

Alberto Fachechi

Activity and research interests

Research field: **Mathematical physics**

My research activity is placed in the wide discipline of statistical mechanics methods for complex systems analysis, in particular concerning **spin-glass theory** and its application to modern **Artificial Intelligence** and **Machine Learning**. The core research interest consists in the development of rigorous mathematical techniques, involving in particular Guerra's interpolating schemes, non-linear PDE theory, probability and statistics and random matrix theory. My research interests also cover the application of statistical inference tools to real-world (in particular, biological) problems.

Positions

- 2023 – Today ● **Researcher** (RTD-A).
Department of Mathematics G. Castelnuovo, Sapienza University of Rome.
SSD: MAT/07
- 2021 – 2023 ● **Post-doc researcher**.
Department of Mathematics G. Castelnuovo, Sapienza University of Rome.
SSD: MAT/07
- 2020 – 2021 ● **Post-doc researcher**.
Department of Mathematics and Physics E. De Giorgi, Unisalento.
SSD: MAT/07
- 2019 – 2020 ● **Research fellow**.
Department of Mathematics and Physics E. De Giorgi, Unisalento.
SSD: MAT/07

Education

- 2016 – 2019 ● **Ph.D. in Physics and Nanosciences**.
Department of Mathematics and Physics E. De Giorgi, Unisalento.
Thesis title: *Statistical mechanics for Artificial Intelligence: Learning, Retrieving, Unlearning and Sleeping*.
- 2013 – 2015 ● **M.Sc. in Theoretical Physics of Fundamental Interactions**.
Department of Mathematics and Physics E. De Giorgi, Unisalento.
Thesis title: *Higher-spin Lifshitz theories and integrable systems*.
- 2009-2013 ● **B.Sc. in Physics**.
Department of Mathematics and Physics E. De Giorgi, Unisalento.
Thesis title: *Integrability in AdS/CFT*.

Communities

- 2023-Today ● **FAIR foundation (Future Artificial Intelligence Research)**.
Partecipation as researcher in the group of Artificial Intelligence at Department of Mathematics, Sapienza University of Rome.
- 2018-Today ● **National Group for Mathematical Physics (GNFM-INdAM)**, section of mechanics for discrete systems.
- 2016-2017 ● **GATIS (GAUge Theory as an Integrable System)**, section of Bologna, National Institute for Nuclear Physics (INFN).
- 2015-2021 ● **National Institute for Nuclear Physics (INFN)**, section of Lecce.

Teaching

- 2024-2025
 - Teaching assistant for the course of **High-dimensional probability and statistics** (Prof. Lorenzo Taggi) for the academic year 2024-2025, Department of Mathematics, Sapienza University of Rome.
 - Lecturer for the course of **Mathematics** for the academic year 2024-2025, B.Sc. in Biotechnologies, Sapienza University of Rome.
- 2023-2024
 - Co-lecturer for the course of **Calculus and Biostatistics** for the academic year 2023-2024 (together with Prof. Elena Agliari), B.Sc. in Biology, Sapienza University of Rome.
 - Teaching assistant for the course of **Elements of Probability and Statistics for Data Science** (Prof. Alessandra Faggionato) for the year 2023-2024, Department of Mathematics, Sapienza University of Rome.
 - Lecturer for the course of **Statistical learning and neural networks: a short introduction to Artificial Intelligence** for the academic year 2023-2024 in the context of the “Excellence Program” (B.Sc. section), Department of Mathematics, Sapienza University of Rome.
- 2021-2022
 - Co-lecturer for the course of **Mathematics** for the academic year 2021-2022 (resp. Prof. Raffaella Capitanelli), Department of Architecture, Sapienza University of Rome.
- 2019-2021
 - Supervisor for the course of **Mathematics for Economy and Finance** for the academic years 2019-2020 and 2020-2021 (resp. Prof. Luca Anzilli), Department of Economy, Unisalento.

Supervising

- 2025
 - Supervisor for the B.Sc. thesis in Mathematics for Artificial Intelligence by Lorenzo Neri with title *Probabilistic methods in sampling and optimization: from Monte Carlo Markov Chain to simulated annealing*, Sapienza Università di Roma, Rome (IT).
 - Main supervisor (together with Prof. Elena Agliari) for the B.Sc. thesis in Mathematics by Shahed Akter with title *From Hebb's rule to projector models: correction mechanisms in Hopfield associative neural networks*, Sapienza Università di Roma, Rome (IT).
 - Co-supervisor (together with Prof. Elena Agliari) for the PhD thesis in Mathematics by Miriam Aquaro with title *Application of spin glass theory in neural networks and evolutionary models*, Sapienza Università di Roma, Rome (IT).
 - Supervisor for the ACU course essay by Shahed Akter with title *Regularization in supervised learning*, Sapienza Università di Roma, Rome (IT).
 - Supervisor for the ACU course essay by Andrea Pettenello with title *An Introduction to statistical inference and neural networks*, Sapienza Università di Roma, Rome (IT).
- 2024
 - Supervisor for the ACU course essay by Yuriy Dosyak with title *Bayesian approach to supervised learning: mathematical approaches to automatic learning*, Sapienza Università di Roma, Rome (IT).
 - Co-supervisor (together with Prof. Elena Agliari) for the M.Sc. thesis in Mathematics by Domenico Luongo with title *A Random Matrix Theory Perspective on Hebbian-Like Neural Networks*, Sapienza Università di Roma, Rome (IT).
- 2023
 - Supervisor for the M.Sc. thesis in Mathematics by Benedetta Giovannelli with title *Statistical mechanics of spin-glasses for Artificial Intelligence and Machine Learning*, Sapienza Università di Roma, Rome (IT).
 - Co-supervisor (together with Prof. Elena Agliari) for the PhD thesis in Mathematics by Chiara Marullo with title *Rigorous techniques for Statistical Mechanics of Machine Retrieval*, Sapienza Università di Roma, Rome (IT).
 - Co-supervisor (together with Prof. Elena Agliari) for the M.Sc. thesis in Mathematics by Donatella Genovese with title *Effective training strategies for Restricted Boltzmann Machines*, Sapienza Università di Roma, Rome (IT).

Supervising (continued)

- Co-supervisor (together with Prof. Elena Agliari) for the M.Sc. thesis in Mathematics by Matteo Notarnicola with title *On the thermodynamic limit of bipartite spin glasses*, Sapienza Università di Roma, Rome (IT).
- 2018 ● Co-supervisor (together with Prof. Elena Agliari) for the M.Sc. thesis in Applied Mathematics by Chiara Marullo with title *Neural network beyond the Hebbian paradigm*, Sapienza Università di Roma, Rome (IT).

Funded projects

- 2023 ● PI for the project **Rigorous statistical mechanics for Artificial Intelligence and Machine Learning** in the context of Progetto Giovani 2023 funded by National Group of Mathematical Physics.
- 2022 ● PI for the project **Replica Symmetry Breaking in modern Artificial Intelligence** in the context of Progetto Avvio alla ricerca 2022 funded by Sapienza University of Rome.
 - Participant to the project **Large scale multicomponent random systems** (ref. Prof. Vittoria Silvestri) funded by Sapienza University of Rome (Progetto di Ricerca Medio).
- 2018 ● Participant to the project **Rigorous approaches to Deep Learning** (ref. Prof. Elena Agliari) in the context of Progetto Giovani 2018 funded by National Group of Mathematical Physics (GNFM).

Other roles

- 2025 ● **Member of the local Organizing Committee** of the 4th Workshop of UMI Group *Mathematics for Artificial Intelligence and Machine Learning*, Department of Mathematics G. Castelnuovo, Sapienza Università di Roma Fourth edition of the workshop of the UMI Group, which will take place in January 2025.
 - **Co-organizer** of the Workshop *Statistical methods for machine learning*, Department of Mathematics G. Castelnuovo, Sapienza Università di Roma. The workshop falls in the thematic period on Data Science of the "Excellence program" for the Department of Mathematics, which will take place in January 2025.
 - **Member of selection committee** for post-doc positions, Department of Mathematics G. Castelnuovo, Sapienza Università di Roma.
- 2024-Today ● **Member of the Department Committee** for Department informatic facilities.
 - **Co-organizer** of the Summer School *Mathematical methods for high-dimensional data* (8-12 September 2025), Department of Mathematics G. Castelnuovo, Sapienza Università di Roma. The school opens the thematic period on Data Science of the "Excellence program" for the Department of Mathematics.
 - **Responsible for communication** for the FAIR foundation, Spoke 5 (WP5,5) for the organization of scientific and dissemination events.
- 2024 ● **Organizer** of the VI Scientific Meeting for the FAIR foundation.
- 2023-Today ● Member of the Department Assembly, Department of Mathematics, Sapienza University of Rome.
- 2022 ● **Project reviewer** for the Isreal Science Foundation.
- 2018-2024 ● **Review editor** for Frontiers in Physics, section of Social Physics.

Other roles (continued)

- 2017-Today ● **Referee** for high-impact journals, in particular *Nature Scientific Reports*; *Journal of Mathematical Physics*; *Journal of Physics A: Mathematical and Theoretical*; *Neural Computation*; *Journal of Physics: Complexity*; *Physica A: Statistical Mechanics and its Applications*; *Journal of Statistical Mechanics: Theory and Experiment*; *Machine Learning: Science and Technology*.

Recognitions and titles

- 2025 ● **National Scientific Qualification (ASN)** in the scientific sector *Mathematical Physics* (SC 01/A4, SSD MATH-04/A ex MAT07)
- 2023 ● **Outstanding reviewer** for IOP publishing for my contributions to the *Journal of Physics: Complexity*.
- 2021 ● **Special mention** for my PhD thesis from the selection board of Fubini Prize 2021 (INFN).
- 2020 ● **Trustee reviewer** for IOP Publishing.

Selected talks to conferences and invited talks

- 2025 ● *Statistical mechanics of equilibrium of learning Boltzmann Machines: fundamental operating regimes, hyper-parameter fine-tuning and glassiness*, invited talk at Chimera Journal Club, Physics Department Sapienza Università di Roma (IT)
- *A random matrix approach to Hopfield-like neural networks: addressing generalization and overfitting*, 3rd Workshop of UMI Group Mathematics for Artificial Intelligence and Machine Learning Politecnico di Bari (IT).
- 2024 ● *A Hopfield-like picture to address generalization and overfitting*, Mathematics for Artificial Intelligence and Machine Learning, University Bocconi of Milano.
- *Modeling information processing systems: a survey of statistical-mechanical results for bio-inspired neural networks*, online invited talk for Dipoppa Lab, Neuroscience group at UCLA.
- 2023 ● *Dreaming Neural Networks: pushing retrieval/learning capabilities to the limit by "sleeping" mechanism*, invited talk at Physics-informed machine learning workshop, Alan Turing Institute.
- *Machine Learning from a spin-glass theory perspective*, invited talk at Stochastic Models for Complex Systems, Department of Mathematics E. De Giorgi, Unisalento.
- *Retrieving, unlearning and learning: there and back again*, invited talk at the Department of Physics, Sapienza University of Rome.
- 2022 ● *Dreaming Neural Networks: pushing retrieval/learning capabilities to the limit by "sleeping" mechanism*, Matematica per l'Intelligenza Artificiale e il Machine Learning - Giovani ricercatori, Politecnico di Torino.
- *PDE/Statistical Mechanics relation: from p-spin ferromagnets to dense associative memories*, Department of Mathematics, Sapienza University of Rome.
- *Dreaming Neural Networks: pushing retrieval/learning capabilities to the limit by "sleeping" mechanism*, invited talk at the Unconventional Computation Workshop, Swansea University.
- 2021 ● *Dreaming Neural Networks: dal richiamo automatico all'apprendimento*, Divulgazioni Notturme di Fisica Matematica, invited online talk for GNFM (Gruppo Nazionale della Fisica Matematica).
- 2018 ● *Sleeping in Hopfield neural networks: some recent results*, invited talk at the Department of Mathematics, King's College London.
- 2017 ● *Chiral trace relations in Ω -deformed $\mathcal{N} = 2$ theories*, XXVth International Conference on Integrable Systems and Quantum symmetries, Czech Technical University Prague.
- *Chiral trace relations in Ω -deformed $\mathcal{N} = 2$ theories*, Physics and Mathematics of Nonlinear Phenomena – "50 years of IST", Unisalento.

Popularization of science

- 2025 ● Invited talks at the divulgative event "Is AI Intelligence? A dialogue between Neuroscience and Physics", Superior School of Advanced Studies (SSAS), Sapienza Università di Roma, 26-27 September 2025
- 2021 ● *Dreaming Neural Networks: dal richiamo automatico all'apprendimento*, Divulgazioni Notturme di Fisica Matematica, online talk for GNFM (Gruppo Nazionale della Fisica Matematica).
- 2019 ● "Notte europea dei ricercatori" (European Researchers' Night 2019) Lecce (IT), 27 September 2019
- 2017 ● "Notte europea dei ricercatori" (European Researchers' Night 2017) Lecce (IT), 29 September 2017

Visiting periods

- January 2023 ● **Alan Turing Institute, London.** During the period, I attended the workshop "Physics-informed Machine-Learning", in which I took part to stimulating discussions about statistical mechanics of spin glasses and their application to Artificial Intelligence. I also gave a talk at the workshop about Dreaming Neural Networks and the possibility to extended the theory to Boltzmann Machines.
- October 2018 ● **Department of Mathematics, King's College London, London** , Ref. Prof. Alessia Annibale. During the period, we discussed several topics in statistical mechanics of spin glasses, especially concerning the application of Machine Retrieval models to the theoretical modeling of biological processes. In this period, I also gave an invited talk. Finally, I also had the chance to discuss with brilliant researchers and professors, in particular with Prof. Reimer Kuhn.
- 2018 (often) ● **Department of Mathematics "Guido Castelnuovo"**, Sapienza Università di Roma, Rome (IT), Ref. Prof. Elena Agliari. During the period, we investigated unlearning theory for Machine Retrieval models. The discussions were crucial for the ideation and the theoretical investigation about Dreaming Neural Networks.
- 2016-2017 (often) ● **Department of Physics "Augusto Righi"**, Alma Mater Studiorum, Bologna (IT) Ref: Prof. Davide Fioravanti During the period, we investigated the relation between supersymmetric gauge theory on deformed background with quantization of classical integrable systems.

Summary of scientific production

Total number of publicatished paper	30
Total number of citations ¹	551
Total <i>h</i> -index ¹	11
Total <i>i</i> 10-index ¹	15

¹Source: GoogleScholar.

Full list of publications

- E. Agliari, A. Alessandrelli, P. D. Mourão, A. Fachechi. *Multi-channel pattern reconstruction through L-directional associative memories*. arXiv:2503.06274 (2025).
- A. Fachechi, E. Agliari, M. Aquaro, A. Coolen, M. Mulder. *Fundamental operating regimes, hyperparameter fine-tuning and glassiness: towards an interpretable replica-theory for trained restricted Boltzmann machines*. *J. Phys. A: Math. Theor.* **58**, 065004 (2025).
- J. Steinberg, U. Adomaityte, A. Fachechi, P. Mergny, D. Barbier, R. Monasson. *Replica method for computational problems with randomness: principles and illustrations*. *J. Stat. Mech.* 2024, 104002 (2024).
- E. Agliari, F. Alemanno, M. Aquaro, A. Fachechi. *Regularization, early-stopping and dreaming: A Hopfield-like setup to address generalization and overfitting*. *Neural Networks* **177**, 106389 (2024).
- E. Agliari, A. Fachechi, D. Luongo. *A spectral approach to Hebbian-like neural networks*. *Applied Mathematics and Computation* **474**, 128689 (2024).
- E. Agliari, M. Aquaro, A. Barra, A. Fachechi, C. Marullo. *From Pavlov conditioning to Hebb learning*. *Neural Computation* **35**(5), 930–957 (2023).
- F. Alemanno, M. Cavo, D. Delle Cave, A. Fachechi, R. Rizzo, E. D'Amone, G. Gigli, E. Lonardo, A. Barra, L. L. Del Mercato. *Quantifying heterogeneity to drug response in cancer–stroma kinetics*. *PNAS* **120**(11), e2122352120 (2023).
- E. Agliari, A. Fachechi, C. Marullo. *Nonlinear PDEs approach to statistical mechanics of dense associative memories*. *J. Math. Phys.* **63**(10) (2022).
- A. Fachechi, A. Barra, E. Agliari, F. Alemanno. *Outperforming RBM feature-extraction capabilities by “dreaming” mechanism*. *IEEE Trans. Neural Netw. Learn. Syst.* **35**(1), 1172–1181 (2022).
- E. Agliari, L. Albanese, F. Alemanno, A. Fachechi. *A transport equation approach for deep neural networks with quenched random weights*. *J. Phys. A: Math. Theor.* **54**(50), 505004 (2021).
- A. Fachechi. *PDE/Statistical Mechanics Duality: Relation Between Guerra’s Interpolated p -Spin Ferromagnets and the Burgers Hierarchy*. *J. Stat. Phys.* **183**(1), 12 (2021).
- E. Agliari, A. Fachechi, C. Marullo. *The relativistic Hopfield model with correlated patterns*. *J. Math. Phys.* **61**(12) (2020).
- E. Agliari, F. Alemanno, A. Barra, O. A. Barra, A. Fachechi, L. F. Vento, L. Moretti. *Analysis of temporal correlation in heart rate variability through maximum entropy principle in a minimal pairwise glassy model*. *Scientific Reports* **10**(1), 15353 (2020).
- E. Agliari, F. Alemanno, A. Barra, A. Fachechi. *Generalized Guerra’s interpolation schemes for dense associative neural networks*. *Neural Networks* **128**, 254–267 (2020).
- E. Agliari, A. Barra, O. A. Barra, A. Fachechi, L. Franceschi Vento, L. Moretti. *Detecting cardiac pathologies via machine learning on heart-rate variability time series and related markers*. *Scientific Reports* **10**(1), 8845 (2020).
- F. Alemanno, M. Centonze, A. Fachechi. *Interpolating between Boolean and extremely high noisy patterns through minimal dense associative memories*. *J. Phys. A: Math. Theor.* **53**(7), 074001 (2020).
- E. Agliari, F. Alemanno, A. Barra, M. Centonze, A. Fachechi. *Neural networks with a redundant representation: Detecting the undetectable*. *Phys. Rev. Lett.* **124**(2), 028301 (2020).
- E. Agliari, F. Alemanno, A. Barra, A. Fachechi. *Dreaming neural networks: rigorous results*. *J. Stat. Mech.* 2019(8), 083503 (2019).
- E. Agliari, F. Alemanno, A. Barra, A. Fachechi. *On the Marchenko–Pastur law in analog bipartite spin-glasses*. *J. Phys. A: Math. Theor.* **52**(25), 254002 (2019).
- A. Fachechi, E. Agliari, A. Barra. *Dreaming neural networks: forgetting spurious memories and reinforcing pure ones*. *Neural Networks* **112**, 24–40 (2019).
- A. Barra, M. Beccaria, A. Fachechi. *A new mechanical approach to handle generalized Hopfield neural networks*. *Neural Networks* **106**, 205–222 (2018).

Full list of publications (continued)

- A. Fachechi, G. Macorini, M. Beccaria. *Chiral Trace Relations in $\mathcal{N} = 2^*$ Supersymmetric Gauge Theories*. *Theor. Math. Phys.* **196**(3), 1282–1293 (2018).
- E. Alfinito, A. Barra, M. Beccaria, A. Fachechi, G. Macorini. *An evolutionary game model for behavioral gambit of loyalists: Global awareness and risk-aversion*. *Europhys. Lett.* **121**(3), 38001 (2018).
- A. Fachechi, G. Macorini, M. Beccaria. *Chiral trace relations in Ω -deformed $\mathcal{N} = 2$ theories*. *J. Phys.: Conf. Ser.* **965**(1), 012013 (2018).
- M. Beccaria, A. Fachechi, G. Macorini. *Chiral trace relations in Ω -deformed $\mathcal{N} = 2$ theories*. *J. High Energy Phys.* 2017(5), 1–37 (2017).
- E. Alfinito, M. Beccaria, A. Fachechi, G. Macorini. *Reactive immunization on complex networks*. *Europhys. Lett.* **117**(1), 18002 (2017).
- E. Alfinito, M. Beccaria, A. Fachechi, G. Macorini. *Probing complexity with epidemics: a new reactive immunization strategy*. In: *COMPLEXIS 2017, 2nd Intl. Conf. on Complexity, Future Information Systems and Risk* **1**, 116–123 (2017).
- M. Beccaria, A. Fachechi, G. Macorini, L. Martina. *Exact partition functions for Ω -deformed $\mathcal{N} = 2$ theories with $N_f = 4$ flavours*. *J. High Energy Phys.* 2016(12), 1–41 (2016).
- M. Beccaria, A. Fachechi, G. Macorini. *On the cusp anomalous dimension in the ladder limit of $N = 4$ SYM*. *J. High Energy Phys.* 2016(6), 1–21 (2016).
- M. Beccaria, A. Fachechi, G. Macorini. *Virasoro vacuum block at next-to-leading order in the heavy-light limit*. *J. High Energy Phys.* 2016(2), 1–22 (2016).