Todd Gingrich

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OVERVIEW

Assistant Professor of Chemistry, Statistical Mechanics of Nonequilibrium Systems.

APPOINTMENTS

Assistant Professor of Chemistry 2018-
Northwestern University

- Research: statistical mechanics, stochastic thermodynamics, chemical kinetics, nonequilibrium self-assembly, and biophysics
- Teaching: Chem 444—Elementary Statistical Mechanics, Chem 348—Physical Chemistry for ISP

Physics of Living Systems Fellow 2015-2018
Massachusetts Institute of Technology

- Department of Physics
- Proved thermodynamic bounds on nonequilibrium steady-state current fluctuations.

EDUCATION

PhD Chemistry (Theoretical) 2010-2015
University of California, Berkeley
"Two Paths Diverged: Exploring Trajectories, Protocols, and Dynamic Phases"
Thesis advisor: Phillip L. Geissler
Hertz Fellow, NSF Fellow

MSc (By Research) Physical and Theoretical Chemistry 2008-2010
University College, Oxford University
"Simulating Surface Charge Effects in Carbon Nanotube Templated Ionic Crystal Growth"
Thesis advisor: Mark Wilson
Rhodes Scholar

BS Chemistry with Honors 2004-2008
California Institute of Technology
Research Advisor: Nathan S. Lewis

PREPRINTS [arXiv]

- A. Albaugh and T.R. Gingrich, "Simulating a Chemically-Fueled Molecular Motor with Nonequilibrium Molecular Dynamics", *cond-mat/2102.06298*.

PEER-REVIEWED JOURNAL PAPERS [Google Scholar]

22. A. Albaugh and T.R. Gingrich, "Estimating Reciprocal Partition Functions to Enable Design Space Sampling", *Journal of Chemical Physics* **153**, 204102 (2020).

21. N.E. Strand, R.-S. Fu, and T.R. Gingrich, "Current inversion in a periodically driven two-dimensional Brownian ratchet", *Physical Review E* **102**, 012141 (2020). [Editor's Suggestion]

20. J.A. Owen, T.R. Gingrich, and J.M. Horowitz, "Universal thermodynamic bounds on nonequilibrium response with biochemical applications", *Physical Review X* **10**, 011066 (2020).

19. H. Vroylandt, K. Proesmans, and T.R. Gingrich, "Isometric Uncertainty Relations", *Journal of Statistical Physics* **178**, 1039-1053 (2020).

18. J.M. Horowitz and T.R. Gingrich, "Thermodynamic uncertainty relations constrain nonequilibrium fluctuations", *Nature Physics* **15**, 1 (2020).

17. J. Li, J.M. Horowitz, T.R. Gingrich, and N. Fakhri, "Quantifying dissipation using fluctuating currents", *Nature Communications* **10**, 1666 (2019).

16. T.R. Gingrich and J.M. Horowitz, "Fundamental Bounds on First Passage Time Fluctuations for Currents", *Physical Review Letters* **119**, 170601 (2017).

15. G. Bisker, M. Polettini, T.R. Gingrich, and J.M. Horowitz, "Hierarchical Bounds on Entropy Production Inferred from Partial Information", *Journal of Statistical Mechanics: Theory and Experiment* , 093210 (2017).

14. J.M. Horowitz and T.R. Gingrich, "Proof of the Finite-Time Thermodynamic Uncertainty Relation for Steady-State Currents'", *Physical Review E (Rapid Communications)* **96**, 020103(R) (2017). [Editor's Suggestion]

13. R. Zakine, A. Solon, T.R. Gingrich, and F. van Wijland, "Stochastic Stirling engine operating in contact with active baths", *Entropy* **19(5)**, 193 (2017).

12. T.R. Gingrich, G.M. Rotskoff, and J.M. Horowitz, "Inferring dissipation from current fluctuations", *Journal of Physics A: Mathematical and Theoretical* **50**, 184004 (2017). [Recognized as an "Emerging Talent"]

11. T.R. Gingrich, G.M. Rotskoff, G.E. Crooks, and P.L. Geissler, "Near-optimal protocols in complex nonequilibrium transformations", *Proceedings of the National Academy of Sciences* **113(37)**, 10263 (2016).

10. T.R. Gingrich, J.M. Horowitz, N. Perunov, and J.L. England, "Dissipation bounds all steady-state current fluctuations", *Physical Review Letters* **116**, 120601 (2016).

9. T.R. Gingrich and P.L. Geissler, "Preserving correlations between trajectories for efficient path sampling", *Journal of Chemical Physics* **142(23)**, 234104 (2015). [Editor's Choice]

8. T.R. Gingrich, G.M. Rotskoff, S. Vaikuntanathan, and P.L. Geissler, "Efficiency and large deviations in time-asymmetric stochastic heat engines", *New Journal of Physics* **16(10)**, 102003 (2014). [Fast Track Communication]

7. T.R. Gingrich, S. Vaikuntanathan, and P.L. Geissler, "Heterogeneity-induced large deviations in activity and (in some cases) entropy production", *Physical Review E* **90**, 042123 (2014).

6. S. Vaikuntanathan, T.R. Gingrich, and P.L. Geissler, "Dynamic phase transitions in simple driven kinetic networks", *Physical Review E* **89**, 062108 (2014).

5. T.R. Gingrich and M. Wilson, "The control of inorganic nanotube morphology using an applied potential", *Journal of Physics: Condensed Matter* **23(13)**, 135306 (2011).

4. T.R. Gingrich and M. Wilson, "On the Ewald summation of Gaussian charges for the simulation of metallic surfaces", *Chemical Physics Letters* **500(1)**, 178 (2010).

3. J.E. Katz, T.R. Gingrich, E.A. Santori, and N.S. Lewis, "Combinatorial synthesis and high-throughput photopotential and photocurrent screening of mixed-metal oxides for photoelectrochemical water splitting", *Energy & Environmental Science* **2(1)**, 103 (2009).

2. P.K. Thallapally, L. Dobrzanska, T.R. Gingrich, T.B. Wirsig, L.J. Barbour, and J.L. Atwood, "Acetylene absorption and binding in a nonporous crystal lattice", *Angewandte Chemie International Edition* **45(39)**, 6506 (2006).

1. G.P. Smith and T.R. Gingrich, "Hydroxyapatite chromatography of phage-display virions", *Biotechniques* **39(6)**, 879 (2005).

PATENT

- N.S. Lewis, J.E. Katz, and T.R. Gingrich, "High-throughput screening and device for photocatalysts", US Patent 9,126,175 B2, 2015.

AWARDS

- 2019 APS Oppenheim Award, Received with Jordan M. Horowitz *For the article, 'Proof of the finite-time thermodynamic uncertainty relation for steady-state currents,' published in Phys. Rev. E *96*, 020103(R) (2017), which demonstrated significance, rigor, and broad impact in the general area of non-equilibrium thermodynamics.*
- 2015 Physics of Living Systems Fellowship, MIT
- 2013 Outstanding Graduate Student Instructor, UC Berkeley
- 2011 Dan Lucas Book Prize awarded to the top first year graduate student in physical chemistry, UC Berkeley
- 2008 George W. Housner Student Discovery Fund Recipient, Caltech
- 2008 Richard P. Schuster Chemistry Prize, Caltech
- 2008 Fannie and John Hertz Foundation Graduate Fellowship

- 2008 National Science Foundation Graduate Research Fellowship
- 2008 Rhodes Scholarship
- 2007 Robert L. Noland Leadership Award, Caltech
- 2007 Amgen Scholars Summer Research Fellowship, Caltech
- 2005-08 Upperclass Merit Award, Caltech
- 2004-08 Robert C. Byrd Honors Scholarship

INVITED PRESENTATIONS

25. *Driving current in classical statistical mechanics: Computational tools and theoretical bounds*, Theoretical Chemistry Group Seminar, Oxford University, February 15, 2021.

24. *Current inversions in Brownian ratchets*, Telluride Science Research Center - Condensed Phase Dynamics Workshop, July 22, 2020.

23. *Nonequilibrium fluctuations in molecular machines: The thermodynamic cost of reliability*, Illinois State Physics Colloquium, February 18, 2020.

22. *The Thermodynamic Uncertainty Relation: Theoretical Introduction*, APS March Meeting, Oppenheim Prize Talk, Boston, March 5, 2019.

21. *How thermodynamics constrains kinetic fluctuations*, Lawrence Berkeley National Lab/UC Berkeley Soft Matter Seminar, January 14, 2019.

20. *Quantifying dissipation using fluctuating currents: The good, the bad, and the ugly*, Why Measure Entropy Production?, Princeton Center for Theoretical Science, November 5, 2018.

19. *Quantifying dissipation using fluctuating currents: A case study*, Stochastic Thermodynamics: Experiment and Theory, Dresden, September 11, 2018.

18. *How thermodynamics constrains kinetic fluctuations*, Telluride Condensed Phase Dynamics Workshop, July 17, 2018.

17. *How thermodynamics constrains kinetic fluctuations*, CCI Solar Fuels Workshop, Ventura, California, July 12, 2018.

16. *Dissipation-based uncertainty bounds for currents*, Large deviation theory in statistical physics: Recent advances and future challenges, ICTS, Bangalore, September 14, 2017.

15. *Dynamical fluctuations in Markov processes—A primer on stochastic thermodynamics, fluctuation theorems, and large deviations [Three pedagogical lectures]*, Igert Summer Institute, Brandeis University, June 5-7, 2017.

14. *Sampling low-dissipation protocols*, Berkeley Statistical Mechanics//Machine Learning meeting, January 12, 2017.

13. *Nonequilibrium fluctuations in molecular machines: The thermodynamic cost of reliability*, NYU Chemistry, December 19, 2016.

12. *Nonequilibrium fluctuations in molecular machines: The thermodynamic cost of reliability*, Stanford Chemistry, December 8, 2016.

11. *Nonequilibrium fluctuations in molecular machines: The thermodynamic cost of reliability*, Columbia Chemistry, November 29, 2016.

10. *Nonequilibrium fluctuations in molecular machines: The thermodynamic cost of reliability*, UCSB Chemistry, November 15, 2016.

9. *Nonequilibrium fluctuations in molecular machines: The thermodynamic cost of reliability*, Northwestern Chemistry, October 21, 2016.

8. *Dissipation bounds all steady-state current fluctuations*, Boston University CMT/Biophysics, March 8, 2016.

7. *Preserving correlations between trajectories for efficient path sampling*, APS March Meeting, JCP Editor's Choice session, Baltimore, March 14, 2016.

6. *Dynamic fluctuations in cyclic processes*, Modeling and Inference from Single Molecules to Cells, MBI workshop, Columbus, Ohio, February 12, 2016.

5. *Large dynamic fluctuations in cyclic processes*, Large deviation theory in principle and practice, Princeton Center for Theoretical Science workshop, November 17, 2015.

4. *Preserving correlations between trajectories for efficient path sampling*, Chemistry & Physics of Liquids Gordon Research Conference, Holderness School, August 6, 2015. [**Poster Prize Short Talk**]

3. *Efficient path sampling of Ising dynamics for identifying low-dissipation protocols*, Statistical mechanics and computation of large deviation rate functions, ENS de Lyon, June 16, 2015.

2. *Large dynamical fluctuations in cyclical kinetic processes*, Princeton Biophysics Symposium, December 5, 2014.

1. *Large deviations and two-dimensional rate functions*, Workshop on large deviations in statistical physics, NITheP, Stellenbosch, South Africa, July 11, 2014.

CONTRIBUTED PRESENTATIONS

15. *How thermodynamics constrains kinetic fluctuations*, Northwestern Theory Seminar, October 29, 2018.

14. *Nonequilibrium fluctuations in molecular machines: The thermodynamics cost of reliability*, Needleman Group Meeting, Harvard, April 10, 2018.

13. *Dissipation-based uncertainty bounds for currents*, APS March Meeting, Los Angeles, March 9, 2018.

12. *The thermodynamic cost of reliability*, Statistical Mechanics Meeting Poster Session, Berkeley, January 13, 2017.

11. *Dissipation bounds all steady-state current fluctuations*, Special Statistical Mechanics Seminar, Berkeley, May 16, 2016.

10. *Low dissipation in nonequilibrium control: Sampling the ensemble of efficient protocols*, APS March Meeting, Baltimore, March 17, 2016.

9. *Dissipation bounds all steady-state current fluctuations*, Statistical Mechanics Meeting Poster Session, Berkeley, January 8, 2016.

8. *Dynamic phase transitions in driven cyclic kinetic networks*, APS March Meeting, Denver, March 2014.

7. *Dynamic phase transition in driven kinetic networks*, Statistical Mechanics Meeting Breakout Session, Berkeley, January 2014.

6. *Dynamic phase transitions in driven kinetic networks*, Chemistry and Physics of Liquids Gordon Research Conference, August 2013.

5. *Dynamic phase transitions in simple kinetic models*, Statistical Mechanics Seminar, Berkeley, April 12, 2013.

4. *Toward dynamical design: Path sampling methods for seeking fast rates in large design spaces*, Statistical Mechanics Meeting Poster Session, Berkeley, January 2013.

3. *Extended ensemble path sampling*, Boulder School for Condensed Matter Poster Session, Boulder, Colorado, July 2012.

2. *Driving complex systems toward assembly*, Graduate Research Conference, Berkeley, March 2012.

1. *Extended ensemble path sampling for identifying optimal out-of-equilibrium protocols*, Statistical Mechanics Meeting Poster Session, Berkeley, January 2012. [**2nd Place Poster Prize Competition**]

SYNERGISTIC ACTIVITIES

- American Physical Society Oppenheim Award Selection Committee Member (2020)
- Searle Fellow for Teaching and Learning, Northwestern (2019-2020)
- Proposal reviewer: NSF (mail review, Fall 2018)
- Referee: Proceedings of the National Academy of Sciences, Physical Review X, Nature Physics, Physical Review Letters, Journal of Physical Chemistry, Journal of Chemical Physics, Physical Review E, Journal of Statistical Physics, Journal of Statistical Mechanics: Theory and Experiment, Journal of Physics A: Theoretical and Mathematical, Europhysics Letters [Named a Distinguished Referee in 2017], Physical Review B, New Journal of Physics
- Seminar organization: Statistical Mechanics Seminar, UC Berkeley College of Chemistry, 2012-2015 (weekly)
- Fellowship selection: District 15 Rhodes Scholar selection committee, 2013-2015

ADVISING

PhD Students:

- Jonah Greenberg (2019–Present)
- Geyao Gu (2019–Present)
- Rueih-Sheng (Ray) Fu (2018–Present)
- Nils Strand (2018–Present)

Postdoctoral Scholars:

- Schuyler (Sky) Nicholson (2020–Present)
- Alex Albaugh (2018–Present)
- Hadrien Vroylandt (2018–2020)

TEACHING

@ Northwestern, Chemistry Dept.:

- Fall 20: **Chem 444 Elementary Statistical Mechanics**
  An introduction to statistical mechanics for physical chemistry graduate students.

  "Dr. Gingrich makes really complicated material very understandable. The course is a lot of work and I found much of the material hard to grasp initially, but I learned a lot. The problem–sets (especially the first few) are difficult, but the exam was pretty reasonable (especially with the take–home format) and Dr. Gingrich is really accessible and office hours were very helpful for the problem sets. The problem–sets are definitely pretty time consuming, and made this course take up more time than my other two courses, but they are really good for establishing an understanding of the material. I also liked the parts of the problem–sets that required some coding, as someone who didn't have a ton of formal experience with python I thought these parts of the problem sets were both reasonable for beginners and fun. I really enjoyed this course – the first problem–set felt impossible and initially made me think I would need to drop the course, but don't be scared off – they get easier throughout the course!"

- Spring 20: **Chem 348 Physical Chemistry for ISP**
  An accelerated introduction to statistical mechanics and kinetics.

  "Probably one of the best professors I have had at Northwestern. An insanely smart guy who is very enthusiastic about the material. I learned so much math, chemistry, statistics, and physics from Todd. He was always available to give help. Although his psets were difficult, they encouraged independent thinking and, in the process, I feel I learned a lot more than if they were easy book problems."

- Fall 19: **Chem 444 Elementary Statistical Mechanics**
  An introduction to statistical mechanics for physical chemistry graduate students.

  "This was a challenging course, but I felt that I learned quite a lot in the span of 10 weeks.

Prof. Gingrich is one of the best instructors I have had; he is clear, compassionate, yet still encourages us to take on material that is difficult (but not impossible). The course covers interesting topics and blended some computational work in to aid in our understanding of physical chemistry effectively. Office hours and the TAs help also supplemented our understanding of the course and I feel that I have a decent amount of new knowledge to take away."

- Spring 19: **Chem 348 Physical Chemistry for ISP**
  An accelerated introduction to statistical mechanics and kinetics.

  "Prof. Gingrich was incredibly knowledgeable and enthusiastic about the class. He taught great concepts with rigorous but well–paced derivations. The problem sets were very good."

- Fall 18: **Chem 444 Elementary Statistical Mechanics**
  An introduction to statistical mechanics for physical chemistry graduate students.

  "I am very happy I took this class. Dr. Gingrich is the best professor I ever had and this is the best class I have ever taken. This is a very good class to take if you like physical chemistry. Going to lecture is very important and the problem sets help you learn. The more time you put in the more you will understand."

@ UC Berkeley, Chemistry Dept.:

- Spring 13: **Chem 220B Advanced Statistical Mechanics**
  Graduate Student Instructor supporting Phill Geissler's advanced graduate student course.

- Spring 12: **Chem 120B Physical Chemistry**
  Graduate Student Instructor supporting David Chandler's physical chemistry course, which covered thermodynamics, statistical mechanics, and kinetics. Received UC Berkeley's Outstanding Graduate Student Instructor Award.

- Fall 10: **Chem 1A: General Chemistry**
  Graduate Student Instructor for a large lecture plus lab course.