

# LEO ZHOU

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## EDUCATION

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### Harvard University

Cambridge, MA

Ph.D. in Physics

2014–21

Thesis: Complexity, Algorithms, and Applications of Programmable Quantum Many-Body Systems

Advisor: Mikhail Lukin

### Massachusetts Institute of Technology

Cambridge, MA

B.Sc. in Physics and Mathematics; Minor in Economics; GPA: 5.0/5.0

2010–14

Thesis: Error-Suppression by Energy-Gap Protection for Quantum Computation in Open Systems

Advisor: Edward Farhi

## RESEARCH EXPERIENCE

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### California Institute of Technology – Walter Burke Institute for Theoretical Physics

Pasadena, CA

DuBridge Postdoctoral Scholar with Prof. John Preskill

2021–Present

- Lead independent research in quantum algorithms for inference and optimization problems
- Investigated the complexity of finding local minima in quantum systems and the computational power of cooling
- Managed graduate and undergraduate students in multiple research projects

### BlueQubit, Inc.

Los Angeles, CA

Quantum R&D Scientist

2023–Present

- Advised quantum research efforts and developed quantum algorithmic solutions for sampling tasks

### Harvard University – Department of Physics

Cambridge, MA

Graduate Research Fellow with Prof. Mikhail Lukin

2014–21

- Analyzed performance and mechanism of QAOA, and invented powerful heuristics for optimizing its parameters
- Designed realistic schemes of quantum information processing applications in cold atoms with error analysis
- Developed specialized software libraries for simulating many-body physics using matrix product state ansatz

### Google AI Quantum

Venice, CA

Research Intern with Prof. Edward Farhi

Summer 2019

- Studied noise-resilience and error-mitigation of the Quantum Approximate Optimization Algorithm (QAOA)
- Calculated the typical-case performance of the QAOA applied to spin glass problems in the thermodynamic limit
- Developed software tools in Google's code base for running quantum algorithms on their quantum processors

### Hebrew University – Department of Computer Science and Engineering

Jerusalem, Israel

Visiting Researcher with Prof. Dorit Aharonov

Summers 2014 & 2015

- Initiated the study of resource requirements of analog quantum simulation of complex systems by simpler ones
- Proved separation of classical vs. quantum systems on the possibility of reducing the degree of connectivity

### Massachusetts Institute of Technology

Cambridge, MA

Undergraduate Researcher

2010–14

- Proved that the energy penalty method can suppress errors in Hamiltonian-based computations with Prof. Farhi
- Investigated hydrodynamic pilot-wave analogues of quantum systems with Prof. John W.M. Bush
- Built graphene and transition-metal dichalcogenide-based nanoelectronics with Prof. Pablo Jarillo-Herrero
- Analyzed high energy heavy ion collisions from RHIC and LHC with Dr. George S.F. Stephans

## AWARDS AND HONORS

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- Outstanding Paper Award at the 17th Conference on Theory of Quantum Computation, Communication and Cryptography (TQC'22) 2022
- Grant Winner (\$5k) for Excellent Contributed Talk at QC40: Physics of Computation Conference 2021
- Burke Prize Fellowship at the California Institute of Technology 2021
- Bloch Fellowship at Stanford University (declined) 2021
- Hartree Fellowship at the Institute of Advanced Computer Studies, University of Maryland (declined) 2021
- Martin & Beate Block Award (for best poster presented by co-author S.-T. Wang) at the Aspen Conference on Advances in Quantum Algorithms and Computation 2018
- National Science Foundation (NSF) Graduate Research Fellowship 2014–17
- Phi Beta Kappa (Academic Honor Society), MIT Xi Chapter 2014
- MIT Junior Lab Edward C. Pickering Award for Outstanding Original Project, Honorable Mention 2013

## PUBLICATIONS

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- C.-F. Chen, H.-Y. Huang, J. Preskill, **L. Zhou**<sup>†</sup>. *Local minima in quantum systems*. Preprint on [arXiv:2309.16596](https://arxiv.org/abs/2309.16596), (2023). Accepted to QIP'24.
- J. Basso, D. Gamarnik, S. Mei, **L. Zhou**<sup>†</sup>. *Performance and limitations of the QAOA at constant levels on large sparse hypergraphs and spin glass models*. In Proceedings of the 63rd Symposium on Foundations of Computer Science, FOCS'22 (2022). [arXiv:2204.10306](https://arxiv.org/abs/2204.10306).
- S. Ebadi, ..., **L. Zhou**, ..., M.D. Lukin. *Quantum Optimization of Maximum Independent Set using Rydberg Atom Arrays*. *Science* 376, 1209 (2022). [arXiv:2202.09372](https://arxiv.org/abs/2202.09372).
- J. Basso, E. Farhi, K. Marwaha, B. Villalonga, **L. Zhou**<sup>†</sup>. *The Quantum Approximate Optimization Algorithm at High Depth for MaxCut on Large-Girth Regular Graphs and the Sherrington-Kirkpatrick Model*. In Proceedings of the 17th Conference on the Theory of Quantum Computation, Communication and Cryptography, TQC '22 (2022), Outstanding Paper Award. [arXiv:2110.14206](https://arxiv.org/abs/2110.14206).
- **L. Zhou**, D. Aharonov. *Strongly Universal Hamiltonian Simulators*. QIP'21 (2021). [arXiv:2102.02991](https://arxiv.org/abs/2102.02991).
- M.P. Harrigan, ..., **L. Zhou**, ..., R. Babbush. *Quantum Approximate Optimization of Non-Planar Graph Problems on a Planar Superconducting Processor*. *Nature Physics* 17, 332 (2021). [arXiv:2004.04197](https://arxiv.org/abs/2004.04197).
- S.H. Cantu, A.V. Venkatramani, W. Xu, **L. Zhou**, B. Jelenković, M.D. Lukin, V. Vuletić. *Repulsive photons in a quantum nonlinear medium*. *Nature Physics* 16, 921 (2020). [arXiv:1911.02586](https://arxiv.org/abs/1911.02586).
- E. Farhi, J. Goldstone, S. Gutmann, **L. Zhou**<sup>†</sup>. *The Quantum Approximate Optimization Algorithm and the Sherrington-Kirkpatrick Model at Infinite Size*. *Quantum* 6, 759 (2022). Also in QIP'21. [arXiv:1910.08187](https://arxiv.org/abs/1910.08187).
- Z. Eldredge, **L. Zhou**, A. Bapat, J.R. Garrison, A. Deshpande, F.T. Chong, A.V. Gorshkov. *Entanglement bounds on the performance of quantum computing architectures*. *Phys. Rev. Research* 2, 033316 (2020). [arXiv:1908.04802](https://arxiv.org/abs/1908.04802).
- **L. Zhou**<sup>\*</sup>, S.-T. Wang<sup>\*</sup>, S. Choi, H. Pichler, and M.D. Lukin. *Quantum Approximate Optimization Algorithm: Performance, Mechanism, and Implementation on Near-Term Devices*. *Phys. Rev. X* 10, 021067 (2020). [arXiv:1812.01041](https://arxiv.org/abs/1812.01041).
- H. Pichler<sup>\*</sup>, S.-T. Wang<sup>\*</sup>, **L. Zhou**<sup>\*</sup>, S. Choi, and M.D. Lukin. *Computational complexity of the Rydberg blockade in two dimensions*. Preprint on [arXiv:1809.04954](https://arxiv.org/abs/1809.04954), (2018).
- H. Pichler<sup>\*</sup>, S.-T. Wang<sup>\*</sup>, **L. Zhou**, S. Choi, and M.D. Lukin. *Quantum Optimization for Maximum Independent Set Using Rydberg Atom Arrays*. Preprint on [arXiv:1808.10816](https://arxiv.org/abs/1808.10816), (2018).

- D. Aharonov and **L. Zhou**<sup>†</sup>. *Hamiltonian Sparsification and Gap-Simulation*. In Proceedings of the 2019 ACM Conference on Innovations in Theoretical Computer Science, *ITCS'19* (2019). [arXiv:1804.11084](#).
- **L. Zhou**<sup>\*</sup>, S. Choi<sup>\*</sup>, and M.D. Lukin. *Symmetry-protected dissipative preparation of matrix product states*. *Phys. Rev. A* (2021). [arXiv:1706.01995](#).
- A.D. Bookatz, E. Farhi, and **L. Zhou**<sup>†</sup>. *Error suppression in Hamiltonian based quantum computation using energy penalties*. *Phys. Rev. A* 92, 022317 (2015). [arXiv:1407.1485](#).
- **L. Zhou** and G.S.F. Stephens. *Energy and centrality dependence of particle multiplicity in heavy ion collisions from  $\sqrt{s_{NN}} = 20$  to 2760 GeV*. *Phys. Rev. C* 90, 0149902 (2014). [arXiv:1312.3656](#).

\* indicates that authors contributed equally

<sup>†</sup> indicates alphabetical ordering of authors

## PRESENTATIONS

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- *Quantum Advantages in Energy Minimization*
  - Colloquium talk at the University of Southern California 11.2023
  - Invited talk at the IPAM “Mathematical and Computational Challenges in Quantum Computing” program at the University of California, Los Angeles 11.2023
- *Exploring Quantum Advantages in Optimization Problems*
  - Invited talk at the NISQ Algorithms and Hardware (NISQAH 2023) conference [\[video\]](#) 06.2023
- *Quantum computing with Rydberg atom arrays*
  - Tutorial talk at the 2023 APS March Meeting 03.2023
- *Performance and limitations of the QAOA at constant levels on large sparse hypergraphs and spin glass models*
  - Accepted talk, 18th Conference on Theory of Quantum Computation, Communication and Cryptography (TQC) [\[video\]](#) 07.2023
  - Accepted talk, 63rd Annual Symposium on Foundations of Computer Science (FOCS) 11.2022
- *Advantages and Limitations of the Quantum Approximate Optimization Algorithm*
  - Invited talk at the 2023 Information: Theory and Applications (ITA) workshop 02.2023
  - Invited talks at the MIT Center for Theoretical Physics and QuEra Computing, Inc. 06.2022
- *The QAOA at High Depth for MaxCut on Large-Girth Regular Graphs and the SK Model*
  - Outstanding Paper Award talk at the 17th Conference on Theory of Quantum Computation, Communication and Cryptography (TQC) [\[video\]](#) 07.2022
- *Quantum Approximate Optimization: Challenges and Opportunities*
  - Invited talk at the 2021 INFORMS Annual Meeting 10.2021
- *Strongly Universal Hamiltonian Simulators*
  - Invited talk at the Simons Institute Quantum Wave in Computing Reunion Workshop 07.2021
  - Accepted talk at QC40: Physics of Computation Conference 40th Anniversary 05.2021
  - Invited talk at the QCDA (Quantum Code Design and Architecture) seminar 04.2021
  - Accepted talk, 24th Annual Conference on Quantum Information Processing (QIP) [\[video\]](#) 02.2021
- *The QAOA and the Sherrington-Kirkpatrick Model at Infinite Size*
  - Accepted talk, 24th Annual Conference on Quantum Information Processing (QIP) [\[video\]](#) 02.2021
- *Quantum Simulation and Optimization in Near-Term Quantum Computers*
  - Invited talk at the Stanford Q-FARM Special Seminar 12.2020
  - Invited talk at the MIT Center for Theoretical Physics 12.2020
  - Invited talk at the QM seminar, UC Berkeley [\[video\]](#) 12.2020
  - Invited talk at the Institute for Quantum Information (IQI) Seminar, Caltech 12.2020
- *Hamiltonian Sparsification and Gap-Simulation*

- Accepted talk, 22nd Annual Conference on Quantum Information Processing (QIP) [[video](#)] 01.2019
  - Accepted talk, 10th Innovations in Theoretical Computer Science conference (ITCS) 01.2019
- *Quantum Approximate Optimization: Performance and Applications with MaxCut and Maximum Independent Set Problems*
  - Talk at the 50th Meeting of APS Division of Atomic, Molecular & Optical Physics 05.2019
  - Poster at the Quantum Science Gordon Research Conference 08.2018
  - Poster at the Aspen Conference on Advances in Quantum Algorithms and Computation 03.2018
- *Symmetry-protected dissipative preparation of matrix product state*
  - Invited talk at the Mathematical Picture Language Project Seminar, Harvard University 11.2019
  - Poster at the 48th Meeting of APS Division of Atomic, Molecular & Optical Physics 06.2017
  - Talk at the Quantum Science: Implementation workshop in Benasque, Spain 07.2016
- *Robust quantum information processing with atomic cat states*
  - Poster at the Atomic Physics Gordon Research Conference 06.2015

## ADDITIONAL EXPERIENCES

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### Teaching

- Guest lecturer for the “Rydberg Computers” tutorial at the 2023 APS March Meeting 2023
- Supporting Teaching Fellow for Physics of Quantum Information (Physics 271) and Modern Atomic and Optical Physics II (Physics 285b) at Harvard University 2016–20
- Teaching Fellow for Electrodynamics (Physics 153) at Harvard University 2018
- Teacher & Mentor at MIT China Development Initiative’s Service Leadership Program 2013
- Teaching high school students in Gaildorf, Germany through MIT’s Global Teaching Lab 2012
- Teaching high school students at the Splash event for the MIT Educational Studies Program 2011

### Service

- Program committee for TQC’23 (18th conference on Theory of Quantum Computation) 2023
- Referee for Physical Review journals 2022–23
- Reviewer for leading quantum computer science conferences (including: QIP, TQC, STOC, SODA) 2019–23
- Referee for *Quantum* (journal) 2019–22
- Referee for ACM Transactions on Quantum Computing 2021
- MIT Society of Physics Students, Executive Council 2011–14

### Mentorship

- Chi-Fang (Anthony) Chen, graduate student at Caltech 2022–23
- Ishaan Kannan, undergraduate student at Caltech 2021–23
- William (Robbie) King, graduate student at Caltech 2021–23
- Hsin-Yuan (Robert) Huang, graduate student at Caltech (now at Google, future Caltech faculty) 2021–23
- Joao Basso, undergraduate student at Tufts (now UC Berkeley graduate student) 2019–23
- Beatrice Nash, graduate student at Harvard 2020–21
- Katherine van Kirk, graduate student at Harvard 2020–21
- Madelyn Cain, graduate student at Harvard 2019–21
- Dylan Li, undergraduate student at Harvard Fall 2020
- Amir Shanehsazzadeh, undergraduate student at Harvard Fall 2020
- Abhishek Anand, undergraduate student at Harvard (now Caltech graduate student) 2018–19

### Software

- MATLAB, Python, Julia, Mathematica, Java, C++, GPGPU computing