Fabio **Anselmi**

ASSISTANT PROFESSOR · MACHINE LEARNING, COMPUTATIONAL NEUROSCIENCE, PHYSICS

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Current Position and Interests

From 2022 I am an assistant professor working at the Department of Mathematics and Geoscience, Computer Science section. I am also affiliated to the Centre for Brains Minds and Machines at the Massachusetts Institute of Technology (MIT). My interests lie in machine learning, in particular artificial neural networks, with applications to computational neuroscience, physics and medicine.

- My current research focuses on:
  - Design and develop artificial networks architectures where the learned representations are adapted to data-priors e.g. symmetries with applications to physics.
  - Understand the implicit computational bias of different neural networks architectures and its impact on adversarial examples and interpretable features.
  - Applications of neural networks to neuroscience (analysis of visual cortex neuronal responses) and medicine.

Education

Assistant professor
Houston, Texas, USA

BAYLOR COLLEGE OF MEDICINE
2020–2022

- Machine learning models for data from Visual Cortex; applications of machine learning to Quantum Mechanics
- *Research areas*: Computational neuroscience, Physics and machine learning.

Research scientist
Cambridge, USA and Genova, Italy

MASSACHUSETTS INSTITUTE OF TECHNOLOGY AND ITALIAN INSTITUTE OF TECHNOLOGY
2011–2019

- Sample efficient deep networks with application to visual cortex.
- *Research areas*: Computational neuroscience and machine learning.

Postdoc in Biophysics
Milano, Italy

HUMANITAS CLINICAL INSTITUTE
2008–10

- Developed and optimized new protocols for immunological-signaling experiments and data analysis.
- *Research areas*: Biology and biophysics of the immunological system.

Postdoc in Biophysics
Padova, Italy

VENETIAN INSTITUTE OF MOLECULAR MEDICINE
2005–08

- Highlighted a new biological pathway for calcium signalling in the inner ear.
- *Research areas*: Biology and biophysics of hearing.

Ph.D. in Quantum Information and Computation
Hatfield, United Kingdom

HERTFORDSHIRE UNIVERSITY (UK) | SCHOOL OF PHYSICS, ASTRONOMY AND MATHEMATICS
2001–04

- *Ph.D. thesis*: Quantifying non local resources and local cloning of quantum states.
- *Research areas*: Quantum computing.

Graduated in Physics
Padova, Italy

UNIVERSITY OF PADOVA
1996–2000

- *Research areas*: Theoretical Physics.
- Thesis: "Magnetic charges and monopoles in generic dimension".

International and national research projects

• I was part (2020−2022) of the international team of **IARPA MICrONS**, a project with the goal of reverse engineering one cubic millimeter—spanning many petabytes of volumetric data—of a rodent's brain tissue and use insights from its study to improve machine learning and artificial intelligence by constructing a connectome. The program is part of the White House BRAIN Initiative (`https://www.microns-explorer.org/team`, `https://en.wikipedia.org/wiki/MICrONS`).

• I am part since **2013** of the **Center for Brains, Minds and Machines** (CBMM), a National Science Foundation funded Science and Technology Center focused on the interdisciplinary study of intelligence - how the brain produces intelligent behavior and how we may be able to replicate intelligence in machines. This effort is a international multi-institutional collaboration headquartered at the McGovern Institute for Brain Research at MIT (`https://cbmm.mit.edu/about/people/anselmi`).

• I was part (**2017 — 2020**) of the international project **TTESLA (Towards Tera-Scale Nonparametric Learning)** funded by the Air Force Grant FA9550-17-1-0390. The project focused on the development of optimal and efficient algorithms for large scale machine learning and their applications.

• I was part (**2008 — 2010**) of the FP7-HEALTH program of the European Union **SYBILLA**, an international project focused on studying the Systems Biology of T-cell Activation in Health and Disease (`https://cordis.europa.eu/project/id/201106`).

• I was part (**2005 — 2008**) of the FP6-LIFESCIHEALTH program of the European Union **EUROHEAR**, (LSHG-CT-20054-512063), an international project aimed to (1) provide fundamental knowledge about the development and function of the inner ear, and (2) identify the molecular defects underlying hereditary hearing impairments (`https://cordis.europa.eu/project/id/512063`).

• I was part (**2005 — 2008**) of the Italian **Telethon** project Connexin defects and congenital hearing loss (GGP05131), aimed to understand the role played by connexins in the inner ear and their relation to hearing impairment.

Peer-reviewed Publications

See also:
Google Schoolar: `https://scholar.google.com/citations?user=ILfgh7UAAAAJ&hl=en`

Under review

• J.O. Caro, Y. Ju, R. Pyle, S. Dey, W. Brendel, **F. Anselmi**, A. Patel, *Local Convolutions Cause an Implicit Bias towards High Frequency Adversarial Examples*, Neural Networks, under review, 2022.

Published

• E. Besier*, N. Karantsaz*, A. Patel, A. Tolias, **F. Anselmi**. *Learning important Fourier features of a neural network's input reveals its computational bias*, Frontiers in Machine Learning and Artificial Intelligence, 2022.

• B.Franceschiello*, T. Di Noto*, A. Bourgeois, M. M.Murray, A. Minier, P. Pouget, J. Richiardi, P. Bartolomeo, **F. Anselmi**, *Convolutional neural networks on eye tracking trajectories classify patients with spatial neglect*, Computer Methods and Programs in Biomedicine, 2022.

• **F. Anselmi**, A. Patel, L. Rosasco. *Neurally plausible mechanisms for learning selective and invariant representations*, Journal of mathematical neuroscience, 10, 12, 2020.

• **F. Anselmi**, M. Murray, B. Franceschiello. *A computational model for grid maps in neural populations*, Journal Of Computational Neuroscience, 48, 149–159 2020.

• **F. Anselmi**, N. Noceti, L. Rosasco, R. Ward. *Genuine personality recognition form highly constrained face images*, Image Analysis and processing conference, Trento, 2019.

• **F. Anselmi***, G. Evangelopoulos*, L. Rosasco, and T. Poggio. *Symmetry-adapted representation learning*, Pattern Recognition, 86, 201–208, 2019.

• **F. Anselmi***, G. Evangelopoulos*, L. Rosasco, and T. Poggio. *Learning representations that account for data symmetries*, Poster, ICML 2018, Stockholm, SE, 2018.

• J.Z. Leibo, Q. Liao, W. Freiwald , **F. Anselmi**, T. Poggio. *View-tolerant face recognition implies mirror-symmetric neural tuning to head orientation*. Current Biology, Volume 27, Issue 1, 62-67, 9, 2017.

• **F. Anselmi**, L. Rosasco, T. Poggio. *On Invariance and Selectivity in Representation Learning*. Information and Inference (part of a special issue on Deep Learning), Volume 5, Issue 2, 134-158, 2016.

• **F. Anselmi**, J.Z. Leibo, L. Rosasco, J. Mutch, A. Tacchetti, T. Poggio. *Unsupervised Learning of Invariant Representations*. Theoretical Computer Science, 663, 112-121, 2016.

• J.Z. Leibo , Q. Liao, **F. Anselmi**, T. Poggio. *The invariance hypothesis implies domain-specific regions in visual cortex*. Plos Computational Biology, vol. 11. no. 10, 2015.

• M.W. Chiuhui, P. Cristina, **F. Anselmi**, A. Sarukhan, A. Viola. *Adenosine triphosphate acts as a paracrine signaling molecule to reduce the motility of T cells* The EMBO Journal,17;33(12):1354-64, 2014.

• M. Kallikourdis, A. E. Trovato, **F. Anselmi**, A. Sarukhan, G. Roselli, L. Tassone, R. Badolato, A. Viola. *The CXCR4 mutations in WHIM syndrome impair the stability of the T-cell immunologic synapse*. Blood, 122(5):666-73,2013.

• J. Z. Leibo, **F. Anselmi**, J. Mutch, A.F. Ebihara, W. A. Freiwald, T. Poggio. *View-invariance and mirror-symmetric tuning in a model of the macaque face processing system*, Poster. Cosyne 2013, Salt Lake City, UT, USA, 2013.

• L. Rodriguez, E. Simeonato, P. Scimemi, **F. Anselmi**, B. Calì, G. Crispino, C.D. Ciubotaru, M. Bortolozzi, F.G. Ramirez, P. Majumder, E. Arslan, P. De Camilli, T. Pozzan, F. Mammano. *Reduced phosphatidylinositol 4,5-bisphosphate synthesis impairs inner ear Ca2+ signaling and high-frequency hearing acquisition*. Proc. Natl. Acad. Sci U S A. ,109(35):14013-8, 2012.

• M. Planat, **F. Anselmi**, P. Solé. *Pauli graphs, Riemann hypothesis, Goldbach pairs*. Theoretical and Mathematical Physics, Volume 171, Issue 3, 780-791, 2012.

• R.L. Contento, S. Campello, A.E. Trovato, E. Magrini, **F. Anselmi**, A. Viola. *Adhesion shapes T cells for prompt and sustained T cell receptor signaling*. EMBO J ,29(23):4035-47, 2010.

• F. Mammano, **F. Anselmi**. *Inner ear connexins, intercellular signalling and deafness*. Audiological Medicine 00:1-6, 2009.

• P. Majumder, G. Crispino, L. Rodriguez, C. D. Ciubotaru, **F. Anselmi**, V. Piazza, M. Bortolozzi, F. Mammano. *ATP-mediated cell-cell signaling in the organ of Corti: the role of connexin channels*. Purinergic Signalling, 6,167-187, 2010.

• **F. Anselmi**, V. H. Hernandez, G. Crispino, A. Seydel, S. Ortolano, S. D. Roper, N. Kessaris, W. Richardson, G. Rickheit, M.A. Filippov, H. Monyer, F. Mammano. *ATP release through connexin hemichannels and gap junction transfer of second messangers propagate Ca2+ signals across the inner ear*. Proc. Natl. Acad. Sci U S A. 105(48):18770-5, 2008.

• S. Ortolano, G. Di Pasquale, G. Crispino, **F. Anselmi**, F. Mammano, J. Chiorini. *Coordinated control of connexin 26 and connexin 30 at the regulatory and functional level in the inner ear*. Proc. Natl. Acad. Sci U S A. 105(48):18776-81, 2008.

• J.A. Vaccaro, **F. Anselmi** , H.M. Wiseman, K. Jakobs. *Tradeoff between extractable mechanical work, accessible entanglement, and ability to act as a reference system, under arbitrary superselection rules*. Phys. Rev. A 77, 032114, 2008.

• F. Mammano, M. Bortolozzi, S. Ortolano, **F. Anselmi**. *Calcium signaling in the inner ear.* Physiology; 22: 131-144, 2007.

• **F. Anselmi**, A. Chefles, M.B. Plenio. *Local copying of orthogonal entangled quantum states*. New. J. Phys., Vol. 6, 164, 2004.

• J.A. Vaccaro, **F. Anselmi**, H.M. Wiseman. *Entanglement of identical particles and reference phase uncertainty*. International Journal of Quantum Information Vol. 1, No. 4,427-441, 2003.

Not peer-reviewed Publications

• T. Poggio, **F. Anselmi**, and L. Rosasco. *I-theory on depth vs width: hierarchical function composition*, CBMM (Center for Brain Minds and Machines). Memo 41, 2015.

• T. Poggio, L. Rosasco, A. Shashua, N. Cohen, **F. Anselmi**. *Notes on Hierarchical Splines, DCLNs and i-theory*. CBMM Memo 37, 2015.

• **F. Anselmi**, L. Rosasco, C. Tan, T. Poggio. *Deep Convolutional Networks are Hierarchical Kernel Machines*. arXiv:1508.01084, 2015.

• **F. Anselmi** and T. Poggio. *Representation Learning in Sensory Cortex: a theory*. CBMM Memo 26, 2014.

• T. Poggio, J. Mutch, **F. Anselmi**, L. Rosasco, J.Z. Leibo, A. Tacchetti. *The computational magic of the ventral stream: sketch of a theory (and why some deep architectures work)*. CSAIL Technical Report, 2012.

Books/Books chapters

• T. Poggio, **F. Anselmi**. *Visual Cortex and Deep Networks*. MIT Press, 2016, (`https://mitpress.mit.edu/books/visual-cortex-and-deep-networks`). The Caltech course Ma 191 b Topics Course: Geometry of Neuroscience, class "Ventral visual system and deep Networks" is based on the book content: (`http://www.its.caltech.edu/~matilde/VCortexDeepNets.pdf`).

• T. Poggio, J. Mutch, **F. Anselmi**, A. Tacchetti, L. Rosasco, J.Z. Leibo. *Invariant Recognition Predicts Tuning of Neurons in Sensory Cortex*. Book chapter, in Computational and Cognitive Neuroscience of Vision, Springer, 2016.

Publications in Preparation

• N. Karantsaz, A. Tolias, **F. Anselmi**. *A novel defence strategy for adversarial attacks by breaking equivariance symmetry in neural networks*.

• B. Franceschiello, M. Murray, **F. Anselmi**. *Relating the location of the periferal retinal locus to the anatomical characteristics of the retinal layers with deep networks*.

• S. Alam, Y. Ju, J. Minoff, **F. Anselmi**, A. Patel, H. Pu *Convolutional Neural Networks and Symmetries of Quantum 1D Spin Chains*.

Popular press

• "How the brain recognize faces". Larry Hardesty, MIT News, 2016 (reported also by reported also by Eurekalert, Sciencedaily, and Neuroscience news).

• "Machines that learn like people". Larry Hardesty, MIT News, 2015 (reported also by PHYS.ORG and Weforum).

Recent invited talks

Conferences and workshops

• January 2021, 18th Annual GCC Theoretical and Computational Neuroscience Conference. **Invited talk as key speaker**: "Neurally plausible mechanisms for learning selective and invariant representations" (`http://tcn2021.blogs.rice.edu/`).

• September 2020, Workshop on Equivariance and Data Augmentation, University of Pennsylvania. **Invited talk as key speaker**: "Neurally plausible mechanisms for learning selective and invariant representations" (`https://sites.google.com/view/equiv-data-aug/home`).

• July 2018, International Conference on Machine Learning, **oral and poster presentation** "Learning representations that account for data symmetries" at the workshop "Towards learning with limited labels: Equivariance, Invariance, and Beyond", Stockholm (`https://sites.google.com/site/icml18limitedlabels/accepted-papers`).

• May 2018, **invited talk as key speaker**: "Invariant and selective image representations for efficient deep networks with applications to visual cortex" at "Neuromathematics of Vision" a satellite workshop at the Conference on Imaging Science (Siam), Bologna (`https://site.unibo.it/summer-school-siam-` `en/workshops/neuro-mathematics-of-vision`).

• February 2018, **invited talk** "Invariant and selective data representations for efficient deep networks with applications to visual cortex" at "Data science workshop" at International School for Advanced Studies, Trieste, Italy (`https://www.sissa.it/news/data-science-workshop`, see program).

• November 2017, **invited talk** "Invariant and selective representations, Deep convolutional networks and visual cortex" at "Cortical Inspired Non-holonomic Control for Imaging" workshop at Institute Henry Poincaire, Paris, France (`https://www.ljll.math.upmc.fr/trelat/SRGI/schedule_` `CINCIN.html`).

• September 2017, **invited talk** "Invariant and selective representations and Deep convolutional networks" at the international workshop "Systematic approaches to deep learning methods for audio", Schrodinger Institute, Vienna, Austria (`https://www.univie.ac.at/nuhag-php/event_NEW/` `make.php?event=esi17`).

Seminars

• August 2020, Brain Research Imaging Centre, Cardiff University. **Invited talk** "A novel computational model for grid maps in neural populations".

• December 2018, College de France, Paris, **invited talk** at Seminaire Neuromathematiques, "Towards a more interpretable deep learning with physical priors and application to Visual cortex".

• November 2018, Eawag (acquatic research, `https://www.eawag.ch/en/`), Zurich, **invited talk**, "Towards a more interpretable deep learning with physical priors".

• November 2018, Baylor College of Medicine, Houston, **invited talk**, "Towards understanding efficient data representations in vision and deep learning".

• September 2018, Mc Govern Institute, MIT, Cambridge, **invited talk** at "A computational model of grid cells".

• November 2017, Graphics and Vision Research Group, University of Basel, Switzerland. **Invited talk** "Face recognition in macaque visual cortex and invariant and selective face representations".

Recent teaching experiences and tutoring

Teaching

• 2020-2021 supervision of a postdoctoral (Nikos Karantzas) student at Baylor College of Medicine.

• 2021: **invited lecturer** on the classes "Group Invariants in Vision" and "Invariance, Neurons, Synaptic Plasticity and Development" for the MIT course 9.520: Statistical Learning Theory and Applications (`https://cbmm.mit.edu/9-520`).

• 2020: **invited lecturer** on the classes "Group Invariants in Vision" and "Invariance, Neurons, Synaptic Plasticity and Development" for the MIT course 9.520: Statistical Learning Theory and Applications (`https://cbmm.mit.edu/9-520`).

• 2019-20: **laboratory teacher and teaching assistant** at the Machine Learning Course at Department of Informatics Bioengineering Robotics and Systems Engineering of the University of Genoa (`http://lcsl.mit.edu/courses/ml/1920`).

• 2018-19: **laboratory teacher and teaching assistant** at the Machine Learning Course at Department of Informatics Bioengineering Robotics and Systems Engineering of the University of Genoa (`http://lcsl.mit.edu/courses/ml/1819/`).

• 2017-18: **laboratory teacher and teaching assistant** at the Machine Learning Course at Department of Informatics Bioengineering Robotics and Systems Engineering of the University of Genoa (`http://lcsl.mit.edu/courses/ml/1718/`).

• 2018: **laboratory teacher** for "Introductory Machine Learning ML101" course at Digital Tree company (Microsoft Partner, Genova, `https://digitaltree.ai/`) in collaboration with the University of Genova.

• 2018: **teacher** for "Introductory Machine Learning" course at Axpo (energy trading company) in Genova, in collaboration with the University of Genova (`https://www.axpo.com/it/en/home.html`).

• 2018: **teacher** in Machine learning and Deep Learning at International Winter School on Humanoid Robot Programming, Santa Margerita Ligure (`http://www.icub.org/school/2018/`).

• 2014: **assistant lecturer** of the course "Computational approaches of biological learning" at MIT (course number 9.54).

• 2014 **Laboratory teacher** at the Brains Minds and Machines International Summer school, Woodshole, MA, USA.

Tutoring

• 2020-2021 supervision of a a master student (Emma Besier) at Baylor College of Medicine.

• 2015: supervision of a master thesis student (Jordan Cotler) at MIT.

Editorial and organizational activity

• Invited **leading guest editor** for Frontiers of Neuroscience on the topic: "Symmetry as a Guiding Principle in Understanding Neural Information Processing", 2020-2021.
(`https://www.frontiersin.org/research-topics/15343/symmetry-as-a-guiding-principle-in-understanding-neural-information-pr`

• **Organizer** of Machine Learning Crash Course, Genova, 2017 (`http://lcsl.mit.edu/courses/mlcc/mlcc2017/`).

• **Local organizer** of Brains, Minds and Machines Workshop in Sestri Levante, Italy, June 2016.
(`https://cbmm.mit.edu/knowledge-transfer/workshops-conferences-symposia/brains-minds-and-machines-workshop-sestri-levante`

Refereeing

Journals and conferences: PloS Computational Biology, Neural Information Processing Systems,Open Journal of Signal Processing, Journal of Machine Learning Research,International Conference on Learning Representations.