# **Paul Breiding** | Curriculum Vitae

Universität Osnabrück, FB Mathematik/Informatik, Albrechtstr. 28a, D-49076 Osnabrück

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Paul Breiding • @_pbrdng • born 12th of May 1988, german citizenship

**Universität Osnabrück**
*Professor for Mathematical Methods in Data Science* *Since 04/2022*

**Max-Plack-Institute for Mathematics in the Sciences Leipzig**
*Head of Emmy Noether Research Group:* *04/2021 – 03/2022*
Numerical and Probabilistic Nonlinear Algebra

**University of Kassel**
*Substitute Professor for Computeralgebra* *11/2020 – 03/2021*

**Akademie der Wissenschaften und der Literatur Mainz**
*Speaker of the Junge Akademie | Mainz* *02/2022 – 02/2023*

**Akademie der Wissenschaften und der Literatur Mainz**
*Member of the Junge Akademie | Mainz* *04/2020 – 03/2024*

**Parental leave**
*7 months in total* *10/2019 – 11/2019 and 04/2020 – 10/2020*

**Technische Universität Berlin**
*Postdoctoral researcher in the algorithmic algebra research group* *04/2019 – 10/2020*

**Max-Plack-Institute for Mathematics in the Sciences Leipzig**
*Postdoctoral researcher in the nonlinear algebra research group* *10/2017 – 03/2019*

**Technische Universität Berlin**
*PhD student with Prof. Dr. Bürgisser* *12/2013 – 09/2017*
Date of thesis defense: July 25, 2017. Evaluation 'summa cum laude'.

**Simons Institute for the Theory of Computing**
*Visiting graduate student* *08/2014 – 10/2014*
Algorithms and Complexity in Algebraic Geometry

## Education

**Georg-August-Universität Göttingen**
*Master of Science* *10/2011 – 11/2013*
Evaluation: excellent.

**Universidad de Sevilla**
*Undergraduate studies, part of the Erasmus exchange program* *02/2011 – 09/2011*

**Georg-August Universität Göttingen**
*Bachelor of Science* *10/2008 – 09/2011*

### Languages

**German**: *fluent, native*

**English**: *fluent*

## Awards

**SIAG/AG Early Career Prize**
Awarded by the SIAM Activity Group on Algebraic Geometry *2021*

## External Funding

**Maßnahme "Digitalisierung sicher gestalten"**
Granted by MWK Niedersachsen, €49.780 *2022*
with T. Römer

**Maßnahme "Unterstützung der Digitalisierung der Lehre für die Digitalisierungsprofessuren"**
Granted by MWK Niedersachsen, €104.125 *2022*
with T. Römer

**BIRS Workshop on Random Algebraic Geometry**
Granted by the Banff International Research Station *2022*
with S. Petrović and G. Smith

**Geometry in Complexity and Computation Conference**
Granted by Foundation Compositio *2021*
with K. Kohn

**Emmy Noether Research Group Grant**
Granted by the Deutsche Forschungsgemeinschaft, €1.132.600 *2020*
Project title: Numerical and Probabilistic Nonlinear Algebra

## Service

**Peer reviewing** for the following journals: SIAM Journal on Applied Algebra and Geometry, Linear Algebra and its Applications, Journal Foundations of Computational Mathematics, Proceedings of the Royal Society A, Journal of the American Mathematical Society, Mathematics of Computation.

**Editorial board member** of Numerical Algebra, Control and Optimization.

## Teaching experience

**Lecture: Analysis 1** **Lecturer**
*Universität Osnabrück* *10/2022–02/2023*

**Lecture: Elemente der Datenanalyse** **Lecturer**
*Universität Osnabrück* *10/2022–02/2023*

**Lecture: Mathematische Grundlagen der Datenanalyse** **Lecturer**
*Universität Osnabrück* *04/2022–07/2022*

**Lecture: Random Algebraic Geometry** **Lecturer**
*Universität Leipzig* *10/2021–03/2022*

**IMPRS Ringvorlesung** **Lecturer**
*Max-Planck Institute for Mathematics in the Sciences* *04/2021–06/2021*

**Lecture: Statistics for engineers** **Lecturer**
*Universität Kassel* *11/2020–03/2021*

All lectures and exercises are available on YouTube and GitHub

**Lecture: Grundlagen der Algebra und Computeralgebra** **Lecturer**
*Universität Kassel* *11/2020–03/2021*

All lectures are available on YouTube and GitHub; lecture for high school teachers

**Seminar: Mathematics for primary school teachers** **Lecturer**
*Universität Kassel* *11/2020–03/2021*

**Lecture: Numerical algebraic geometry with Julia** **Lecturer**
*Freie Universität Berlin* *09/2019–03/2020*

**Lecture: Condition – the geometry of numerical algorithms** **Lecturer**
*Max-Planck Institute for Mathematics in the Sciences* *10/2018–01/2019*

**Mathematik für unbegleitete minderjährige Flüchtlinge** **Teacher**
*Stiftung SPI Berlin* *03/2016–11/2016*

**Statistische Beratung** **Tutor**
*Institut für medizinische Statistik, UMG Göttingen* *06/2013 – 09/2013*

## Organizational experience

**Random Algebraic Geometry** — **Organizer**
*BIRS Workshop* — *04/2023*

**Stochastic Geometry** — **Organizer**
*Universität Osnabrück* — *11/2023*

**Geometry in Complexity and Computations** — **Organizer**
*Universität Konstanz* — *09/2022*

**The 1st and 2nd East German Tensor Day** — **Organizer**
*One-day workshop* — *09/2021 and 12/2021*

**Workshop on Software and Applications of Numerical Nonlinear Algebra** — **Organizer**
*Online workshop* — *06/2021*

**Workshop Computational Algebra 2020** — **Organizer**
*Online workshop* — *11/2020*

**Minisymposium on Random Geometry and Topology** — **Organizer**
*SIAM Conference on Applied Algebraic Geometry* — *07/2019*

**Minisymposium on Numerical Methods in Algebraic Geometry** — **Organizer**
*SIAM Conference on Applied Algebraic Geometry* — *07/2019*

**Summer School on Randomness and Learning in Nonlinear Algebra** — **Organizer**
*Max-Planck Institute for Mathematics in the Sciences* — *07/2019*

**Workshop on Random Algebraic Geometry** — **Organizer**
*SISSA* — *11/2018*

**Max-Planck Day (presentation of MPI MiS to a general audience)** — **Organizer**
*Munich* — *09/2018*

**Summer School on Numerical Computing in Algebraic Geometry** — **Organizer**
*Max-Planck Institute for Mathematics in the Sciences* — *08/2018*

**EROC - European Roller Derby Organizational Conference** — **Organizer**
*International conference with ∼150 participants; topics included diversity and inclusion* — *2016 and 2017*

## Publications

### Journal articles


[1] C. Beltrán, P. Breiding, and N. Vannieuwenhoven. The average condition number of most tensor rank decomposition problems is infinite. *Foundations of Computational Mathematics (2022).*

[2] C. Beltrán, P. Breiding, and N. Vannieuwenhoven. Pencil-based algorithms for tensor rank decomposition are not stable. *SIAM J. Matrix Anal. and Appl. 40(2), 739–773 (2019).*

[3] P. Breiding. An algebraic geometry perspective on topological data analysis. *SIAM News 53(1) (2020).*

[4] P. Breiding. The expected number of eigenvalues of a real gaussian tensor. *SIAM J. Appl. Algebra Geometry, 1(1), 254–271 (2017).*

[5] P. Breiding. How many eigenvalues of a random symmetric tensor are real? *Trans. Amer. Math. Soc. 372, 7857–7887 (2019).*

[6] P. Breiding and P. Bürgisser. Distribution of the eigenvalues of a random system of homogeneous polynomials. *Linear Algebra and its Applications, 497, 88–107 (2016).*

[7] P. Breiding, P. Bürgisser, A. Lerario, and L. Mathis. The zonoid algebra, generalized mixed volumes, and random determinants. *Adv. in Math. 402 (2022).*

[8] P. Breiding, T. Çelik, T. Duff, A. Heaton, A. Maraj, A. Sattelberger, L. Venturello, and O. Yürük. Nonlinear algebra and applications. *Numerical Algebra, Optimization and Control (2021).*

[9] P. Breiding, R. Hodges, C. Ikenmeyer, and M. Michalek. Equations for GL invariant families of polynomials. *Vietnam Journal of Mathematics (2022).*

[10] P. Breiding, H. Keneshlou, and A. Lerario. Quantitative singularity theory for random polynomials. *International Mathematical Research Notices (2020).*

[11] P. Breiding, K. Kozhasov, and A. Lerario. On the geometry of the set of symmetric matrices with repeated eigenvalues. *Arnold Math J. 1(4), 423–443 (2018).*

[12] P. Breiding, K. Kozhasov, and A. Lerario. Random spectrahedra. *SIAM J. Optim. 29(4), 2608–2624 (2019).*

[13] P. Breiding and O. Marigliano. Random points on an algebraic manifold. *SIAM J. Mathematics of Data Science 2(3), 683–704 (2020).*

[14] P. Breiding, F. Sottile, and J. Woodcock. Euclidean distance degree and mixed volume. *Foundations of Computational Mathematics (2021).*

[15] P. Breiding, B. Sturmfels, S. Kalisnik Verovsek, and M. Weinstein. Learning algebraic varieties from samples. *Revista Matemática Complutense, 31, 545–593 (2018).*

[16] P. Breiding, B. Sturmfels, and S. Timme. 3264 conics in a second. *Not. Amer. Math. Soc. 67, 30–37 (2020). Article is featured on the title page.*

[17] P. Breiding and N. Vannieuwenhoven. The condition number of join decompositions. *SIAM J. Matrix Anal. and Appl., 39(1), 287–309 (2018).*

[18] P. Breiding and N. Vannieuwenhoven. The condition number of Riemannian approximation problems. *SIAM J. Optim. 31(1), 1049–1077 (2021).*

[19] P. Breiding and N. Vannieuwenhoven. Convergence analysis of Riemannian Gauss-Newton methods and its connection with the geometric condition number. *Applied Mathematics Letters, 78 , 42–50 (2018).*

[20] P. Breiding and N. Vannieuwenhoven. On the average condition number of tensor rank decompositions. *IMA J. Num. Anal. (2019).*

[21] P. Breiding and N. Vannieuwenhoven. A Riemannian trust region method for the canonical tensor rank approximation problem. *SIAM J. Optim., 28, 2435-2465 (2018).*

[22] P. Breiding and N. Vannieuwenhoven. Sensitivity of low-rank matrix recovery. *Numerische Mathematik (2022).*

[23] N. Dewaele, P. Breiding, and N. Vannieuwenhoven. The condition number of many tensor decompositions is invariant under Tucker compression. *Numerical Algorithms (to appear).*

## Preprints

[24] P. Blagojević, P. Breiding, and A. Heaton. Facet volumes of polytopes. *arXiv:2112.08437.*

[25] P. Breiding. An efficient randomized homotopy method to approximate eigenpairs of tensors. *arXiv1512.03284.*

[26] P. Breiding, F. Gesmundo, M. Michalek, and N. Vannieuwenhoven. Algebraic compressed sensing. *arXiv2108.13208.*

[27] P. Breiding, J. Lindberg, G. Ong, and L. Sommer. Real circles tangent to 3 conics. *arXiv:2211.06876.*

[28] P. Breiding, M. Michałek, L. Monin, and S. Telen. The algebraic degree of coupled oscillators. *arXiv:2208.08179.*

[29] P. Breiding, K. Ranestad, and M. Weinstein. Enumerative geometry of curvature of algebraic hypersurfaces. *arXiv:2206.09130.*

[30] P. Breiding, K. Rose, and S. Timme. Certifying zeros of polynomial systems using interval arithmetic. *arXiv:2011.05000.*

[31] P. Breiding, F. Rydell, E. Shehu, and A. Torres. Line multiview varieties. *arXiv:2203.01694.*

[32] N. Dewaele, P. Breiding, and N. Vannieuwenhoven. Three decompositions of symmetric tensors have similar condition numbers. *arXiv:2110.04172.*

## Software projects

[33] P. Breiding and S. Timme. Homotopycontinuation.jl: A package for homotopy continuation in Julia. juliahomotopycontinuation.org. github.com/JuliaHomotopyContinuation. Open Source software.

**Homotopy Continuation.jl**

## Lecture notes

[34] P. Breiding and S. Fairchild. *Mathematical Methods in Data Science.* Unpublished work in progress. Available at `https://pbrdng.github.io/MathData.pdf`.

[35] P. Breiding and A. Lerario. *Lectures on Random Algebraic Geometry.* Unpublished work in progress. Available at `https://pbrdng.github.io/rag.html`.

## Websites

[36] P. Breiding, B. Sturmfels, and S. Timme. juliahomotopycontinuation.org/do-it-yourself/. A website, where the user can compute and plot the conics which are tangent to their 5 own conics.

Theses

[37] P. Breiding. Zyklotomische Körper und die Fermat–Gleichung zum Exponent $p^2$., 2011. Grade: 1.0. First supervisor: Preda Mihailescu. Second supervisor: Maarten Solleveld.

[38] P. Breiding. On a p-adic newton method. Master's thesis, Georg-August Universität Göttingen, 2013. Grade: 1.0. First supervisor: Preda Mihailescu. Second supervisor: Peter Bürgisser.

[39] P. Breiding. *Numerical and Statistical Aspects of Tensor Decompositions*. PhD thesis, TU Berlin, 2017. Grade: summa cum laude. First supervisor: Peter Bürgisser. Second supervisor: Felipe Cucker.

## References

**Carlos Beltrán**: beltranc@unican.es
Universidad de Santander, Av. de los Castros, 39005 Santander, Spain

**Peter Bürgisser**: pbuerg@math.tu-berlin.de
Technische Universität Berlin, Straße des 17. Juni 136, 10623 Berlin, Germany.

**Antonio Lerario**: lerario@sissa.it
SISSA, Via Bonomea 265 Trieste, Italy.

**Bernd Sturmfels**: bernd@mis.mpg.de
MPI für Mathematik in den Naturwissenschaften, Inselstraße 22, 04103 Leipzig, Germany

**Nick Vannieuwenhoven**: nick.vannieuwenhoven@cs.kuleuven.be
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