

Alex Townsend
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Research resume

Numerical analysis, scientific computing, and theoretical aspects of deep learning. My research focuses on spectral methods, low rank approximation, the mathematics of deep learning, and polynomial system solving.

Education

DPhil in Numerical Analysis University of Oxford Oct 2010 – July 2014

Supervised by Prof. L. N. Trefethen FRS
Thesis title: *Computing with functions in two dimensions*

MMath Mathematics University of Oxford Oct 2006 – July 2010

Awarded 1st class degree (ranked 2nd in the year)

Professional experience

Associate Professor Cornell University Feb 2022 – Present

Taught MATH 2210: Linear algebra

Assistant Professor Cornell University July 2016 – Jan 2022

Taught MATH 2220: Multivariable calculus
MATH 2930: Differential equations for engineers
MATH 2940: Linear algebra for engineers
MATH 4250: Numerical analysis and ODEs
[MATH 7270: Top-ten algorithms of the 20th century](#)
MATH 6220: Applied functional analysis

Applied Math Instructor MIT Aug 2014 – June 2016

Taught 18.336: Fast Numerical methods for PDEs
18.085: Computational Science and Engineering
18.06: Linear Algebra

Adjunct Instructor Courant Institute Sept 2013 – Oct 2013

Tutored: Approximation Theory and Approximation Practice

Honors and prizes

- [SIGEST award from SIAM Review](#) for “The singular values of matrices with displacement structure” in 2019
- Junior Faculty Teaching Award from Cornell Math Department in 2018
- [The SIAM Activity Group on Linear Algebra Early Career Prize in 2018](#)
- [Leslie Fox prize \(1st place\)](#) for work on the discrete Hankel transform in 2015
- [Leslie Fox prize \(2nd place\)](#) for work on the ultraspherical spectral method in 2013
- SIAM UKIE prize for the best student research talk in 2011
- Junior Mathematics Prize in 2008 and 2009, and IMA prize in 2009 and 2010. Awarded through the University of Oxford for top undergraduate examination results

Research and curriculum grants

- US DoE grant with LLNL: Jan. 2023 to July 2023.
- Simons Fellowship in Mathematics: July 2022 to July 2022.
- US DoE grant with LBNL: Sept. 2021 to Aug. 2022.
- [NSF CAREER DMS-2045646](#) (sole PI): July 2021 to June 2026.
- NSF DMS-1952757 (lead PI): July 2020 to June 2023.
- Data Science Curriculum Initiative grant (lead PI): Sept. 2019 to Sept. 2021.
- FACE Foundation (lead PI): Sept. 2019 to Aug. 2021.
- [NSF DMS-1818757](#) (sole PI): June 2018 to July 2021.
- [Engaged Cornell curriculum grant](#) (lead PI): Sept. 2018 to Aug. 2020.
- [NSF DMS-1645445](#) (sole PI): Aug. 2015 to July 2018.

Current graduate students

[Diana Halikias](#) (Math graduate student, due to graduate in May 2025)
[Phuong Mai Huynh Pham](#) (CAM graduate student, due to graduate in May 2027)
[Christopher Wang](#) (Math graduate student, due to graduate in May 2027)
[Annan Yu](#) (CAM graduate student, due to graduate in May 2026)
[Jennifer Zvonek](#) (CAM graduate student, due to graduate in May 2025)

Past graduate students

[Nicolas Boule](#) (DPhil at University of Oxford in Mathematics, jointly supervised with Patrick Farrell, graduated August 2022. Now a postdoc at Cambridge University.)
[Marc Gilles](#) (CAM graduate student, graduated May 2019. Now postdoc at Princeton.)
[Andrew Horning](#) (CAM graduate student, graduated in August 2021. Now Applied Instructor at MIT.)
[Dan Fortunato](#) (Harvard graduate student in SEAS, jointly supervised with Chris Rycroft, graduated August 2020. Now at Simons Institute in NYC.)
[Tianyi Shi](#) (CAM graduate student, graduated in May 2022. Now at LBNL.)
[Heather Wilber](#) (Cornell graduate student, graduated in May 2021. Now NSF postdoc at UT Austin.)

Other past students

- Jane Du (MSc student in CS in 2019-2020. Now, graduate student at UIUC.)
Diego Antolin–Ruiz (Cornell intern in 2016. Now, lecturer in Spain.)
David Darrow (MIT PRIMES student in 2018. Now, undergraduate at MIT.)
Sujit Rao (Cornell undergraduate, mentored in 2018. Now, graduate at MIT)
Xingrun Xing (Intern from Shanghai Jiao Tong University in 2019)
[Aaron Yeiser](#) (MIT PRIMES student in 2017. Now, undergraduate at MIT.)

Journal publications

- [48] N. BOULLÉ, S. KIM, T. SHI, AND A. TOWNSEND, *Learning Green's functions associated with parabolic partial differential equations*, to appear in J. Mach. Learn. Res., 2022.
- [47] M. KASSABOV, S. H. STROGATZ, AND A. TOWNSEND, *A global synchronization theorem for oscillators on a random graph*, to appear in Chaos, 2022.
- [46] D. RUBIN, A. TOWNSEND, AND H. WILBER, *Bounding Zolotarev numbers using Faber rational functions*, Constr. Approx., pp. 1-26.
- [45] N. BOULLÉ, C. J. EARLS, AND A. TOWNSEND, *Data-driven discovery of physical laws with human-understandable deep learning*, Scientific Reports, 12 (2022), pp. 1–9.
- [44] N. BOULLÉ AND A. TOWNSEND, *A generalization of the randomized singular value decomposition*, ICLR 2022.
- [43] H. WILBER, A. DAMLE, AND A. TOWNSEND, *Data-driven Algorithms for signal processing with rational functions*, SIAM J. Sci. Comput., 2022.
- [42] N. BOULLE AND A. TOWNSEND, *Learning elliptic partial differential equations with randomized linear algebra*, Found. Comput. Math., 2022.
- [41] G. LI, A. TOWNSEND, L. A. ARCHER, AND D. L. KOCH, *Suppression of electroconvective and morphological instabilities by an imposed cross flow of the electrolyte*, Phys. Rev. J., 6.3 (2021), 033701.
- [40] G. LI, A. TOWNSEND, L. A. ARCHER, AND D. L. KOCH, *Electroconvection and Electrodeposition on a Surface with Butler–Volmer Kinetics*, J. Fluid Mechanics, 930 (2022).
- [39] Y. YANG, A. TOWNSEND, AND D. APPELÖ, *Anderson acceleration using the \mathcal{H}^{-s} norm*, J. Comput. Appl. Math., 403 (2022), 113844.
- [38] M. KASSABOV, S. H. STROGATZ, AND A. TOWNSEND, *Sufficiently dense Kuramoto networks are globally synchronizing*, Chaos, 31 (2021), 073135.
- [37] M. J. COLBROOK, A. HORNING, AND A. TOWNSEND, *Computing spectral measures of self-adjoint operators*, SIAM Review, 63 (2021), pp. 489–524.
- [36] D. FORTUNATO, N. HALE, AND A. TOWNSEND, *The ultraspherical spectral element method*, J. Comput. Phys., 436 (2021), 110087.
- [35] T. SHI AND A. TOWNSEND, *On the compressibility of tensors*, SIAM J. Mat. Anal. Appl., 42 (2021), pp. 275–298.
- [34] N. BOULLÉ, Y. NAKATSUKASA, AND A. TOWNSEND, *Rational neural networks*, NeurIPS, 33 (2020).
- [33] Y. NAKATSUKASA AND A. TOWNSEND, *Error localization of best L_1 polynomial approximants*, SIAM J. Numer. Anal., 2020.

- [32] A. TOWNSEND, M. STILLMAN, AND S. H. STROGATZ, *Dense networks that do not synchronize and sparse ones that do*, *Chaos*, 30 (2020), 083142.
- [31] N. BOULLE AND A. TOWNSEND, *Computing with functions on the ball*, *SIAM J. Sci. Comput.*, 42 (2020), C169–C191.
- [30] A. HORNING AND A. TOWNSEND, *FEAST for differential eigenvalue problems*, *SIAM J. Numer. Anal.*, 58 (2020), pp. 1239–1262.
- [29] S. OLVER, A. TOWNSEND, AND G. M. VASIL, *Recurrence relations for a family of orthogonal polynomials on a triangle*, *ICOSAHOM Proceedings*, Springer 2020, pp. 79–92.
- [28] D. FORTUNATO AND A. TOWNSEND, *Fast Poisson solvers for spectral methods*, *IMA Numer. Anal.*, 40 (2020), pp. 1994–2018.
- [27] S. OLVER, A. TOWNSEND, AND G. VASIL, *A sparse spectral method on triangles*, *SIAM J. Sci. Comput.*, 41 (2019), A3728–3756.
- [26] K. N. QUINN, H. WILBER, A. TOWNSEND, AND J. P. SETHNA, *Chebyshev approximation and the global geometry of sloppy models*, *Physical Review Letters*, 122, 158302.
- [25] M. A. GILLES AND A. TOWNSEND, *Continuous analogues of Krylov methods for differential operators*, *SIAM J. Numer. Anal.*, 57 (2019), pp. 899–924.
- [24] B. BECKERMANN AND A. TOWNSEND, *Bounds on the singular values of matrices with displacement structure*, *SIAM Review*, 61 (2019), pp. 319–344.
- [23] M. UDELL AND A. TOWNSEND, *Why are big data matrices approximately of low rank?*, *SIAM J. Math. Data Sci.*, 1 (2019), pp. 144–160.
- [22] J. SŁOMKA, A. TOWNSEND, AND J. DUNKEL, *Stokes’ second problem and an Einstein-de Haas analogue effect in active fluids*, *Physical Review Fluids*, 3 (2018).
- [21] A. TOWNSEND AND H. WILBER, *On the singular values of matrices with high displacement rank*, *Linear Alg. Appl.*, 548 (2018), pp. 19–41.
- [20] D. ANTOLN–RUIZ AND A. TOWNSEND, *A nonuniform fast Fourier transform based on low rank approximation*, *SIAM J. Sci. Comput.*, 40 (2018), A529–A547.
- [19] A. TOWNSEND, M. WEBB, AND S. OLVER, *Fast polynomial transforms based on Toeplitz and Hankel matrices*, *Math. Comp.*, 87, (2018).
- [18] B. BECKERMANN AND A. TOWNSEND, *On the singular values of matrices with displacement structure*, *SIAM J. Mat. Anal. Appl.*, 38 (2017), pp. 1227–1248.
- [17] A. TOWNSEND, H. WILBER, AND G. B. WRIGHT, *Computing with functions in spherical and polar geometries II. The disk*, *SIAM J. Sci. Comput.*, 39 (2017), C238–C262.
- [16] L. DEMANET AND A. TOWNSEND, *Stable extrapolation of analytic functions*, *Found. Comput. Math.*, (2016), pp. 1–35.
- [15] V. NOFERINI, Y. NAKATSUKASA, AND A. TOWNSEND, *Vector spaces of linearizations for matrix polynomials: A bivariate polynomial approach*, *SIAM J. Mat. Anal. Appl.*, 38 (2016), pp. 1–29.
- [14] N. HALE AND A. TOWNSEND, *A fast FFT-based discrete Legendre transform*, *IMA Numer. Anal.*, 36 (2016), pp. 1670–1684.
- [13] A. TOWNSEND, H. WILBER, AND G. B. WRIGHT, *Computing with functions in spherical and polar geometries I. The sphere*, *SIAM J. Sci. Comput.*, 38 (2016), C403–C425.

- [12] V. NOFERINI AND A. TOWNSEND, *Numerical instability of resultant methods for multidimensional rootfinding*, SIAM J. Numer. Anal., 54 (2016), pp. 719–743.
- [11] A. TOWNSEND, T. TROGDON, AND S. OLVER, *Fast computation of Gauss quadrature nodes and weights on the whole real line*, IMA Numer. Anal., 36 (2016), pp. 337–358.
- [10] A. TOWNSEND AND S. OLVER, *The automatic solution of partial differential equations using a global spectral method*, J. Comp. Phys., 299 (2015), pp. 106–123.
- [9] A. TOWNSEND, *A fast analysis-based discrete Hankel transform using asymptotic formulas*, SIAM J. Numer. Anal., 53 (2015), pp. 1897–1917.
- [8] Y. NAKATSUKASA, V. NOFERINI, AND A. TOWNSEND, *Computing the common zeros of two bivariate functions via Bézout resultants*, Numer. Math., 129 (2015), pp. 181–209.
- [7] A. TOWNSEND AND L. N. TREFETHEN, *Continuous analogues of matrix factorizations*, Proc. Roy. Soc. A., 471 (2015).
- [6] N. HALE AND A. TOWNSEND, *An algorithm for the convolution of Legendre series*, SIAM J. Sci. Comput., 36 (2014), A1207–A1220.
- [5] N. HALE AND A. TOWNSEND, *A fast, simple, and stable Chebyshev–Legendre transform using an asymptotic formula*, SIAM J. Sci. Comput., 36 (2014), A148–A167.
- [4] A. TOWNSEND AND L. N. TREFETHEN, *An extension of Chebfun to two dimensions*, SIAM J. Sci. Comput., 35 (2013), C495–C518.
- [3] N. HALE AND A. TOWNSEND, *Fast and accurate computation of Gauss–Legendre and Gauss–Jacobi quadrature nodes and weights*, SIAM J. Sci. Comput., 35 (2013), A652–A672.
- [2] S. OLVER AND A. TOWNSEND, *A fast and well-conditioned spectral method*, SIAM Review, 55 (2013), pp. 462–489.
- [1] A. TOWNSEND AND H. WENDLAND, *Multiscale analysis in Sobolev spaces on bounded domains with zero boundary values*, IMA J. Numer. Anal., 33 (2013), pp. 1095–1114.

Submitted papers, conference proceedings, and technical reports

- A. YU, Y. YANG, AND A. TOWNSEND, *A Quadrature Perspective on Frequency Bias in Neural Network Training with Nonuniform Data*, submitted to NeurIPs, 2022.
- M. LIPTON, S. STROGATZ, AND A. TOWNSEND, *Zeros of the electric field around a charged knot*, submitted to Phys. Rev. Res., 2022.
- A. YU AND A. TOWNSEND, *On the stability of unevenly spaced samples for interpolation and quadrature*, submitted to BIT Numer. Math.
- M. J. COLBROOK AND A. TOWNSEND, *Rigorous data-driven computation of spectral properties of Koopman operators for dynamical systems*, submitted to Comm. Pure Appl. Math.
- T. SHI, M. RUTH, AND A. TOWNSEND, *Parallel algorithms for computing the tensor-train decomposition*, submitted to SIAM J. Sci. Comput.
- A. YU, C. BECQUEY, D. HALIKIAS, M. E. MALLORY, AND A. TOWNSEND, *Arbitrary-depth universal approximation theorems for operator neural networks*, submitted to Neural Computations.
- S. OLVER AND A. TOWNSEND, *A practical framework for infinite-dimensional linear algebra*, First Workshop for High Performance Technical Computing in Dynamic Languages, in IEEE conference proceedings, 2014.

Other articles

- A. TOWNSEND, *A review of “Orthogonal Polynomials in MATLAB” by Gautschi*, SIAM Review, 59 (2017), pp. 463–464.
- A. TOWNSEND, *A review of “A Graduate Introduction to Numerical Methods” by Corless and Fillion*, SIAM Review, 58 (2016), pp. 795–798.
- A. TOWNSEND, *The race for high order Gauss–Legendre quadrature*, SIAM News, March 2015.
- A. TOWNSEND AND L. N. TREFETHEN, *Gaussian elimination as an iterative algorithm*, SIAM News, March 2013.

Presentations at conferences and workshops (since 2018)

Talk at Daniel Szyld’s 65th birthday conference in Temple	March 2022
2020 Canadian Mathematical Society Winter Meeting, online	December 2020
SIAM Mathematical Data Science, online	June 2020
ICIAM2019 in Valencia	July 2019
29th Biennial Numerical Analysis conference in Strathclyde	June 2019
Approximation Theory 16, Nashville	May 2019
Software and Mathematics of spectral methods, London	July 2018

Invited presentations (since 2018)

Householder 2022 plenary talk in Bari	June 2022
NASC Seminar in Manchester (invited by Marcus Webb)	May 2022
Numerical Analysis seminar at Imperial (invited by Sheehan Olver)	May 2022
Colorado Boulder’s Applied Math Colloquium (online)	April 2022
DACO seminar in ETH Zurich (invited by Afonso Banderia)	March 2022
E-seminar for SciML (invited by Benjamin Erichson)	February 2022
Applied Math Colloquium at UW Madison (invited by Qin Li)	February 2022
SCAN seminar, online (invited by Anil Damle)	January 2022
LLNL’s data science seminar, online (invited by Keith Brendan)	October 2021
NPS’s AM seminar, online (invited by Anthony Austin)	April 2021
Cornell’s CAM Colloquium, online (invited by David Bindel)	March 2021
Columbia Applied Math colloquium, online (invited by Qiang Du)	March 2021
MIT math colloquium, online (invited by Peter Shor)	March 2021
Manitoba math colloquium, online (invited by Shaun Lui)	February 2021
Maryland Applied Math talk, online (invited by Maria Cameron)	January 2021
Data Science seminar at Purdue, online (invited by Haizhao Yang)	January 2021
JMM keynote talk, online (invited by Maria Cameron)	January 2021
University of Washington, AMATH, online (invited by Thomas Trogdon)	January 2021
PNWNAS, online	October 2020
Michigan, AIM seminar, online	October 2020
CTAC2020 plenary talk, online	September 2020

Berkeley, Applied Math Colloquium (invited by Lin Lin)	September 2020
Householder 2020 plenary talk (postponed)	June 2020
University of Oxford, NA seminar (invited by Nick Trefethen)	May 2020
CRM, University of Montreal (invited by Jean-Philippe Lessard)	April 2020
Isaac Newton Institute at Cambridge University	December 2019
UW Madison, Colloquium (invited by Qin Li)	October 2019
Rensselaer Polytechnic Institute, Keynote talk for RPI day	May 2019
UT Austin, Colloquium (invited by Gunnar Martinsson)	April 2019
Princeton University, Colloquium (invited by Amit Singer)	February 2019
NII in Tokyo (invited by Yuji Nakatsukasa)	December 2018
ICOSAHOM 2018, plenary speaker	July 2018
BYU (invited by Tyler Jarvis)	April 2018
Courant Institute, Applied Math seminar (invited by Michael Overton)	April 2018
MIT student Engineering symposium, keynote speaker	March 2018

Professional activities

Referee for numerous journals, including SIAM Review, CPAM, SINUM, SIMAX, SISC, JCOMP, and Numerische Mathematik. Also referee for SIAM Books and Cambridge University Press.

Judging panel for National Science Foundation grant proposals in 2016, 2017, 2019, and 2021.

Co-organize an [undergraduate math modeling competition](#) at Cornell with engagement from the local community and businesses. Lead PI on [Engaged Cornell curriculum grant](#) and the lead PI on the data science curriculum initiative in Arts & Sciences at Cornell University. Co-organized REU programs in the summer of 2020 and 2021.

Part of an Active Learning Initiative for linear algebra, developing materials to help students engage with the curriculum. The chair of the Engineering Liaison committee, helping to organize the teaching of large engineering classes in calculus, linear algebra, and differential equations. Member of the Diversity Committee in the Mathematics Department.

Math consultant for the two episodes of PBS infinite series [“Why Computers are Bad at Algebra”](#) and [“How to Generate Pseudorandom Numbers”](#).

Co-organizer for an [online numerical linear algebra seminar \(e-NLA\) seminar](#) with 1400 participants. Also, co-organizer for an [online discussion seminar \(CMC seminar\)](#) between numerical linear algebra and theoretical computer science with 600 participants.