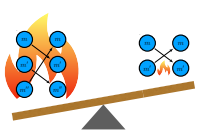

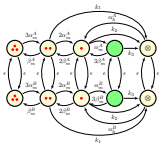
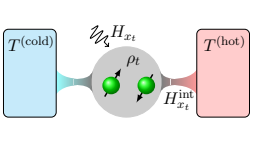

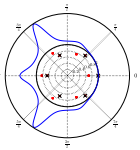


# Paul M. Riechers

csc.ucdavis.edu/∼priech
pmriechers@gmail.com
+1 (707) 815-9050


**Research Interests**

I work at the intersection of quantum information, thermodynamics, computation, and prediction—a beautiful playground with entire fields of fresh ideas. I have published work on nonequilibrium thermodynamics, thermodynamics of computation, theory of complex systems, nanotechnology, novel computation, nonlinear dynamics, non-normal spectral theory, chaotic crystallography, experimental cosmology, and quantum memory advantage. I am currently pursuing implications of physical law beyond the jurisdiction of the Second Law of thermodynamics.

**Affiliations**

*Research Fellow* 2018 - present
The Quantum and Complexity Science Initiative
Complexity Institute and School of Physical and Mathematical Sciences
Nanyang Technological University, Singapore

*Postdoctoral Scholar* 2018
Complexity Sciences Center and Department of Physics
University of California at Davis

**Education**

*Ph. D., Physics*, University of California, Davis, 2016
"Exact Results Regarding the Physics of Complex Systems via Linear Algebra, Hidden Markov Models, and Information Theory"

- The state of a complex system is revealed only over time. This dissertation considers the generation, prediction, and physical implication of stochastic time-series with hidden structure. It extends the bedrock of linear algebra and the frontier of nonequilibrium thermodynamics.

*M. S., Electrical and Computer Engineering*, University of California, Davis, 2012
"Influencing Nanoscale Dynamical and Complex Systems for Advanced Computation and Materials"

- This thesis introduced the concept of *attractor logic* and gave examples of implementation via gated interactions among non-linear oscillators.

*B. S., Applied Physics*, with Honors, University of California, Davis, 2009
Minors in Philosophy and Technology Management

**Service and Honors**

- Satellite Co-Chair for the International Conference on Complex Systems CCS2019
- Received $5000 grant for an Excellent Contributed Talk at QC40: Physics of Computation Conference 40th Anniversary (2021)
- Member of ΣΠΣ, physics honor society
- Reviewer for *Chaos*, *Entropy*, *Scientific Reports*, *Proceedings of the Royal Society A*, & others

**Publications**

· *Book Chapter* ·
**P. M. Riechers**. "Transforming metastable memories: the nonequilibrium thermodynamics of computation." In D. Wolpert, C. Kempes, P. Stadler, and J. Grochow, editors, *The Energetics of Computing in Life and Machines. SFI Press*, (2019).

· *Scientific Journal Papers* ·

**P. M. Riechers** and M. Gu. "Impossibility of achieving Landauer's bound for almost every quantum state." *Physical Review A*, 104 (1),012214, (2021).

**P. M. Riechers** and M. Gu. "Initial-state dependence of thermodynamic dissipation for any quantum process." *Physical Review E*, 103 (4), 042145, (2021).

G. W. Wimsatt, A. B. Boyd, **P. M. Riechers**, and J. P. Crutchfield. "Refining Landauer's Stack: Balancing Error and Dissipation When Erasing Information." *Journal of Statistical Physics*, 183 (1), 1-23, (2021).

**P. M. Riechers** and J. P. Crutchfield. "Fraudulent white noise: Flat power spectra belie arbitrarily complex processes." *Physical Review Research*, 3 (1), 013170, (2021).

**P. M. Riechers**, A. B. Boyd, G. W. Wimsatt, and J. P. Crutchfield. "Balancing error and dissipation in computing." *Physical Review Research* 2 (3), 033524, (2020).

**P. M. Riechers** and J. P. Crutchfield. "Beyond the spectral theorem: spectrally decomposing arbitrary functions of nondiagonalizable operators." *AIP Advances*, 8, 065305, (2018).

**P. M. Riechers** and J. P. Crutchfield. "Spectral simplicity of apparent complexity, Part I: the nondiagonalizable metadynamics of prediction." *Chaos*, 28, 033115, (2018). (**Featured** by *Chaos*)

**P. M. Riechers** and J. P. Crutchfield. "Spectral simplicity of apparent complexity, Part II: exact complexities and complexity spectra." *Chaos*, 28, 033116, (2018).

**P. M. Riechers** and J. P. Crutchfield. "Fluctuations when driving between nonequilibrium steady states." *Journal of Statistical Physics*, 168(4), 873–918, (2017).

A. B. Boyd, D. Mandal, **P. M. Riechers**, and J. P. Crutchfield. "Transient dissipation and structural costs of physical information transduction." *Physical Review Letters*, 118, 220602, (2017).

**P. M. Riechers**, J. R. Mahoney, C. Aghamohammadi, and J. P. Crutchfield. "Minimized state complexity of quantum-encoded cryptic processes." *Physical Review A*, 93, 052317, (2016).

J. P. Crutchfield, C. J. Ellison, and **P. M. Riechers**. "Exact complexity: the spectral decomposition of intrinsic computation." *Physics Letters A*, 380(9-10): 998–1002, (2016).

**P. M. Riechers**, D. P. Varn, and J. P. Crutchfield. "Pairwise correlations in layered close-packed structures." *Acta Crystallographica Section A: Foundations and Advances*, 71(4): 423–43, (2015).

D. Wittman, **P. M. Riechers**, and V. E. Margoniner. "Photometric redshifts and photometry errors." *The Astrophysical Journal Letters*, 671(2): L109, (2007).

· *Scientific Preprints* ·

A. B. Boyd, **P. M. Riechers**, G. W. Wimsatt, J. P. Crutchfield, and M. Gu. "Time symmetries of memory determine thermodynamic efficiency." arXiv:2104.12072.

**P. M. Riechers**, D. P. Varn, and J. P. Crutchfield. "Diffraction patterns of layered close-packed structures from hidden Markov models." arXiv:1410.5028.

· *Refereed Conference Proceedings* ·

**P. M. Riechers** and R. A. Kiehl, "A scheme for computation in nanoscale dynamical systems: Gated discrete phase-shift interactions." *2011 IEEE/ACM Intl. Symposium on Nanoscale Architectures*, June 8-9, San Diego, Calif, 2011.

**P. M. Riechers** and R. A. Kiehl, "CNN Implemented by Nonlinear Phase Dynamics in Nanoscale Processes." *12th IEEE Intl. Workshop on Cellular Nanoscale Networks and Applications*, Feb. 3-5, Berkeley, Calif, 2010.

· *Other Publications* ·

**P. M. Riechers**. "Collaborative disappearing act trumps levitation as useful trick for future electronics." *Prized Writing 2008-2009*. Ed. Pamela Demory. University Writing Program of the University of California at Davis, 2009. 144-50.

**Invited Talks**

*The impossibility of Landauer's bound for almost every quantum state*. Information Engines at the Frontiers of Nanoscale Thermodynamics, Telluride Science Research Center, Colorado USA (Virtual), July 22, 2021.

*The Error–Dissipation Tradeoff when Computing with Time-Symmetric Protocols*. Stochastic Thermodynamics of Complex Systems, Vienna, Austria, (Virtual, due to Covid), May 28$^{\text{th}}$ 2020.

*Thermodynamic cost of misaligned expectations*. Agency at the Interface of Quantum and Complexity Science, Singapore, January 14$^{\text{th}}$ 2020.

*The Error–Dissipation Tradeoff when Agents Compute*. Nonequilibrium Thermodynamics of Complex Agents: Information Processing from Nanophysics to Life, CCS2019, Singapore, October 2$^{\text{nd}}$ 2019.

*Detecting Information Processing? The Case of Structured White Noise*. Information Processing in Complex Systems, CCS2018, Thessaloniki, Greece, September 26$^{\text{th}}$ 2018.

*The Error–Dissipation Tradeoff when Computing with Time-Symmetric Protocols*. Information Engines at the Frontiers of Nanoscale Thermodynamics, Telluride, Colorado, July 21$^{\text{st}}$ 2018.

*Physics of very simple observers—some very simple observations*. FQXi Workshop on The Physics of Very Simple Observers, Scotts Valley, California, July 1$^{\text{st}}$ 2018.

*Strongly Coupled Systems, Exact Excess, and Renormalized Housekeeping*. Information Engines at the Frontiers of Nanoscale Thermodynamics, Telluride, Colorado, July 1$^{\text{st}}$ 2016.

*Drazin Inverse per Spectral perSpective, with applications to complex systems*. Learning, Information Theory, and Non-Equilibrium Thermodynamics seminar series, Berkeley, California, October 23$^{\text{rd}}$ 2015.

*Broken Reversibility, Structured Environments: New Theory, Exact Results*. Santa Fe Institute, Santa Fe, New Mexico, June 24$^{\text{th}}$ 2015.

*The Computational Burden of Reward-Harvesting Bayes-Optimal Agents in an Environment with Hidden Structure*. 2015 Computational Neuroscience seminar series, Center for Neuroscience, Davis, California, April 14$^{\text{th}}$ 2015.

*Thermodynamics of Agency*. Information Engines meeting, Berkeley, California, January 8$^{\text{th}}$ 2015.

*Dynamics and Exact Complexity from Hidden Markov Models in Neuroscience*. 2014 Computational Neuroscience seminar series, Center for Neuroscience, Davis, California, May 6$^{\text{th}}$ 2014.

*Complexity per Spectral perSpective*. Complexity Sciences Center, Davis, California, May 22$^{\text{nd}}$ 2013.

*Information Processing through the Interactions of Phase Locked Neurons: the Attractive Logic of Interacting Attractors*. 2012 Computational Neuroscience seminar series, Center for Neuroscience, Davis, California, February 21$^{\text{st}}$ 2012.

*A Scheme for Computation Beyond the Digital Hegemony: Gated Discrete Phase Shift Interactions*. Complexity Sciences Center, Davis, California, May 11$^{\text{th}}$ 2011.

**Contributed Talks**

*The impossibility of Landauer's bound for almost every quantum state*. AQIS 2021, Japan (virtual), September 3, 2021.

*The impossibility of Landauer's bound for almost every quantum state*. Thermodynamics and Information in the Quantum Regime, Online conference, July 7$^{\text{th}}$, 2021.

*The impossibility of Landauer's bound for almost every quantum state*. QC40: Physics of Computation Conference 40th Anniversary, Hosted jointly by IBM and MIT, May 6$^{\text{th}}$ 2021. (One of 18 talks selected out of 120+ submissions.)

*$Fe_3O_4/GaAs$ Hybrid Ferromagnet/Semiconductor Nanostructures*. 53$^{\text{rd}}$ Electronic Materials Conference, Santa Barbara, California, June 23$^{\text{rd}}$ 2011.

**Predoctoral Research Experience**

*Graduate Student Researcher* 2012 - 2016
in Physics and Complex Systems with James P. Crutchfield

- Developed meromorphic functional calculus to treat functions of hidden Markov model transition dynamics via spectral analysis.
- Contributed theoretical advances in chaotic crystallography, analysis of complexity measures, quantum memory compression, and nonequilibrium thermodynamics.

*Graduate Student Researcher* 2009 - 2012
in Electrical and Computer Engineering with Richard A. Kiehl

- Introduced novel computational strategies of *attractor logic* and *programmable analog spin glass*, both realizable in nanoscale dynamical systems.
- Worked in a Class 100 cleanroom to fabricate magnetic nanostructures (magnetic nanocrystals coupled to 2-D electron gas in semiconductor heterostructure), induced spatially resolved phase transformation of mesoporous silica via electron beam lithography, and analyzed samples with atomic force microscopy and scanning electron microscopy.

*Research Assistant* 2007
in Cosmology with David Wittman

- Explored and mitigated the effect of non-Gaussian noise in photometric redshift estimation by incorporating alternative noise models in Bayesian inference algorithms—these improved estimates can then be used to infer the history and fate of large-scale cosmological evolution.

**Programming**

*Python*
Regularly implement sophisticated numerical validations of new theoretical results.

*Matlab*
Simulations for networks of nonlinear oscillators and models of neural computation.

*LaTeX, HTML, C,* etc.

**Teaching Experience**

*Guest Lecturer* August 2019
for PH3404: The Physics of Classical and Quantum Information NTU, Singapore

*Guest Lecturer* Spring 2014 and Spring 2015
for PHY 256: The Physics of Information Processing in Complex Systems UC Davis

- Wrote and presented lectures to Professor J. P. Crutchfield's graduate physics class on natural computation and self organization. This course won the 2013 SIAM Teaching Dynamical Systems award.

*Teaching Assistant* Spring 2014
for NPB 100L: Experimental Neuroscience UC Davis

*Teaching Assistant* Spring 2012

for EEC 142B: Engineering Electromagnetics — UC Davis

*Lab Instructor* — Spring 2012
for PHY 9C: Electromagnetics — UC Davis

*Teaching Assistant* — Fall 2011
for NPB/NSC 167/267: Computational Neuroscience — UC Davis

**Advising**

Co-advising undergraduate Final Year Project for Chaitanya Gupta, who won Best Presentation in Physics for the project in the Odyssey Symposium (2021-)

Co-advised undergraduate Final Year Project for Ruo Cheng Huang, who is now continuing this research as a PhD student at NTU (2020-2021)

Co-advised undergraduate Final Year Project for Hon Lin Too, who received a 'Highly Commended' recognition for the project from The Global Undergraduate Awards (2019-2020)