

Moon Duchin

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Mathematics · STS · Tisch College of Civic Life | Tufts University

Education

University of Chicago Mathematics Advisor: Alex Eskin	MS 1999, PhD 2005 <i>Dissertation: Geodesics track random walks in Teichmüller space</i>
Harvard University Mathematics and Women's Studies	BA 1998

Appointments

Tufts University Professor of Mathematics Assistant Professor, Associate Professor	2021— 2011–2021
<i>Principal Investigator</i> MGGG Redistricting Lab	2017—
<i>Senior Fellow</i> Jonathan M. Tisch College of Civic Life	2017—
<i>Director</i> Program in Science, Technology, & Society	2015–2021
University of Michigan Assistant Professor (postdoctoral)	2008–2011
University of California, Davis NSF VIGRE Postdoctoral Fellow	2005–2008

Research Interests

Data science for civil rights, computation and governance, elections, geometry and redistricting.
Science, technology, and society, science policy, census data, technology and law, algorithmic fairness.
Random walks and Markov chains, random groups, random constructions in geometry.
Large-scale geometry, metric geometry, isoperimetric inequalities.
Geometric group theory, growth of groups, nilpotent groups, dynamics of group actions.
Geometric topology, hyperbolicity, Teichmüller theory.

Selected Awards & Distinctions

Research Professor - MSRI Program in Analysis and Geometry of Random Spaces	Spring 2022
Guggenheim Fellow	2018
Radcliffe Fellow - Evelyn Green Davis Fellowship	2018–2019
Fellow of the American Mathematical Society	elected 2017
NSF C-ACCEL (PI) - Harnessing the Data Revolution: Network science of Census data	2019–2020
NSF grants (PI) - CAREER grant and three standard Topology grants	2009–2022
Professor of the Year , Tufts Math Society	2012–2013
AAUW Dissertation Fellowship	2004–2005
NSF Graduate Fellowship	1998–2002
Lawrence and Josephine Graves Prize for Excellence in Teaching (U Chicago)	2002
Robert Fletcher Rogers Prize (Harvard Mathematics)	1995–1996

Political Geometry: Rethinking Redistricting in the U.S. with Math, Law, and Everything In Between

25 chapters, 475 pages. Birkhäuser Books 2022. Preprint online. (eds. Moon Duchin, Olivia Walch)
see: Introduction, Compactness, Communities of Interest, Clustering, Random Walks, Ranked Choice Voting.

Blind Justice: Algorithms and neutrality in the case of redistricting

Proceedings of 2nd ACM Symposium on Computer Science and Law (CS&Law), to appear 2022. (with Doug Spencer)

Aggregating Community Maps

Submitted. (with Erin Chambers, Ranthony Edmonds, Parker Edwards, JN Matthews, Anthony Pizzimenti, Chanel Richardson, Parker Rule, and Ari Stern)

Private numbers in public policy: Census, differential privacy, and redistricting

Harvard Data Science Review, Special Issue 2, June 2022. Online. (with Aloni Cohen, JN Matthews, and Bhushan Suwal)

The (homological) persistence of gerrymandering

Foundations of Data Science, to appear 2022. Online first. (with Thomas Needham and Thomas Weighill)

Implementing partisan symmetry: Problems and paradoxes

Political Analysis, to appear 2022. arXiv:2008.06930
(with Daryl DeFord, Natasha Dhamankar, Mackenzie McPike, Gabe Schoenbach, and Ki-Wan Sim)

Measuring segregation via analysis on graphs

SIAM Journal on Matrix Analysis and Apps., to appear 2022. arXiv:2212.10708 (with James Murphy and Thomas Weighill)

Ranked choice voting and proportional representation

Submitted. Online. (with Gerdus Benade, Ruth Buck, Dara Gold, and Thomas Weighill)

A reversible recombination chain for graph partitions

Preprint. (with Sarah Cannon, Dana Randall, and Parker Rule)

Clustering propensity: Segregation in networks

Preprint. (with Emilia Alvarez, Everett Meike, and Marshall Mueller; appendix by Tyler Piazza)

Discrete geometry for electoral geography

Preprint. (with Bridget Eileen Tenner) arXiv:1808.05860

Recombination: A family of Markov chains for redistricting

Harvard Data Science Review. Issue 3.1, Winter 2021. Online. (with Daryl DeFord and Justin Solomon)

Census TopDown: The impact of differential privacy on redistricting

2nd Symposium on Foundations of Responsible Computing (FORC 2021), 5:1–5:22. Available online.
(with Aloni Cohen, JN Matthews, and Bhushan Suwal)

Models, Race, and the Law

Yale Law Journal Forum, Vol. 130 (March 2021). Available online. (with Doug Spencer)

Computational Redistricting and the Voting Rights Act

Election Law Journal, Volume 20, Number 4 (2021), 407–441. Available online.
(with Amariah Becker, Dara Gold, and Sam Hirsch)

Mathematics of nested districts: The case of Alaska

Statistics and Public Policy. Vol 7, No 1 (2020), 39–51. (w/ Sophia Caldera, Daryl DeFord, Sam Gutekunst, & Cara Nix)

A computational approach to measuring vote elasticity and competitiveness

Statistics and Public Policy. Vol 7, No 1 (2020), 69–86. (with Daryl DeFord and Justin Solomon)

Locating the representational baseline: Republicans in Massachusetts

Election Law Journal, Volume 18, Number 4, 2019, 388–401.
(with Taissa Gladkova, Eugene Henninger-Voss, Ben Klingensmith, Heather Newman, and Hannah Wheelen)

Redistricting reform in Virginia: Districting criteria in context

Virginia Policy Review, Volume XII, Issue II, Spring 2019, 120–146. (with Daryl DeFord)

Geometry v. Gerrymandering

The Best Writing on Mathematics 2019, ed. Mircea Pitici. Princeton University Press.
reprinted from *Scientific American*, November 2018, 48–53.

Gerrymandering metrics: How to measure? What's the baseline?

Bulletin of the American Academy for Arts and Sciences, Vol. LXII, No. 2 (Winter 2018), 54–58.

Rebooting the mathematics of gerrymandering: How can geometry track with our political values?

The Conversation (online magazine), October 2017. (with Peter Levine)

A formula goes to court: Partisan gerrymandering and the efficiency gap

Notices of the American Mathematical Society **64** No. 9 (2017), 1020–1024. (with Mira Bernstein)

International mobility and U.S. mathematics

Notices of the American Mathematical Society **64**, No. 7 (2017), 682–683.

Pure Mathematics Publications & Preprints

Conjugation curvature for Cayley graphs

Journal of Topology and Analysis, Vol 14, Number 02 (2022), 439–459. (with Assaf Bar-Natan and Robert Kropholler)

You can hear the shape of a billiard table: Symbolic dynamics and rigidity for flat surfaces

Commentarii Mathematici Helvetici, Vol 96, Issue 3 (2021), 421–463. Available online.
(with Viveka Erlandsson, Christopher Leininger, and Chandrika Sadanand)

Stars at infinity in Teichmüller space

Geometriae Dedicata, Volume 213, 531–545 (2021). (with Nate Fisher) arXiv:2004.04321

The Heisenberg group is pan-rational

Advances in Mathematics **346** (2019), 219–263. (with Michael Shapiro)

Random nilpotent groups I

International Mathematics Research Notices, Vol. 2018, Issue 7 (2018), 1921–1953.
(with Matthew Cordes, Yen Duong, Meng-Che Ho, and Ayla Sánchez)

Hyperbolic groups

chapter in *Office Hours with a Geometric Group Theorist*, eds. M.Clay, D.Margalit, Princeton U Press (2017), 177–203.

Counting in groups: Fine asymptotic geometry

Notices of the American Mathematical Society **63**, No. 8 (2016), 871–874.

A sharper threshold for random groups at density one-half

Groups, Geometry, and Dynamics **10**, No. 3 (2016), 985–1005.
(with Katarzyna Jankiewicz, Shelby Kilmer, Samuel Lelièvre, John M. Mackay, and Ayla Sánchez)

Equations in nilpotent groups

Proceedings of the American Mathematical Society **143** (2015), 4723–4731. (with Hao Liang and Michael Shapiro)

Statistical hyperbolicity in Teichmüller space

Geometric and Functional Analysis, Volume 24, Issue 3 (2014), 748–795. (with Howard Masur and Spencer Dowdall)

Fine asymptotic geometry of the Heisenberg group

Indiana University Mathematics Journal **63** No. 3 (2014), 885–916. (with Christopher Mooney)

Pushing fillings in right-angled Artin groups

Journal of the LMS, Vol 87, Issue 3 (2013), 663–688. (with Aaron Abrams, Noel Brady, Pallavi Dani, and Robert Young)

Spheres in the curve complex

In the Tradition of Ahlfors and Bers VI, Contemp. Math. **590** (2013), 1–8. (with Howard Masur and Spencer Dowdall)

The sprawl conjecture for convex bodies

Experimental Mathematics, Volume 22, Issue 2 (2013), 113–122. (with Samuel Lelièvre and Christopher Mooney)

Filling loops at infinity in the mapping class group

Michigan Math. J., Vol 61, Issue 4 (2012), 867–874. (with Aaron Abrams, Noel Brady, Pallavi Dani, and Robert Young)

The geometry of spheres in free abelian groups

Geometriae Dedicata, Volume 161, Issue 1 (2012), 169–187. (with Samuel Lelièvre and Christopher Mooney)

Statistical hyperbolicity in groups

Algebraic and Geometric Topology **12** (2012) 1–18. (with Samuel Lelièvre and Christopher Mooney)

Length spectra and degeneration of flat metrics

Inventiones Mathematicae, Volume 182, Issue 2 (2010), 231–277. (with Christopher Leininger and Kasra Rafi)

Divergence of geodesics in Teichmüller space and the mapping class group

Geometric and Functional Analysis, Volume 19, Issue 3 (2009), 722–742. (with Kasra Rafi)

Curvature, stretchiness, and dynamics

In the Tradition of Ahlfors and Bers IV, Contemp. Math. **432** (2007), 19–30.

Geodesics track random walks in Teichmüller space

PhD Dissertation, University of Chicago 2005.

Teaching

Courses Developed or Customized

Mathematics of Social Choice | sites.tufts.edu/socialchoice

Voting theory, impossibility theorems, redistricting, theory of representative democracy, metrics of fairness.

Have designed and taught variants at entry level and at math-major level.

History of Mathematics | sites.tufts.edu/histmath

Social history of mathematics, organized around episodes from antiquity to present. Themes include materials and technologies of creation and dissemination, axioms, authority, credibility, and professionalization. In-depth treatment of mathematical content from numeration to cardinal arithmetic to Galois theory.

Reading Lab: Mathematical Models in Social Context | sites.tufts.edu/models

One hr/wk discussion seminar of short but close reading on topics in mathematical modeling, including history of psychometrics; algorithmic bias; philosophy of statistics; problems of model explanation and interpretation.

Reading Lab: Classification | sites.tufts.edu/classification

One hr/wk discussion seminar of short but close reading on topics in classifications and taxonomies, including censuses; race and ethnicity; academic disciplines, mathematical and legal definition; chemical elements; species and model organisms; sex and gender.

Geometric Literacy

Module-based graduate topics course. Modules have included: p -adic numbers, hyperbolic geometry, nilpotent geometry, Lie groups, convex geometry and analysis, the complex of curves, ergodic theory, the Gauss circle problem.

Markov Chains (graduate topics course)

Teichmüller Theory (graduate topics course)

Fuchsian Groups (graduate topics course)

Continued Fractions and Geometric Coding (undergraduate topics course)

Mathematics for Elementary School Teachers (inquiry-based course for pre-service teachers)

Standard Courses

Mathematical Modeling and Computation (with Python), Discrete Mathematics, Calculus I-II-III, Intro to Proofs, Linear Algebra, Complex Analysis, Differential Geometry, Abstract Algebra, Graduate Real Analysis

Selected Talks and Lectures

AMS Einstein Public Lecture in Mathematics Central Sectional Meeting of the AMS, Omaha, NE	October 2023
Distinguished Plenary Lecture 75th Anniversary Meeting of Canadian Mathematical Society, Ottawa, Ontario	June 2021 <i>online (COVID)</i>
BMC/BAMC Public Lecture Joint British Mathematics/Applied Mathematics Colloquium, Glasgow, Scotland	April 2021 <i>online (COVID)</i>
Radcliffe Fellow Lecture Radcliffe Institute for Advanced Study, Cambridge, MA	November 2018
Gerald and Judith Porter Public Lecture AMS-MAA-SIAM, Joint Mathematics Meetings, San Diego, CA	January 2018
Mathematical Association of America Distinguished Lecture MAA Carriage House, Washington, DC	October 2016
American Mathematical Society Invited Address AMS Eastern Sectional Meeting, Brunswick, ME	September 2016

Named University Lectures

- Loeb Lectures in Mathematics Washington University in St. Louis	April 2022
- Mathematics and Natural Sciences Divisional Lecture Reed College	March 2022
- Parsons Lecture UNC Asheville	October 2020
- Math, Stats, CS, and Society Macalester College	October 2019
- MRC Public Lecture Stanford University	May 2019
- Freedman Memorial Colloquium Boston University	March 2019
- Julian Clancy Frazier Colloquium Lecture U.S. Naval Academy	January 2019
- Barnett Lecture University of Cincinnati	October 2018
- School of Science Colloquium Series The College of New Jersey	March 2018
- Kieval Lecture Cornell University	February 2018
- G. Milton Wing Lectures University of Rochester	October 2017
- Norman Johnson Lecture Wheaton College	September 2017
- Dan E. Christie Lecture Bowdoin College	September 2017

Math/Computer Science Department Colloquia

- UC Berkeley	Apr 2022	- Worcester Polytechnic Inst.	Dec 2016
- Reed College	Dec 2020	- Université de Neuchâtel	Jun 2016
- Georgetown (CS)	Sept 2020	- Brandeis University	Mar 2016
- Santa Fe Institute	July 2020	- Swarthmore College	Oct 2015
- Univ of Illinois - Chicago	Oct 2019	- Bowling Green	May 2015
- UC Berkeley	Sept 2018	- City College of New York	Feb 2015
- Brandeis-Harvard-MIT-NEU	Mar 2018	- Indiana University	Nov 2014
- Northwestern University	Oct 2017	- the Technion	Oct 2014
- University of Illinois	Sept 2017	- Wisconsin-Madison	Sept 2014
- University of Utah	Aug 2017	- Stony Brook	March 2013
- Wesleyan	Dec 2016		

Minicourses

- Integer programming and combinatorial optimization (two talks) | Georgia Tech May 2021
- Workshop in geometric topology (main speaker, three talks) | Provo, UT June 2017
- Growth in groups (two talks) | MSRI, Berkeley, CA August 2016
- Hyperbolicity in Teichmüller space (three talks) | Université de Grenoble May 2016
- Counting and growth (four talks) | IAS Women's Program, Princeton May 2016

Visiting Lectures

- Election Law | Yale Law School Spring 2022
- Election Law | Harvard Law School Spring 2022
- Privacy, Policy, and the U.S. Census | University of Chicago (CS) Spring 2022
- Optimized Democracy | Harvard (CS) Spring 2021, 2022

Science, Technology, and Society

- The Mathematics of Accountability | Sawyer Seminar, Anthropology, Johns Hopkins February 2020
- STS Circle | Harvard Kennedy School of Government September 2019
- Data, Classification, and Everyday Life Symposium | Rutgers Center for Cultural Analysis January 2019
- Science Studies Colloquium | UC San Diego January 2019
- Arthur Miller Lecture on Science and Ethics | MIT Program in Science, Tech, and Society November 2018

Data Science, Computer Science, Quantitative Social Science

- Can Algorithms Bend the Arc Towards Fairness? | Algorithmic Justice Project, UNM/SFI March 2022
- Data Linkage Seminar | Massive Data Institute, McCourt School of Public Policy August 2021
- Mechanism Design for Social Good (MD4SG) Colloquium | MD4SG Initiative November 2020
- Data Science for Social Good (DS4SG) Workshop | Georgia Tech November 2020
- Privacy Tools Project Retreat | Harvard May 2020
- Women in Data Science Conference | Microsoft Research New England March 2020
- Quantitative Research Methods Workshop | Yale Center for the Study of American Politics February 2020
- Societal Concerns in Algorithms and Data Analysis | Weizmann Institute December 2018
- Quantitative Collaborative | University of Virginia March 2018
- Quantitative Social Science | Dartmouth College September 2017
- Data for Black Lives Conference | MIT November 2017

Political Science, Geography, Law, Democracy, Fairness

- The Long 19th Amendment: Women, Voting, and American Democracy | Radcliffe Institute Nov–Dec 2020
- "The New Math" for Civil Rights | Social Justice Speaker Series, Davidson College November 2020
- Math, Law, and Racial Fairness | Justice Speaker Series, University of South Carolina November 2020
- Voting Rights Conference | Northeastern Public Interest Law Program September 2020
- Political Analysis Workshop | Indiana University November 2019
- Program in Public Law Panel | Duke Law School October 2019
- Redistricting 2021 Seminar | University of Chicago Institute of Politics May 2019
- Geography of Redistricting Conference Keynote | Harvard Center for Geographic Analysis May 2019
- Political Analytics Conference | Harvard University November 2018
- Cyber Security, Law, and Society Alliance | Boston University September 2018
- Clough Center for the Study of Constitutional Democracy | Boston College November 2017
- Tech/Law Colloquium Series | Cornell Tech November 2017
- Constitution Day Lecture | Rockefeller Center for Public Policy, Dartmouth College September 2017

Program Development

Principal Investigator MGGG Redistricting Lab mggg.org

Multidisciplinary research lab with postdocs, research staff, and undergraduate researchers drawn from mathematics, computer science, software development, geography, policy. Hosts law student externs. Provided public mapping support for roughly 100 localities after 2020 Census data released.

Support includes NSF Convergence Accelerator, Sloan Foundation, Thornburg Foundation, Arnold Foundation.

Co-Founder, Program Director Science, Technology, and Society Program sts.tufts.edu

Interdisciplinary program offering a major and minor, with ~40 affiliated faculty. Runs popular weekly lunch seminar, Reading Labs on topics from Automation to Representation to Life to Energy.

Organizer

Semester Program in *Algorithms, Fairness, and Equity*, Fall 2023

Mathematical Sciences Research Institute, Berkeley CA

Program will host ~50 research members on topics connected to mechanism design, fair partitioning, and fair ML.

Short workshops and training programs

- GeoData Bootcamp 2020 (2 weeks, 20 students from around the country)
- Mapping Training 2020 (1 week, 30 students from around the country)
- Graphs and Networks Workshop 2020 (1 day, 500 live participants)
- Data for Election Administration 2019, 2021 (multi-day, dozens of administrators and scholars)

Program Building Research and mentorship programs

- Voting Rights Data Institute 2018, 2019
Six-week summer research programs hosting 52 and 33 undergraduate and graduate students, respectively, with dozens of visitors from math, CS, law, political science, geography, urban planning, and more.
- Polygonal Billiards Research Cluster 2017, Random Groups Research Cluster 2014
Five-week intensive summer research programs for vertically integrated groups of 12-14 undergraduate, graduate, postdoctoral, and junior faculty researchers, combining experimental and theoretical work.
- Directed Reading Program and DRP Network sites.google.com/view/drp-network/
Co-founded highly successful near-peer mentoring program in 2003 at UChicago. Now exists at >40 math departments as grad-student-run reading program with excellent outcomes for broadening participation in mathematics. Secured NSF grant to expand the program to more campuses and to fund social science research on outcomes.

Graduate Advising in Mathematics

Nate Fisher (PhD 2021), Sunrose Shrestha (PhD 2020), Ayla Sánchez (PhD 2017),
Kevin Buckles (PhD 2015), Mai Mansouri (MS 2014)

Outside committee member for Chris Coscia (PhD 2020), Dartmouth College

Postdoctoral Advising in Mathematics

Principal supervisor Thomas Weighill (2019–2020)

Co-supervisor Daryl DeFord (MIT 2018–2020), Rob Kropholler (2017–2020), Hao Liang (2013–2016)

Selected Professional Service and Public-Facing Work

Program committees and editorial boards

ACM Conference on Fairness, Accountability, and Computing (FAccT)	2022
Symposium on Foundations of Responsible Computing (FORC)	2021
Harvard Data Science Review	since 2019
Advances in Mathematics	since 2018

Committee on Science Policy

American Mathematical Society	2020–2022
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Amicus Brief of Mathematicians, Law Professors, and Students

<i>principal co-authors: Guy-Uriel Charles and Moon Duchin</i>	2019
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Supreme Court of the United States, in *Rucho v. Common Cause* - cited in dissent

Expert work for redistricting litigation

<i>reports, deposition, and/or trial testimony</i>	2018—
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Wisconsin, North Carolina, Alabama, Pennsylvania, South Carolina, Texas

Johnson v. Wis. Elections Comm'n, No. 2021AP1450-OA, 2022 WL 621082 (Wis. Mar. 3, 2022); *NC League of Conservation Voters, et al. v. Hall, et al.* No. 21-cvs-500085 (Wake Cnty. Sup. Ct. 2021); *Milligan, et al. v. Merrill, et al.*, Case No. 2:21-cv-01530-AMM and *Thomas, et al. v. Merrill, et al.*, Case No. 2:21-cv-01531-AMM (N.D. Ala. 2021); *Carter v. Chapman*, No. 7 MM 2022, 2022 WL 702894 (Pa. Mar. 9, 2022); *SC NAACP et al. v. Alexander, et al.*, Case No. 3-21-cv-03302-MBS-TJH-RMG (D.S.C.) (three-judge ct.); *TX NAACP et al. v. Abbott*, Case No. 1:21-CV-00943-RP-JES-JVB.

Presenter on Public Mapping, Statistical Modeling

National Conference of State Legislatures	2019, 2020
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Committee on The Future of Voting: Accessible, Reliable, Verifiable Technology

National Academies of Science, Engineering, and Medicine	2017–2018
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Committee on the Human Rights of Mathematicians

American Mathematical Society	2016–2019
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Selected Visiting Positions and Residential Fellowships

Research Professor Analysis and Geometry of Random Spaces program Mathematical Sciences Research Institute Berkeley, CA	Spring 2022
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Visiting Professor Department of Mathematics Boston College Chestnut Hill, MA	Fall 2021
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Fellow Radcliffe Institute for Advanced Study Harvard University Cambridge, MA	2018–19
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Member Center of Mathematical Sciences and Applications Harvard University Cambridge, MA	2018–19
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Visitor Microsoft Research MSR New England Cambridge, MA	2018–19
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Research Member Geometric Group Theory program Mathematical Sciences Research Institute Berkeley, CA	Fall 2016
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Research Member Random Walks and Asymptotic Geometry of Groups program Institut Henri Poincaré Paris, France	Spring 2014
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