

William J Fefferman

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Date: April 2024

Current Positions

7.2019–
present

Assistant Professor
Department of Computer Science, University of Chicago

2.2022–
present

Senior Associate (by courtesy)
Kadanoff Center for Theoretical Physics, Department of Physics, University of Chicago

Education

2014

Ph.D in Computer Science, California Institute of Technology, Pasadena, CA

- Advisors: Alexei Kitaev and Christopher Umans
- Committee: Venkat Chandrasekaran, Alexei Kitaev, John Preskill, Christopher Umans

2011

M.S in Computer Science, California Institute of Technology, Pasadena, CA

2008

B.S in Computer Science, The University of Chicago, Chicago, IL

2008

B.A in Mathematics, The University of Chicago, Chicago, IL

Postdoctoral Positions

2017–2018

Department of Electrical Engineering and Computer Science (EECS), University of California at Berkeley, Berkeley, CA

- Advisor: Umesh Vazirani

2014–2017

Quantum Information and Computer Science (QuICS), University of Maryland Institute for Advanced Computer Studies (UMIACS), University of Maryland, College Park, MD

Awards

2022

Google Research Scholar Award

- PROPOSAL TITLE: “Understanding the feasibility of practical applications from quantum supremacy experiments”

- 2021 National Science Foundation CAREER award
- PROPOSAL TITLE: “Near-term quantum computing: achieving quantum advantage, and next steps”
 - AWARD NUMBER: CCF- 2044923 (CAREER)
- 2018 Air Force Young Investigator Award from the Air Force Office of Scientific Research
- PROPOSAL TITLE: “Characterizing the Power of Experimentally Feasible Quantum Computation with Applications to Rigorous Security Guarantees for Quantum-safe Cryptography”
 - YOUNG INVESTIGATOR AWARD: FA9550-18-1-0148.

Service

- September 16-20, 2024 (expected)
- *Chair*, Quantum Algorithms workshop, Statistical Methods and Mathematical Analysis for Quantum Information Science Program, Institute for Mathematical and Statistical Innovation, The University of Chicago, Chicago, IL
- Spring 2024 (expected)
- *Chair*, Quantum Complexity workshop, Simons Institute for the Theory of Computing, University of California Berkeley, Berkeley, CA
- Spring 2024 (expected)
- *Co-chair*, Near-term quantum computers workshop, Simons Institute for the Theory of Computing, University of California Berkeley, Berkeley, CA
- 2024
- *Program committee member*, Innovations in Theoretical Computer Science Conference (ITCS 2024)
- Summer 2023
- *Chair*, Quantum Summer Cluster Workshop, Simons Institute for the Theory of Computing, University of California Berkeley, Berkeley, CA
- Summer 2023
- *Program organizer*, Summer Cluster on Quantum Computing, Simons Institute for the Theory of Computing, University of California Berkeley, Berkeley, CA
- 2.22.2023-2.24.2023
- *Organizing committee member*, Winter School on Contemporary Quantum Algorithms and Applications, Institute for Pure and Applied Mathematics (IPAM), University of California Los Angeles, Los Angeles, CA
- 2023
- *Program committee member*, 26th Annual Conference on Quantum Information Processing (QIP 2023)
- 8.1.2022-8.3.2022
- *Chair*, NSF Workshop on Quantum Advantage and Next Steps, University of Chicago, Chicago, IL
- 2022
- *Program committee member*, 17th Conference on the Theory of Quantum Computation, Communication and Cryptography (TQC 2022)
- 2022
- *Program committee member*, Quantum Computing Theory in Practice, (QCTIP 2022)

- 2022 • *Program committee member*, 25th Annual Conference on Quantum Information Processing (QIP 2022)
- 2021 • *Program committee member*, 16th Conference on the Theory of Quantum Computation, Communication and Cryptography (TQC 2021)
- 2021 • *Program committee member*, 24th Annual Conference on Quantum Information Processing (QIP 2021)
- 7.26.2020-7.31.2020 • *Co-chair*, Dagstuhl Workshop on “Quantum Complexity: Theory and Application”, Dagstuhl, Germany.
Co-chair of international workshop on quantum computation and near-term quantum applications at the Dagstuhl conference center for computer science, Dagstuhl, Germany.
- 8.1-8.5.2016 • *Chair*, QuICS Workshop on QMA(2) and the Complexity of Entanglement, University of Maryland, College Park, Maryland.
Organized an international workshop at QuICS on the computational power of quantum entanglement.

Selected Press Articles

- “The Quest to Quantify Quantumness”, Quanta Magazine, October 19, 2023: [link](#)
- “In New Paradox, Black Holes Appear to Evade Heat Death”, Quanta Magazine, June 6, 2023: [link](#)
- “New Algorithm Closes Quantum Supremacy Window”, Quanta Magazine, January 9, 2023: [link](#)
- “Computer Scientists Eliminate Pesky Quantum Computations”, Quanta Magazine, January 19, 2022: [link](#)
- “Quantum Supremacy Is Coming: Here’s What You Should Know”, Quanta Magazine, July 18, 2019: [link](#)
- “Why haven’t we got useful quantum computers yet?”, New Scientist, September 5, 2023: [link](#)
- “Berkeley computer theorists show path to verifying that quantum beats classical”, UC Berkeley News, October 29, 2018: [link](#)
- “UChicago Scientists Make New Discovery Proving Entanglement Is Responsible for Computational Hardness In Quantum Systems”, UChicago CS Department News, July 25, 2023: [link](#)

Invited Tutorials

- 7.31.2023 - 8.4.2023 • Invited Tutorial, 5 lecture mini-course on modern topics in quantum computing (one out of nine lecturers), Institute for Advanced Study, Princeton, NJ, hosted at Park City Math Institute, Park City, Utah
- 2.23.2023 • Invited Tutorial (one of out five invited tutorial speakers), Winter School on Contemporary Quantum Algorithms and Applications, Institute for Pure and Applied Mathematics (IPAM), University of California Los Angeles, Los Angeles, CA
- 2.4.2023 • Invited Tutorial (one of four invited tutorial speakers for three hour talk at the yearly conference), QIP 2023 conference, Ghent, Belgium

Selected Invited Talks (since 2020)

- 3.13.2024 • Physics Department Colloquium, University of Michigan, Ann Arbor, MI.
- 2.23.2024 • IQIM Seminar, Caltech, Pasadena, CA.
- 2.12.2024 • Princeton Quantum Colloquium, Princeton University, Princeton, NJ.
- 2.5.2024 • Simons Institute, UC Berkeley, Berkeley, CA.
- 12.11.2023 • National Institute of Informatics (Japan), Shonan Meeting No.198 “New Directions in Provable Quantum Advantages”, Shonan Village Center, Kanagawa, Japan.
- 11.9.2023 • Workshop on Many-body Quantum Systems via Classical and Quantum Computation, Institute for Pure and Applied Mathematics (IPAM), University of California Los Angeles, Los Angeles, CA
- 10.26.2023 • Invited speaker (one of ten at yearly conference), Southwest Quantum Information and Technology Conference (SQuInT 2023), Albuquerque, NM
- 6.12.2023 • Entangle This: Randomness, Complexity and Quantum Circuits, Centro de Ciencias de Benasque Pedro Pascual, Benasque, Spain
- 6.7.2023 • NISQ Algorithms and Hardware 2023, organized by Hebrew University of Jerusalem in Neve Ilan, Israel
- 3.28.2023 • Quantum Interactive Dynamics Workshop II, Physics Department, University of Oxford, Oxford, UK
- 12.7.2022 • Workshop on Spacetime and Quantum Information, Institute for Advanced Study, Princeton, NJ
- 10.25.2022 • Cambridge-Warwick Quantum Computing Colloquium, University of Cambridge, Online Colloquium (virtual)
- 9.12.2022 • Workshop on Noisy Intermediate-Scale Quantum Systems: Advances and Applications, Kavli Institute for Theoretical Physics, Santa Barbara, CA

- 6.23.2022 • Quantum Interactive Dynamics Workshop I, Physics Department, University of Oxford, Oxford, UK
- 5.12.2022 • Stanford Quantum Information Talk, Physics Department, Stanford University, Stanford, CA (virtual)
- 1.11.2022 • Towards Classically Intractable Quantum Simulations of Physics and Chemistry workshop, Kavli Institute for Theoretical Physics, Santa Barbara, CA
- 7.13.2021 • Quantum Wave in Computing Reunion Workshop, Simons Institute, University of California, Berkeley, CA
- 7.1.2021 • Dagstuhl workshop “Quantum Complexity: Theory and Application”, Dagstuhl, Germany (virtual)
- 5.12.2021 • Quantum Information Seminar, Perimeter Institute, Waterloo, ON, Canada (virtual)
- 3.16.2021 • American Physical Society March Meeting 2021, Invited Speaker (the only invited talk in the session) for Noisy Intermediate Scale Quantum Computers I session (virtual)
- 3.4.2021 • Center for Quantum Information and Control Seminar, University of New Mexico, New Mexico (virtual)
- 10.2.2020 • Workshop on Dynamics, criticality, and universality in random quantum circuit, Max Planck Institute for the Physics of Complex Systems, Dresden, Germany (virtual)
- 6.17.2020 • Los Alamos Quantum Computing Summer School, Los Alamos, New Mexico (virtual)
- 5.6.2020 • Workshop on Quantum Devices: Simulation, Supremacy, and Optimization, Simons Institute, UC Berkeley, Berkeley, CA

Publications (in reverse chronological order)

1. **Classical algorithm for simulating experimental Gaussian boson sampling** with C. Oh, M. Liu, Y. Alexeev, L. Jiang
Accepted article (to appear), Nature Physics, February 2024
arXiv: [2306.03709](https://arxiv.org/abs/2306.03709).
2. **Quantum-inspired classical algorithm for graph problems by Gaussian boson sampling** with C. Oh, L. Jiang, N. Quesada.
Accepted article (to appear), PRX Quantum Journal, April 2024.
arXiv: [2302.00536](https://arxiv.org/abs/2302.00536).

3. **Effect of non-unital noise on random circuit sampling** with S. Ghosh, M. Gullans, K. Kuroiwa, K. Sharma
Accepted talk at Conference on Quantum Information Processing (QIP 2024)
arXiv: [2306.16659](https://arxiv.org/abs/2306.16659).
4. **Public-key pseudoentanglement and the hardness of learning ground state entanglement structure** with A. Bouland, S. Ghosh, T. Metger, U. Vazirani, C. Zhang and Z. Zhou.
Accepted talk at Conference on Quantum Information Processing (QIP 2024)
arXiv: [2311.12017](https://arxiv.org/abs/2311.12017).
5. **Complexity-theoretic foundations of BosonSampling with a linear number of modes** with A. Bouland, D. Brod, I. Datta, D. Grier, F. Hernandez and M. Oszmaniec
Accepted talk at Conference on Quantum Information Processing (QIP 2024)
6. **Quantum Merlin-Arthur and proofs without relative phase** with R. Bassirian, K. Marwaha
Accepted talk at Conference on Quantum Information Processing (QIP 2024)
In Proceedings, Fifteenth Conference on Innovations in Theoretical Computer Science (ITCS 2024), Simons Institute, Berkeley
arXiv: [2306.13247](https://arxiv.org/abs/2306.13247).
7. **Quantum Pseudoentanglement** with S. Aaronson, A. Bouland, S. Ghosh, U. Vazirani, Z. Zhou
Accepted talk at Conference on Quantum Information Processing (QIP 2023).
In Proceedings, Fifteenth Conference on Innovations in Theoretical Computer Science (ITCS 2024), Simons Institute, Berkeley
arXiv: [2211.00747](https://arxiv.org/abs/2211.00747).
8. **Quantum-inspired classical algorithm for molecular vibronic spectra** with C. Oh, Y. Lim, Y. Wong, L. Jiang
In Nature Physics, Volume 20, pages 225–231 (2024) August 2023.
arXiv: [2202.01861](https://arxiv.org/abs/2202.01861).
9. **Sharp complexity phase transitions generated by entanglement** with S. Ghosh, A. Deshpande, D. Hangleiter, A. Gorshkov
In Physical Review Letters, vol. 131, 030601
arXiv: [2212.10582](https://arxiv.org/abs/2212.10582).
10. **On the power of nonstandard quantum oracles** with R. Bassirani, K. Marwaha
In Proceedings of the Eighteenth Conference on the Theory of Quantum Computation, Communication and Cryptography (TQC 2023), Aveiro, Portugal.
arXiv: [2212.00098](https://arxiv.org/abs/2212.00098).

11. **Spoofing cross entropy measure in boson sampling** with C. Oh, L. Jiang
In Physical Review Letters, vol. 131, 010401
arXiv: [2210.15021](https://arxiv.org/abs/2210.15021).
12. **The learnability of Pauli noise** with S. Chen, Y. Liu, M. Otten, A. Seif and L. Jiang
In Nature Communications, Volume 14, Article 52
arXiv: [2206.06362](https://arxiv.org/abs/2206.06362).
13. **Tight bounds on the convergence of noisy random circuits to the uniform distribution** with A. Deshpande, P. Niroula, O. Shtanko, A. V. Gorshkov and M. J. Gullans
In PRX Quantum Journal, vol. 3, 040329
Accepted talk at Conference on Quantum Information Processing (QIP 2022)
arXiv: [2110.01564](https://arxiv.org/abs/2110.01564).
14. **Classical simulation of boson sampling based on graph structure** with C. Oh, Y. Lim, L. Jiang
In Physical Review Letters, vol. 128, 190501
arXiv: [2110.01564](https://arxiv.org/abs/2110.01564).
15. **Intractability of Electronic Structure in a Fixed Basis** with B. O’Gorman, S. Irani, J. Whitfield
In PRX Quantum Journal, vol. 3, 020322
arXiv: [2103.08215](https://arxiv.org/abs/2103.08215).
16. **Quantum Computational Supremacy via High-Dimensional Gaussian Boson Sampling** with A. Deshpande, A. Mehta, T. Vincent, N. Quesada, M. Hinsche, M. Ioannou, L. Madsen, J. Lavoie, H. Qi, J. Eisert, D. Hangleiter, I. Dhand
In Science Advances, Vol 8, Issue 1, 2022
arXiv: [2102.12474](https://arxiv.org/abs/2102.12474).
17. **Classical simulation of lossy boson sampling using matrix product operators** with C. Oh, K. Noh, L. Jiang
In Phys. Rev. A, vol. 104, 022407
arXiv: [2101.11234](https://arxiv.org/abs/2101.11234).
18. **Noise and the Frontier of Quantum Supremacy** with A. Bouland, Z. Landau, Y. Liu
In Proceedings of IEEE Foundations of Computer Science (FOCS 2021).
Accepted talk at Conference on Quantum Information Processing (QIP 2021).
arXiv: [2102.01738](https://arxiv.org/abs/2102.01738).

19. **The importance of the spectral gap in estimating ground-state energies** with A. Deshpande, A.V. Gorshkov
In PRX Quantum Journal, vol. 3, 040327.
In Proceedings, Tenth Conference on Innovations in Theoretical Computer Science (ITCS 2022), Berkeley, California.
Accepted talk at Conference on Quantum Information Processing (QIP 2021).
arXiv: [2007.11582](https://arxiv.org/abs/2007.11582).
20. **Eliminating Intermediate Measurements in Space-Bounded Quantum Computation** with Z. Remscrim
In Proceedings of ACM Symposium on Theory of Computing (STOC 2021).
Accepted talk at Conference on Quantum Information Processing (QIP 2021).
arXiv: [2006.03530](https://arxiv.org/abs/2006.03530).
21. **Complexity phase diagram for interacting and long-range bosonic Hamiltonians** with N. Maskara, A. Deshpande, A. Ehrenberg, M.C. Tran, A. V Gorshkov
In Physical Review Letters 125, 250501, 2020.
arXiv: [1906.04178](https://arxiv.org/abs/1906.04178).
22. **Efficient classical simulation of noisy random quantum circuits in one dimension** with K. Noh, L. Jiang
In Quantum Journal, volume 4, page 318, 2020.
arXiv: [2003.13163](https://arxiv.org/abs/2003.13163).
23. **Closing gaps of a quantum advantage with short-time Hamiltonian dynamics** with Jonas Haferkamp, Dominik Hangleiter, Adam Bouland, Jens Eisert, Juani Bermejo-Vega.
In Physical Review Letters 129, 150604, 2022.
arXiv: [1908.08069](https://arxiv.org/abs/1908.08069).
24. **Computational pseudorandomness, the wormhole growth paradox, and constraints on the AdS/CFT duality** with A. Bouland, U. Vazirani.
In Proceedings, Tenth Conference on Innovations in Theoretical Computer Science (ITCS 2020), Seattle, Washington.
arXiv: [1910.14646](https://arxiv.org/abs/1910.14646)
25. **On the Complexity and Verification of Quantum Random Circuit Sampling** with A. Bouland, C. Nirkhe, U. Vazirani.
In Nature Physics ([Article](#)), 2018.
Also accepted talk, Twenty-second Conference on Quantum Information Processing (QIP 2019), Boulder, Colorado.

Also in Proceedings, Tenth Conference on Innovations in Theoretical Computer Science (ITCS 2019), San Diego, CA.

arXiv: [1803.04402](https://arxiv.org/abs/1803.04402).

26. **Dynamical phase transitions in sampling complexity** with A. Deshpande, M.C Tran, M. Foss-Feig, and A.V Gorshkov.

In Physical Review Letters, vol. 121, 030501, 2018.

arXiv: [1703.05332](https://arxiv.org/abs/1703.05332).

27. **Exact Sampling Hardness of Ising Spin Models** with A.V Gorshkov and M. Foss-Feig.

In Physical Review A, vol. 96, no. 3, 2017.

arXiv: [1701.03167](https://arxiv.org/abs/1701.03167).

28. **Space-Efficient Error Reduction for Unitary Quantum Computations** with H. Kobayashi, C. Lin, T. Morimae, and H. Nishimura

In Proceedings of the Fourty-third International Colloquium on Automata, Languages, and Programming (ICALP 2016), Tacoma, Washington, US.

Also Accepted talk, Sixteenth Asian Quantum Information Science Conference (AQIS 2016), Taipei, Taiwan.

arXiv: [1604.08192](https://arxiv.org/abs/1604.08192).

29. **Computational Security of Quantum Encryption** with G. Alagic, A. Broadbent, T. Gagliardoni, C. Schaffner, and M. St. Jules

Accepted talk, Sixth International Conference on Quantum Cryptography, (QCrypt 2016), Washington D.C.

Also in Proceedings of Ninth International Conference on Information Theoretic Security (ICITS 2016), Tacoma, Washington, US.

arXiv: [1602.01441](https://arxiv.org/abs/1602.01441).

30. **On Quantum Obfuscation** with G. Alagic.

Accepted talk, Sixth International Conference on Quantum Cryptography (QCrypt 2016), Washington D.C.

arXiv: [1602.01771](https://arxiv.org/abs/1602.01771).

31. **A Complete Characterization of Unitary Quantum Space** with C. Lin

Accepted talk, Twentieth Conference on Quantum Information Processing (QIP 2017), Seattle, Washington.

Also in Proceedings, Ninth Conference on Innovations in Theoretical Computer Science (ITCS 2018), Cambridge, MA.

arXiv: [1604.01384](https://arxiv.org/abs/1604.01384).

32. **Quantum Merlin Arthur with Exponentially Small Gap** with C. Lin
Merged with “A Complete Characterization of Unitary Quantum Space”, 2016.
arXiv: [1601.01975](https://arxiv.org/abs/1601.01975).
33. **Quantum vs Classical Proofs and Subset Verification** with S. Kimmel
In Proceedings of Mathematical Foundations of Computer Science (MFCS 2018), Liverpool, England.
arXiv: [1510.06750](https://arxiv.org/abs/1510.06750).
34. **On the Power of Quantum Fourier Sampling** with C. Umans
In Proceedings of the Eleventh Conference on the Theory of Quantum Computation, Communication and Cryptography (TQC 2016), Berlin, Germany.
arXiv: [1507.05592](https://arxiv.org/abs/1507.05592).
35. **On the Power of Quantum Fourier Sampling**
Ph.D Thesis, California Institute of Technology, 2014.
36. **On Beating the Hybrid Argument** with R. Shaltiel, C. Umans and E. Viola.
In Theory of Computing, 9(26):809-843, 2013.
Also in Proceedings, Third Conference on Innovations in Theoretical Computer Science (ITCS 2012), Cambridge, MA.
ECCC: [TR10-186](https://eccc.weizmann.edu/report/TR10-186).
37. **On Quantum Computing and Pseudorandomness**
M.S Thesis, California Institute of Technology, 2011.
38. **Pseudorandom Generators and the BQP vs PH Problem** with C. Umans
Featured talk, Fourteenth Conference on Quantum Information Processing (QIP 2011), Singapore.
arXiv: [1007.0305](https://arxiv.org/abs/1007.0305).
39. **The Power of Unentanglement** with S. Aaronson, S. Beigi, A. Drucker, P. Shor
In Theory of Computing, 5(1):1-42, 2009.
Also in Proceedings, Twenty-third IEEE Conference on Computational Complexity (CCC 2008), College Park, MD.
arXiv: [0804.0802](https://arxiv.org/abs/0804.0802).

Grants

2021

Department of Energy, National Quantum Initiative Project (co-PI)

- PROPOSAL TITLE: “Next Generation Quantum Science and Engineering (QNEXT)”

- 2021 Department of Energy, HEP-QIS QuantISED multi-institution collaborative program (co-PI)
- PROPOSAL TITLE: “Complex Quantum Systems and The Quantum Universe Consortium”
- 2020 Air Force Office of Scientific Research grant (single PI)
- PROPOSAL TITLE: “The verification and benchmarking of near-term quantum computations”
 - AWARD NUMBER: FA9550-21-1-0008

Advising

- 2015-2021 Abhinav Deshpande (graduated, University of Maryland, co-advised with Alexey Gershkov, After graduation: Postdoc at Caltech, Current employment: Research Staff Member at IBM Research, Almaden in San Jose, California)
- 2019- Roozbeh Bassirianjahromi (PhD student)
- 2020- Soumik Ghosh (PhD student)
- 2021- Kunal Marwaha (PhD student)
- 2020- Zachary Remscrim (Postdoctoral scholar)
- 2020-2023 Nicholas Laracuente (Postdoctoral scholar), currently Assistant Professor, Computer Science Department, University of Indiana Bloomington)

Previous Positions

- 10.2018-7.2019 *Assistant Research Professor*
University of Maryland at College Park
Quantum Information and Computer Science (QuICS), University of Maryland Institute for Advanced Computer Studies (UMIACS)
- 7.2017-8.2019 *Computer Scientist*
National Institute of Standards and Technology, Computer Security Division
- 2009-2011 *Graduate research fellow*
Institute for Quantum Information, California Institute of Technology. Pasadena, CA
- 2008 *Adjunct research staff member*
Quantum Information Group, NEC Laboratories. Princeton, NJ
- 2006,2007,2014 *Adjunct research staff member*
Institute for Defense Analysis, Center for Communications Research. Princeton, NJ