FRANCESCO CAMILLI

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SUMMARY OF RESEARCH INTERESTS

Statistical Mechanics of Disordered Systems, Information Theory and Inference, High-dimensional Probability, Artificial Intelligence.

My research interests lie at the intersection of Statistical Mechanics, Information Theory and High-Dimensional Inference with applications to artificial intelligence. During my PhD I focused on breaking some limitations that usually pervade theoretical studies in spin-glasses and high-dimensional inference, as the homogeneity of couplings in statistical physics models and of signal to noise ratios in inference. Another new aspect that I have investigated is the modelization of correlations inside noise elements in inferential models. Recent efforts are devoted to the application of Mathematical Physics techniques to learning theory, with a particular attention to establishing theoretical guarantees to performance of neural networks and modern data science tools.

BIBLIOMETRIC INDICES

On December 9th 2025:
    H index: **9** on Google Scholar, **6** on Scopus;
    Published articles (international journals and conferences): **15**, excluding PhD thesis;
    Citations: **242** on Google Scholar, **115** on Scopus.
Eligible for the Italian National Scientific Habilitation as Associate Professor in Mathematical Physics.

ACADEMIC POSITIONS

Tenure-track Assistant Professor	December 2025 – current
Alma Mater Studiorum - Università di Bologna	Bologna, Italy
Postdoctoral Fellow	April 2023 – November 2025
ICTP - International Centre for Theoretical Physics	Trieste, Italy
Funded by Prof. Jean Barbier's CHORAL ERC project. ICTP is a UNESCO category 1 institute.	
Predoctoral visiting scientist	December 2022 – January 2023
Institute of Science and Technology Austria (ISTA)	Vienna, Austria
Supervised by Prof. Marco Mondelli.	
Guest Scientist	Dec. 2021, 11-16 May 2022, Feb. - Mar. 2023
ICTP - International Centre for Theoretical Physics	Trieste, Italy
Invited by Prof. Jean Barbier, Quantitative Life Sciences (QLS) section.	

HONORS, AWARDS AND GRANTS

Indam-UMI-SIMAI national prize for best PhD thesis in applied math	November 2023
University of Bologna	Italy

Every three years Indam, UMI and SIMAI award four prizes for the best PhD theses defended in Italian Universities. Two are reserved to pure math, and two to applied math. The prize is worth 2500 EUR.

Attestato di Merito	November 16, 2023
Accademia delle Scienze dell'Istituto di Bologna	Bologna,Italy

Selected among young researchers to present the best results in my field in recent years for a wide, interdisciplinary audience.

Scholarship of the Collegio Superiore	September 2014 – October 2019
University of Bologna	Bologna, Italy

Collegio Superiore is an institute of excellence of the University of Bologna. Admission and permanence are based exclusively on merits. It provides its students with some benefits, among which:

- exemption from tuition fees;
- a yearly scholarship;
- lodging.

INSTITUTIONAL ACTIVITY

Coordinator of postdocs meetings — May 2025 - Current
International Centre for Theoretical Physics — Trieste, Italy
Responsibilities: collect data about general well-being of postdocs at ICTP, call meetings with postdoc representatives, organize discussions with ICTP's Scientific Council and Faculty Board members.

TEACHING ACTIVITY

Meccanica Razionale T — Feb - Jun 2026
Alma Mater Studiorum - Università di Bologna — Bologna, Italy
Course of Analytical Mechanics for the B.Sc. in Architecture-Engineering.

Mathematical Methods (3 Academic ys) — Sep 2023, Sep 2024, Sep 2025
ICTP - International Centre for Theoretical Physics — Trieste, Italy
Lecturer of the course for the postgraduate diploma programme, an intense pre-PhD programme for talented students from developing countries. **16 hours + exams (48 total)**.

Two-week intensive course for United World College — May 2025
United World College — Duino, Italy
Two-week course on the basics of learning theory for 3 talented, worldwide-selected high-school students.
Contents: elements of multivariate calculus, gradient descent, universal approximation theorem, basics of python, implementation of a two-layer NN. **30 hours total.**

XLIX summer school on mathematical physics — Sep. 2024
Istituto Nazionale di Alta Matematica (INdAM) — Ravello, Italy
Seminar titled: "Fundamental limits of overparametrized shallow neural networks".
1h-lecture titled: "Statistical mechanics and information theoretical bounds for shallow neural networks".

Introduction to high-dimensional inference and spin glasses (2 Academic ys) — Feb 2024, Dec 2024
Theoretical and Scientific Data Science PhD course, SISSA — Trieste, Italy
Co-lecturer, **8 hours (16 total)**. Topics: replica method, cavity method, interpolation, message passing algorithms.

Advanced mean-field theory of high-dimensional inference — June 2024
Theoretical and Scientific Data Science PhD course, SISSA — Trieste, Italy
Co-lecturer, **5 hours**. Spiked models with structured noise.

From coin tossing to the Parisi theory of complexity — Aug 28 - Sep 8 2023
SMI - Scuola Matematica Interuniversitaria — Cortona, Italy
PhD school: 40 hours plus exercises. **Lecturer for 10hs**.

Lecturer at the Summer School Corso Estivo a Cesenatico — 2 September 2022
University of Bologna — Cesenatico, Italy
1-hour lecture on maximum likelihood estimation for the training of Boltzmann machines.

Teaching assistant for Statistical Mechanics of Complex Systems (4 Academic ys) — Feb. 2020 – Feb. 2023
University of Bologna — Bologna, Italy
I assisted the professor during the exams of the course. **Total amount of hours: 48.**

Teaching assistant for Mathematical Physics 1 (5 Academic ys). — Feb. 2018 – May 2023
University of Bologna — Bologna, Italy
I gave some lessons focusing on exercises for the course. I assisted the professor in correcting written tests and in oral exams. **Total amount of hours: 246.**

BOOK

Lezioni di Meccanica Elementare e oltre — January 2023
Camilli, F., Contucci, P.
Textbook for a first course in Mathematical Physics.
ISBN: 979-12-5477-191-4, Bologna University Press (BUP).

SUPERVISED STUDENTS

Gianpaolo Santarsiero, 2025. Supervisor of B.Sc. thesis in Physics, University of Trieste. Topics: high-rank spherical integrals and their applications.

Suhanee Korpe, 2025. Master student at Indian Institute of Science Education and Research (IISER), Bhopal. Currently intern in J. Barbier's group at ICTP, working on asymmetric high-rank matrix denoising problems. Ongoing.

Yizhou Xu, 2024. Intern in J. Barbier's group at ICTP, now PhD student at EPFL. Our collaboration led to *Information limits and Thouless-Anderson-Palmer equations for spiked matrix models with structured noise*.

Federico Menegazzo, 2024. Co-supervisor of the B.Sc. thesis in Mathematics *Transizioni di fase e matrici aleatorie (ITA)*, University of Bologna.

Eleonora Bergamin, 2024. Co-supervisor of the M.Sc. thesis in Physics of data *Information Theoretic Analysis of Deep Neural Networks*, University of Padova. Now PhD student at SISSA, Trieste.

DIVULGATION ACTIVITIES

I have presented a science game based on the group testing problem, in collaboration with ICTP's Public Information Office at the following events:

Trieste NEXT	September 2025
International Centre for Theoretical Physics	Trieste, Italy
Group activity with high school students: *How easy is it to train a neural network?*	
German Italian Physics Exchange (GIPE)	Sept. 2025
International Centre for Theoretical Physics	Trieste, Italy
Seminar titled: *The Phases of Nature: Emergence and Universality*	
Trieste Maker Faire	May 2025
International Centre for Theoretical Physics	Trieste, Italy
Science game for children	April 2025
International Centre for Theoretical Physics	Trieste, Italy
Trieste NEXT	September 2024
International Centre for Theoretical Physics	Trieste, Italy

CONFERENCES, TALKS AND SCHOOLS

Mathematics for Artificial Intelligence and Machine Learning	Jan 2026
La Sapienza - University of Rome	Rome, Italy
Speaker. 4th Workshop of UMI Group "Mathematics for Artificial Intelligence and Machine Learning".	
The role of Data Science: from statistical to quantum and relativistic mechanics.	Jan 2026
La Sapienza - University of Rome	Rome, Italy
Invited speaker. A two-day conference in memory of Francesco Guerra	
ROccella Conference on INference and AI - ROC(K)IN' AI	2024-2026
Roccella Jonica	Roccella Jonica, Italy
Conference, held every year the first week of September. Member of the organizing committee.	
STATPHYS 29	July 13-18, 2025
Florence	Florence, Italy
Talk in the session TOPIC 9 - Statistical physics of machine learning and information.	
38th Annual Conference on Learning Theory (COLT 2025)	June 30 - July 4, 2025
École Normale Supérieure	Lyon, France
Talk: "Information-theoretic reduction of deep neural networks to linear models in the overparametrized proportional regime", Deep Learning session.	
Workshop Data Science, ML and Physics	13 January 2025
ICTP - International Centre for Theoretical Physics	Trieste, Italy
Co-organizer.	

Mathematical Physics and Beyond   15 May 2024
Bologna Academy of Sciences   Bologna, Italy
Workshop. Member of the organizing committee and speaker.

Workshop on Learning and Inference from Structured Data   3-7 July 2023
ICTP - International Centre for Theoretical Physics   Trieste, Italy
Speaker.

Mathematical Physics of Complex Systems   11-16 June 2023
Cortona   Cortona, Italy
Conference. Member of the organizing committee.

Youth in High-Dimensions   29 May – 2 June 2023
ICTP - International Centre for Theoretical Physics   Trieste, Italy
Speaker.

Matrix factorization with neural networks   5 December 2022
Institute of Science and Technology Austria   Klosterneuburg, Austria
Talk for the ELLIS network.

A spin-glass perspective on a mismatched inference problem   20-22 June 2022
Parma   Italy
Talk for the II Conference of the Italian Society of Statistical Physics - SIFS.

Glassy behaviour in mismatched rank-one matrix estimation   26 May 2022
University of Padova   Padova, Italy
Talk for the First UMI meeting of Ph.D. students during the 100UMI - 800UniPD conference.

Boltzmann Machines on the Nishimori line   28 April 2021
University of Bologna   Bologna, Italy (Remote)
Speaker at the kick-off workshop AlmaHAI: Hard Sciences.

The deep Boltzmann machine on the Nishimori line   2 March 2021
ICTP - International Centre for Theoretical Physics   Trieste, Italy (Remote)
Seminar for the Quantitative Life Sciences (QLS) group at ICTP.

Mathematical Methods and Models in Machine Learning   27-28 April 2020
University of Bologna   Bologna, Italy
Member of the organizing committee.

EDUCATION

PhD in Mathematics | *cum laude*   November 2019 – March 2023
University of Bologna   Bologna, Italy
Supervisor: prof. Pierluigi Contucci.

Cotutelle: PhD in Physics | *cum laude*   May 2021 – March 2023
École Normale Supérieure   Paris, France
Supervisor: prof. Marc Mézard.

M.Sc. in Physics | *110/110 cum laude*   September 2017 – October 2019
University of Bologna   Bologna, Italy
Master Thesis: Statistical Mechanics Perspectives on Boltzmann Machines. Supervisor: prof. Pierluigi Contucci.
Co-supervisor: dott. Emanuele Mingione.

Collegio Superiore   September 2014 – October 2019
University of Bologna   Bologna, Italy

B.Sc. in Physics | *110/110 cum laude*   September 2014 – September 2017
University of Bologna   Bologna, Italy
Thesis (ITA): Teoria classica dei campi: campo elettromagnetico e radiazione di cariche in moto. Supervisor: prof.
Alexandre Kamenchtchik.

High School Diploma | *100/100 cum laude*   September 2009 – September 2014
Liceo Scientifico G. Marconi   Pesaro, Italy
Elected student representative in 2012/2013.

PUBLICATIONS

Fundamental limits of overparametrized shallow neural networks for supervised learning October 2025
Camilli, F., Tieplova, D., Barbier, J.
Bollettino dell'Unione Matematica Italiana, 1-38.

Phase diagram of extensive-rank symmetric matrix denoising beyond rotational invariance June 2025
Barbier, J., Camilli, F., Ko, J., Okajima, K.
Physical Review X **15**, 021085.

Information-theoretic reduction of deep neural networks to linear models in the overparametrized proportional regime May 2025
Camilli, F., Tieplova, D., Barbier, J., Bergamin, E.
38th Annual Conference on Learning Theory (COLT 2025).

On the phase diagram of the multiscale mean-field spin-glass May 2025
Camilli, F., Contucci, P., Mingione, E., Tantari, D.
Annales Henri Poincaré, 1-36.

Limit theorems for the non-convex multispecies Curie-Weiss model April 2025
Camilli, F., Mingione, E., Osabutey, G.,
Mathematics 2025, 13(8).

Central limit theorem for the overlaps in mean-field spin glasses on the Nishimori line January 2025
Camilli, F., Contucci, P., Mingione, E.
Electronic Journal of Probability, **30**, pp. 1-28.

Information limits and Thouless-Anderson-Palmer equations for spiked matrix models with structured noise January 2025
Barbier, J., Camilli, F., Mondelli, M., Xu, Y.
Phys. Rev. Research **7**, 013081.

The Decimation Scheme for Symmetric Matrix Factorization January 2024
Camilli, F., Mézard, M.
J. Phys. A: Math. Theor. **57** 085002

The Onset of Parisi's Complexity in a Mismatched Inference Problem December 2023
Camilli, F., Contucci, P., Mingione, M.
Entropy 2024, **26**(1), 42

Fundamental limits in structured principal component analysis and how to reach them July 2023
Barbier, J, Camilli, F., Mondelli, M., Sáenz., M.
Proceedings of the National Academy of Sciences **120** (30) e2302028120 (2023)

Matrix factorization with neural networks May 2023
Camilli, F., Mézard, M.
Physical Review E **107**, 064308 (2023)

New perspectives in statistical mechanics and high-dimensional inference March 2023
Camilli, F.
PhD thesis. Alma Mater Studiorum - Università di Bologna and École Normale Supérieure de Paris.
Supervisors: Contucci, P. and Mézard, M.

An inference problem in a mismatched setting: a spin-glass model with Mattis interaction April 2022
Camilli, F., Contucci, P., Mingione, E.
SciPost Physics **12**, 125 (2022)

A statistical physics approach to a multi-channel Wigner spiked model March 2022
Alberici, D., Camilli, F., Contucci, P., Mingione, E.
Europhysics Letters **136**, Article number: 4, (2022)

The Solution of the Deep Boltzmann Machine on the Nishimori Line July 2021
Alberici, D., Camilli, F., Contucci, P., Mingione, E.
Communications in Mathematical Physics **387**, 1191–1214, (2021)

The Multi-species Mean-Field Spin-Glass on the Nishimori Line January 2021
Alberici, D., Camilli, F., Contucci, P., Mingione, E.
Journal of Statistical Physics **182**, Article number: 2, (2021)

Preprints

From entropic constraints to reinforced processes: a probabilistic origin of multiscale measures   December 2025
Camilli, F., Contucci, P., Mingione, E.
arXiv e-prints, arXiv:2512.18313

Statistical physics of deep learning: optimal learning of a multi-layer perceptron near interpolation   October 2025
Barbier, J., Camilli, F., Nguyen, M.T., Pastore, M., Skerk, R.
arXiv e-prints, arXiv:2510.24616.

Statistical mechanics of extensive-width Bayesian neural networks near interpolation   June 2025
Barbier, J., Camilli, F., Nguyen, M.T., Pastore, M., Skerk, R.
arXiv e-prints, arXiv:2505.24849.

Optimal generalisation and learning transition in extensive-width shallow neural networks near interpolation   Feb. 2025
Barbier, J., Camilli, F., Nguyen, M.T., Pastore, M., Skerk, R.
arXiv e-prints, arXiv:2501.18530

Reviewing activity

Journal of Physics A: Mathematical and Theoretical   2025
IOP Science

EurIPS   2025
Workshop on Principles of Generative Modeling

Physical Review E   2025
American Physical Society

Information and Inference: A Journal of the IMA   2024 - 2025
Institute of Mathematics

IEEE Transactions on Information Theory   2024
IEEE Xplore

Journal of Statistical Physics   2023
Springer Nature

Neural Networks   2023
Elsevier

Applied and Computational Harmonic Analysis   2023
Elsevier

Skills

Languages: Italian (Native), English (C2), French (Basic interactions and understanding)
Programming: Python, C++ (Proficient user), Matlab, Mathematica
Document Creation: Microsoft Office Suite, LaTex (Proficient user)