

References on sloppy models, information geometry, and hyperribbons

Reviews

[Information geometry for multiparameter models: New perspectives on the origin of simplicity](#), Katherine N. Quinn, Michael C. Abbott, Mark K. Transtrum, Benjamin B. Machta, and James P. Sethna, *Rep. Prog. Phys.* **86**, 035901 (2022), [DOI:10.1088/1361-6633/aca6f8](https://doi.org/10.1088/1361-6633/aca6f8), [pdf](#).

[Perspective: Sloppiness and Emergent Theories in Physics, Biology, and Beyond](#), Mark K. Transtrum, Benjamin B. Machta, Kevin S. Brown, Bryan C. Daniels, Christopher R. Myers, and James P. Sethna, *J. Chem. Phys.* **143**, 010901 (2015), [pdf](#).

Web pages (early stages)

<https://sethna.lassp.cornell.edu/Sloppy/>

Particularly readable

["Universally Sloppy Parameter Sensitivities in Systems Biology"](#), Ryan N. Gutenkunst, Joshua J. Waterfall, Fergal P. Casey, Kevin S. Brown, Christopher R. Myers, James P. Sethna, *PLoS Comput Biol* **3**(10) e189 (2007). ([PLoS, doi:10.1371/journal.pcbi.0030189](https://doi.org/10.1371/journal.pcbi.0030189)), [pdf](#). [Reviewed in [NewsBytes](#) of [Biomedical Computation Review](#) (Winter 07/08); [rated "Exceptional" on Faculty of 1000](#)].

["Why are nonlinear fits to data so challenging?"](#), Mark K. Transtrum, Benjamin B. Machta, and James P. Sethna, *Phys. Rev. Lett.* **104**, 060201 (2010), [pdf](#).

Original papers (in reverse chronological order)

Learning trajectories in deep neural networks:

[The Training Process of Many Deep Networks Explores the Same Low-Dimensional Manifold](#), Jialin Mao, Itay Griniasty, Han Kheng Teoh, Rahul Ramesh, Rubing Yang, Mark K. Transtrum, James P. Sethna, and Pratik Chaudhari, <https://arxiv.org/abs/2305.01604> (submitted).

isKLe and the Ising model isometric embedding:

[Visualizing probabilistic models in Minkowski space with intensive symmetrized Kullback-Leibler embedding](#), Han Kheng Teoh, Katherine N. Quinn, Jaron Kent-Dobias, Colin B. Clement, Qingyang Xu, and James P. Sethna, [Phys. Rev. Research](#) **2**, 033221 (2020).

inPCA and replica theory limit of zero data:

[Visualizing probabilistic models with Intensive Principal Component Analysis](#), Katherine N. Quinn, Colin B. Clement, Francesco De Bernardis, Michael D. Niemack, and James P. Sethna, [Proceedings of the National Academy of Sciences](#) **116**, 13762-13767 (2019); [pdf](#). See also [Data visualization could reveal nature of the universe](#) (Cornell Chronicle article by Melanie Lefkowitz), and [Algorithm to map universe, solve mysteries: Study](#) (Times of India, June 26, 2019).

Proof of hyperellipsoid bounds on model manifold for NLLS models:

[Chebyshev approximation and the global geometry of sloppy models](#), Katherine N. Quinn, Heather Wilber, Alex Townsend, and James P. Sethna [Phys. Rev. Lett](#) **122**, 158302 (2019); [pdf](#), and [supplement pdf](#).

Mutual information priors:

H. H. Mattingly, M. K. Transtrum, M. C. Abbott and B. B. Machta, Maximizing the information learned from finite data selects a simple model, PNAS 115 (2018) 1760–1765 [arXiv:1705.01166].

M. C. Abbott and B. B. Machta, Far from Asymptopia: Unbiased high-dimensional inference cannot assume unlimited data, arXiv:2205.03343.

RG flow on the model manifold:

Information loss under coarse graining: A geometric approach, Archishman Raju, Benjamin B. Machta, James P. Sethna [Physical Review E](#) **98**, 052112 (2018)

Ising model becomes sloppy under coarse graining:

[Parameter Space Compression Underlies Emergent Theories and Predictive Models](#), Benjamin B. Machta, Ricky Chachra, Mark K. Transtrum, James P. Sethna, [Science](#) **342**, 604-607 (2013); [pdf](#), [full text](#). See also [Physicists unify the structure of scientific theories](#) in the Cornell Chronicle (Anne Ju); Jesse Silverberg's [Huffington Post blog](#) and Kathryn McGill's vblog [Soft Matters with Jim Sethna](#) from [The Physics Factor](#); and [\(Unedited\) Interview of Sethna by Steven Reiner](#), Stony Brook School of Journalism ([smaller version](#)).

Sloppiness and Lyapunov exponents are related:

[Structural susceptibility and separation of time scales in the van der Pol Oscillator](#), Ricky Chachra, Mark K. Transtrum, and James P. Sethna, *Phys. Rev. E* **86**, 026712 (2012), [pdf](#).

You can measure all the parameters, but it's hard:

J. F. Apgar, D. K. Witmer, F. M. White and B. Tidor, Sloppy models, parameter uncertainty, and the role of experimental design, *Molecular BioSystems* 6 (2010) 1890.

Comment on "Sloppy Models, parameter uncertainty, and the role of experimental design", Ricky Chachra, Mark K. Transtrum, and James P. Sethna, *Mol. BioSyst.*, 2011, [pdf](#)

Reply to Comment on "Sloppy models, parameter uncertainty, and the role of experimental design", David R Hagen, Joshua F Apgar, David K Witmer, Forest M White, Bruce Tidor, *Mol Biosyst.* 2011 Aug 1;7(8):2523-2524.
doi: 10.1039/C1MB05200D.

Transtrum's MBAM approach to model reduction:

M. K. Transtrum and P. Qiu, Model reduction by manifold boundaries, *Phys. Rev. Lett.* 113 (2014) 098701–6.

** Our first papers on information geometry:

["Why are nonlinear fits to data so challenging?"](#), Mark K. Transtrum, Benjamin B. Machta, and James P. Sethna, *Phys. Rev. Lett.* **104**, 060201 (2010), [pdf](#).

["Geometry of nonlinear least squares with applications to sloppy models and optimization"](#), Mark K. Transtrum, Benjamin B. Machta, and James P. Sethna *Phys. Rev. E* **83**, 036701 (2011); [pdf](#).

Sloppiness vs. robustness in biology:

["Sloppiness, robustness, and evolvability in systems biology"](#), Bryan C. Daniels, Yan-Jiun Chen, James P. Sethna, Ryan N. Gutenkunst, and Christopher R. Myers, *Curr Opin Biotechnol* **19**, 389-395 (2008), [doi:10.1016/j.copbio.2008.06.008](https://doi.org/10.1016/j.copbio.2008.06.008), [pdf](#), and [supplemental material](#).

** Ubiquity of sloppiness, and measuring parameters is fruitless, although people tried:

["Universally Sloppy Parameter Sensitivities in Systems Biology"](#), Ryan N. Gutenkunst, Joshua J. Waterfall, Fergal P. Casey, Kevin S. Brown, Christopher R. Myers, James P. Sethna, *PLoS Comput Biol* **3**(10) e189 (2007). (*PLoS*, [doi:10.1371/journal.pcbi.0030189](https://doi.org/10.1371/journal.pcbi.0030189)), [pdf](#)). [Reviewed in [NewsBytes](#) of [Biomedical Computation Review](#) (Winter 07/08); [rated "Exceptional" on Faculty of 1000](#)].

J. W. Zwolak, J. J. Tyson and L. T. Watson, Globally optimised parameters for a model of mitotic control in frog egg extracts, *IEE Proceedings-Systems Biology* 152 (2005), no. 2 81–92.

Sloppiness and optimal experimental design:

["Optimal experimental design in an EGFR signaling and down-regulation model"](#), Fergal P. Casey, Dan Baird, Qiyu Feng, Ryan N. Gutenkunst, Joshua J. Waterfall, Christopher R. Myers, Kevin S. Brown, Richard A. Cerione, and James P. Sethna, *IET Systems Biology* 1, 190-202 (2007) ([pdf](#)).

Sloppiness outside of biology, fitting exponential decays, and our first discussion of monomials and Vandermonde determinants:

["Sloppy model universality class and the Vandermonde matrix"](#), Joshua J. Waterfall, Fergal P. Casey, Ryan N. Gutenkunst, Kevin S. Brown, Christopher R. Myers, Piet W. Brouwer, Veit Elser, and James P. Sethna, *Phys. Rev. Letters* 97, 150601 (2006), [pdf](#), also selected for [Virtual Journal of Biological Physics Research 12 \(8, Miscellaneous\), \(2006\)](#)

Using sloppiness to estimate *systematic* errors in atomistic and electronic structure calculations:

"Bayesian Ensemble Approach to Error Estimation of Interatomic Potentials", Søren L. Frederiksen, Karsten W. Jacobsen, Kevin S. Brown, and James P. Sethna, *Phys. Rev. Letters* 93, 165501 (2004). [pdf](#).

["Bayesian Error Estimation in Density Functional Theory"](#), J. J. Mortensen, K. Kaasbjerg, S. L. Frederiksen, J. K. Nørskov, James P. Sethna, K. W. Jacobsen, *Phys. Rev. Letters* 95, 216401 (2005), [pdf](#).

Our original papers discussing sloppiness in a systems biology model:

["Statistical Mechanics Approaches to Models with Many Poorly Known Parameters"](#), Kevin S. Brown and James P. Sethna, *Phys. Rev. E* 68, 021904 (2003).

["The Statistical Mechanics of Complex Signaling Networks: Nerve Growth Factor Signaling"](#), Kevin S. Brown, Colin C. Hill, Guillermo A. Calero, Christopher R. Myers, Kelvin H. Lee, James P. Sethna, and Richard A. Cerione, *Physical Biology* 1, 184-195 (2004) . ([pdf](#), and [supplemental material](#).)