# Elies **Gil-Fuster**

GOOGLE PHD FELLOW · ELLIS PHD STUDENT · QUANTUM MACHINE LEARNING

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## # about

I am a PhD student working in quantum machine learning. I am based in Jens Eisert's research group at FU Berlin, I also work with Vedran Dunjko's group in Leiden University. My goal is to contribute to the mathematical foundations of quantum machine learning theory.

## # education

**Freie Universität Berlin, Fraunhofer HHI Berlin, Leiden University, ELLIS**  *Berlin, Germany*

PH.D. IN THEORETICAL PHYSICS  *Oct. 2021 - present*

- Research in theoretical quantum machine learning.  *Supervisors: Prof. Jens Eisert, Prof. Thomas Wiegand, Prof. Vedran Dunjko*
- Jul. - Oct. 2024: Research stay in Leiden University.  *Host: Prof. Vedran Dunjko*
- 4 first-author papers (including publication in *Nature Communications*), 4 co-authored papers.
- Over 20 research talks in international conferences, workshops, and research seminars.

**Freie Universität Berlin**  *Berlin, Germany*

M.SC. IN PHYSICS  *Apr. 2019 - Oct. 2021*

- Master's thesis in theoretical quantum machine learning with Prof. Jens Eisert.
- 2 co-authored papers.

**Universitat de Barcelona**  *Barcelona, Spain*

B.SC. IN MATHEMATICS, B.SC. IN PHYSICS  *Sep. 2013 - Mar. 2019*

- Bachelor's thesis in differential geometry for physical systems with Prof. Ignasi Mundet and Prof. Chris Wendl.
- Bachelor's thesis in quantum machine learning with Prof. José Ignacio Latorre.
- 1 co-authored paper.
- Erasmus exchange program at Humbolt Universität-zu-Berlin.  *Sep. 2017 - Jul. 2018*

## # work experience

**IBM Research**  *Zürich, Switzerland*

RESEARCH INTERN  *April - July 2025*

- Conducted research in quantum optimization in the team of Dr. Stefan Woerner.

**Institut für Theoretische Physik, Freie Universität Berlin**  *Berlin, Germany*

RESEARCH ASSISTANT  *Oct. 2021 - present*

- Leads the quantum machine learning seminar.
- Conducts research in quantum machine learning.
- Reviewed papers for: American Physical Society, Quantum journal, Nature Publishing Group, IOP Publishing, QIP, QTML, TQC, QCTiP, ICLR.

**Xanadu Quantum Technologies**  *Toronto, Canada (remote)*

RESEARCH SUMMER RESIDENT  *May 2021 - August 2021*

- Conducted research in quantum machine learning under the supervision of Dr. Maria Schuld.
- Wrote documentation for the open-source python package PennyLane, including a blogpost and two demos.

## # publications & pre-prints

An up-to-date list of publications can be found in my 🎓 Google scholar profile.

### PEER-REVIEWED

| | | |
|---|---|---|
| 2025 | **Potential and limitations of random Fourier features for dequantizing quantum machine learning**: <br> Sweke R., Recio E., Jerbi S., Gil-Fuster E., Fuller B., Eisert J., and Meyer J. J., *Quantum* **9**, 1640 | *Quantum, arXiv* |
| 2025 | **On the relation between trainability and dequantization of variational quantum learning models**: <br> Gil-Fuster E., Gyurik C., Pérez-Salinas A., and Dunjko V., *ICLR 2025* | *OpenReview, arXiv* |

| 2024 | **On the expressivity of embedding quantum kernels**: | *Mach Learn Sci Tech, arXiv* |
|---|---|---|
| | Gil-Fuster E., Eisert J., and Dunjko V., *Mach. Learn.: Sci. Technol.* **5** 025003 | |
| 2024 | **Understanding quantum machine learning also requires rethinking generalization**: | *Nat. Comms., arXiv* |
| | Gil-Fuster E., Eisert J., and Bravo-Prieto C., *Nat. Comms.* **15**, 2277 | |
| 2023 | **Exploiting symmetry in variational quantum machine learning**: | *PRX Quantum, arXiv* |
| | Meyer J.J., Mularski M., Gil-Fuster E., Mele A.A., Arzani F., Wilms A., and Eisert J., *PRX Quantum* **4**, 010328 | |
| 2022 | **Training Quantum Embedding Kernels on Near-Term Quantum Computers**: | *PRA, arXiv* |
| | Hubregtsen T., Wierichs D., Gil-Fuster E., Derks P.J.H.S., Faehrmann P.K., and Meyer J. J., *PRA* **106**, 042431 | |
| 2021 | **Encoding-dependent generalization bounds for parametrized quantum circuits**: | *Quantum, arXiv* |
| | Caro M.C., Gil-Fuster E., Meyer J.J., Eisert J., and Sweke R., *Quantum* **5**, 582 | |
| 2020 | **Data re-uploading for a universal quantum classifier**: | *Quantum, arXiv* |
| | Pérez-Salinas A., Cervera-Lierta A., Gil-Fuster E., and Latorre J. I., *Quantum* **4**, 226 | |

## PREPRINTS

| 2025 | **Kernel-based dequantization of variational QML without Random Fourier Features**: | *arXiv* |
|---|---|---|
| | Sweke. R., Shin. S., Gil-Fuster E., *arXiv:2503.23931* | |
| 2025 | **Double descent in quantum machine learning**: | *arXiv* |
| | Kempkes M., Ijaz A., Gil-Fuster E., Bravo-Prieto C., Spiegelberg J., van Nieuwenburg E., Dunjko V., *arXiv:2501.10077* | |
| 2024 | **Opportunities and limitations of explaining quantum machine learning**: | *arXiv* |
| | Gil-Fuster E., Naujoks J.R., Montavon G., Wiegand T., Samek W., Eisert J., *arXiv:2412.14753* | |
| 2024 | **Concept learning of parameterized quantum models from limited measurements**: | *arXiv* |
| | Gan B.Y., Huang P.-W., Gil-Fuster E., Rebentrost P., *arXiv:2408.05116* | |

# # conferences & talks

## CONFERENCES

| Nov. 2024 | **Talk: On the expressivity of embedding quantum kernels**: | *Melbourne, Australia* |
|---|---|---|
| | QTML2024: Quantum Techniques in Machine Learning | |
| Sep. 2024 | **Poster: On the relation between trainability and dequantization of variational quantum learning models**: | *Oxford, UK* |
| | SeeQA 2024: Seeking Quantum Advantage | |
| Apr. 2024 | **Talk: Understanding quantum machine learning also requires rethinking generalization**: | *Edinburg, UK* |
| | QCTiP 2024: Quantum Computing Theory in Practice | |
| Apr. 2024 | **Poster: On the expressivity of embedding quantum kernels**: | *Edinburg, UK* |
| | QCTiP 2024: Quantum Computing Theory in Practice | |
| Mar. 2024 | **Talk: On the expressivity of embedding quantum kernels**: | *Berlin, Germany* |
| | DPG March Meeting 2024 | |
| Mar. 2024 | **Talk: Understanding quantum machine learning also requires rethinking generalization**: | *Berlin, Germany* |
| | DPG March Meeting 2024 | |
| Jan. 2024 | **Poster: Understanding quantum machine learning also requires rethinking generalization**: | *Taipei, Taiwan* |
| | QIP2024: Quantum Information Processing | |
| Nov. 2023 | **Talk: Understanding quantum machine learning also requires rethinking generalization**: | *CERN, Switzerland* |
| | QTML2023: Quantum Techniques in Machine Learning | |
| Nov. 2022 | **Poster: Non-Embedding Quantum Kernels, do they exist?**: | *Naples, Italy* |
| | QTML2022: Quantum Techniques in Machine Learning | |
| Nov. 2021 | **Talk: Encoding-dependent generalization bounds for parametrized quantum circuits**: | *Osaka, Japan (remote)* |
| | QTML2021: Quantum Techniques in Machine Learning | |
| Mar. 2020 | **Poster: Data re-uploading for a universal quantum classifier**: | *Cambdridge, UK (remote)* |
| | QCTIP 2020: Quantum Computing Theory in Practice | |

## SEMINARS AND WORKSHOPS

| Mar. 2025 | **Tutorial: The quantum kernel saga**: | *Berlin, Germany* |
|---|---|---|
| | Tutorial seminar at AG Eisert, FU Berlin | |

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|---|---|---|
| Feb. 2025 | **Seminar: On the relation between trainability and dequantization of variational quantum learning models**: | *Berkeley, United States* |
| | Quantum pod seminar at Simons Institute, UC Berkeley | |
| Feb. 2025 | **Seminar: On the relation between trainability and dequantization of variational quantum learning models**: | *Pasadena, United States* |
| | IQIM seminar at Caltech | |
| Oct. 2024 | **Talk: Machine Learning on Quantum Computers: how it started vs. how it's going**: | *Munich, Germany (remote)* |
| | BMW QC Community | |
| Oct. 2024 | **Seminar: On the relation between trainability and dequantization of variational quantum learning models**: | *Delft, Netherlands* |
| | QMAI team seminar at TU Delft | |
| Oct. 2024 | **Workshop talk: On the expressivity of embedding quantum kernels**: | *Paris, France* |
| | Défi Eqip | |
| Aug. 2024 | **Poster: On the relation between trainability and dequantization of variational quantum learning models**: | *Copenhagen, Denmark* |
| | QMATH Summer School on quantum simulation | |
| Jul. 2024 | **Seminar: On the relation between trainability and dequantization of variational quantum learning models**: | *Nijmegen, Netherlands* |
| | Bert Kappen's group seminar at Radboud University | |
| Jul. 2024 | **Seminar: On the relation between trainability and dequantization of variational quantum learning models**: | *CERN, Switzerland (remote)* |
| | Quantum Technology Initiative Journal Club | |
| Apr. 2024 | **Seminar: On the expressivity of embedding quantum kernels**: | *Barcelona, Spain* |
| | GIQ Seminar at UAB | |
| Feb. 2024 | **Seminar: On the expressivity of embedding quantum kernels**: | *United Kingdom (remote)* |
| | IBM Q UK seminar | |
| Jan. 2024 | **Seminar: On the expressivity of embedding quantum kernels**: | *Singapore* |
| | QAISG QML seminar | |
| Dec. 2023 | **Seminar: On the expressivity of embedding quantum kernels**: | *Leiden, Netherlands* |
| | aQa seminar at Leiden University | |
| Nov. 2023 | **Seminar: On the expressivity of embedding quantum kernels**: | *Lausanne, Switzerland* |
| | QIC seminar at EPFL | |
| Nov. 2023 | **Seminar: Understanding quantum machine learning also requires rethinking generalization**: | *Berlin, Germany* |
| | Einstein Research Unit update meeting | |
| Oct. 2023 | **Seminar: Understanding quantum machine learning also requires rethinking generalization**: | *California, USA (remote)* |
| | Google Quantum AI QML meeting | |
| Oct. 2023 | **Seminar: Understanding quantum machine learning also requires rethinking generalization**: | *Singapore (remote)* |
| | QAISG QML seminar | |
| Sep. 2023 | **Seminar: Understanding quantum machine learning also requires rethinking generalization**: | *Barcelona, Spain* |
| | QUANTIC group seminar at Barcelona Supercomputing Center | |
| Jun. 2023 | **Participated: Quantum Information Workshop**: | *Benasque, Spain* |
| | Centro de Ciencias de Benasque Pedro Pascual | |
| Apr. 2023 | **Workshop talk: Exploiting symmetry in variational quantum machine learning**: | *Obergurgl, Austria* |
| | Machine Learning and (Quantum) Physics workshop | |
| Jan. 2023 | **Seminar: Exploiting symmetry in variational quantum machine learning**: | *Barcelona, Spain* |
| | QUANTIC group seminar at Barcelona Supercomputing Center | |
| Dec. 2021 | **Workshop talk: Training quantum embedding kernels on near-term quantum computers**: | *Leiden, Netherlands and Berlin, Germany (remote)* |
| | Theory of Quantum Machine Learning | |
| Nov. 2021 | **Seminar: Encoding-dependent generalization bounds for parametrized quantum circuits**: | *Singapore (remote)* |
| | Marco Tomamichel's group seminar at Centre for Quantum Technologies | |
| Sep. 2021 | **Workshop poster: Generalization bounds in the quantum realm**: | *Tübingen, Germany* |
| | EDS2021: ELLIS Doctoral Symposium | |
| May. 2020 | **Participated: Hands-on Quantum Computing Summer School**: | *Benasque, Spain (remote)* |
| | Centro de Ciencias de Benasque Pedro Pascual, and Technology Innovation Institute Abu Dhabi | |

# honors & awards

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|---|---|---|
| Oct. 2023 | **Google PhD Fellowship,** Quantum Computing. | *Google AI* |
| Mar. 2021 | **First prize and sponsor prize,** QHACK2021, the Xanadu quantum machine learning hackathon. | *Global (remote)* |
| Oct. 2020 | **Second prize,** Qiskit Hackathon Global, the IBM quantum hackathon. | *Global (remote)* |
| Oct. 2019 | **Team leader,** Quantum futures hackathon 2019, the CERN cooperative quantum hackathon. | *CERN, Switzerland* |

# skills

**(Quantum) programming,** Pennylane, Qiskit, Python, C/C++, R.

**Computer skills,** LaTeX, git, MS Office, web, image, and video editing.

**Language,** Catalan (*mother tongue*), Spanish (*native*), English (*proficient*), German (*advanced*).

# teaching

**True randomness from quantum computers** — *Freie Universität Berlin, Germany*

TUTOR AT "GIRLSDAY" — *Apr. 2023, Apr. 2024*

- Co-designer and teaching assistant of a 3-hour workshop for high-schoolers.

**Quantum Information Theory** — *Freie Universität Berlin, Germany*

TEACHING ASSISTANT — *Oct. 2023 - Mar. 2024*

- Teaching assistant of Prof. Jens Eisert for the master's course "Quantum Information Theory".

**Analytical geometry** — *Freie Universität Berlin, Germany*

TEACHING ASSISTANT — *Apr. 2020 - Sep. 2020*

- Teaching assistant of Prof. Alexander Schmitt for the course "Geometrie" (in German) in the Mathematics institute.

**Informatics** — *Freie Universität Berlin, Germany*

TEACHING ASSISTANT — *Oct. 2019 - Mar. 2020*

- Teaching assistant of Prof. Carsten Gräser for the course "Computerorientierte Mathematik I" (in German) in the Mathematics institute.

**The mathematics of Cryptography** — *Freie Universität Berlin, Germany*

SUMMER TUTOR AT "SOMMERUNI" — *Jul. 2020*

- Teaching assistant of a two-day course "Die Mathematik hinter Codes, Chiffrierung, und verschlüsselten Nachrichten" (in German) for high-schoolers.

**Web design and video game development** — *Barcelona, Spain*

SUMMER TUTOR AT CAMPTECNOLÓGICO — *Jul. 2016*

- Summer camp teacher for primary school students.

**Mathematics and Physics** — *Barcelona, Spain*

PRIVATE TUTOR — *Jul. 2013 - Jun. 2017*

- Private teacher for high-schoolers.

# extracurricular activity

**insideQuantum podcast** — *Berlin, Germany*

VOLUNTEER ORGANIZATION ASSISTANT — *Jun. 2022 - present*

- Manage communication and logistics with the podcast guests.
- Curate the list of invited podcast guests.

**Les Vinyes del Convent** — *Horta de Sant Joan, Spain*

FAMILY-BUSINESS ASSISTANT — *Aug. 2007 - Sep. 2019*

- 2018, 2019: Performed quality control of ripening grapes, fermenting must, and wine. Advised in harvest and conservation decisions.
- 2017, 2018: Lead winery tours, guided wine tastings, and attended the wine shop.
- 2007 - 2016: Worked in the vineyards and winery.

**Talents of Barcelona** — *Barcelona, Spain*

VOLUNTEER ORGANIZATION ASSISTANT — *Feb. 2017 - May 2017*

- Co-organized entrepreneurship events.
- Managed communication and maintained the webpage.

**17th National Meeting of Mathematics Students** — *Barcelona, Spain*

VOLUNTEER ORGANIZATION ASSISTANT — *Jun. 2016*

- Managed participants and organized events.

**Artistic Legends**                                          *Offenbach, Germany*

Volunteer                                                         *Jul. 2014*

• Took part in cultural week with German youths in risk of social exclusion.

**World youth day**                                              *Madrid, Spain*

Volunteer                                                         *Aug. 2011*

• Worked in event organization and logistics.