Filippo Vicentini, Prof.

Computational Quantum Physicist

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Address
15 Avenue de Jurigoz,
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Switzerland

Birth
Born in Padova, Italy
1st August 1992

Skills
Machine Learning
Quantum Computing
Quantum Machine L.
VQE
Scientific Progr.
Differentiable Progr.
Neural Networks
Natural Gradient
Python
Jax
Julia
LLVM
C++
Matlab
Parallel-Computing
(S)DE solvers

In short: I am a professor in Physics, holding the chair of Quantum Physics and Artificial Intelligence of Ecole Polytechnique in Paris. I am among the most influential figures in the field of Machine-Learning for Quantum Physics, and my major contributions involve the development of a machine-learning-inspired algorithm, Neural-Network Quantum States, to solve quantum mechanical problems. My career goal is to effectively solve hard problems in quantum chemistry and material science with flexible algorithms. I am a strong proponent of scientific computing and actively push for change in the scientific ecosystem to better support open-, high-quality scientific software. I also leverage my knowledge to work on Quantum Computing algorithms and hybric quantum-classical techniques. Within that realm, I am a consultant for some quantum computing companies.

Work

January 2023 - : *Assistant Professor,* Ecole Polytechnique, France

May 2022 - now: *Scientific Consultant,* Xanadu (Toronto)
- Provide expert guidance to the Pennylane R&D team into scientific applications of Differentiable Quantum Computing and their algorithmic improvements;

Sept 2020 - March 2023: *Postdoctoral Researcher,* Swiss Federal Institute of Technology (EPFL), Lausanne, Switzerland
- Lead developer for NetKet, an open-source project on machine-learning techniques for quantum physics
- Research on symmetry-encoding neural-networks for non-equilibrium;
- Development of Variational Quantum Algorithms for time evolution;
- Teaching assistant and advisor to several doctoral students.

May-Sep 2020: *Visiting Research Scholar,* Flatiron Institute, New York
Development of Neural Network simulation methods for open quantum systems and DFT methods for dissipative light-matter systems.

Jan-Mar 2020: *Postdoctoral Researcher,* Universitè de Paris, France

Education

2016 - 2019: *Ph.D. in Physics,* Universitè de Paris, France
- Laboratoire Matériaux et Phénomènes Quantiques
- **Thesis:** Stochastic and Neural Network methods for many-body open quantum systems (defended December 11, 2019)

  Advisor: Prof. Cristiano CIUTI

2014 - 2016: *M.Sc. in Physics,* Università di Padova, Italy
- **2015-2016: Exchange Student, Ecole Normale de Paris, France**
  - **Thesis:** Single Spin Manipulation in a cQED architecture **(110/110 cum Laude)**

  Advisor: Prof. Takis KONTOS (**LPA-ENS, Paris**)

April 2013: *Masterclass in Plasma Physics,* TU/Eindhoven, NL

2011 - 2014: *B.Sc. in Physics,* Università di Padova, Italy
- **Thesis:** Variational study of a 1D supersolid model **(104/110)**

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Prizes

ATOS Joseph Fourier Award 2019
- **Special Jury Prize for Artificial Intelligence** - awarded for my research bridging machine learning and quantum physics. For more info see (press release) and (link to University communication).

Grants

ANR JCJC (240k EUR)
- French National Research grant on the project "Neural Dynamics of Quantum Matter", 3.5 years duration.

Organised Conferences

Bernoulli Workshop: Variational Learning Quantum Matter II
- **Lausanne, *8-12 May 2023*** Second edition of the workshop. Curiously being organised with Annabelle Bohrdt and Ryan LaRose.

APS March Meeting 2023: Focus Session "Machine Learning for Quantum Matter"
- **Las Vegas, *5-10 March 2023*** organiser of the focus session together with Evert van Nieuwenburg. More than 63 planned talks.

Bernoulli Workshop: Variational Learning Quantum Matter
- **Lausanne, *4-8 July 2022*** First edition of the workshop listed above with 50 partecipants. Secured $\approx 75k$CHF funding from 2 different entities. Conference website: https://vlqm.org Organised with Jannes Nys.

EPFL AI4Science Day
- **Swisstech Convention center, *18 June 2022*** The goal of the AI-4Science day was to gather faculty, researchers and students who work or are interested in applications of machine learning to science. Conference Website

Articles

17 S. Barison, <u>F. Vicentini</u>, [...], Embedding Classical Variational methods in Quantum Circuits, arXiv:2309.08666

16 D. Eeltink, <u>F. Vicentini</u>, [...], Variational Dynamics of open quantum systems, arXiv:2307.07429

15 H. Zhao, G. Carleo, <u>F. Vicentini</u>, Empirical Sample Complexity of Neural Network Mixed State Reconstruction, arXiv:2307.01840

14 A. Sinibaldi, C. Giuliani, [...], <u>F. Vicentini</u>, [...], Unbiasing time-dependent Variational Monte Carlo by projected quantum evolution, Quantum 7, 1131 (2023)

13 D. Wu, R. Rossi, <u>F. Vicentini</u>, [...], Variational Benchmarks for Quantum Many-Body Problems, arXiv:2302.04919

12 <u>F. Vicentini</u>, R. Rossi and G. Carleo, Positive-definite parametrization of mixed quantum states with deep neural networks, arXiv:2206.13488

11 D. Wu, R. Rossi, <u>F. Vicentini</u>, and G. Carleo, From Tensor Network Quantum States to Tensorial Recurrent Neural Networks, Physical Review Research 5 (3), L032001

10 Anna Dawid, [...], <u>F. Vicentini</u> et Al., Modern applications of machine learning in quantum sciences (Lecture notes), arXiv:2204.04198, (accepted pending revisions by Cambridge University Press)

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9   S. Barison, <u>F. Vicentini</u>, I.Cirac and G. Carleo, Variational dynamics as a ground-state problem on a quantum computer, Phys. Rev. Research **4**, 043161 (2022)

8   <u>F. Vicentini</u>, D. Hoffman et Al. NetKet 3: Machine Learning Toolbox for Many-Body Quantum Systems, Scipost Physics Codebases **7**, (2022),

7   D. Hafner and <u>F. Vicentini</u>, mpi4jax: Zero-copy MPI communication of JAX arrays, Journal of Open Source Software 6, 3419 (2021)

6   S. Barison <u>F. Vicentini</u> and G. Carleo, An efficient quantum algorithm for the time evolution of parameterized circuits, Quantum 5, 512 (2021)

5   G.Carleo, [...] <u>F. Vicentini</u> et Al., NetKet: A Machine Learning Toolkit for Many-Body Quantum Systems, SoftwareX 100311 (2019)

4   V. Goblot, B. Rauer, <u>F. Vicentini</u>, A. Le Boité, E. Galopin, A. Lemaitre, L. Le Gratiet, A. Harouri, I. Sagnes, S. Ravets, C. Ciuti, A. Amo, J. Bloch, Discrete nonlinear domains for polariton fluids in a flat band, Phys. Rev. Lett **123** (11) 113901 (2019)

3   <u>F. Vicentini</u>, A. Biella, N. Regnault and C. Ciuti, Variational neural network ansatz for steady states in open quantum systems, Phys. Rev. Lett. **122** (25) 250503 (2019)

2   <u>F. Vicentini</u>, F. Minganti, A. Biella , G. Orso and C. Ciuti, Optimal stochastic unraveling of disordered open quantum systems: Application to driven-dissipative photonics lattices, Phys. Rev. A **99** (1) 032115 (2019)

1   <u>F. Vicentini</u>, F. Minganti, R. Rota, G. Orso and C. Ciuti, Critical slowing down in driven-dissipative Bose-Hubbard lattices, Phys. Rev. A **97** (1) 013853 (2018)

Scientific Software

2   NetKet collaboration: The machine learning toolbox for quantum many-body physics. Lead developer and maintainer for the collaboration which counts about 5 co-maintainers and several tens of users. 420 Github stars as of february 2023.

1   MPI4jax: automatic differentiation for distributed computing. Co-maintainer and creator with Dion Haefner. 250 GitHub stars as of february 2023.

Talks and Schools

22. November 2023: Invited speaker at the workshop "**Machine Learning techniques in Quantum Physics**" Kyoto, Japan

21. September 2023: Invited speaker at the workshop "**Many Body quantum physics with Machine Learning**" Trento, Italy

20. July 2023: Lecturer at the Doctoral training program "**Ab Initio Methods and emerging tehcnologies for Nuclear Structure**" Trento, Italy

19. May 2023: Invited talk at the "**Quantum Science Generation**" Workshop, Trento, Italy

18. April 2023: Invited lecturer at the spring school "**ML Approaches in Computational Material Science**", Roscoff, France

17. January 2023: Invited lecturer at the doctoral school "**The Mathematics of Deep Learning**", Scuola Normale di Pisa, Italy

16. January 2023: Invited Speaker at workshop "**Numerical Methods for many-body quantum systems**", Dundee, Scotland

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15. September 2022: Contributed talk at conference "**Machine Learning in Natural Sciences**", Hamburg, Germany
14. July 2022: Invited lecturer at the Perimeter Institute, Waterloo (Canada)
13. July 2022, Invited academic lecturer at Xanadu Quantum Computing, Toronto (Canada)
12. April 2022: Invited lecturer at doctoral school "**Toulouse Summer School on Machine Learning for Quantum-Many Body Physics**", Toulouse, France
11. March 2022: Contributed talk "Neural Network Ansatz for Finite Temperature" at APS March Meeting, Chicago, USA
10. November 2021-February 2021: Contract Lecturer at doctoral course "**Introduction to Deep Learning**", Como, Italy
9. September 2021: Invited Lecturer at Doctoral school "**Machine-Learning for Quantum Physics**", Warsaw, Poland
8. January 2021: Lecturer at "**Machine Learning for Condensed Matter**" conference, ICTP Trieste, Italy
7. June 2020: Invited talk at **Machine Learning for Quantum Simulation** virtual conference hosted by Flatiron Institute, New York
6. July 2019: Contributed talk at **Congres General de la Societé Francaise de Physique**, Nantes, France
5. June 2019: *Machine Learning for Physical application*, talk at UFR Physique, Paris 7 University
4. May 2019: Contributed talk at **ML for Quantum Technologies** conference, Max Planck for Quantum Optics, Erlangen
3. March 2019: Invited seminar at **ENS Lyon**, Lyon, France
2. March 2019: Contributed talk at **Artificial Intelligence and Physics Conference** conference, Paris, France
1. January 2018: Invited talk at **Numerical Methods for Quantum Optics** workshop, Max Planck for Quantum Physics, Munich

Supervised Students

16-. (November 2023 - ongoing) Supervision of PhD student Ahmedeo Shokry (Ecole Polytechnique).
15-. (October 2023 - ongoing) Supervision of PhD student Adrien Kahn (Ecole Polytechnique).
14-. (September 2023 - ongoing) co-Supervision of PhD student Alessandro Sinibaldi (EPFL).
13-. (September-* 2023) **Supervision** of four 2nd year X student for their PSC.
12 (April-*August* 2023) co-**Supervision** of visiting PhD student "Pavlo Pelikh" from University of Ottawa.
10-11. (April-*July* 2023) **Supervision** of 2 ICFP **M2 Master students** for their internship projects (Edison Carrera and Naila Betatache).
8-9. (January-*June* 2022) Co-Supervision of 2 **M2 Master students** for their internship projects (Alessandro Sinibaldi and Wuan Phi).
6-7. (January-*June* 2022) Co-Supervision of 2 **M1 Master students** for their internship projects (Alessandro Sinibaldi and Pauline de Schoulepnikoff)
5. (February-July 2021) Co-Supervised **1 M2 Master** student (Louis Pezon) from another group for his 6+ months internship project.

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4. (2021-*ongoing*) Co-Supervised **1 M2 Master** student (Clemens Giuliani) for his 6 months internship project. He is **now a Ph.D. Student** whom I co-supervise on his project about ML methods for Quantum Dynamics.

3. (2021-*ongoing*) Co-Supervision of Ph.D. Student **Stefano Barison** working on Hybrid Quantum Algorithms

1-2. (March-June 2020) tutored two M2 internship students at the C12 Startup (LPA-ENS) on Machine Learning techniques and device modelling for Quantum Optical Control.

Professional Skills

Programming

- I mainly code in **Python** (Jax) or **Julia**. I'm familiar with the tech stach down to LLVM and MLIR. I'm also familiar with **Matlab**.
- I used to code in **C++14** and parallelize code with threads and MPI. Nowdays I'd rather work in **Julia** unless necessary.
- I am lead developer of the **NetKet** collaboration, an open-source project in Python with 12 active contributors, and organize the work of the whole collaboration. I wrote some high-profile code for Jax.

[M]ath, [P]hysics and [N]eural-Networks

P I worked daily on **Open Quantum System**, and extensively studied their mapping to **Stochastic Markov Equations**. I studied Out-Of-Equilibiurm Phase Transitions. I am familiar with **Quantum MonteCarlo** Methods and with **MPS/MPO** solvers.

P I have developed variational quantum algorithms (p-VQD) to compress the time-evolution of a quantum system, inspired by higher-order techniques such as Natural Gradient.

M I have a very good knowledge on numerically solving Stocastic Differential Equations (**SDE**).

N I have worked extensively with Machine Learning frameworks and Neural Networks in uncommon use-cases, mainly higher-order optimisation methods and generative models.

Languages

- **Italian:** Mothertongue
- **English:** (C1 in 2011) Fluent, used daily in work and life
- **French:** (B2) Fluent, used daily in work and life

References

Prof. Giuseppe **Carleo**, EPFL (Lausanne) *Collaborator, Postdoc Advisor*
   giuseppe.carleo@epfl.ch

Prof. Cristiano **Ciuti**, MPQ (Paris) *Ph.D. Advisor*
   cristiano.ciuti@univ-paris-diderot.fr

Prof. Vincenzo **Savona**, EPFL (Lausanne) *Collaborator*
   vincenzo.savona@epfl.ch

Prof. Fabien **Alet**, CNRS (Toulouse) *Worked with him during the Toulouse Summer School*
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