Casey O. Barkan

PhD Candidate @ UCLA Physics
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Summary: Theoretical physicist and engineer aiming to pivot to AI safety research. Experienced in mathematical modeling of physical, biological, ecological, and economic systems. Track record of developing creative mathematical methods to solve a wide range of practical and theoretical problems at the intersection of statistical physics and complex systems. Award-winning teacher and skilled writer and communicator. I excel in both independent and collaborative roles.

Education

Ph.D. Physics, UCLA — Expected: Summer 2025
M.S. Physics, University of Pennsylvania — 2019
B.S.E. Chemical and Biomolecular Engineering, University of Pennsylvania — 2018

- Minors in Economics, Mathematics. 2nd Major in Physics. *Summa Cum Laude*.

Experience

Doctoral Researcher in Theoretical Physics, UCLA — 2019-Present

- Led multiple collaborations with three professors resulting in 6 first-author publications in selective journals. Publications listed on page 2.
    - Developed long-term research vision, guided research direction, designed and implemented technical methods, and wrote papers for all projects.
    - Topics: Non-equilibrium statistical mechanics, Protein mechanics, Evolutionary dynamics, Gene regulatory dynamics.
- Solved decade-old puzzle about protein-ligand binding dynamics.
- Coded simulations, visualizations, optimizations, and statistical analyses in Python.
- Communicated research in 9 conference presentations (4 oral, 5 poster).
- Published single-author paper (highly unusual in my field).
- Led summer tutoring and mentorship program.

Teaching Assistant, Univ. of Penn. & UCLA — 2016-2017 & 2019-2022

- Courses: Quantum computation, Electrodynamics, Electronic circuits, + 5 more.
- Received Outstanding Teaching Award and excellent teaching evaluations.

Researcher in Computational and Quantum Chemistry, Univ. of Penn. — 2016-2018

- Designed and implemented optimization tools for quantum materials computations.
- Wrote successful grant to fund team of 5 undergraduate researchers.

Research Intern in Neurobiology, University of Chile — 2013-2014

- Performed electrophysiology experiments studying olfaction.

Technical Skills

Programming & Tools: Python (PyTorch, Numpy, Scipy, Matplotlib), Matlab, Linux.
Machine learning & AI: Physics-informed neural networks, Transformers & LLMs, Q-learning.
Quantitative methods: Optimization & optimal control, Stochastic processes, Mathematical modeling & simulation, Monte Carlo, Economic & financial theory and modeling.

Projects in Machine Learning & Economics

Neural networks for high-dimensional partial differential equations.

- Implemented cutting-edge machine learning method useful for finance, optimization, and quantum mechanics.
- https://github.com/cbarkan1/physics-informed-neural-networks

Economic modeling of AI automation impacts.

- Developed macroeconomic model to analyze counterintuitive labor market impacts of automation technology.
- https://cbarkan1.github.io/Barkan-AI_productivity_and_GDP.pdf

Steering a large language model with a pre-trained sparse autoencoder.

- Utilized mechanistic interpretability method to steer the behavior of an LLM.
- https://github.com/cbarkan1/mechanistic-interpretability

Selected Courses and Conferences

- AI Safety Fundamentals: AI Alignment (BlueDot Impact) — Fall 2024-Winter 2025
- AI Safety Fundamentals: AI Governance (BlueDot Impact) — Summer 2024-Fall 2024
- Multiple selective biophysics conferences and workshops. — Multiple dates

Selected Awards

- Outstanding Teaching Award, UCLA Physics (2021)
- NSF Graduate Research Fellowship (2019)
- 1st Place Prize for best chemical engineering design project, Penn CBE (2018)
- American Chemical Society Scholastic Achievement Award (2018)

Publications

IN PREPARATION: Barkan, C.O. & Chou, T. Working title: Combining Waddington and fitness landscapes to describe the coordinated development of tissue.

IN REVISION: Barkan, C.O. & Wang, S. (2024). Migration feedback induces emergent ecotypes and abrupt transitions in evolving populations. *In revision at Physical Review E*. https://arxiv.org/abs/2309.10884

Barkan, C.O. (2024). On the convergence of phase space distributions to microcanonical equilibrium: dynamical isometry and generalized coarse-graining. *Journal of Physics A: Mathematical and Theoretical*, 57(47), 5001. https://doi.org/10.1088/1751-8121/ad7c9e

Barkan, C.O. & Bruinsma, R.F. (2024). Topology of molecular deformations induces triphasic catch bonding in selectin–ligand bonds. *Proceedings of the National Academy of Sciences*, 121(6), e2315866121. https://doi.org/10.1073/pnas.2315866121

Barkan, C.O. & Wang, S. (2023). Multiple phase transitions shape biodiversity of a migrating population. *Physical Review E*, 107(3), 034405. https://doi.org/10.1103/PhysRevE.107.034405

Barkan, C.O. & Bruinsma, R.F. (2023). Catch-slip bonding, pathway switching, and singularities in the flow of molecular deformation. *Physical Review Research*, 5(2), 023161. https://doi.org/10.1103/PhysRevResearch.5.023161