

Casey O. Barkan

PhD Candidate
Department of Physics and Astronomy
University of California, Los Angeles

barkanc@ucla.edu
541-914-9443

Education

PhD Candidate in Physics, University of California, Los Angeles (2019-Present)

- GPA: 3.98/4.00
- Thesis committee: Robijn F. Bruinsma (chair), Tom Chou, William Gelbart, Shenshen Wang, Giovanni Zocchi.
- Expected graduation: December 2024

MS in Physics, University of Pennsylvania (2018-2019)

- GPA: 3.93/4.00

BSE in Chemical and Biomolecular Engineering, University of Pennsylvania (2014-2018)

- GPA 3.83/4.00
- Second major: Physics
- Minors: Mathematics, Economics
- *Summa Cum Laude*

Honors and Awards

Outstanding Teaching Assistant Award, UCLA Physics (2021)

NSF Graduate Research Fellowship (2019)

American Chemical Society Scholastic Achievement Award (2018)

Melvin C. Molstad Prize for best Chemical Engineering design project, Penn CBE (2018)

A. Norman Hixson Laboratory Report Prize in Chemical Engineering, Penn CBE (2018)

Tau Beta Pi Engineering Honors Society (2017)

Research Focus

My research falls under the categories of theoretical soft condensed matter physics, biophysics, statistical physics, and mathematical biology. Below are brief descriptions of the research topics I have pursued during my PhD.

Theory of protein interactions: I am working on theories of mechanically sensitive receptor-ligand interactions. I developed a mathematical theory of catch bonding, showing how the catch-to-slip switch results from singularities in the flow field of force-induced molecular deformation. With this theory, I addressed a long-standing challenge in mechanobiology: to explain how selectin proteins can convert between slip, catch-slip, and slip-catch-slip behavior through minor structural changes. I am now working to apply this theory to T cell receptors, whose catch bonding behavior is believed to be essential for immune function.

Foundations of statistical mechanics: In an upcoming paper, I explore the convergence (and lack of convergence) of classical systems to microcanonical equilibrium. I show that for classical phase space distributions functions, time evolution is an *isometry* according to standard statistical

distance metrics. I propose a generalization of phase space coarse-graining that generalizes the result that coarse-grained entropy converges to its equilibrium value under *strong mixing* dynamics.

Evolutionary and ecological dynamics: I investigated the effects of migration patterns on evolving populations in spatially-structured environments using minimal models. This work uncovered counterintuitive phase transitions and emergent effects, and it motivates specific experiments that may be able to investigate these behaviors.

Publications

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

C.O. Barkan and S. Wang. (2023). Multiple phase transitions shape biodiversity of a migrating population. *Physical Review E*.
DOI: <https://doi.org/10.1103/PhysRevE.107.034405>

C.O. Barkan and R.F. Bruinsma. (2024). Topology of molecular deformation induces triphasic catch bonding in selectin-ligand bonds. *Proceedings of the National Academy of Sciences*.
DOI: <https://doi.org/10.1073/pnas.2315866121>

C.O. Barkan and S. Wang. (Submitted 2023). Migration feedback yields novel critical transitions and emergent ecotypes in connected populations. *Under review at PRX Life*.
ArXiv preprint: <https://arxiv.org/abs/2309.10884>

Conference Presentations

Oral presentations:

- C.O. Barkan. (March 2024). Modeling the structural mechanism of TCR-pMHC catch bonding. *APS March Meeting, Minneapolis, MN*.
- C.O. Barkan and S. Wang. (Sept 2023). Migration feedback yields novel critical transitions and emergent ecotypes in connected populations. *UCLA QCBio Retreat, Los Angeles, CA*.
- C.O. Barkan and R.F. Bruinsma. (March 2023). Geometric Signatures of Switching Behavior in Mechanobiology. *APS March Meeting, Las Vegas, NV*.
- C.O. Barkan. (March 2023). Theory of force-sensitive bonds: complex behavior from simple mechanisms. *APS March Meeting, Las Vegas, NV*.

Poster presentations:

- C.O. Barkan. (Nov 2023). Mechanical Allostery Induces Tunable Catch Bonding. *5th course on multi-scale integration in biological systems, Curie Institute, Paris*.
- C.O. Barkan and R.F. Bruinsma. (Feb 2023). Geometric Signatures of Switching Behavior in Mechanobiology. *Biophysical Society Meeting, San Diego, CA*.
- C.O. Barkan and R.F. Bruinsma. (Sept 2022). Geometric Signatures of Switching Behavior in Mechanobiology. *EMBO Physics of Cells, Ein Gedi, Israel*.
- C.O. Barkan and S. Wang. (March 2022) Phase Transitions Shape Biodiversity of a Migrating Population. *APS March Meeting, Chicago, IL*.

- C.O. Barkan and S. Wang. (Sept 2021). Emergent Ecological Phenomena in an Evolving and Migrating Population. *UCLA QCBio Retreat, Los Angeles, CA.*

International Research Schools Attended

- 5th Course in Multi-scale Integration in Biological Systems (Nov. 8-14, 2023). *Curie Institute, Paris, France.*
- International School on Biological Physics of Cells (Sept 11-23, 2022). *Weizmann Institute, Rehovot, Israel.*

Teaching Experience (as a TA)

At UCLA:

- Phys 245: Quantum Computation, *graduate level course* (Fall 2022)
- Phys 117: Electronics for Physical Measurement, *upper division course* (Spring 2021)
- Phys 5B: Thermodynamics for Life Sciences (Winter 2021)
- Phys 110A: Electrodynamics, *upper division course* (Fall 2020)
- Phys 5BL: Thermodynamics for Life Sciences, Laboratory (Summer 2020)
- Phys 1A: Introductory Mechanics (Fall 2019)

At Penn:

- Chem 115: Honors Introductory Chemistry (Fall 2017)
- Math 103: Introductory Calculus (Fall 2016)

Computer & Programming Skills

Python (Numpy, Scipy, TensorFlow, Matplotlib), Matlab, Mathematica, Linux.

Outreach

YEE STEM Tutoring and Mentorship program (UCLA student group)

- Lead organizer (2022): Wrote a grant to provide funding for background checks for 27 tutors/mentors. Worked with community partner (Innovate Public Schools) to organize summer tutoring and mentoring.
- Volunteer tutor/mentor (2020-2023).

West Philadelphia Tutoring Project (Penn student group)

- Volunteer tutor for underprivileged youth in Philadelphia (2018-2019).