

Sven Heydenreich

Research interests

Topological deep learning, persistent and zigzag homology applied to neural-network representations, AI interpretability via geometric and topological methods. Background in algebraic topology and applied topological data analysis.

Academic work experience

- since 2026 **Postdoctoral researcher in AI interpretability**, Area Science Park, Trieste, PI: Dr. Matteo Biagetti.
Topological deep learning; sheaf cohomology as an interpretability tool; zigzag persistence on token-level LLM embedding trajectories for performance analysis and prompt-injection detection.
- 2022–2026 **Postdoctoral researcher in Astrophysics**, University of California, Santa Cruz, PI: Prof. Dr. Alexie Leauthaud.
High-dimensional cosmological inference combining spectroscopic, imaging and CMB surveys; large-collaboration data analysis (DESI).
- 2017–2018 **Research Internship**, *Quasar microlensing for primordial black hole abundance constraints*, Instituto de Astrofísica de Canarias, Supervisor: Prof. Dr. Evencio Mediavilla.

Education

- 2019–2022 **Ph.D. in Astrophysics**, *Thesis: “Higher-order statistics in cosmic shear”*; developed persistent-homology pipelines for cosmological inference, yielding the first cosmological parameter constraints derived from persistent homology, Rheinische Friedrich-Wilhelms-Universität Bonn, Supervisor: Prof. Dr. Peter Schneider.
Summa cum laude; finalist for the Ph.D. prize of the University of Bonn.
- 2016–2019 **M.Sc. in Astrophysics**, *Thesis: “The effects of varying depth in cosmic shear surveys”*, Rheinische Friedrich-Wilhelms-Universität Bonn, Supervisor: Prof. Dr. Peter Schneider.
Grade 1.1 with distinction.
- 2014–2016 **M.Sc. in Mathematics**, *Thesis: “Wall’s finiteness criterion F_n for groups” (algebraic topology, geometric group theory)*, Westfälische Wilhelms-Universität Münster, Supervisor: Prof. Dr. Johannes Ebert.
Grade 1.0 with distinction.
- 2011–2014 **B.Sc. in Mathematics**, *Thesis: “Geometrical aspects of Kepler’s two-body problem” (differential geometry)*, Westfälische Wilhelms-Universität Münster, Supervisor: Prof. Dr. Peter Albers.
Grade 1.2 with distinction.

Qualifications

Programming

Python (incl. JAX, TensorFlow, gudhi), CUDA C++, C++, C, Bash, Mathematica, git, Java, Fortran.

Languages

English **fluent**

TOEFL iBT 2016: 119/120

German **native**

Spanish **elementary**

Erasmus OLA: A2

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Scholarships, awards & service

- 2013–2022 **Scholarship** — German Academic Scholarship Foundation (Studienstiftung des deutschen Volkes).
- 2022 **Award** — Finalist, Ph.D. prize of the University of Bonn (best thesis of the year).
- since 2024 **Service** — Chair, DESI-Lensing working group; coordinating the key-project analysis combining DESI with weak-lensing surveys
- since 2024 **Referee** — JCAP, Open Journal of Astrophysics, MNRAS.
- since 2018 **Collaboration memberships** — DESI, Euclid Consortium, Dark Energy Science Collaboration, Kilo-Degree Survey, German Centre for Cosmological Lensing, Bonn-Cologne Graduate School.
- 2014–2022 **Teaching** — Tutor in mathematics and astrophysics at U. Münster and U. Bonn; weekly tutorials, exercise-sheet design and grading, exam preparation.

Selected publications

This list highlights publications most relevant to topological data analysis and methodological work in cosmological inference. A complete and up-to-date list (currently 40+ co-authored papers in DESI, Euclid, KiDS, and DES collaborations) is available on the NASA ADS author search.

Topological data analysis in Machine Learning

1. Biagetti, M., Carrière, M., Conti, F., Ferrari, E. M., **Heydenreich, S.**, Viswanathan, K. *TopoFisher: Learning Topological Summary Statistics by Maximizing Fisher Information*. Submitted (2026). arXiv:2605.07720

Topological data analysis in cosmology

1. **Heydenreich, S.**, Brück, B., Burger, P., Harnois-Déraps, J., et al. *Persistent homology in cosmic shear. II. A tomographic analysis of DES-Y1* (the first cosmological parameter constraints derived from persistent homology) A&A 667, A125 (2022). arXiv:2204.11831
2. **Heydenreich, S.**, Brück, B., Harnois-Déraps, J. *Persistent homology in cosmic shear: constraining parameters with topological data analysis*. A&A 648, A74 (2021). arXiv:2007.13724
3. Harnois-Déraps, J., **Heydenreich, S.**, Giblin, B., Martinet, N., et al. *KiDS-1000 and DES-Y1 combined: cosmology from peak count statistics*. MNRAS 534, 3305 (2024). arXiv:2405.10312
4. Euclid Collaboration: Ajani, V., Baldi, M., . . . , **Heydenreich, S.**, et al. *Euclid preparation. XXVIII. Forecasts for ten different higher-order weak-lensing statistics*. A&A 675, A120 (2023). arXiv:2301.12890

Selected first-author work in cosmology

1. **Heydenreich, S.**, Leauthaud, A., Blake, C., Sun, Z., Lange, J. U., et al. *Lensing Without Borders: Galaxy-galaxy lensing and projected galaxy clustering in DESI DR1*. Submitted (2025). arXiv:2506.21677
2. **Heydenreich, S.**, Leauthaud, A., DeRose, J. *Can dynamic dark energy explain the S_8 tension, the ‘lensing is low’ effect, or strong baryon feedback?* Submitted (2025). arXiv:2508.05746
3. **Heydenreich, S.**, Linke, L., Burger, P., Schneider, P. *A roadmap to cosmological parameter analysis with third-order shear statistics. I. Modelling and validation*. A&A 672, A44 (2023). arXiv:2208.11686
4. **Heydenreich, S.**, Schneider, P., Hildebrandt, H., Asgari, M., Heymans, C., et al. *The effects of varying depth in cosmic shear surveys*. A&A 634, A104 (2020). arXiv:1910.11327
5. **Heydenreich, S.** & Linke, L. *threepoint: Covariance of third-order aperture statistics*. Astrophysics Source Code Library, ascl:2306.054 (2023). [Software]