Nathaniel Bottman

CONTACT INFORMATION

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PROFESSIONAL APPOINTMENTS

CEO and Principal Scientist, Incubilate, Seattle, WA, July 2025–.

Research Group Leader and Advanced Researcher (W2 position), Max Planck Institute for Mathematics, Bonn, Germany, January 2021–June 2025.

Assistant Professor (postdoctoral position), University of Southern California, Los Angeles, CA, August 2019–December 2020.

Member, Institute for Advanced Study, Princeton, NJ, 2016–2019

Postdoctoral Research Fellow, Princeton University, Princeton, NJ, 2016–2019

Instructor, Northeastern University, Boston, MA, 2015–2016

INTERESTS

Applications of mathematics to deep learning

EDUCATION

Massachusetts Institute of Technology, Cambridge, MA
Ph.D., Mathematics, September 2015, advised by Katrin Wehrheim

University of Washington, Seattle, WA
B.S., Mathematics, B.A., Slavic Languages and Literatures, June 2010

GRANTS

Grant titled "An Operad-Based Framework for Deep Learning" via **DARPA's AIQ Program**, $836K, 2025–.

National Science Foundation Standard Grant DMS-1906220, *Relating Fukaya Categories Using Combinatorics, Operads, and Nonlinear Elliptic Partial Differential Equations*, $144K, 2019–22.

HONORS AND AWARDS

National Science Foundation Mathematical Sciences Postdoctoral Research Fellowship, 2016–2019
National Science Foundation Graduate Research Fellowship, 2010–2015
University of Washington Dean's Medal, 2010 (given to the top senior in the natural sciences)

MACHINE LEARNING PAPERS

21. Operadic consistency: a label-free signal for compositional reasoning failures in LLMs. Nathaniel Bottman, Yinhong Liu, Kyle Richardson. Preprint available at https://arxiv.org/abs/2606.13649.

20. Operads for compositional reasoning in LLMs. Nathaniel Bottman, Kyle Richardson. Preprint available at https://arxiv.org/abs/2606.13634. Presented at the Compositional Learning and the Combining Theory and Benchmarks workshops at ICML 2026.

SYMPLECTIC GEOMETRY PAPERS
(= undergraduate mentee, * = postdoctoral mentee.)*

19. Foundations of $(A_\infty, 2)$-categories: from flow to linear. Nathaniel Bottman, Katrin Wehrheim. Submitted.

18. Adiabatic Fredholm theory. Nathaniel Bottman, Katrin Wehrheim. Preprint, 74pp.

17. The focus-focus addition graph is immersed. Mohammed Abouzaid, Nathaniel Bottman, Yunpeng Niu. Preprint, 13pp.

16. Higher-categorical associahedra. Spencer Backman, Nathaniel Bottman, Daria Poliakova**. Preprint, 143pp.

15. Functoriality in categorical symplectic geometry. Mohammed Abouzaid, Nathaniel Bottman. *Bull. Amer. Math. Soc.* 61 (2024), no. 4, 525–608.

14. Constrainahedra. Nathaniel Bottman and Daria Poliakova**. Submitted.

13. A compactification of the space of marked vertical lines in $\mathbb{C}^2$. Nathaniel Bottman, Alexei Oblomkov. Revising in response to referee report at *Advances in Mathematics*.

12. The 2-associahedra are Eulerian. Nathaniel Bottman, Dylan Mavrides*. Accepted (2022), Ezra Getzler Festschrift.

11. A simplicial version of the 2-dimensional Fulton–MacPherson operad. Nathaniel Bottman. *Algebr. Geom. Topol.* 24 (2024), 1183–1202.

10. Explicit constructions of quilts with seam condition coming from symplectic reduction. Nathaniel Bottman. *Kyoto J. Math.* 62 (2022), no. 1, 151–162.

9. $(A_\infty, 2)$-categories and relative 2-operads. Nathaniel Bottman, Shachar Carmeli. *Higher Structures* 5 (2021), no. 1, 401–421.

8. Pseudoholomorphic quilts with figure eight singularity. Nathaniel Bottman. *J. Symplectic Geom.* 18 (2020), no. 1, 1–55.

7. Moduli spaces of witch curves topologically realize the 2-associahedra. Nathaniel Bottman. *J. Symplectic Geom.* 17 (2019), no. 6, 1649–1682.

6. 2-associahedra. Nathaniel Bottman. *Algebr. Geom. Topol.* 19 (2019), no. 2, 743–806.

5. Gromov compactness for squiggly strip shrinking in pseudoholomorphic quilts. Nathaniel Bottman, Katrin Wehrheim. *Selecta Mathematica* (2018) 24, pp. 3381–3443.

Applied math papers

4. How regularization affects the geometry of loss functions. Nathaniel Bottman, Yaim Cooper, Antonio Lerario. 16pp. Submitted.

3. A comparison of group testing architectures for COVID-19 testing. Joshua Batson, Nathaniel Bottman, Yaim Cooper, Felix Janda. Preprint available at `https://arxiv.org/abs/2005.03051`. 19pp.

2. Elliptic solutions of the defocusing NLS equation are stable. Nathaniel Bottman, Bernard Deconinck, Michael Nivala. *J. Phys. A* 44 (2011), no. 28, 24 pp.

1. KdV cnoidal waves are spectrally stable. Nathaniel Bottman, Bernard Deconinck. *Discrete Contin. Dyn. Syst.* 25 (2009), no. 4, 1163–1180.

Service

Member of the MPIM Gender Equality Task Force, early 2023–June 2025. Developed and helped put into place a new Gender Equality Plan.

Member of the MPIM Scientific Committee, late 2020–June 2025. Met 2–3 times annually in order to make hiring decisions at MPIM.

Activities mentored

Mentor, with Mohammed Abouzaid, of the first European Kylerec Workshop, held in Oppdal, Norway, in March 2025. Under our guidance, a group of masters students, PhD students, and young postdocs spent a week living communally in a mountain cabin and learning about the topic, "Lagrangian Correspondences and Quilts".

Activities organized

Co-organized the Combining Theory and Benchmarks Workshop at ICML 2026, Seoul, South Korea, July 2026.

Co-organized (with Grigori Avramidi, Tobias Barthel, Viktoriya Ozornova, Arunima Ray, and Peter Teichner) the MPIM Topology Seminar, Fall 2023–June 2025.

Co-organized (with Laurent Côté) the Bonn Symplectic Geometry Seminar, Fall 2023–June 2025.

Co-organized (with Mohammed Abouzaid, Catherine Cannizzo, Sheel Ganatra, and Kyler Siegel) the Western Hemisphere Virtual Symplectic Seminar (a weekly event which presented one or two talks per week), Spring 2020–Spring 2023.

Co-organized (with Sheel Ganatra, Alexei Oblomkov, and Abigail Ward) a Special Session on Quantum Structures in Mirror Symmetry at the 2022 Joint Mathematical Meetings in Seattle, WA.

Co-organized (with Sheel Ganatra) the USC Symplectic Geometry and Floer Theory Reading Group, Fall 2019.

Co-organized the IAS/Princeton Symplectic Geometry Seminar, Fall 2016–Spring 2019.

Co-organized the RTG Workshop on Polyfold Theory towards the Fukaya Category at UC Berkeley in June 2017. With Joel Fish and Katrin Wehrheim, arranged a weeklong workshop where ∼30 graduate students, postdocs, and professors learned about the new technology of polyfolds. Helped to launch a wiki compendium of polyfolds knowledge, now hosted at `http://polyfolds.org`.

Co-organized a Special Session on Moduli Spaces in Symplectic Geometry at the 2016 Joint Mathematical Meetings in Seattle, WA.

Co-organized the GPRT Seminar at Northeastern during 2015–16.

Co-organized the 2013 MIT-RTG Geometry Workshop in Big Bear Lake, CA. Arranged a weeklong workshop where 30 graduate students and postdocs lectured on mirror symmetry.

Co-organized the 2012 MIT-RTG Geometry Workshop in Watsonville, CA: a weeklong workshop where 35 graduate students and postdocs learned about polyfolds, under Helmut Hofer's supervision.

Invited talks

CAST Conference, University of Grenoble, February 2025.

Combinatorics Seminar, University of Frankfurt, November 2024.

Colloquium, University of Hamburg, June 2024.

Symplectic Geometry Seminar, ETH Zürich, May 2024.

Quantum Mathematics Seminar, University of Southern Denmark, March 2024.

University of Grenoble Topology Seminar, December 2023.

University of Vermont Topology and Combinatorics Seminar, September 2023.

Symplectix Seminar, Paris, February 2023.

Introductory workshop, MSRI semester on Floer homotopy theory, Fall 2022.

Mini-course, PIMS Summer School on Floer Homotopy Theory, UBC, Summer 2022.

Topology Seminar, Max Planck Institute for Mathematics, Spring 2022.

Talk + mini-course, Ezra Getzler's birthday conference, Northwestern University, Spring 2022.

Mirror symmetry seminar, Boston University, Spring 2022.

Topology Seminar, University of Notre Dame, Fall 2021.

Symplectic Geometry Seminar, University of Illinois, Fall 2021.

Topology Seminar, University of Minnesota, Fall 2021.

Topology Seminar, EPFL, Fall 2021.

Peter Teichner's Topology Seminar, Max Planck Institute for Mathematics, March 2021.

Geometry Seminar, University of Southern California, November 2020.

"Operad Pop-up" workshop, online event, August 2020.

Workshop entitled "Structural aspects of Fukaya categories," Harvard University, May 2020. (Cancelled due to COVID-19.)

Geometry Seminar, University of Georgia, Spring 2020. (Postponed due to COVID-19.)

Topology Seminar, Northeastern Universiy, Spring 2020.

Workshop entitled "Recent developments in Lagrangian Floer theory," Simons Center for Geometry and Physics, March 2020.

Southern California Algebraic Geometry Seminar, UC San Diego, February 2020.

Ezra Getzler's seminar, Northwestern University, January 2020.

Combinatorics Seminar, University of Southern California, January 2020.

Special Colloquium, University of British Columbia, December 2019.

Special Colloquium, Max Planck Institute for Mathematics, December 2019.

Special Colloquium, University of Southern California, December 2019.

Joint Los Angeles Topology Seminar, UCLA, November 2019.

Algebra and Geometry Seminar, Caltech, October 2019.

Discrete Geometry and Combinatorics Seminar, Cornell University, September 2019.

Valley Geometry Seminar, University of Massachusetts, Amherst, September 2019.

Topology Seminar, University of Indiana, March 2019.

Symplectic Geometry Seminar, Stony Brook University, March 2019.

Symplectic Geometry, Gauge Theory, and Categorification Seminar, Columbia, February 2019.

Combinatorics Seminar, University of Washington, February 2019.

Topology Seminar, UC Berkeley, November 2018.

AMS Sectional Meeting, Northeastern University, April 2018

Master Lecture Series Workshop on Dusa McDuff's works, Tsinghua Sanya International Mathematics Forum, December 2017 (could not accept invitation)

Deformation Theory Seminar, University of Pennsylvania, December 2017

RTG Workshop on Polyfold Theory towards the Fukaya Category, UC Berkeley, June 2017

Mirror Symmetry Seminar, Kansas State University, March 2017

Members Seminar, Institute for Advanced Study, December 2016

Deformation Theory Seminar, University of Pennsylvania, February 2016

Quantum Fields and String Seminar, Perimeter Institute, Spring 2016

Jonathan Weitsman's Seminar, Northeastern University, December 2015

Mathematics Colloquium, University of Massachusetts, Boston, November 2015

Summer School on Moduli Problems in Symplectic Geometry, IHES, July 2015

Columbia Symplectic Geometry, Gauge Theory, and Categorification Seminar, April 2015

Rutgers Geometry, Symmetry, and Physics Seminar, March 2015

AMS Sectional Meeting, Michigan State University, March 2015

Northeastern University Analysis and Geometry Seminar, January 2015

Harvard Gauge Theory Seminar, October 2014

S. T. Yau's Seminar, Harvard University, October 2014

Workshop on Moduli Spaces of Pseudo-holomorphic Curves II, Simons Center, June 2014

Northern California Symplectic Geometry Seminar, Stanford University, March 2014

University of Texas Geometry Seminar, February 2014

Teaching

Instructor, Math 114 (foundations of statistics), USC, Fall 2020.

Instructor, Math 226 (multivariable calculus), USC, Fall 2020.

Instructor, Math 245 (ODEs for engineers), USC, Spring 2020

Instructor, Math 226 (multivariable calculus), USC, Fall 2019

Instructor, Math 5122 (graduate course on manifolds), Northeastern University, Spring 2016

Instructor, Math 2321 (multivariable calculus for engineers), Northeastern University, Fall 2015

Recitation instructor, 18.01A/02A (single- and multivariable calculus), MIT, Fall 2013

Postdocs supervised

Yao Xiao, Fall 2024–Fall 2025, Max Planck Institute for Mathematics

Chi Hong Chow, Fall 2024–Fall 2025, Max Planck Institute for Mathematics

Nicholas Wilkins, Fall 2023–Fall 2024, Max Planck Institute for Mathematics

Yash Deshmukh, Fall 2023–Spring 2024, Max Planck Institute for Mathematics

Daria Poliakova, Spring 2022, Max Planck Institute for Mathematics

Jie Min, Fall 2021–Spring 2022, Max Planck Institute for Mathematics

Masters theses supervised

Stefano Rocca, "Functorial aspects of homological mirror symmetry", Max Planck Institute for Mathematics, to be submitted February 2025.

Undergraduate theses supervised

Leonard Weismantel, "Building a computer package for manipulating 2-associahedra", Max Planck Institute for Mathematics, submitted August 2023.

Dylan Mavrides, "2-associahedra are Eulerian posets", Princeton University, submitted Spring 2019.