Michael Bleher, Dr.

Institute for Mathematics, Ruprecht-Karls-Universität Heidelberg, Germany.
mbleher@mathi.uni-heidelberg.de
0000-0002-7796-1665
https://michael.bleher.me

Academic Positions

2023–Present **Postdoctoral Researcher**, *Heidelberg University*.

STRUCTURES Cluster of Excellence
Exploratory Project: New Methods for Single Cell Data Analysis – a Promising Future Direction for STRUCTURES?
Prof. Dr. Fred Hamprecht, Prof. Dr. Anna Marciniak-Czochra, Prof. Dr. Anna Wienhard.

ERC Grant 'PErPetuating Stemness: From single-cell analysis to mechanistic spatio-temporal models of neural stem cell dynamics'.
Prof. Dr. Anna Marciniak-Czochra.

Research focus:

- Geometry-preserving embeddings for scRNA-seq data.
- Modeling single cell differentiation dynamics as Hamiltonian systems on low-dimensional manifolds.
- Topological signatures for model selection in stochastic differentiation dynamics.

Education

2017 - 2023 **PhD Physics and Mathematics (Interdisciplinary)**, *Heidelberg University*.
Advisor: Prof. Dr. Johannes Walcher
'Haydys-Witten Instantons and Symplectic Khovanov Homology'

2017 - 2020 **Distinguished Doctoral Fellowship**, *Heidelberg Graduate School of Fundamental Physics*.

2013 - 2016 **M.Sc. Physics**, *Heidelberg University*.
Advisor: Prof. Dr. Johannes Walcher
'A Survey of Defects in $\mathcal{N} = 4$ Supersymmetric Yang-Mills Theory'

2014 - 2015 **Graduate Course**, *University of Durham, UK* (Student Exchange).
M.Sc. in Particles, Strings and Cosmology at the Centre for Particle Theory.

2010 - 2013 **B.Sc. Physics**, *Heidelberg University*.
Advisor: Dr. Werner Rodejohann
'Neutrinoloser Doppelbeta-Zerfall – Untersuchung einer Methode zur Auswahl eines Nuklearen Matrix-Elements'

Publications

12. **Bleher**, **M.** (2025). *The tangled web they weave: Exploring neural networks with directed simplicial complexes* (in preparation).
11. **Bleher**, **M.**, Brazke, D. and Nill, S. (2025). *A Riemannian Autocorrelation Function and its Application to Non-Local Isoperimetric Energies in Pattern Formation* (in preparation).
10. Bodt, C. de, Diaz-Papkovich, A., **Bleher**, **M.**, Bunte, K., Coupette, C., Damrich, S., Sanmartin, E. F., Hamprecht, F. A., Horvát, E.-Á., Kohli, D., Krishnaswamy, S., Lee, J. A., Lelieveldt, B. P. F., McInnes, L., Nabney, I. T., Noichl, M., Poličar, P. G., Rieck, B., Wolf, G., Mishne, G. and Kobak, D. (2025). *Low-Dimensional Embeddings of High-Dimensional Data*. arXiv: 2508.15929 [cs] (preprint).
9. **Bleher**, **M.** (2025). *Adiabatic Solutions of the Haydys-Witten Equations and Symplectic Khovanov Homology*. arXiv: 2501.01365 [math-ph] (to appear in Advances in Theoretical and Mathematical Physics).
8. **Bleher**, **M.** (2024). *A Family of Instanton-Invariants for Four-Manifolds and Their Relation to Khovanov Homology*. arXiv: 2412.13285 [math-ph] (preprint).
7. Bleher, J. and **Bleher**, **M.** (2024). *An Algebraic Framework for the Modeling of Limit Order Books*. arXiv: 2406.04969 [q-fin.TR] (preprint).
6. **Bleher**, **M.** (2023). *Haydys-Witten Instantons and Symplectic Khovanov Homology* PhD thesis, Ruprecht-Karls Universität Heidelberg. DOI: 10.11588/HEIDOK.00034010.
5. **Bleher**, **M.** (2023). *The Decoupled Haydys-Witten Equations and a Weitzenböck Formula*. arXiv: 2307.15056 [math.DG] (preprint).
4. **Bleher**, **M.** (2023). *Growth of the Higgs Field for Kapustin-Witten Solutions on ALE and ALF Gravitational Instantons*. arXiv: 2306.17017 [math.DG] (preprint).
3. Neumann, M., **Bleher**, **M.**, Hahn, L., Braun, S., Obermaier, H., Soysal, M., Caspart, R. and Ott, A. (2022). *MuRiT: Efficient Computation of Pathwise Persistence Barcodes in Multi-Filtered Flag Complexes via Vietoris-Rips Transformations*. arXiv: 2207.03394 [math.AT] (preprint).
2. **Bleher**, **M.**, Hahn, L., Patino-Galindo, J. A., Carriere, M., Bauer, U., Rabadan, R. and Ott, A. (2021). *Topology Identifies Emerging Adaptive Mutations in SARS-CoV-2*. arXiv: 2106.07292 [q-bio.PE] (preprint).
1. Bleher, J., **Bleher**, **M.** and Dimpfl, T. (2020). *From Orders to Prices: A Stochastic Description of the Limit Order Book to Forecast Intraday Returns*. arXiv: 2004.11953 [q-fin.TR] (preprint).

Teaching Experience

2025–present **PhD Co-Supervision**, *Zeynab Razzaghpanah, Heidelberg University*.
Persistence-based optimization of latent representations for time series data.
Main advisor: Zahra Monfared, Dynamical Systems and Artificial Intelligence Group, Heidelberg University.

2022 **Mathematics Refresher for Master Students in Economics**, *Teaching Assistant, Prof. Dr. Thomas Dimpfl, University of Hohenheim* (available on YouTube).

2020–2021 **Helpdesk for First-Year Math Students**, *Teaching Assistant, Heidelberg University*.

2019 **Theoretische Physik IV**, *Teaching Assistant, Prof. Dr. Arthur Hebecker, Heidelberg University*.

2018 **Theoretische Physik I**, *Teaching Assistant, Prof. Dr. Tilman Plehn, Heidelberg University*.

2018 **Höhere Mathematik für Physiker III**, *Teaching Assistant, Prof. Dr. Hans Knüpfer, Heidelberg University*.

2018 **Theoretische Physik II**, *Teaching Assistant, Prof. Dr. Matthias Bartelmann, Heidelberg University*.

2017 **Applied Topology I**, *Teaching Assistant, Prof. Dr. Daniel Roggenkamp, University of Mannheim*.

Scientific Engagement and Outreach

2026 (upcoming) **MATRIX Research Program**, *Applications of Computational Geometry and Topology to Data Analysis of Complex Biological Data. MATRIX Institute, Creswick, Australia* (Invited participant).

2025 **Workshop on Geometry, Topology, and Machine Learning**, *MPI-MiS, Leipzig*.
Co-Organizer, with F. Jensen, L. Maier, D. Taha, A. Wienhard.

2025–present **Persistent Seminar**, *TDA Research Seminar, Heidelberg & MPI of Biochemistry*.
Co-Organizer, with F. Jensen (Heidelberg) and B. Stolz-Pretzer (MPIB).

2024 **Dagstuhl Seminar 24122**, *Low-Dimensional Embeddings of High-Dimensional Data. Schloss Dagstuhl, Germany* (Invited participant).

2024–present **Tea, Coffee, Cake & TDA**, *Invited Speaker Series, Heidelberg University*.
Co-Organizer, with F. Jensen.

2023 **Workshop on Topological Methods in Data Analysis**, *Heidelberg University*.
Co-Organizer, with F. Jensen, V. Noel, A. Marciniak-Czochra.

2021 **Workshop on Topological Methods in Data Analysis**, *Heidelberg University*.
Co-Organizer, with D. Spitz, M. Schmahl, A. Wienhard.

2020 **Workshop on Topological Methods in Data Analysis**, *Heidelberg University*.
Co-Organizer, with D. Spitz, M. Schmahl, A. Wienhard.

2019–2022 **Topics in TDA**, *Journal Club, Heidelberg University*.
Co-Organizer, with F. Jensen, V. Noel, D. Spitz, M. Schmahl, A. Wienhard.

Research Blog, *Notes on TDA, geometric ML, and mathematical physics*.
subthaumic.substack.com

Software Development

markovmodus **Markov-modulated unspliced/spliced count simulator**, *Python package*.
Generate snapshot datasets where a hidden state graph (the support of a continuous-time generator) modulates single cell unspliced->spliced RNA dynamics.
https://github.com/subthaumic/markovmodus
https://pypi.org/project/markovmodus/

gNE **geometric Neighbour Embeddings**, *Python package*.
https://github.com/subthaumic/gne.

MuRiT **Multiparameter Rips Transform**, *Go standalone*.
A Ripser add-on for exploration of persistence in multi-filtered metric spaces.
https://github.com/tdalife/murit

Presentations

17. *The Tangled Web They Weave – Exploring Neural Networks with Directed Topology*. ATMCS 12, Leipzig (upcoming). 26th Jan. 2026.
16. *Population Dynamics, scRNA-seq Data, and the Euler Characteristic Profile*. PEPS Seminar Heidelberg, 30th Oct. 2025.
15. *Haydys-Witten Instantons and the Gauge Theoretic Approach to Khovanov Homology*. Rutgers Gauge Theory Seminar, (invited talk). 14th Oct. 2025.
14. *The Tangled Web They Weave – Exploring Neural Networks with Directed Topology*. Geometric Realization of the AATRN, Chicago (poster). 19th Aug. 2025.
13. *The Tangled Web They Weave – Exploring Neural Networks with Directed Topology*. Young Topologists Meeting 2025, Stockholm (contributed talk). 25th June 2025.
12. *Harmonic Persistent Homology*. Persistent Seminar, Heidelberg. 28th May 2025.
11. *Persistence and Coarse-Graining in Dynamical Biological Systems*. TDA Symposium at MPI-MCG, Dresden (invited talk). 12th Dec. 2024.
10. *Fast Computation of Pathwise Persistence in Pandemic-Scale SARS-CoV-2 Genome Data*. 4th Workshop on Computational Persistence, TU Graz. 23rd Sept. 2024.
9. *Haydys-Witten Instantons and the Gauge Theoretic Approach to Khovanov Homology*. Gauge Theory and Mathematical Physics Seminar, Morningside Center of Mathematics, Beijing (invited talk). 3rd July 2024.
8. *RNA Velocity Embeddings in Curved Spaces - Exploring Cellular Dynamics*. Seminar 24122, Dagstuhl. 20th Mar. 2024.
7. *On Haydys-Witten Instantons and the Gauge Theoretic Approach to Khovanov Homology*. HU Gauge Theory Research Seminar, Berlin (invited talk). 31st Jan. 2024.
6. *Haydys-Witten Instantons in the Gauge Theoretic Approach to Khovanov Homology*. ULB Geometry Seminar, Brussels (invited talk). 4th Dec. 2023.
5. *Topological Signatures of Convergence in Viral Evolution*. CompTopNN Meeting 2023, Sevilla (invited talk). 8th Nov. 2023.
4. *Feature Representation of scRNA Data in Symmetric Spaces*. Structures Symposium, Heidelberg (poster). 20th July 2023.
3. *Persistent Homology Detects Emerging Adaptive Mutations*. TDA Journal Club, Heidelberg. 7th June 2021.
2. *Welcome Notes and an Introduction to Mapper*. Heidelberg TDA Workshop 2020, Heidelberg (organizer). 26th Oct. 2020.
1. *Nahm Pole Boundary Conditions and Lagrangian Intersection Floer Homology*. Quantum Fields, Knots, and Strings, Warsaw (poster). 2018.