

LOREN E. HOUGH
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University of Colorado, Boulder
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EDUCATION

University of Colorado, Boulder

PhD in Physics, April 2007

University of California, Santa Barbara

Graduate work in Physics, 2001–2002

Harvard University, Cambridge, Massachusetts

BA in Physics, *Magna cum laude with Highest Honors* 2000

POSITIONS

Assistant Professor, Department of Physics and BioFrontiers Institute, University of Colorado at Boulder, 2012 – present

Postdoctoral Fellow, Laboratory of Cellular and Structural Biology, Rockefeller University, 2007–2012

HONORS AND AWARDS

Maximizing Investigators' Research Award, NIH National Institute of General Medical Sciences, 2016

Diversity Service Recognition Award by the Chancellors Committee on Race and Ethnicity to CU Café, 2016

IMPART Grant recipient, CU Boulder, 2015

Boettcher Investigator, 2014

Postdoctoral Research Award, Intrinsically Disordered Proteins Subgroup of the Biophysical Society, 2011

Charles H. Revson Fellowship in Life Sciences 2010

NIH Ruth L. Kirschstein National Research Service Postdoctoral Fellowship, 2009

Glenn Brown Prize, International Liquid Crystal Society, 2008

Trainee, NIH Biophysics Training Grant (T32-CU Boulder), 2006–2007

GAANN Fellowship, Liquid Crystal Materials Research Center, CU Boulder, 2005–2006

NSF Graduate Research Fellowship, 2002–2005

Broida and GAANN Fellowships, Physics Department, UC Santa Barbara 2001–2002

Phi Beta Kappa, 2000

Barry Goldwater Scholarship, 1998

RESEARCH ACCOMPLISHMENTS

In cell NMR. We were the first lab to perform protein NMR experiments in living budding yeast, opening a new approach to study disordered proteins in their native environments. Using this new technique, we explained why one disordered protein adopts a fundamentally different structural state in cells versus in solution. We are continuing this work to determine how the cell respond to changes in environmental conditions, especially those that induce a stress response.

Microtubule regulation. Microtubules are a key component of the cytoskeleton of eukaryotic cells, and contain small flexible segments called the C-terminal tails that acts as sites of regulation. We were the first to measure NMR spectra of the tubulin tails. We found that despite remaining highly dynamic, the tubulin tails interact significantly with the ordered tubulin body, and that modifications of the disordered tails alter microtubule stiffness. Our results demonstrate a mechanism by which an atomic-level change in a disordered domain modulates the behavior of a protein complex, in this case the mechanical properties of a cytoskeletal filament. We are continuing this work to determine the molecular mechanisms by which modification of the tails modulates binding interactions.

Polymer Biofilters. Disordered proteins are key components of polymer biofilters that define cellular compartments. These filters differ from synthetic filters because they select based on binding rather than size or charge. We have identified a novel mechanism of binding-based filtration in which the inherent flexibility of disordered proteins allows movement of the transported protein. We are continuing this work with development bench-top experiments and analytical theory to determine how transient binding can be used to control transport in diverse biological systems.

WORKS IN PROGRESS

“C-terminal tail polyglutamylation alters microtubule mechanical properties”, Kathryn Wall, Harold Hart, Thomas Lee, Cynthia Page, Taviere Hawkins, Loren Hough, (in revision, <https://www.biorxiv.org/content/10.1101/791194v1>).

“Moving while youre stuck; a mechanical model of binding facilitated transport in biological systems”, Kanghyeon Koo, Shankar Lalitha Sridhar, Noel Clark, Franck Vernerey, and Loren Hough, (under review).

“Non-classical diffusion by reversible binding to elastic chains”, Shankar Lalitha Sridhar, Kanghyeon Koo, Loren Hough, and Franck Vernerey, (under review).

“Characterization of predicted small proteins”, Allison M. Whited, Christina L. Cleveland, Jeffrey Allen, Irwin Jungreis, John L. Rinn, Loren E. Hough, (In preparation).

“Facilitated diffusion in damped systems by reversible binding of elastic tethers”, Jeffrey Dunagin, Shankar Lalitha Sridhar, Franck Vernerey, Loren Hough, (In preparation).

PEER-REVIEWED PUBLICATIONS

An up to date list of publications is available at: <https://tinyurl.com/hough-lab>

“Bound-state diffusion due to binding to flexible polymers in a hydrogel biofilter”, Laura Maguire, Meredith Betterton, Loren Hough, *Biophysical Journal* 100(2), 376-385 (2020).

“Design principles of selective transport through biopolymer barriers”, Laura Maguire, Michael Stefferson, Meredith Betterton, Loren E. Hough, *Physical Review E* 100, 042414 (2019).

“In-cell NMR within budding yeast reveals cytoplasmic masking of hydrophobic residues of FG repeats”, Kathryn P. Wall, Loren E. Hough, *Biophysical Journal* 115(9), 1690-1695 (2018).

“Effects of soft interactions and bound mobility on diffusion in crowded environments: a model of sticky and slippery obstacles.”, Michael Stefferson, Samantha Norris, Franck Vernerey, Meredith Betterton, Loren E. Hough, *Physical biology* 14(4), 045008 (2017).

“Physical determinants of bipolar mitotic spindle assembly and stability”, Robert Blackwell, Christopher Edelmaier, Oliver Sweezy-Schindler, Adam Lamson, Zachary Gergely, Eileen

- O'Toole, Ammon Crapo, Loren E. Hough, J. Richard McIntosh, Matthew A. Glaser, Meredith D. Betterton, *Science Advances* 3(1), e1601603 (2017).
- “Molecular Determinants of Tubulin’s C-Terminal Tail Conformational Ensemble”, Kathryn P. Wall, Maria Pagratis, Geoffrey Armstrong, Jeremy L. Balsbaugh, Eric Verbeke, Chad G. Pearson, Loren E. Hough, *ACS Chemical Biology* 11, 2981 (2016).
- “Kinesin-8 effects on mitotic microtubule dynamics contribute to spindle function in fission yeast”, Zachary Gergely, Ammon Crapo, Loren E. Hough, J. Richard McIntosh, Meredith D. Betterton, *Molecular Biology of the Cell* 27, 3490–3514 (2016).
- “Microscopic origins of anisotropic active stress in motor-driven nematic liquid crystals”, Robert Blackwell, Oliver Sweezy-Schindler, Christopher Baldwin, Loren E. Hough, Matthew A. Glaser, M. D. Betterton, *Soft Matter* 12, 2676–87 (2016).
- “The molecular mechanism of nuclear transport revealed by atomic scale measurement”, Loren E. Hough, Kaushik Dutta, Sam Sparks, Deniz Temel, Jacklyn Tetenbaum-Novatt, Brian Chait, Michael Rout, David Cowburn, *eLife*, eLife 2015;10.7554/eLife.10027 (2015).
- “Hysteresis, reentrance, and glassy dynamics in systems of self-propelled rods”, Hui-Shun Kuan, Robert Blackwell, Loren E. Hough, Matthew A. Glaser, and M. D. Betterton, *Physical Review E* 92, 060501 (2015).
- “Rapid, optimized interactomic screening”, Zhanna Hakhverdyan, Michal Domanski, Loren E. Hough, Asha A. Oroskar, Anil R. Oroskar, David J. Dilworth, Kelly Molloy, Vadim Sherman, John D. Aitchison, Brian T. Chait, Torben H. Jensen, Michael P. Rout and John LaCava, *Nature Methods* 12(6), 553-60 (2015).
- “The role of competition in karyopherin-FG Nup interactions; a key to efficient transport through the nuclear pore complex”, Jaclyn Tetenbaum-Novatt, Loren E. Hough, Roxana Mironska, A. Sophie McKenney, Michael Rout, *Mol Cell Proteomics* 11(5), 31-46 (2012).
- “Structure of the B4 Liquid Crystal Phase near a Glass Surface”, Dong Chen, Michael S. Heberling, Michi Nakata, Loren E. Hough, Joseph MacLennan, Matthew Glaser, Eva Korblova, David Walba, Junji Watanabe, Noel A. Clark, *ChemPhysChem* 13, 155-159 (2012).
- “Interface structure of the dark conglomerate liquid crystal phase”, Dong Chen, Yongqiang Shen, Chenhui Zhu, Loren E. Hough, Nlida Gimeno, Matthew A. Glaser, Joseph E. MacLennan, M. Blanca Ros, Noel A. Clark, *Soft Matter* 7, 1879-1883 (2011).
- “Chiral isotropic liquids from achiral molecules”, Loren E. Hough, Melissa Spannuth, Michi Nakata, David A. Coleman, Christopher D. Jones, G. Dantlgraber, C. Tschierske, Junji Watanabe, Eva Krblova, David M. Walba, Joseph E. MacLennan, Matthwe A. Glaser, Noel A. Clark, *Science* 24, 452-456 (2009).
- “Helical nanofilament phases”, L.E. Hough, H. T. Jung, D. Krerke, M. S. Heberling, M. Nakata, C. D. Jones, D. Chen, D. R. Link, J. Zasadzinski, G. Heppke, J. P. Rabe, W. Stocker, E. Krblova, D. M. Walba, M. A. Glaser, N. A. Clark, *Science* 24, 456-460 (2009).
- “A model of microtubule depolymerization by kinesin-8 motors”, Loren E. Hough*, Anne Schwabe*, Matt Glaser, J. Richard McIntosh, M. D. Betterton, *Biophysical Journal* 96, 3050-64 (2009).
- “Direct observation of optical activity produced by layer chirality in bent-core liquid crystals”, L.E. Hough, C. Zhu, M. Nakata, N. Chattham, G. Dantlgraber, C. Tschierske, N.A. Clark, *Physical Review Letters* 98, 037802 (2007).

- “Phantom nanoparticles as probes of biomolecular interactions”, Davide Prosperi, Carlo Morasso, Francesco Mantegazza, Marco Buscaglia, Loren E. Hough, Tommaso Bellini, *Small* 2, 1060–1067 (2006).
- “Layer-scale optical chirality of liquid-crystalline phases”, Loren E. Hough and Noel A. Clark, *Physical Review Letters* 95, 107802 (2005).
- “Giant-block twist grain boundary smectic phases”, J Fernsler, L.E. Hough, R.-F. Shao, J. E. Maclellan, L. Navailles, , M. Brunet, N. V. Madhusudana, O. Mondain-Monval, C . Boyer, J. Zasadzinski, J. A. Rego, D. M. Walba, and N. A. Clark, *PNAS* 102, 14191-14196 (2005).
- “Smooth Vortex Precession in Superfluid ^4He ”, L.E. Hough, L.A.K. Donev, and R.J. Zieve, *Physical Review B* 65, 024511 (2002).
- “Depinning of a Superfluid Vortex Line by Kelvin Waves”, L.A.K. Donev, L. E. Hough and R.J Zieve, *Physical Review B* 64, 180512(R) (2001).
- Authors marked with * are co-first authors.

INVITED PRESENTATIONS

Invited Conference Presentations

- 2019, Gibbs Conference on Biothermodynamics, Carbondale, Illinois.
- 2019, CALCON, Santa Fe, NM.
- 2019, Emergent Simplicity in Biophysical Dynamics, Telluride science research center.
- 2019, Macromolecular Crowding, Telluride science research center.
- 2019, American Physical Society March Meeting, Boston, Massachusetts.
- 2018, FEBS European Cytoskeletal Forum Meeting, Prague, Czech Republic.
- 2018, Nuclear Pore Complex/Smart Polymer meeting, Telluride science research center.
- 2018, Protein and Peptide Interactions in Cellular Environments, Telluride science research center.
- 2018, Intrinsically Disordered Protein Gordon Conference, Les Diablerets, Switzerland.
- 2018, q-Bio Conference, Rice University.
- 2016, Front Range Cytoskeleton Meeting, University of Denver.
- 2016, Nuclear Pore Complex/Smart Polymer meeting, Telluride science research center.
- 2015, Intrinsically disordered proteins meeting, Telluride science research center.
- 2012, Revson Fellow Meeting, New York, NY.
- 2011, Biophysical Society, Intrinsically Disordered Protein Subgroup Postdoctoral Award.
- 2008, International Liquid Crystal Conference, Jeju, Korea.

External Seminars and Colloquia

- 2020, Department of Biochemistry and Molecular Biophysics, Washington University School of Medicine.
- 2019, Department of Physics, University at Buffalo, SUNY .
- 2020, Department of Physics, University of California, Merced.
- 2020, Department of Chemistry, Syracuse University.
- 2019, Department of Physics, Arizona State University.
- 2017, Department of Molecular & Cellular Biology Thursday Seminar, Harvard University.

2017, Chemistry Department Seminar, CU Denver.
2017, Informal Seminar, Cal Tech.
2017, Physics Colloquium, University of Denver.
2015, NIST Bioimaging seminar, NIST, Boulder.
2011, Physics Colloquium, University of Colorado, Boulder.
2011, Departmental Seminar, Biodesign Institute, Arizona State University.
2011, Biophysics Seminar, University of Michigan.
2011, Physical Society Colloquium, McGill University.
2011, Departmental Seminar, Department of Physics and Astronomy, University of Pennsylvania.
2011, Center for Soft Matter Research Seminar, Physics Department, NYU.
2011, Physics Colloquium, Emory University.
2011, Weill Institute for Cell & Molecular Biology and Biomedical Engineering Candidate Seminar, Cornell University.
2011, Applied Mathematics and Physics Seminar, University of California, Merced.
2011, Applied Physics Seminar, Cornell University.
2010, Seminar, Department of Bioengineering, University of Colorado, School of Medicine.

FUNDING

Current Support

Molecular dissection of the C-terminal tails of tubulin and the effect of their polyglycylation on binding and microtubule assembly.

PI: Loren Hough

Agency: NIH

Type: Maximizing Investigators' Research Award (R35)

Dates: 9/2016 - 8/2021

Funds: \$1,824K (total)

Molecular mechanisms underlying yeast cellular starvation tolerance; spatial reasoning to increase STEM participation.

PI: Loren Hough

Agency: NSF

Type: CAREER Award

Dates: 7/1/20-6/30/25

Funds: \$1,076k (approximate) (total)

Boettcher Collaboration Grants

PI: Loren Hough

Agency: Boettcher Foundation

Type: Webb-Waring Biomedical Research Award

Dates: intermittently, fall 2015-current

Funds: \$20K (total)

Past Support

Tubulin structure and binding interactions probed by NMR using new labeling techniques

PI: Loren Hough

Agency: Boettcher Foundation
Type: Webb-Waring Biomedical Research Award
Dates: 7/1/2014 -7/31/2017
Funds: \$225K (total)

Tubulin-drug interactions revealed by nuclear magnetic resonance spectroscopy

PI: Loren Hough
Agency: CU Boulder
Type: Innovative Seed Grant
Dates: 7/1/2014 -6/30/2015
Funds: \$46K (total)

SERVICE AND OUTREACH

Scientific Community and Professional Societies

Secretary and Council Member, Intrinsically Disordered Protein Subgroup, Biophysical Society
Proposal Reviewer, Platform Technologies Challenge
Journal Reviewer, Biophysical Journal
Journal Reviewer, Journal of Molecular Biology
Journal Reviewer, Biomacromolecules
Journal Reviewer, Journal of Molecular Biology
Journal Reviewer, PNAS
Journal Reviewer, Proteomics
Journal Reviewer, Nature Chemistry

University of Colorado

Faculty advisor to CU Café. CU Café is a group of students and postdocs who strive to improve the environment for STEM students from underrepresented groups by bringing diverse speakers, role models, and potential mentors to campus. Invited speakers include Jim Gates from University of Maryland, Geraldine Cochran from Rutgers University, Hidayah-Nicole Green from Morehouse School of Medicine, Ruthe Farmer from National Center for Women, Ahna Skop from University of Wisconsin-Madison, and Enrique de la Cruz from Yale University.

DAT committee (R³) on diversity and inclusion within the physics department Fall 2014-present

Undergraduate advising committee - Fall 2014

Graduate Student Opportunities Seminar Organizer- Fall 2012

Task Force Member, Biofrontiers Institute, 2012-present.

IQ Biology Working Group, 2012-present

Working on developing interdisciplinary curriculum, IQ biology graduate program.

Molecular Biophysics Supergroup, 2012-present

Attended and gave feedback to graduate students and postdocs who presented at meetings of the Biophysics supergroup. Part of the steering committee which selects awardees and sets policies and activities.

TEACHING

Physics 7810: Foundations of Quantitative Biology

Fall 2012, Fall 2013; 9,18 students.

Made significant changes to this relatively new course for quantitative biology graduate program. Double-credit course co-taught with Tom Cech (Fall 2012) and Xuedong Liu (Fall 2013). Developed course syllabus, readings, and assignments and projects.

Physics 3340: Advanced Lab

Spring 2014, Spring 2016; 10 students.

Senior lab class with emphasis on training of lab skills - including experiment troubleshooting, record keeping and presentation.

Physics 2170: Modern Physics

Fall 2015, Spring 2018, Fall 2019; 90-120 students.

Physics 3 course covering special relativity and the introduction to quantum mechanics. Introduced group exams and some elements of a 'flipped' classroom.

Physics 1110: Calculus based Physics 1

Fall 2016, Fall 2018, Spring 2020; 60, 320, 295 students.

Fall 2016 I was a TA and wrote spatial reasoning quizzes for the entire course. Fall 2018 and Spring 2020, I co-taught the course.

Physics 4560-5560: Introduction to Biophysics

Spring 2017, Spring 2019; 20 students.

In 2017, I completely restructured the course to make it a flipped classroom. Developed in class exercises, homework problems and readings. Spring 2019, I again rewrote the class in a more traditional format.

ADVISING

Research Advising: Current

Jeffre Allen, graduate student, Department of Biochemistry: May 2018-present.

Allison Holt, postdoctoral fellow: August 2017-present.

Lindsey Hamblin, undergraduate, Physics and Chemical Engineering: Fall 2018-present.

Jolie Freeman, undergraduate: Fall 2019-present.

Chengrui Qiu, undergraduate: January 2020-present.

Alex Adler, undergraduate: January 2020-present.

Research Advising: Past Graduate Students and Postdocs

Nabanita Das, postdoctoral fellow: July 2017-March 2020. Genentech

Kathryn Wall, postdoctoral fellow Jan 2019-current, previously my graduate student, IQ Biology and Department of Biochemistry: Graduated Dec 2018. science writer

Laura Maguire, graduate student, Department of Physics: May 2014-May 2019. Biodesix

Michael Stefferson, graduate student, Department of Physics, co-advised with Meredith Betterton and Matt Glaser: May 2014-May 2018. Industry

Research Advising: Past Undergraduates

Jenna Trost, undergraduate, Applied Math and Chemical Engineering: Fall 2018-Spring 2019.

Paul Marchando, undergraduate, Chemical and Biological Engineering: March 2015-May 2018.
Graduated with *summa cum laude*, Graduate student, University of California, Berkeley

Caroline Rhoades, undergraduate, MCDB: August 2017-Spring, 2019. Graduated with *magna cum laude*

Tanner Bobak, undergraduate, Chemical Engineering: January 2017-December 2018.

Elena Arroyo, SMART student, Physics: Summer 2017. Graduate student, University of Washington, Seattle

Taylor Moon, undergraduate, Physics: May 2015-January 2017. Graduate student, Cornell University

Sophie Reskin, undergraduate, Integrated Physiology: April 2014-May 2017. Graduated with *magna cum laude*

Lucrezia Cester, undergraduate, Physics: May 2015-Dec 2016. Graduate student, University of Glasgow

Grant Huckels, undergraduate, Biochemistry and MCDB: April 2014-August 2016.

Eric Verbeke, undergraduate, Chemical and Biological Engineering: June 2013-December 2015. Graduate student, UT Austin

Seth Perry, undergraduate, Computer Science: August 2013-May 2014.

Taylor Pauls, SMART student, Physics: Summer 2014. Graduate student, Boston University

Professional Research Assistants

Maria Pagratis, professional research assistant: September 2012-June 2016. Researcher in Will Old's lab at CU

Nick Bax, post-bac: Fall 2013-Summer 2014. Graduate student at Stanford University

Amanda Burnett, professional research assistant: June 2014-February 2015. High school teacher

Christopher Lawkin, post-bac: August 2014-June 2015. Researcher at Kaiser Permanente

Tyler Gates, post-bac: August 2012-January 2014. Technician at Virocyt

Bart Black, post-bac: August 2012-September 2014. Researcher at National Jewish

Comprehensive Exam and Thesis Committees

Physics Thesis Committees (graduation date if appropriate): Christopher Edelmaier (5/2018, advisor Meredith Betterton), Matt Siewny (5/2018, advisor Tom Perkins), Rayshan Visvanathan (12/18, advisor Noel Clark), Patrick Heenan (advisor Tom Perkins)

Biochemistry Thesis Committees : Jennifer Lubbeck (4/2013, advisor Ralph Jimenez), Laura Johnson (8/2013, advisor Art Pardi), Thayne Dickey (1/2014, advisor Deborah Wuttke), Yao Xiao (7/2015, advisor Art Pardi), Sabrina Hunter (5/2017, advisor Art Pardi), Marissa McKercher (5/2017, advisor Deborah Wuttke), Neil Lloyd (8/2018, advisor Deborah Wuttke), Elina Ly (8/2019, advisor Jim Goodrich), Garrett Edwards (advisor Karolin Luger)

Committees of students in other departments: Russell Perkins (7/2017, Chemistry, advisor Veronica Vaida), Samantha Summers (Chemical and Biochemical Engineering advisor Joel Kaar)

TRAINING

Postdoctoral Work, 10/2007–8/2012

PRIMARY TOPIC: Biophysical studies of the central transporter of the nuclear pore complex

SECONDARY TOPIC: Developing methodologies for the rapid isolation of native complexes by improved cryo-grinding and development of high-throughput techniques

ADVISER: Mike Rout, Lab. of Cellular and Structural Biology, Rockefeller University

Graduate Research, 7/2006–4/2007

TOPIC: Klp5/6: kinetochore localized kinesins of the kinesin 8 family

ADVISER: J. Richard McIntosh, MCD Biology, University of Colorado at Boulder

Graduate Research, 6/2002–10/2007

TOPIC: Layer curvature and optical activity in bent-core liquid crystals

ADVISER: Noel Clark, Physics, University of Colorado at Boulder

Undergraduate Research, 1997–2000 (summers)

TOPIC: Vortices in superfluid helium 4

ADVISER: Rena Zieve, Physics, University of California, Davis

Undergraduate Research, 1/1997–6/1999 (academic year)

TOPIC: Surface chemistry

ADVISER: Cynthia Friend, Chemistry, Harvard University

Teaching Assistant, winter 2002: Optics Lab, Physics Department, University of California, Santa Barbara

Teaching Assistant, fall 1998: Lab electronics, Physics Department, Harvard University

SUMMER SCHOOLS AND WORKSHOPS

EMBO Practical Course: Structure, dynamics and function of biomacromolecules by solution NMR 2011

Physiology Course, Woods Hole Marine Biological Laboratory, 2006

ICMR Biomaterials Summer School, University of California, Santa Barbara, 2005

Boulder School for Condensed Matter and Materials Physics: Soft Condensed Matter, University of Colorado at Boulder, 2002