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# Zhuo Chen

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## EDUCATION

### Massachusetts Institute of Technology

Cambridge, MA

Ph.D. Candidate in Physics, Statistics and Data Science

Research Areas: Physics for ML; Foundation Model; (Quantum) Information Theory; AI for Science; Optimization

09/2021–05/2026(Expected)

GPA: 5.00/5.00

### University of Illinois at Urbana-Champaign

Urbana, IL

B.S in Physics with Summa Cum Laude and Highest Distinction in Curriculum

Minor in Mathematics and Computer Science

08/2017–05/2021

GPA: 4.00/4.00

## WORK EXPERIENCE

### Two Sigma Investment

New York, NY

Quantitative Research Intern

06/2025–08/2025

## HIGHLIGHTED PUBLICATIONS

† Co-first authors

Google Scholar: <https://scholar.google.com/citations?user=4QjfQtwAAAAJ&hl=en>

### Physics for AI:

1. [Zhuo Chen](#), Oriol Mayné i Comas, Zhuotao Jin, Di Luo, Marin Soljačić. “L<sup>2</sup>M: Mutual Information Scaling Law for Long-Context Language Modeling” (**NeurIPS, 2025**)
2. [Zhuo Chen](#), Rumen Dangovski, Charlotte Loh, Owen Dugan, Di Luo, Marin Soljačić. “QuanTA: Efficient High-Rank Fine-Tuning of LLMs with Quantum-Informed Tensor Adaptation” (**NeurIPS, 2024**)
3. Owen Dugan, Donato Manuel Jimenez Beneto, Charlotte Loh, [Zhuo Chen](#), Rumen Dangovski, Marin Soljačić. “OccamLLM: Fast and Exact Language Model Arithmetic in a Single Step” (**NeurIPS, 2024**)
4. [Zhuo Chen](#), Esteban Vizcaino, Jacob McCarran, Marin Soljačić, Di Luo. “TENG: Time-Evolving Natural Gradient for Solving PDEs with Deep Neural Net.” (**ICML, 2024**)
5. Seou Choi, Yannick Salamin, Charles Roques-Carnes, Rumen Dangovski, Di Luo, [Zhuo Chen](#), Michael Horodyski, Jamison Sloan, Shiekh Zia Uddin, Marin Soljačić. “Photonic probabilistic machine learning using quantum vacuum noise” (**Nature Communications, 2024**)

### Quantum Information Theory:

6. [Zhuo Chen](#), Yimu Bao, Soonwon Choi. “Optimized trajectory unraveling for classical simulation of noisy quantum dynamics” (**Physical Review Lett., 2024**)
7. Adam L. Shaw†, [Zhuo Chen](#)†, Joonhee Choi†, Daniel K. Mark†, Pascal Scholl, Ran Finkelstein, Andreas Elben, Soonwon Choi, Manuel Endres, “Benchmarking Highly Entangled States on a 60-Atom Analog Quantum Simulator.” (**Nature, 2024**)

### AI for Quantum Physics:

8. Viggo Moro, Charlotte Loh, Rumen Dangovski, Ali Ghorashi, Andrew Ma, [Zhuo Chen](#), Peter Y Lu, Thomas Christensen, Marin Soljačić. “Multimodal Learning for Crystalline Materials” (**Newton, 2025**)
9. [Zhuo Chen](#), Laker Newhouse, Eddie Chen, Di Luo, Marin Soljačić. “ANTN: Bridging Autoregressive Neural Networks and Tensor Networks for Quantum Many-Body Simulation.” (**NeurIPS, 2023**)
10. [Zhuo Chen](#)†, Di Luo†, Kaiwen Hu, Bryan K. Clark. “Simulating 2+1D Lattice Quantum Electrodynamics at Finite Density with Neural Flow Wavefunctions.” (**2022**)
11. Di Luo†, [Zhuo Chen](#)†, Kaiwen Hu, Zhizhen Zhao, Vera Mikyoung Hur, Bryan K. Clark. “Gauge Invariant Autoregressive Neural Network for Quantum Lattice Models.” (**Physical Review Research, 2023**)
12. Di Luo†, [Zhuo Chen](#)†, Juan Carrasquilla, & Bryan K. Clark. “Autoregressive Neural Network for Simulating Open Quantum Systems via a Probabilistic Formulation.” (**Physical Review Lett., 2022**)
13. Jiangran Wang, [Zhuo Chen](#), Di Luo, Zhizhen Zhao, Vera Mikyoung Hur, Bryan K. Clark. “Neural Network for High Dimensional Quantum Dynamics.” (**Workshop at ICML, 2021**)

14. Di Luo†, Zhuo Chen†, Juan Carrasquilla, Bryan K. Clark. “Quantum Dynamics by Solving Probabilistic Differential Equations via Autoregressive Networks.” (**Workshop at NeurIPS, 2020**)

#### Numerical Relativity:

15. Zhuo Chen, E. A. Huerta, Joseph Adamo, Roland Haas, Eamonn O’Shea, Prayush Kumar, and Chris Moore. “Observation of eccentric binary black hole mergers with second and third generation gravitational wave detector networks.” (**Physical Review D, 2021**)

### **HIGHLIGHTED HONORS & AWARDS**

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|--|------|
| • MathWorks Research Fellowship.   | 2024 |
| • Stanford Shoucheng Zhang Fellowship (elected to decline).                                    | 2021 |
| • Harvard Quantum Initiative Fellowship (elected to decline).                                  | 2021 |
| • A. C. Anderson Undergraduate Research Award.   | 2020 |
| • Phi Beta Kappa Society member.   | 2019 |
| • Sixth place (team) in International Theoretical Physics Olympiad for Undergraduate Students. | 2019 |
| • Top gold in British Physics Olympiad (China).  | 2015 |
| • Second Prize in China National Linguistics Olympiad Individual Contest.                      | 2015 |

### **HIGHLIGHTED CURRENT RESEARCH PROJECTS**

**NSF AI Institute for Artificial Intelligence and Fundamental Interactions (IAIFI)**      Massachusetts Institute of Technology  
 Advisors: Prof. Marin Soljačić      *Present*

#### Physics & Information Theory for Foundation Models:

- **Pioneering information-theoretic approaches to advance long-range capabilities of large language models (LLMs).**
  - Developed mutual information-based frameworks for analyzing the sample distributions of natural languages [Publication #1].
  - Creating massive synthetic datasets replicating the mutual information scaling of natural languages.
  - Benchmarking and analyzing existing LLM architectures’ long-range capabilities on the synthetic datasets.
  - Designing a series of novel LLM architectures that efficiently capture long-range dependencies with linear complexity.
  - Investigating optimal autoregressive sampling strategies to improve text generation and reduce hallucination.
- **Advancing diffusion models using statistical physics and renormalization group theory.**
  - Investigating information flow in diffusion stochastic differential equations using tools from statistical physics.
  - Developing multi-scale diffusion models inspired from renormalization group techniques.
  - Designing new training and inference algorithms considering energy landscapes at various scales.

#### AI for Quantum Computation & Quantum Simulation:

- **Designing advanced optimization techniques for quantum dynamics simulation using neural networks.**
  - Pioneering advanced optimization algorithms for dynamical systems by generalizing two fundamental physics principles.
  - Creating novel adaptations of the variational Monte Carlo optimization for both in- and out-of-distribution samples.
  - Achieving state-of-the-art fidelity in quantum computer and analog quantum simulator simulations using neural networks.
- **Innovating foundation models for quantum lattice systems.**
  - Crafting graph-based transformer neural networks for variational Monte Carlo simulations of lattice systems.
  - Implementing versatile strategies to optimize the foundation model across diverse Hamiltonians on various lattice configurations.

### **HIGHLIGHTED PAST RESEARCH EXPERIENCE**

**NSF AI Institute for Artificial Intelligence and Fundamental Interactions (IAIFI)**      Massachusetts Institute of Technology  
 Advisors: Prof. Marin Soljačić      *2021–Present*

#### Physics for AI:

- Pioneered an extremely parameter-efficient fine-tuning method for large language models using tensor operations inspired by quantum circuits [Publication #2].
- Introduced a groundbreaking framework for simulating partial differential equations with neural networks by generalizing two existing principles, achieving optimization results near numerical precision [Publication #4].

#### AI for Quantum Many-Body Physics:

- Designed novel neural network architecture generalizing autoregressive neural networks and tensor networks to achieve the state-of-the-art result for studying quantum many-body physics with variational Monte Carlo [Publication #9].

- Developed discrete flow-based autoregressive neural network that satisfies gauge symmetry and fermionic antisymmetry for variational Monte Carlo simulation of full 2+1D quantum electrodynamics for the first time [Publication #10].

#### **Center for Theoretical Physics (CTP)**

Massachusetts Institute of Technology

Advisor: Prof. Soonwon Choi

2021–Present

##### **Quantum Information Theory:**

- Pioneered both analytical and numerical techniques to optimize the unraveling of quantum Monte Carlo trajectories, enabling efficient simulation of open quantum dynamics that were previously computationally intractable [Publication #6].
- Innovated a state-of-the-art algorithm using tensor networks to simulate long-range quantum dynamics, integrating statistical methods to verify the quantum advantage of near-term quantum simulators in collaboration with experimentalists at Caltech [Publication #7].

#### **Clark Research Group**

University of Illinois, Urbana-Champaign

Advisor: Prof. Bryan K. Clark

2020–2021

##### **AI for Quantum Many-Body Physics:**

- Developed the world's first framework of gauge-invariant autoregressive neural networks, integrating transformers and RNNs with efficient exact sampling for quantum lattice gauge theories, enabling the accurate simulation of complex models like the quantum link and X-cube fracton models [Publication #11].
- Pioneered the simulation of many-body open quantum systems using the POVM formulation, marking the world's first application of transformer neural networks in quantum physics, and delivering state-of-the-art results across multiple benchmarks [Publications #12 & #13].

#### **National Center for Supercomputing Applications**

University of Illinois, Urbana-Champaign

Advisor: Prof. Eliu A. Huerta

2018–2021

##### **Numerical Relativity:**

- Leveraged massive parallel computation on supercomputers to conduct a numerical sensitivity analysis of second and third generation gravitational wave detectors for binary black hole mergers [Publication 15].

### **MENTORING & LEADERSHIP EXPERIENCE**

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- Mentored a high school student during the Research Science Institute (RSI), guiding them to achieve a top 10 placement in the final presentation.
- Supervised and mentored undergraduate students and junior graduate students, leading to co-authorship on multiple research papers.
- Guided 2 undergraduate students during my undergraduate studies, resulting in co-authored publications.
- Advised 2 undergraduate students during Illinois Guidance for Physics Students (GPS).
- Led numerous collaborative research projects, coordinating efforts with teams and researchers from other universities to drive successful outcomes and joint publications.

### **PROFESSIONAL SERVICE & TECHNICAL MANAGEMENT EXPERIENCE**

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- Served as a reviewer for top conferences and workshops, including ICML, NeurIPS, and ICLR.
- Operated and maintained three group research computing clusters and a group AI chatbot.
- Utilized various clusters and supercomputers, including NCSA DeltaAI, MIT SuperCloud, MIT Satori, Harvard Cannon Cluster, Open Science Grid, and Blue Water.
- Collaborated with AWS in a pilot program, leveraging AWS cloud resources to run complex research projects.
- Provided technical expertise and support for research teams.

### **HIGHLIGHTED EXTRACURRICULAR ACTIVITIES**

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#### **Independent Technical Projects**

2017–Present

- Engineered and assembled portable electric refrigerators, air humidifiers with variable speed control, modular power banks, and uninterrupted power supplies for wireless routers.
- Diagnosed and corrected a common flaw in power adapters related to improper capacitor discharge after unplugging.
- Built and configured multiple computers, experimented with diverse operating systems, deployed personal cloud servers using virtualization technology, and repurposed several broken laptops into home (media) servers.

#### **Overseas China Education Foundation (OCEF) non-profit organization**

2019–2021

- Coordinated fundraising efforts and educational initiatives, contributing to supporting underprivileged students in rural areas.
- Managed communications between donors and the organization, ensuring transparency and fostering continued support for educational programs.

## HIGHLIGHTED SKILLS

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### Programming Languages & Libraries:

- Python: Advanced, including libraries such as PyTorch, JAX, NumPy, SciPy, Pandas, Matplotlib, Plotly
- Other Languages: Mathematica (advanced), Julia (beginner), MATLAB (basic), C++ (basic), Java (basic), CUDA (basic)

### Computational Techniques & Algorithms:

- Statistical & Monte Carlo Methods: Variational Monte Carlo (VMC), Diffusion Monte Carlo (DMC), Path Integral Monte Carlo (PIMC), Markov Chain Monte Carlo (MCMC)
- Machine Learning: Supervised and unsupervised learning, neural networks, reinforcement learning, generative modeling, large language models (LLMs)
- Numerical Analysis: Numerical quadrature/time integration, finite difference & spectral methods, Krylov subspace methods
- Optimization: SGD, Adam/AdamW, (Hilbert) natural gradient, conjugate gradient methods, simulated annealing

### Operating Systems:

- Windows & macOS: Proficient in both GUI and CLI usage; familiar with various shells and WSL
- Linux: Experienced with various distros (Ubuntu, CentOS, Debian); proficient in CLI usage and shell scripting

### Software & Development Tools:

- Environment Management: Conda, PyPI
- Code Editors: VSCode, PyCharm, Vim, Jupyter Notebook

### Hardware & Technical Skills:

- Electronics & Soldering: Skilled in soldering and assembling electronic components for custom hardware projects
- System Assembly & Troubleshooting: Extensive experience in building and diagnosing custom PCs and servers
- Virtualization: Proficient in setting up and managing virtual environments using platforms like Hyper-V and VMware
- RAID Configuration: Experienced in setting up and maintaining RAID arrays for enhanced data redundancy and performance

### High-Performance & Cloud Computing Tools:

- Slurm, HTCondor, AWS

### Document Preparation:

- LaTeX, Office 365 (Word, Excel, PowerPoint)

### Other Skills:

- Swimming, Clarinet, First Aid (Red Cross-certified first aider)