpected dynamical behaviours. In paper **8.**, it has been investigated the system's phase-space structure and it has been analysed the peculiar behaviours displayed by the system as the population self-trapping. Furthermore, in part of paper **8.**, and in paper **9.**, it has been considered the dimer quantum dynamics and it has been analysed the link between classical trajectories and quantum energy level spectrum. In **10. 12.** and **14.** it has been shown that the apparently harmless addition of a further coupled condensate to the dimer system, is sufficient to make the dynamics of three coupled Bose-Einstein condensates (trimer) non-integrable. Indeed, in **10. 12.** and **14.** has been investigated the trimer classical dynamics in different inequivalent, and experimentally meaningful, configurations showing that it displays instabilities in extended regions of the phase space. Besides the chaotic nature of the trimer dynamics in the latter papers they have been investigated the collective modes associated with the system's equations and the non-linear self-trapping that emerges in the super-fluid regime.
The non-linear character of the classical equations of motion of Bose-Einstein condensates in arrays of arbitrary length, is at the base of the self-localization phenomenon that, in **23.,** has been predicted to take place in condensates loaded in dissipative optical lattices. The dynamical

configurations that in **23.** has been shown to spontaneously appear, have the nature of “breathing dynamical solutions” that are the very genuine non-linear discrete dynamical states. These macroscopic effects are, and have been, of primary importance in leading toward their experimental observation also in small (few interacting condensates) systems.

Dynamics and Thermodynamics of Classical and Quantum Systems. In paper J. Stat. Phys. (2011) 143: 824–830 I have considered a generic classical many particle system described by an autonomous Hamiltonian $H(x_{1,}\ldots,x_{N+2})$ which, in addition, has a conserved quantity $V(x_{1,}\ldots,x_{N+2})$, so that the Poisson bracket $\{H,V\}$ vanishes. I have derived in detail the microcanonical expressions for entropy and temperature. I have shown that both of these quantities depend on multidimensional integrals over submanifolds given by the intersection of the constant energy hypersurfaces with those defined by $V(x_{1,}\ldots,x_{N+2})=v$. I have shown that temperature and higher order derivatives of entropy are microcanonical observable that, under the hypothesis of ergodicity, can be calculated as time averages of suitable functions. Finally I have derived the explicit expression of the function that gives the temperature. In paper [S. Iubini, R. Franzosi, R. Livi, G.-L. Oppo and A. Politi, “Discrete breathers and negative-temperature states”[**36.**]] We have shown how **negative temperature states** can be obtained in the Nonlinear Discrete Schroedinger Equation. The definition of the microcanonical temperature given by me in paper J. Stat. Phys. (2011) 143: 824–830, associated with the corresponding Hamiltonian, allows to obtain a consistent thermodynamic description for both positive and negative temperature states. We have also described how one can pass from positive to negative temperatures by applying energy dissipation to the Nonlinear Discrete Schroedinger Equation chain boundaries. We have found that the microscopic evolution in thermalized negative temperature states is characterized by the mechanism of focusing of particle density (and energy), characterized by the formation of localized breather states.

Microcanonical entropy for Classical Systems. The validity of the concept of negative temperature has been recently challenged by arguing that the Boltzmann entropy (that allows negative temperatures) is inconsistent from a mathematical and statistical point of view, whereas the Gibbs entropy (that does not admit negative temperatures) provides the correct definition for the microcanonical entropy. In [**42.**] and [**43.**] we have proved that the Boltzmann entropy is thermodynamically and mathematically consistent. In [**45.**] we have proposed a novel definition for the microcanonical entropy that resolve the debate on the correct definition of the microcanonical entropy. In particular we have show that this entropy definition fixes the problem inherent the exact extensivity of the caloric equation. Furthermore, this entropy reproduces results which are in agreement with the ones predicted with standard Boltzmann entropy when applied to macroscopic systems. On the contrary, the predictions obtained with the standard Boltzmann entropy and with the entropy we propose, are different for small system sizes. Thus, we conclude that the Boltzmann entropy provides a correct description for macroscopic systems whereas extremely small systems should be better described with the entropy that we propose [**49.**].

Entanglement Characterisation. In [**52.**] We propose a measure of entanglement that can be computed for any pure and mixed state of an *M*-qudit hybrid system. The entanglement measure has the form of a distance that we derive from an adapted application of the Fubini-Study metric. This measure is invariant under local unitary transformations and defined as trace of a suitable metric that we derive, the entanglement metric **g**. Furthermore, the analysis of the eigenvalues of **g** gives information about the robustness of entanglement.

Signature

Date, October 13 2021.