

# Paul Breiding | Curriculum Vitae

Max-Planck-Institute for Mathematics in the Sciences, Inselstr. 22, 04103 Leipzig, Germany

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

## Max-Planck-Institute for Mathematics in the Sciences Leipzig

Head of Emmy Noether Research Group: Numerical and Probabilistic Nonlinear Algebra Since 04/2021

## University of Kassel

Substitute Professor for Computeralgebra 11/2020 – 03/2021

## Akademie der Wissenschaften und der Literatur Mainz

Member of the Junge Akademie 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-Planck-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

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### 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

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### SIAG/AG Early Career Prize

Awarded by the SIAM Activity Group on Algebraic Geometry 2021

## External Funding

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### Emmy Noether Research Group Grant

Total amount: €1.132.600

Granted by the Deutsche Forschungsgemeinschaft

2020

Project title: Numerical and Probabilistic Nonlinear Algebra

## Service

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**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



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**Lecture: Statistics for engineers**

*Universität Kassel*

**Lecturer**

11/2020–03/2021

All lectures and exercises are available on  and 

**Lecture: Grundlagen der Algebra und Computeralgebra**

*Universität Kassel*

**Lecturer**

11/2020–03/2021

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

**Seminar: Mathematics for primary school teachers**

*Universität Kassel*

**Lecturer**

11/2020–03/2021

**Lecture: Numerical algebraic geometry with Julia**

*Freie Universität Berlin*

**Lecturer**

09/2019–03/2020

**Seminar: Numerical nonlinear algebra**

*Technische Universität Berlin*

**Lecturer**

04/2019–07/2019

**Lecture: Condition – the geometry of numerical algorithms**

*Max-Planck Institute for Mathematics in the Sciences*

**Lecturer**

10/2018–01/2019

**Mathematik für unbegleitete minderjährige Flüchtlinge**

*Stiftung SPI Berlin*

**Teacher**

03/2016–11/2016

**Statistische Beratung**

*Institut für medizinische Statistik, UMG Göttingen*

**Tutor**

06/2013 – 09/2013

## Organizational experience

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**Workshop on Software and Applications of Numerical Nonlinear Algebra**

*Online workshop*

**Organizer**

06/2021

**Workshop Computational Algebra 2020**

*Online workshop*

**Organizer**

11/2020

**Minisymposium on Random Geometry and Topology**

*SIAM Conference on Applied Algebraic Geometry*

**Organizer**

07/2019

**Minisymposium on Numerical Methods in Algebraic Geometry**

*SIAM Conference on Applied Algebraic Geometry*

**Organizer**

07/2019

**Summer School on Randomness and Learning in Nonlinear Algebra**

*Max-Planck Institute for Mathematics in the Sciences*

**Organizer**

07/2019

**Workshop on Random Algebraic Geometry**

*SISSA*

**Organizer**

11/2018

**Max-Planck Day (Presentation of MPI MiS to a general audience)**

*Munich*

**Organizer**

09/2018

**Summer School on Numerical Computing in Algebraic Geometry**

*Max-Planck Institute for Mathematics in the Sciences*

**Organizer**

08/2018

**Berlin-Leipzig Seminar on Algebra, Geometry and Combinatorics**

*MPI for Mathematics in the Sciences/TU Berlin/FU Berlin*

**Organizer**

10/2017 – 12/2017

**EROC - European Roller Derby Organizational Conference**

*International conference with ~150 participants; topics included diversity and inclusion*

**Organizer**

2016 and 2017



## Publications

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### 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 (to appear)*.
- [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, T. Çelik, T. Duff, A. Heaton, A. Maraj, A. Sattelberger, L. Venturello, and O. Yürük. Nonlinear algebra and applications. *Numerical Algebra, Optimization and Control (to appear)*.
- [8] P. Breiding, H. Keneshlou, and A. Lerario. Quantitative singularity theory for random polynomials. *International Mathematical Research Notices* (2020).
- [9] 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).
- [10] P. Breiding, K. Kozhasov, and A. Lerario. Random spectrahedra. *SIAM J. Optim.* 29(4), 2608–2624 (2019).
- [11] P. Breiding and O. Marigliano. Random points on an algebraic manifold. *SIAM J. Mathematics of Data Science* 2(3), 683–704 (2020).
- [12] P. Breiding, F. Sottile, and J. Woodcock. Euclidean distance degree and mixed volume. *Foundations of Computational Mathematics*, 2021.
- [13] P. Breiding, B. Sturmfels, S. Kalisnik Verovsek, and M. Weinstein. Learning algebraic varieties from samples. *Revista Matemática Complutense*, 31, 545–593 (2018).
- [14] 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.
- [15] P. Breiding and N. Vannieuwenhoven. The condition number of join decompositions. *SIAM J. Matrix Anal. and Appl.*, 39(1), 287–309 (2018).
- [16] P. Breiding and N. Vannieuwenhoven. The condition number of Riemannian approximation problems. *SIAM J. Optim.* 31(1), 1049–1077 (2021).
- [17] 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).
- [18] P. Breiding and N. Vannieuwenhoven. On the average condition number of tensor rank decompositions. *IMA J. Num. Anal.* (2019).
- [19] P. Breiding and N. Vannieuwenhoven. A Riemannian trust region method for the canonical tensor rank approximation problem. *SIAM J. Optim.*, 28, 2435–2465 (2018).

### Software projects.....

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

### Preprints.....

- [21] P. Breiding. An efficient randomized homotopy method to approximate eigenpairs of tensors. *arXiv1512.03284*.
- [22] P. Breiding, N. Dewaele, and N. Vannieuwenhoven. The condition number of many tensor decompositions is invariant under Tucker compression. *arXiv2106.13034*.
- [23] P. Breiding, F. Gesmundo, M. Michalek, and N. Vannieuwenhoven. Algebraic compressed sensing. *arXiv2108.13208*.
- [24] P. Breiding, C. Ikenmeyer, R. Hodges, and M. Michalek. Equations for GL invariant families of polynomials. Preprint available at <http://pcwww.liv.ac.uk/~iken/GL-paper/GL-paper.pdf>.
- [25] P. Breiding, K. Rose, and S. Timme. Certifying zeros of polynomial systems using interval arithmetic. *arXiv:2011.05000*.
- [26] P. Breiding and N. Vannieuwenhoven. Sensitivity of low-rank matrix recovery. *arXiv:2103.00531*.

- Book projects.....
- [27] P. Breiding and A. Lerario. *Lectures on Random Algebraic Geometry*. Unpublished work in progress. Available at <https://pbrdng.github.io/rag.html>.
- Websites.....
- [28] P. Breiding, B. Sturmfels, and S. Timme. [juliahomotopycontinuation.org/do-it-yourself/](http://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.....
- [29] P. Breiding. Zyklotomische Körper und die Fermat–Gleichung zum Exponent  $p^2$ ., 2011. Grade: 1.0. First supervisor: Preda Mihailescu. Second supervisor: Maarten Solleveld.
- [30] 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.
- [31] 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

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

**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.

**Nick Vannieuwenhoven:** nick.vannieuwenhoven@cs.kuleuven.be  
 KU Leuven, Celestijnenlaan 200 A, B-3001 Heverlee, Belgium.