Antoine Maillard — Hermann-Weyl Instructor

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About me

I am a Hermann-Weyl Instructor at the Institute for Mathematical Research (FIM) and the Department of Mathematics at ETH Zürich, working in the group of Prof. Afonso Bandeira. I defended my PhD in 2021 at École Normale Supérieure (ENS) de Paris, and prepared it under the supervision of Prof. Florent Krzakala, and the additional guidance of Prof. Lenka Zdeborová.

My research is at the intersection of statistical physics, statistical learning and high-dimensional statistics, probability theory, information theory, optimization, and random matrix theory.

Education

- **PhD in theoretical physics** *2018-2021*
  "Fundamental limits of high-dimensional estimation" — École Normale Supérieure, Paris, France
  Under the supervision of Prof. Florent Krzakala.
- **École Normale Supérieure graduate degree** *2013-2018*
  Research-oriented Master's degree validating my studies at ENS. — École Normale Supérieure, Paris, France
- **M.Sc. in Theoretical Physics** *2014-2016*
  Ranked 1^{st}*/140, grade: 18.82/20.* — École Normale Supérieure, Paris, France
- **Master 1 in Mathematics** *2013-2015*
  Overall grade: 17.86/20. — École Normale Supérieure, Paris, France
- **B.Sc. in Physics** *2013-2014*
  Ranked 2^{nd}*/35, grade: 18.8/20.* — École Normale Supérieure, Paris, France
- **Classes Préparatoires MPSI-MP** *2011-2013*
  Admitted at ENS by competitive exams ("concours"). — Lycée Sainte Geneviève, Versailles, France

Teaching and Mentoring

- **Mathematics of Data Science** *Fall 2023*
  Teaching (50 %) of a master's course in mathematics, 3 hours/week, ≃ 150 students – ETH Zürich.
  Based on the book draft: https://people.math.ethz.ch/~abandeira/BandeiraSingerStrohmer-MDS-draft.pdf
- **Mathematics of Signals, Networks and Learning** *Spring 2023*
  Teaching (50 %) of a bachelor course in mathematics, 2 hours/week, ≃ 60 students – ETH Zürich.
  Lecture notes: https://anmaillard.github.io/teaching/msnl_spring_2023.pdf
- **Student supervision at ETH Zürich** *2021 - Now*
  - Mentoring of **Cheng Shi**, PhD student from the University of Basel (Spring 2024).
  - Supervision of the theses of 3 students (Bachelor & Master):
    * **Kevin Lucca**, Master Thesis, 2023. *Norms of Random Multilinear Forms.*
    * **Michał Mikuta**, Bachelor Thesis, 2023. *Average-Case Tensor Discrepancy: A First Moment Prediction.*
    * **Fabio Hehli**, Bachelor Thesis, 2022. *Parallel Tempering for Tensor PCA.*
  - Student seminar on Matrix Discrepancy (Spring 2022).

- **Teaching Assistant at ENS Paris** *2018 - 2021*

  – "Mathematics for Physicists", taught by Prof. Van Wijland at ENS in Fall 2019, 2 hours/week.
  – Participation in the design of competitive exams ("concours") of ENS in 2020.

- **Private lessons** *2013 - 2020*
  From high school to bachelor degree, in physics and mathematics.

Awards & Fellowships

- **Hermann-Weyl-Instructor fellowship** *2021-2024*
  Postdoctoral fellowship of ETH's Institute for Mathematical Research (FIM).
  https://math.ethz.ch/fim/postdocs.html
- **Prix de thèse Daniel Guinier** *2022*
  French nationwide PhD prize of the Société Française de Physique.
  https://www.sfpnet.fr/laureats-des-grands-prix-de-theses-2021-de-la-sfp
- **PhD scholarship "Jean-Pierre Aguilar"** *2018-2021*
  Competitive PhD scholarship from Fondation CFM pour la recherche.
  https://www.fondation-cfm.org/

Research experience

- **Hermann-Weyl Instructor** *Oct 2021 - Now*
  Post-doctoral position at ETH Zürich.
- **Visit to Prof. Afonso Bandeira at ETH Zürich** *Feb-Apr 2020*
  Invitation in the Department of Mathematics.
- **The rough high-dimensional landscape problem** *Winter 2019*
  Two-months program at Kavli Institute for Theoretical Physics, Santa Barbara.
- **Research internship, NYU (Shanghai & NYC)** *Feb-Jul 2018*
  Energy landscape of inference models w. G. Ben Arous.
- **Research internship, École Normale Supérieure (Paris)** *Sep 2017 - Feb 2018*
  Statistical learning and inference w. F. Krzakala.
- **Research internship, Capital Fund Management (Paris)** *Sep 2016 - Feb 2017*
  Message-passing algorithms for optimization of discrete trade systems w. J-P. Bouchaud & F. Altarelli.
- **Research internship, CERN (Geneva, Switzerland)** *Jun-Jul 2016*
  Quadrupole structures for transverse Landau damping in circular accelerators w. E. Métral.
- **Research internship, CEA & Collège de France (Paris)** *Jan-May 2016*
  Out-of-equilibrium computations in quantum impurity models by Monte-Carlo methods w. O. Parcollet & A. Georges.
- **Research internship, Perimeter Institute (Waterloo, Canada)** *Feb-Jul 2015*
  Islands of stability and recurrence times in Anti-de-Sitter spacetimes w. S. Green & L. Lehner.
- **Intensive arabic internship (Cairo, Egypt)** *Aug-Sep 2014*
  At the "Institut Francais d'Égypte", in El Mounira..

Language skills

French (Native), **English** (Fluent), **Arabic** (Conversational), **German** (Basic).

Programming skills

Python, C++, Mathematica, LateX

Other services & responsibilities

- Organization of the DACO seminar from Fall 2021 until Fall 2023: https://math.ethz.ch/news-and-events/events/research-seminars/daco-seminar.html
- **Outstanding Reviewer award** at ICLR 2021.
- Reviewer for conferences : *Conference on Neural Information Processing Systems* (NeurIPS), *International Conference on Learning Representations* (ICLR), *International Conference on Machine Learning* (ICML), *IEEE International Workshop on Computational Advances in Multi-Sensor Adaptive Processing* (CAMSAP).
- Reviewer for journals : *Annals of Statistics* (AoS), *Foundations of Computational Mathematics* (FoCM), *Transactions in Machine Learning Research* (TMLR), *SIAM Journal on Mathematics of Data Science* (SIMODS), *Information and Inference: A Journal of the IMA* (IMAIAI), *IEEE Journal on Selected Areas in Information Theory* (JSAIT), *Journal of Statistical Mechanics: Theory and Experiment* (JSTAT), *Journal of Physics A: Mathematical and Theoretical* (J. Phys. A), *Physical Review X* (PRX), *Physical Review Letters* (PRL), *Journal of Statistical Physics* (J. Stat. Phys.).

Selected communications

Slides or notes can usually be found on my website. The communications are grouped by topic, and invited talks are highlighted.

On ellipsoid fitting and Bayes-optimal learning of neural networks:

- (**Invited**) LemanTh workshop, EPFL, Lausanne, Switzerland (May 2024).

Disordered systems and the mathematics of data science:

- (**Invited**) Statistics seminar, ENSAE / CREST (Paris) (March 2024).
- (**Invited**) Mathematics of Machine Learning and Data Science Seminar, University of Vienna (March 2024).
- (**Invited**) ARGO seminar, INRIA Paris (February 2024).
- (**Invited**) Disordered systems group, King's College London (January 2024).

On the ellipsoid fitting of random points:

- (**Invited**) Department of Mathematics, University of Fribourg, Switzerland (January 2024).
- (**Invited**) Probability and Statistics seminar, McMaster University, Canada (December 2023).
- (**Invited**) SIERRA seminar, INRIA Paris (December 2023).
- (**Invited**) Machine Learning and Signal Processing seminar, École Normale Supérieure de Lyon (November 2023).
- (**Invited**) Séminaire Centre science des données, École Normale Supérieure, Paris (November 2023).
- (**Invited**) Harvard CMSA Probability Seminar, Harvard University, USA (November 2023).
- (**Invited**) Statistical physics and machine learning back together again, Cargèse, France (August 2023).

On large-rank matrix denoising and factorization:

- (**Invited**) 21st INFORMS Applied Probability Society Conference, Nancy, France (June 2023).
- (**Invited**) 29th Nordic Conference in Mathematical Statistics, Gothenburg, Sweden (June 2023).

On the injectivity of ReLU networks:

- (**Invited**) High Dimensional Statistics and Random Matrices, Porquerolles, France (June 2023).
- (**Invited**) Workshop on Spin Glasses, Les Diablerets, Switzerland (September 2022).

On high-dimensional phase retrieval:

- (**Invited**) Matrices et Graphes Aléatoires, Institut Henri Poincaré, Paris (December 2022).
- Youth in High dimensions (poster), ICTP, Trieste (June 2022).
- (**Invited**) Rigorous Evidence for Information-Computation Trade-offs, Simons Institute for the Theory of Computing, Berkeley (September 2021).
- Mathematical and Scientific Machine Learning, EPFL, Lausanne (August 2021).
- (**Invited**) Random Matrix Theory and Networks, Max Planck Institute for the Physics of Complex Systems, Dresden (June 2021).
- (**Invited**) INRIA seminar "Mokaplan", INRIA, Paris (December 2020).
- Advances in Neural Information Processing Systems (NeurIPS) (poster), Online (December 2020).
- Les Houches summer school on Statistical Physics and Machine Learning, Les Houches, France (August 2020).
- (**Invited**) Youth in high dimensions, ICTP, Trieste (June 2020).

On the landscape complexity of generalized linear models:

- (**Invited**) Probability Seminar, university of Basel (October 2021).
- Mathematical and Scientific Machine Learning, Princeton, USA (July 2020).

On the spiked matrix model with generative priors:

- Advances in Neural Information Processing Systems (NeurIPS) (poster), Vancouver, Canada (December 2019).
- Science of Data Science (poster), ICTP, Trieste (October 2019).

On computational-to-statistical gaps in two-layers neural networks:

- Advances in Neural Information Processing Systems (NeurIPS) (poster), Montreal, Canada (December 2018).
- Cargese Summer School (poster), Cargese, France (August 2018).
- Beg Rohu Summer School (poster), Quiberon, France (June 2018).

More general talks:

- "Fundamental limits of high dimensional estimation", Rencontre des Jeunes Physicien(ne)s – Ceremony for Daniel Guinier PhD award, Collège de France, Paris (November 2022).
- "On replica symmetry breaking", Graduate seminar of probability, ETH Zürich (October 2022).
- "The Kac-Rice formula", KITP, Santa Barbara and ETH Zürich (February 2019 and December 2022).

List of publications

On the order of authors – In most of my publications, the authors are ranked by order of contribution. However, in some works, the order is instead alphabetical. Whenever this is the case, this is indicated clearly by a symbol ($\boldsymbol{\alpha}$).

The full text of all my publications is available on my personal webpage: https://anmaillard.github.io/.

Preprints

($\boldsymbol{\alpha}$) [1] A. S. Bandeira and **A. Maillard**. "Exact threshold for approximate ellipsoid fitting of random points". *arXiv preprint arXiv:2310.05787* (Oct. 2023).

[2] **A. Maillard** and D. Kunisky. "Fitting an ellipsoid to random points: predictions using the replica method". *arXiv preprint arXiv:2310.01169* (Oct. 2023).

($\boldsymbol{\alpha}$) [3] A. S. Bandeira, **A. Maillard**, S. Mendelson, and E. Paquette. "Fitting an ellipsoid to a quadratic number of random points". *arXiv preprint arXiv:2307.01181* (July 2023).

[4] **A. Maillard**, A. S. Bandeira, D. Belius, I. Dokmanić, and S. Nakajima. "Injectivity of ReLU networks: perspectives from statistical physics". *arXiv preprint arXiv:2302.14112* (Feb. 2023).

Journal publications

[5] J. Dong, L. Valzania, **A. Maillard**, T.-a. Pham, S. Gigan, and M. Unser. "Phase retrieval: From computational imaging to machine learning: A tutorial". *IEEE Signal Processing Magazine* 40.1 (2023), pp. 45–57.

($\boldsymbol{\alpha}$) [6] A. S. Bandeira, **A. Maillard**, R. Nickl, and S. Wang. "On free energy barriers in Gaussian priors and failure of cold start MCMC for high-dimensional unimodal distributions". *Philosophical Transactions of the Royal Society A* 381.2247 (2023), p. 20220150.

($\boldsymbol{\alpha}$) [7] A. S. Bandeira, **A. Maillard**, and N. Zhivotovskiy. "A remark on Kashin's discrepancy argument and partial coloring in the Komlós conjecture". *Portugaliae Mathematica* 79.3 (2022), pp. 311–316.

[8] **A. Maillard**, F. Krzakala, M. Mézard, and L. Zdeborová. "Perturbative construction of mean-field equations in extensive-rank matrix factorization and denoising". *Journal of Statistical Mechanics: Theory and Experiment* 2022.8 (2022), p. 083301.

[9] **A. Maillard**. "Large deviations of extreme eigenvalues of generalized sample covariance matrices". *Europhysics Letters* 133.2 (2021), p. 20005.

[10] B. Aubin, B. Loureiro, **A. Maillard**, F. Krzakala, and L. Zdeborová. "The Spiked Matrix Model With Generative Priors". *IEEE Transactions on Information Theory* 67.2 (2020), pp. 1156–1181.

[11] C. Bertrand, O. Parcollet, **A. Maillard**, and X. Waintal. "Quantum Monte Carlo algorithm for out-of-equilibrium Green's functions at long times". *Physical Review B* 100.12 (2019), p. 125129.

[12] B. Aubin, **A. Maillard**, J. Barbier, F. Krzakala, N. Macris, and L. Zdeborová. "The committee machine: computational to statistical gaps in learning a two-layers neural network". *Journal of Statistical Mechanics: Theory and Experiment* 2019.12 (2019), p. 124023.

[13] **A. Maillard**, L. Foini, A. L. Castellanos, F. Krzakala, M. Mézard, and L. Zdeborová. "High-temperature expansions and message passing algorithms". *Journal of Statistical Mechanics: Theory and Experiment* 2019.11 (2019), p. 113301.

[14] M. Schenk, X. Buffat, K. Li, and A. Maillard. "Vlasov description of the effects of nonlinear chromaticity on transverse coherent beam instabilities". *Physical Review Accelerators and Beams* 21.8 (2018), p. 084402.

[15] S. R. Green, **A. Maillard**, L. Lehner, and S. L. Liebling. "Islands of stability and recurrence times in AdS". *Physical review D* 92.8 (2015), p. 084001.

Conference publications

[16] E. Troiani, V. Erba, F. Krzakala, **A. Maillard**, and L. Zdeborová. "Optimal denoising of rotationally invariant rectangular matrices". *Mathematical and Scientific Machine Learning*. PMLR. 2022, pp. 97–112.

[17] **A. Maillard**, F. Krzakala, Y. M. Lu, and L. Zdeborová. "Construction of optimal spectral methods in phase retrieval". *Mathematical and Scientific Machine Learning*. PMLR. 2022, pp. 693–720.

[18] **A. Maillard**, B. Loureiro, F. Krzakala, and L. Zdeborová. "Phase retrieval in high dimensions: Statistical and computational phase transitions". *Advances in Neural Information Processing Systems* 33 (2020), pp. 11071–11082.

[19] **A. Maillard**, G. Ben Arous, and G. Biroli. "Landscape complexity for the empirical risk of generalized linear models". *Mathematical and Scientific Machine Learning*. PMLR. 2020, pp. 287–327.

[20] B. Aubin, B. Loureiro, **A. Maillard**, F. Krzakala, and L. Zdeborová. "The spiked matrix model with generative priors". *Proceedings of the 33rd International Conference on Neural Information Processing Systems*. 2019, pp. 8366–8377.

[21] J. Barbier, N. Macris, **A. Maillard**, and F. Krzakala. "The mutual information in random linear estimation beyond iid matrices". *2018 IEEE International Symposium on Information Theory (ISIT)*. IEEE. 2018, pp. 1390–1394.

[22] B. Aubin, **A. Maillard**, F. Krzakala, N. Macris, L. Zdeborová, et al. "The committee machine: Computational to statistical gaps in learning a two-layers neural network". *Advances in Neural Information Processing Systems* 31 (2018).

PhD thesis

[23] **A. Maillard**. "Fundamental limits of high-dimensional estimation: a stroll between statistical physics, probability and random matrix theory". PhD thesis. Université Paris sciences et lettres, 2021.

Lecture notes

[24] A. S. Bandeira and **A. Maillard**. *Mathematics of Signals, Networks, and Learning*. 2023. URL: https://anmaillard.github.io/teaching/msnl_spring_2023.pdf.

[25] **A. Maillard**. *The Kac-Rice formula: basic definitions and a first application*. 2019. URL: https://anmaillard.github.io/teaching/kac_rice_2019.pdf.