Sarah E. Marzen

CONTACT INFORMATION

W. M. Keck Science Department
Pitzer, Scripps, and Claremont McKenna
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RESEARCH INTERESTS

Sensory prediction, reinforcement learning, resource rationality, the intersection of information theory and biology

EDUCATION

University of California, Berkeley, Berkeley, CA, USA

Ph.D., Physics, September 2011 - May 2016

- Dissertation Topic: "Bio-inspired problems in rate-distortion theory"
- Advisor: Michael R. DeWeese

Summer schools

American Physical Society New Faculty Workshop, 2022
Machine Learning Summer School, 2013
Santa Fe Institute Complex Systems School, 2014

California Institute of Technology, Pasadena, CA, USA

B.S., Physics, September 2007 - May 2011

FUNDING

Co-PI, **DARPA**
Project: Hyperspectral-Hyperdimensional Engines via Ultralow-Power Resonant In-Memory- Compute Systems and Tunable Phononic Combs (HEURISTIC)
Amount: $\sim \$3,800,000$
Period of Performance: Dec 2023-Oct 2027

PI, **Keck DEI Mini-Grant**
Amount: $\sim \$2,000$
Period of Performance: Feb 2023-Dec 2023

PI, **National Science Foundation, Santa Fe Institute, and the W. M. Keck Science Department**
Workshop: Sensory Prediction, Engineered and Evolved
Amount: $\sim \$75,000$
Workshop Date: July 10-14, 2023

PI, **OCAC Data Science Development Grant**
Amount: $\$1,500$
Period of Performance: 2021-present

Co-PI, **Templeton Foundation**
Project: Grokking the Voices of the Deep—Detecting Bioacoustic Signatures of Cetacean Intelligence through Semantic Information Theory
Amount: $\sim \$250,000$
Period of Performance: 09/01/2021-08/31/2023

PI, **Air Force Office of Scientific Research**, Computational and Cognitive Sciences
Project: "Minimal Models of Sensory Prediction"

Amount: $\sim \$600,000$
Period of Performance: 08/2019-08/2023

Professional Affiliations

Society for Industrial and Applied Mathematics, American Physical Society, Sigma Xi

Academic Experience

Assistant Professor of Physics, W. M. Keck Science Department, Claremont, CA
August 2019 - present

Postdoctoral Fellow, MIT, Cambridge, MA
Collaborated with Professor Nikta Fakhri and Professor Jeremy England 2016 - August 2019

Seminar XL/LE Facilitator, MIT, Cambridge, MA
February 2018 - May 2018, October 2018 - present

Advisor for Stealth Startup 2016 - present

Graduate Researcher, U.C. Berkeley, Berkeley, CA
Advised by Professor Michael R. DeWeese 2011 - 2016

Teaching Assistant for Professor James Crutchfield, U. C. Davis, Davis, CA
Natural Computation and Self-Organization, a graduate-level course with ~ 30 students Fall 2015

Teaching Assistant for Professor Rob Phillips, Caltech, Pasadena, CA

Physical Biology of the Cell (APh161), graduate-level course with ~ 30 students Winter 2010
Freshman biology laboratory (Bi1x), with ~ 20 students Spring 2010

Research Assistant to Professor Rob Phillips, Caltech, Pasadena, CA

Studied cooperativity in ligand-receptor binding models as Class of '52 SURF Fellow Summer 2010

Studied information-theoretic non-equilibrium statistical mechanical models as Amgen Scholar Summer 2009

Research Assistant to Professor Tom Tombrello, Caltech, Pasadena, CA
Studied simulation and fabrication of nanolasers as Physics 11 Research Fellow Summer 2008

Research Assistant to Dr. James Ellenbogen, MITRE Corporation, McLean, VA
Intern in MITRE Nanosystems Student Program Summers 2004-2007

Honors, Awards and Service

Service to Claremont Colleges 2019-

DEI Committee
Executive Committee
Data Science Curriculum Coherence Committee
Data Science Hub Blogger
Scripps Post-Bac Interview Committee
W. M. Keck Seminar Series Committee
Scripps Student Funding Opportunities Committee
Scripps Advisor
Professional Development Network Committee on AI Ethics

Guest Editor

Computational Brain and Behavior Special Issue on "Sensory Prediction: Engineered and Evolved" 2023-
Entropy Special Issue on "The Role of Information in Cultural Evolution" 2022-
Open Mind Special Issue on "Information-Theoretic Principles in Cognitive Systems" 2023-

NeurIPS Workshop co-organizer, Information-Theoretic Principles in Cognitive Systems 2022

Scialog Research Fellow, Molecular Basis of Cognition 2022

Mary W. Johnson Faculty Scholarship Award 2022

American Physical Society Division of Biological Sciences Executive Committee, Early Career Member and Newsletter Editor 2022-present

Aspen Workshop co-organizer, Learning Dynamical Models from Biophysical Data 2022

Google Summer of Code Mentor with Christopher Hillar to Shiven Tripathi 2021

Entropy Topic Advisory Board 2021-present
Organizes and Guest Edits Special Issues for Entropy

Entropy Reviewer Board 2020-present

Graduate of MIT Kauffman Teaching Certificate Program 2018

MIT Physics of Living Systems Fellowship 2016

Fellowship from Ling-Lie Chau Excellence Award at U.C. Berkeley 2015

Reviewer for fQXi, Princeton Press, MIT Press, Alfred P. Sloan Foundation, Physical Review X, European Journal of Physics Plus, Biophysical Journal, Physical Review B, PLoS Computational Biology, Physical Review Research, Nature Physics, Frontiers in Computational Neuroscience, New Journal of Physics, Science Advances, Journal of Theoretical Biology, Advances in Complex Systems, Entropy, Bulletin of Mathematical Biology, Chaos, Biochemical Society Transactions, and Physics Letters A 2014 -

National Science Foundation Graduate Research Fellowship in Biophysics 2011

U.C. Berkeley Chancellor's Fellowship 2011

Haren Lee Fisher Memorial Award 2010
Awarded to one junior at Caltech per year for excellence in physics

Caltech Admissions Committee member and blogger 2010

Physics 11 Research Fellowship 2008
Freshman-only research fellowship awarded to top six freshman applicants

John Stauffer Merit Award 2008
One of ~ 50 Caltech students to receive a merit award

Caltech Tech News and Copy Editor 2008-2011

Caltech Axline Award 2007-2011
Merit scholarship that provides free tuition, room, and board

Intel Science Talent Search Finalist 2007
Hydrophobic hydration model chosen as one of the top 40 science fair projects in the United States

U.S. Physics Team finalist 2005, 2007
Chosen as one of 24 students in United States to train for International Physics Olympiad

Publications

V. Ferdinand, A. Yu*, and **S. Marzen**. "Humans are resource-rational predictors in a sequence learning task," in preparation.

M. Lamberti*, M. van Putten, **S. Marzen** and J. le Feber. "The role of NMDA receptors in memory and prediction", submitted to PLoS One.

S. Marzen, P. M. Riechers, and J. P. Crutchfield, "Complexity-calibrated Benchmarks for Machine Learning Reveal When Next-Generation Reservoir Computer Predictions Succeed and Mislead", submitted to Scientific Reports.

E. Dong* and **S. Marzen**. "Cognitive biases can move opinion dynamics from consensus to transient chaos", submitted to American Journal of Physics (invited).

G. Seifert*, A. Sealander*, **S. Marzen****, and M. Levin**. "From reinforcement learning to agency: Frameworks for goal-directed agents", Biosystems 235 (2024).

Y. Sawaya*, G. Issa*, and **S. Marzen**. "A framework for solving time-delayed Markov Decision Processes", Physical Review Research 5 (2023)

M. Lamberti*, S. Tripathi*, M. van Putten, **S. Marzen**, and J. le Feber. "Prediction in cultured cortical neural networks", PNAS Nexus 2(6) (2023)

J. Soriano* and **S. Marzen**. "How Well Can We Infer Selection Benefits and Mutation Rates from Allele Frequencies?", Entropy 25(4), 615 (2023).

D. Levenstein, V. Alvarez, A. Amarasingham, H. Azab, Z. S. Chen, R. C. Gerkin, A. Hasenstaub, R. Iyer, R. B. Jolivet, **S. Marzen**, J. Monaco, A. A. Prinz, S. Quraishi, F. Santamaria, S. Shivkumar, M. F. Singh, R. Traub, F. Nadim, H. G. Rotstein, A. D. Redish. "On the Role of Theory and Modeling in Neuroscience", J. Neurosci. 43 (2023).

A. Duran* and **S. Marzen**. "Not so optimal: The evolution of mutual information in potassium voltage-gated channels", PLoS One (2023)

A. Hsu* and **S. Marzen**. "Strange properties of linear reservoirs in the infinitely large limit for continuous-time prediction", J. Stat. Phys. 190 (2023)

S. Marzen and J. P. Crutchfield. "Inference, Prediction, and Entropy-Rate Estimation of Continuous-Time, Discrete-Event Processes", Entropy 24, 1675 (2022).

M. Lamberti*, M. Hess*, I. Dias, M. van Putten, J. le Feber** and **S. Marzen****. "Maximum entropy models provide functional connectivity estimates in neural networks", Scientific Reports 12 (2022).

C. Tyler*, J. Monroy and **S. Marzen**. "Mathematically modelling prey-catching behavior of the tomato frog", Spora 8, 1-6 (2022).

S. Marzen and J. P. Crutchfield. "Probabilistic deterministic finite automata and recurrent networks, revisited", Entropy 24 (1), 90 (2022)

S. Marzen. "Choosing dynamical systems that predict weak input", Physical Review E 102 (2021)

B. Arul*, D. Lee*, and **S. Marzen**. "A proposed probabilistic method for distinguishing between delusions and other environmental judgements, with applications to psychotherapy", Frontiers in Psychology (2021)

A. Hsu* and **S. Marzen**. "Time cells might be optimized for predictive capacity, but not for redundancy reduction or memory capacity", Physical Review E 102 (2020)

W. Zhong, J. M. Gold, **S. Marzen**, J. L. England, and N. Y. Halpern. "Machine learning outperforms thermodynamics in measuring how well a many-body system learns a drive", Scientific Reports 11, 9333 (2021).

A. Uppal*, V. Ferdinand, and **S. Marzen**. "Inferring an observer's strategy in sequence learning experiments", Entropy 22(8), 896 (2020). Chosen as a Featured Article for a Special Issue on Social Processes.

M. Razo-Mejia, **S. Marzen**, G. Chure, R. Taubman*, M. Morrison, and R. Phillips. "First-principles prediction of the information processing capacity of a simple genetic circuit", Physical Review E 102, 022404 (2020). Chosen as an Editor's Suggestion.

S. Marzen and J. P. Crutchfield. "Prediction and Dissipation in Nonequilibrium Molecular Sensors: Conditionally Markovian Channels Driven by Memoryful Environments", Bulletin of Mathematical Biology 82, 25 (2020)

S. Marzen. "Novelty detection improves reinforcement learning in fluctuating, partially observable environments", Journal of Theoretical Biology 477, 44-50 (2019)

S. Marzen. "Intrinsic computation of a Monod-Wyman-Changeux molecule", Entropy 20 (8), 599 (2018)

S. Marzen. "Infinitely large, randomly wired sensors cannot predict their input unless they are close to deterministic", PLoS ONE 13 (8), e0202333 (2018)

S. Marzen and J. P. Crutchfield. "Optimized bacteria are environmental prediction engines", Physical Review E 98, 012408 (2018)

S. Marzen. "Difference between memory and prediction in linear recurrent networks", Physical Review E 96, 032308 (2017)

S. Marzen and J. P. Crutchfield. "Structure and randomness of continuous-time discrete-event processes", Journal of Statistical Physics 169 (2) 303-315 (2017)

S. Marzen and J. P. Crutchfield. "Nearly maximally predictive features and their dimensions", Physical Review E 95, 051301(R) (2017)

S. Marzen and S. DeDeo. "The evolution of lossy compression", Journal of the Royal Society Interface 14 (2017)

S. Marzen and J. P. Crutchfield. "Informational and causal architecture of continuous-time renewal processes", Journal of Statistical Physics 168 (1) 109-127 (2017)

C. Hillar and **S. Marzen**. "Revisiting perceptual distortion for natural images: mean discrete structural similarity index", Data Compression Conference (2016)

S. Marzen and S. DeDeo. "Weak universality in sensory tradeoffs", Physical Review E 94, 060101(R) (2016)

A. Goudarzi, **S. Marzen**, P. Banda, G. Feldman, M. R. Lakin, C. Teuscher, and D. Stefanovic. "Memory and information processing in recurrent neural networks", submitted (2016)

S. Marzen and J. P. Crutchfield. "Predictive rate-distortion for infinite-order Markov processes", Journal of Statistical Physics 163 (6), 1312-1338 (2016)

S. Marzen and J. P. Crutchfield. "Statistical Signatures of Structural Organization: The case of long memory in renewal processes", Physics Letters A 380 (17), 1517-1525 (2016)

S. Marzen, M. R. DeWeese and J. P. Crutchfield. "Time resolution dependence of spike train information measures", Frontiers in Computational Neuroscience 9 (2015)

J. P. Crutchfield and **S. Marzen**. "Signatures of Infinity: Nonergodicity in Prediction, Complexity, and Learning", Physical Review E 91, 050106(R) (2015). Selected as an Editor's Suggestion.

J. P. Crutchfield, R. G. James, **S. Marzen**, and D. P. Varn. "Understanding and Designing Complex Systems: Response to 'A framework for optimal high-level descriptions in science and engineering–preliminary report"', arXiv:1412.8520 [cond-mat.stat-mech] (2015)

S. Marzen and J. P. Crutchfield. "Informational and causal architecture of discrete-time renewal processes", Entropy 17 (7), 4891-4917 (2015)

S. Marzen and J. P. Crutchfield. "Information anatomy of stochastic equilibria", Entropy 16 (9), 4713-4748 (2014)

S. Marzen, H. G. Garcia, and R. P. Phillips. "Statistical Mechanics of the Monod-Wyman-Changeux (MWC) Models," Journal of Molecular Biology 425(9): 1433-1460 (2013)

S. Marzen, D. Wu, M. Imandar, and R. P. Phillips. "Maximum Caliber model of the two-state system is equivalent to the one-dimensional Ising model," arXiv:1008.2726 [physics.bio-ph] (2011)

Book Chapters

C. J. Hillar and **S. E. Marzen**. "Neural network coding of natural images with applications to pure mathematics," Proceedings of the AMS Special Session on Algebraic and Geometric Methods in Discrete Mathematics, edited by: Heather Harrington, Mohamed Omar, and Matthew Wright (2017).

Conferences

Proceedings

R. Tikhonov, **S. Marzen**, and S. Dedeo. "How Predictive Minds Explain and Control Dynamical Systems", in publication by NeurIPS Workshop on Information-Theoretic Principles in Cognitive Systems (2022).

Contributed talks

J. Soriano* and **S. Marzen**. "The information acquired by evolution", American Physical Society March Meeting, March 2023.

S. Marzen and J. P. Crutchfield. "Predictive feature extraction by conditionally Markovian channels in memoryful, fluctuating environments", Information Engines Workshop, October 2018.

S. Marzen and J. P. Crutchfield. "Optimized bacteria are environmental prediction engines", Society of Industrial and Applied Mathematics, August 2018.

S. Marzen and J. P. Crutchfield. "Optimized bacteria are environmental prediction engines", Telluride Information Engines Workshop, July 2018.

S. Marzen and S. DeDeo. "Evolution of lossy compression", Society of Industrial and Applied Mathematics, July 2016.

S. Marzen and S. DeDeo. "Evolution of lossy compression", American Physical Society, March 2016.

S. Marzen. "New tools for dimensionality reduction in prediction", Conference on Complex Systems Satellite Session, October 2015.

R. Mehta, **S. Marzen**, and C. Hillar. "Exploring discrete approaches to lossy compression of natural image patches", 2015 European Signal Processing Conference.

S. E. Marzen, J. Zylberberg, and M. R. DeWeese. "How efficient coding of binocular disparity statistics in the primary visual cortex influences eye rotation strategy", BMC Neurosci. 2013; 14(Suppl1): O7. (talk) Recipient of travel grant from Organization of Computational Neuroscience.

Invited talks

S. Marzen. "How well do neurons, humans, and artificial neural networks predict?" Organization of Computational Neuroscience Workshop on Information Theory (2023)

S. Marzen. "How well do neurons, humans, and artificial neural networks predict?" Santa Fe Institute Workshop on Sensory Prediction, Engineered and Evolved (2023)

S. Marzen. "How well do neurons, humans, and artificial neural networks predict?" American Mathematical Society, Sectional Meeting (2023)

S. Marzen. "How well do neurons, humans, and artificial neural networks predict?" American Physical Society March Meeting (2023)

S. Marzen. "How well do neurons, humans, and artificial neural networks predict?" CSU Long Beach Physics Seminar Series (2022)

S. Marzen. "How well do neurons, humans, and artificial neural networks predict?" UCSB Biology Seminar Series (2022)

S. Marzen. "How well do neurons, humans, and artificial neural networks predict?" UCSD Institute of Neural Computation Seminar Series (2022)

S. Marzen. "How well do neurons, humans, and artificial neural networks predict?" MITRE Tech Talk, McLean campus (2022)

S. Marzen. "Information theory in biology", Redwood Neuroscience Seminar Series 2018.

S. Marzen. "Prediction and dissipation: faster calculations, bounds, and optimized sensors", BIRS

(2022)

S. Marzen. "Optimal sensors in random environments", Flatiron Research Institute (2022)

S. Marzen. "Everything's a reservoir: Using the back of the brain to improve machine learning prediction algorithms", FlatIron Research Institute (2021)

S. Marzen. "Everything's a reservoir: Using the back of the brain to improve machine learning prediction algorithms", Emory Physics Colloquium (2021)

S. Marzen. "Using lossy representations to understand the neural code?", Organization of Computational Neuroscience Workshop on Information Theory (2020)

S. Marzen. "New methods for continuous-time, discrete-event prediction", Workshop on Agency at the Interface of Quantum and Complexity Science (2020)

S. Marzen. "How can we predict efficiently?", Okinawa Institute of Science and Technology Seminar Series 2020.

S. Marzen. "How can we predict efficiently?", USC Physics Colloquium 2019.

S. Marzen. "How can we predict efficiently?", Harvey Mudd Physics Colloquium 2019.

S. Marzen. "Bio-inspired problems in rate-distortion theory", USC Information Sciences Institute 2019.

S. Marzen. "Bio-inspired problems in rate-distortion theory", IEEE International Symposium on Information Theory 2019.

S. Marzen and A. Hsu. "Difference between memory and prediction in linear recurrent networks", American Physical Society 2019.

S. Marzen. "Optimal sensors in random environments", Redwood Neuroscience Seminar Series 2018.

S. Marzen. "Extracting lossy predictive features", Info-Metrics Workshop on Causality 2018.

S. Marzen. "Optimal sensors in random environments", U. Michigan 2018.

S. Marzen. "Predicting with limited resources", W. M. Keck Science Department 2017.

S. Marzen. "Thinking in machines, not statistics", American Physical Society 2017 [missed due to sickness] .

S. Marzen. "Avoiding the curse of dimensionality with maximally predictive models", Theoretical Computer Science seminar at Indiana University, Bloomington, December 2014.

S. Marzen and J. P. Crutchfield. "Predictive inference in non equilibrium steady state", Information Engines Minisymposium of SIAM Annual Meeting 2014.

S. Marzen. "Information-theoretic approaches to time series modeling", Machine Learning Seminar Series at the University of Hawaii, Honolulu 2014.

Posters

M. Lamberti, S. Tripathi, **S. Marzen**, and J. le Feber. "Cultured neurons predict their input", Society for Neuroscience (2022).

S. Marzen et al. "Inference of functional connectivity in living neural cultures", Organization for Computational Neuroscience (2020).

S. Marzen and J. P. Crutchfield. "Optimized bacteria are environmental prediction engines", 2018 Theory in Biology Conference.

S. Marzen and S. DeDeo. "Weak universality in sensory tradeoffs", 2017 International Conference on Mathematical Neuroscience.

C. Hillar and **S. Marzen**. "Revisiting perceptual distortion for natural images: mean discrete structural similarity index", 2017 International Conference on Mathematical Neuroscience.

S. Marzen, M. R. DeWeese, and J. P. Crutchfield. "Predictive models of spike trains from integrate-and-fire neurons", 2015 International Conference on Mathematical Neuroscience.

S. Marzen, M. R. DeWeese, and J. P. Crutchfield. "Statistical complexity of neural spike trains", Cosyne 2014. Recipient of travel grant from Cosyne.

C. Hillar, **S. Marzen**, U. Koster, and K. Koepsell. "A Hopfield net trained on images matches retinal spike statistics and encodes images efficiently", Cosyne 2014.

S. Marzen, J. Zylberberg, and M. R. DeWeese. "Modified visuomotor optimization theory to explain Listing's Law", J. of Vis. abstract, Vision Science Society 2013.