Haimeng Zhao

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Education

- **Tsinghua University** — Beijing, China
  B.Sc. in Physics & Maths, Minor in Statistics, Advisor: *Dongling Deng*, *Wei Zhu* — 2020–2024(Expected)
  GPA: **3.96/4.00**, Major GPA: **4/4**, Rank: **1/100**; English: TOEFL 113/120 (25/Speaking), GRE 335/340
- **California Institute of Technology** — Pasadena, CA, USA
  Undergrad Research Fellow @ IQIM, Advisor: *John Preskill*, *Matthias Caro*, *Hsin-Yuan Huang* — 2023 - Now
- **EPFL (École Polytechnique Fédérale de Lausanne)** — Lausanne, Switzerland
  Exchange, GPA: **6/6** (4 grad courses), Advisor: *Giuseppe Carleo*, *Filippo Vicentini* — 2022 Fall

Research Interest

- How to better understand the universe,
and how is understanding even possible?

- Quantum Information, Statistics & Learning Theory
- Quantum Many-body Physics: Theory & Computation
- AI for Science, especially Physics & Astrophysics
- Generative Learning, Neural Differential Equations

Skills

- **Computational Physics:** Neural Quantum States, Tensor Network, (Quantum) Monte Carlo, DFT. NetKet and NASA EMAC contributor.
- **(Quantum) Machine Learning:** (Quantum) Learning Theory, Variational Quantum Algorithms, Generative Learning, Neural Differential Equations.
- **Programming:** High performance scientific computing with Python & C++. Differentiable programming with JAX, PyTorch (6 years) & TensorFlow.

Selected Publications

[1] **Haimeng Zhao**, Laura Lewis, Ishaan Kannan, Yihui Quek, Hsin-Yuan Huang, and Matthias Caro, "Learning Quantum States and Unitaries of Bounded Gate Complexity", (2023), arXiv:2310.19882, accepted by QIP 2024, in preperation for Nature Physics.

[2] **Haimeng Zhao**, Giuseppe Carleo, and Filippo Vicentini, "Empirical Sample Complexity of Neural Network Mixed State Reconstruction", (2023), arXiv:2307.01840, under review in Quantum.

[3] **Haimeng Zhao**, "Non-IID Quantum Federated Learning with One-shot Communication Complexity", Quantum Machine Intelligence **5**, 3 (2023), short talk at QTML 2023 (acceptance rate 8%).

[4] **Haimeng Zhao** and Wei Zhu, "MAGIC: Microlensing Analysis Guided by Intelligent Computation", The Astronomical Journal **164**, 192 (2022).

[5] **Haimeng Zhao** and Wei Zhu, "Parameter Estimation in Realistic Binary Microlensing Light Curves with Neural Controlled Differential Equation", ICML Workshop on Machine Learning for Astrophysics (2022).

[6] Junyi Liu, Yifu Tang, **Haimeng Zhao**, Fangyu Li, and Jingyi Zhang, "CPS Attack Detection under Limited Local Information in Cyber Security: An Ensemble Multi-Node Multi-Class Classification Approach", ACM Transactions on Sensor Networks (2023).

Selected Research Experience

- **The Complexity of Learning Physical Systems, Evolution, and Functions** — Feb. 2023 - Now
  Advisor: John Preskill, Matthias Caro, Hsin-Yuan Huang, IQIM @ Caltech — **First Author [1]**

- Rigorously proved that #experiments needed to learn states/unitaries is linear in their circuit complexity.
- Established an exponential separation between average-case and worst-case unitary learning.
- Proved a computational efficiency transition point of learning at logarithmic circuit complexity.
- Formulated a unifying information-theoretic perspective on the quantum no-free-lunch theorem.
- Proved that certain unphysical functions cannot be efficiently implemented or learned in Nature.

- **AI4Q: Sample Complexity of Neural Quantum State Tomography** Aug. 2022 - Jul. 2023
  Advisor: Giuseppe Carleo & Filippo Vicentini, Computational Quantum Science Lab @ EPFL **First Author [2]**
  - Introduced control variates to control gradient variance and significantly reduce sample complexity.
  - Discovered the temperature dependence of sample complexity behavior via theory and extensive numerics.
  - Benchmarked different tomography methods and highlighted quantum-resource efficiency of various NQSs.
- **AI4Astro: ML Framework for Realistic Microlensing Event Analysis** Oct. 2021 - Sep. 2022
  Advisor: Wei Zhu, Department of Astronomy @ Tsinghua **First Author [4, 5]**
  - Introduced neural controlled differential equations to robustly learn *irregular* astronomical time-series.
  - Developed a machine learning framework for microlensing data of realistic quality, listed on NASA EMAC.
  - Accelerated microlensing analysis by $\times 10^5$ and successfully applied to real events for the first time.
- **QAI: Non-IID Quantum Federated Learning** Jul. 2022 - Sep. 2022
  Single authored work. Extending [6] to the quantum regime. **Single Author [3]**
  - Proposed and studied the quantum data heterogeneity problem both theoretically and numerically.
  - Quantized algorithms in [6], substantially more robust to heterogeneity and communication efficient.
- **Services**: reviewer for QIP 2024, QTML 2023, NeurIPS 2023, ICML 2023 ML4Astro, NeurIPS 2022 ML4PS, etc.

Selected Coursework

High Dimensional Probability⋆	A	Quantum Artificial Intelligence⋆	A
Interacting Quantum Matter⋆	6/6	Stat. Phys. of Computation⋆	6/6
Information Theory and Coding⋆	6/6	Biophysics⋆	6/6
Computational Quantum Physics⋆	A+	Solid State Physics	A+
Atom and Molecule Physics	A	General Relativity	A
Analytical Mechanics	A	Quantum Mechanics	A
Statistical Mechanics	A	Electrodynamics	A+
Complex Analysis	A+	Partial Differential Equations	A+

⋆ for graduate courses. Audited/self-taught: Quantum Field Theory, Lattice Field Theory, Topology, Group Theory, Theoretical Computer Science, Quantum Information Theory, Ultracold Atomic Physics.

Scholarships and Awards

- Caltech Summer Undergraduate Research Fellowship 2023
- Tsinghua Highest Scholarship (清华特等奖学金, Highest Honor for Undergrads in Tsinghua, top 10) 2023
- National Scholarship (National Highest Honor for Undergrads) 2022
- Scholarship of the National Astronomical Observatory of China 2022
- Chi-sun Yeh Scholarship (Highest Honor for Physics Major), Tsinghua Xuetang Talents Program 2020–2022
- S.-T. Yau College Maths Contest, Silver Medal (2^{nd} place) in Mathematical Physics 2022
- S.-T. Yau High School Science Award, Gold Medal (1^{st} place) in Computer Science 2019