Chang-Han Chen

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Education

- **Ph.D. in Theoretical Physics, University of California, Berkeley** expected end of 2026
- **B.Sc. in Physics and Mathematics, Massachusetts Institute of Technology** 2022
  GPA 4.9/5; Morse/Orloff award for best senior thesis.

Research Interest

Over my PhD years, I hope to infer the minimal structure of quantum gravity solely from general relativity and quantum mechanics. No string theory or loop quantum gravity. I successfully derive holographic entropy formulas and construct gauge-invariant observables in, for instance, slow-roll inflation, two-dimensional dilaton gravity, and general regions bounded by extremal surfaces. This opens up a promising research program for von Neumann algebras as the bottom-up framework for quantum gravity.

I also study data-efficient training of deep neural networks and the science of reinforcement learning. My empirical work has explored accelerating diffusion language model pretraining and using agents to improve MoE architectures. More recently, I focus on developing a principled framework for reinforcement learning in large language models, in which scores and critics form coupled martingales, with applications to variance reduction.

Selected Projects

- **The two principles of LLM policy gradients** (work in progress) Oct. 2026
  Developing a framework for LLM policy gradients using the martingale structure of cumulative scores and conditional expected rewards; exploring branching and control variates for variance reduction.
- **MoE autoresearch** Jun. 2026
  Explored LLM-agent-driven "autoresearch" on autoregressive mixture-of-experts transformers, stacking interventions to a 1.75% bits-per-byte gain that persists under compute-optimal scaling.
- **Optimal block-size curriculum for diffusion language models** Jun. 2026
  Designed a block-size curriculum for pretraining block-diffusion language models, sweeping the autoregressive vs. diffusion training budget and finding a consistent sample-efficiency optimum near 30%.
- **Holographic algebras at null infinity** Sep. 2026
  Constructed algebras at null infinity that reconstruct bulk regions in asymptotically flat spacetimes; recovered generalized black hole entropy from a regulated von Neumann algebra.
- **An apologia for islands** Jun. 2025
  Showed how entanglement islands and the Page curve arise with massless gravitons and no external reservoir; constructed compactly supported gravitational observables to all perturbative orders.
- **A clock is just a way to tell the time** (with G. Penington) Jun. 2024
  First demonstration of gauge-invariant algebras without an observer, contrary to the common belief. Derive holographic entropy for cosmological spacetimes and more general subregions.
- **Geometry and entanglement in AdS/CFT and beyond** May 2022
  Independent senior thesis, awarded MIT's Morse/Orloff prize for best senior thesis in theoretical physics.

Honors and Awards

- Morse/Orloff Research Award – **best senior thesis in theoretical physics, MIT** 2022
- **Gold medal, International Physics Olympiad (IPhO)** 2018

Skills

- **Programming:** Python, PyTorch, JAX, Megatron-LM, SGLang, SkyRL.
- **Research:** von Neumann algebras, random matrix and free probability, language model training.