

Alex H. Barnett

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Born: 7th December, 1972
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RESEARCH FOCUS

- Numerical analysis, scientific computing, computational partial differential equations: Helmholtz equation, particularly high frequency and/or high accuracy; eigenvalue, wave scattering and periodic problems, photonic crystals; corner singularities, high-order methods, integral equations; heat equation.
- Mathematical physics: quantum chaos and ergodicity, Laplacian eigenfunctions, scarring, billiards.
- Applied mathematics: mathematical ecology (animal home range modeling), inverse problems in imaging (diffuse optical tomography), mathematics of music.

EDUCATION

Harvard University. Ph. D. in Physics: *Dissipation in Deforming Chaotic Billiards* October 2000
Thesis advisor: Eric J. Heller

Cambridge University, England. B. A. (*First class*) in Theoretical Physics June 1994
Undergraduate thesis advisor: David J. C. MacKay

POSITIONS

Associate Professor. 2011–present
Department of Mathematics, Dartmouth College, NH

Assistant Professor. 2005–2011
Department of Mathematics, Dartmouth College, NH

Courant Instructor / Assistant Professor. 2002–2005
Courant Institute of Mathematical Sciences, New York University, NY

Postdoctoral Research Fellow. February–August 2002
Photon Migration Imaging Laboratory, Dept. of Radiology, Harvard Medical School, Charlestown, MA

Head Teaching Fellow. January–June 2001
Department of Physics, Harvard University, Cambridge, MA

Consultant. November–December 2000
TrueWind Solutions LLC, Lowell, MA

Teaching Fellow. 1994–1999
Department of Physics, Harvard University, Cambridge, MA

FELLOWSHIPS AND AWARDS

- *Elizabeth R. and Robert A. Jeffe 1972 Fellowship*, Dartmouth College 2011
- *Karen E. Wetterhahn Memorial Award for Distinguished Creative or Scholarly Achievement*, Dartmouth College 2011
- *Burke Initiation Award*, Dartmouth College 2011
- *National Science Foundation, Grant DMS-1005360*, co-PI, award amount \$42,355 2010
Funding support for *International Conference on Spectral Geometry*
- *The Class of 1962 Faculty Fellowship*, Dartmouth College 2010

- *National Science Foundation, Grant DMS-0811005*, PI, award amount \$310,517 2008–2011
“Efficient spectrally accurate global basis methods for high frequency wave scattering, eigenmodes, and photonics”
- *National Science Foundation, Grant DMS-0507614*, PI, award amount \$102,520 2005–2008
“High frequency cavity eigenmodes: rapid computation methods, applications and asymptotics”
- *Courant Instructorship*, New York University 2002–2005
- *Harvard University Certificate of Distinction in Teaching* Fall 1997, Spring 2001 and Fall 2001
- *Harold T White Prizes*, teaching introductory physics, Harvard Physics Department 1996 and 1997
- *Kennedy Scholarship*, Kennedy Memorial Trust, London 1994
- *Hockin Prize, Duchess of Somerset Scholarships*, St John’s College, Cambridge 1993 and 1994
- *XXI International Physics Olympiad, First Prize* of 155 entrants, Groningen, The Netherlands 1990

PUBLICATIONS

- [20] “Fast computation of high frequency Dirichlet eigenmodes via the spectral flow of the interior Neumann-to-Dirichlet map,” A. H. Barnett and A. Hassell, [arxiv:1112.5665](https://arxiv.org/abs/1112.5665), 48 pages, *submitted*, *Comm. Pure Appl. Math.* (2012)
- [19] “Boundary quasi-orthogonality and sharp inclusion bounds for large Dirichlet eigenvalues,” A. H. Barnett and A. Hassell, *SIAM J. Numer. Anal.* **49**, 1046–1063 (2011)
- [18] “A new integral representation for quasi-periodic scattering problems in two dimensions,” A. H. Barnett and L. Greengard, *BIT Numer. Math.* **51**, 67–90 (2011)
- [17] “A few more words about James Tenney: dissonant counterpoint and statistical feedback,” L. Polansky, A. H. Barnett, and M. Winter, *J. Math. Music*, **5** (2), 63–82 (2011)
- [16] “A new integral representation for quasi-periodic fields and its application to two-dimensional band structure calculations,” A. H. Barnett and L. Greengard, *J. Comput. Phys.*, **229** (19), 6898–6914 (2010)
- [15] “An exponentially convergent nonpolynomial finite element method for time-harmonic scattering from polygons,” A. H. Barnett and T. Betcke, *SIAM J. Sci. Comp.* **32** (3), 1417–1441 (2010)
- [14] “Perturbative analysis of the Method of Particular Solutions for improved inclusion of high-lying Dirichlet eigenvalues,” A. H. Barnett, *SIAM J. Numer. Anal.* **47**, 1952–1970 (2009)
- [13] “Stability and convergence of the Method of Fundamental Solutions for Helmholtz problems on analytic domains,” A. H. Barnett and T. Betcke, *J. Comput. Phys.* **227** (14), 7003–7026 (2008)
- [12] “Analytic steady-state space use patterns and rapid computations in mechanistic home range analysis,” A. H. Barnett and P. R. Moorcroft, *J. Math. Biol.* **57** (1), 139–159 (2008)
- [11] “Quantum mushroom billiards,” A. H. Barnett and T. Betcke, *CHAOS* **17**, 043125, 13 pages (2007)
- [10] “Mechanistic home range models and resource selection analysis: a reconciliation and unification,” P. R. Moorcroft and A. H. Barnett, *Ecology* **89** (4), 1112–1119 (2008)
- [9] “Asymptotic rate of quantum ergodicity in chaotic Euclidean billiards,” A. H. Barnett, *Comm. Pure Appl. Math.* **59**, 1457–1488 (2006)
- [8] “Effective scattering coefficient of the cerebral spinal fluid in adult head models for Diffuse Optical Imaging”, A. Custo, W. M. Wells III, A. H. Barnett, E. M. C. Hillman, and D. A. Boas, *Applied Optics* **45**, 4747–55 (2006)
- [7] “A fast numerical method for time-resolved photon diffusion in general stratified turbid media,” A. H. Barnett, *J. Comput. Phys.* **201**, 771–797 (2004)
- [6] “Robust inference of baseline optical properties of the human head with 3D segmentation from magnetic resonance imaging,” A. H. Barnett, J. P. Culver, A. G. Sorensen, A. M. Dale, and D. A. Boas, *Applied Optics* **42**, 3095–3108 (2003)

- [5] “Parametric evolution for a deformed cavity,” D. Cohen, A. H. Barnett, and E. J. Heller, *Phys. Rev. E* **63**, 046207, 12 pages (2001)
- [4] “Mesoscopic scattering in the half-plane: squeezing conductance through a small hole,” A. H. Barnett, M. Blaauboer, A. Mody, and E. J. Heller, *Phys. Rev. B* **63**, 245312/1 (2001)
- [3] “Rate of energy absorption for a driven chaotic cavity,” A. H. Barnett, D. Cohen, and E. J. Heller, *J. Phys. A* **34**, 413–437 (2001)
- [2] “Deformations and dilations of chaotic billiards: dissipation rate, and quasi-orthogonality of the boundary wavefunctions,” A. H. Barnett, D. Cohen, and E. J. Heller, *Phys. Rev. Lett.* **85**, 1412–15 (2000)
- [1] “Substrate-based atom waveguide using guided two-color evanescent light fields,” A. H. Barnett, S. P. Smith, M. Olshanii, K. S. Johnson, A. W. Adams, M. Prentiss, *Phys. Rev. A* **61**, 023608, 11 pages (2000)

Conference proceedings, technical reports:

“Estimates on Neumann eigenfunctions at the boundary, and the ‘Method of Particular Solutions’ for computing them,” A. Hassell and A. H. Barnett, *to appear, Spectral Geometry* (P. S. P. M. proceedings of the International Conference on Spectral Geometry, July 2010, Dartmouth College) (submitted Mar 2011)

“Robust high-order numerical scattering from multi-layer dielectric gratings using a new integral representation for quasi-periodic fields,” A. H. Barnett and L. Greengard, *extended abstract*, WAVES2011 The 10th International Conference on Mathematical and Numerical Aspects of Wave Propagation (4 pages).

“Tensor product of kernel models,” O. de la Cruz, A. H. Barnett, H. Tang, and S. Holmes, *NIPS extended abstract*, 4 pages (2010).

“Accurate and robust computation of photonic crystal band structure using second-kind integral equations,” A. H. Barnett and L. Greengard, *extended abstract*, Proceedings of WAVES2009: The 9th International Conference on Mathematical and Numerical Aspects of Wave Propagation, 2 pages (2009).

“Quasi-orthogonality on the boundary for Euclidean Laplace eigenfunctions,” A. H. Barnett, *preprint*, [math-ph/0601006](http://arxiv.org), available at <http://arxiv.org>, 21 pages (2004).

“Bayesian estimation of optical properties of the human head via 3D structural MRI,” A. H. Barnett, J. P. Culver, A. G. Sorensen, A. M. Dale, and D. A. Boas, *Proc. SPIE* **5138**, 9 pages (2003)

“Bayesian Comparison of Models for Images,” A. H. Barnett and D. J. C. MacKay, in *Maximum Entropy and Bayesian Methods*, Proceedings of MAXENT94 (Kluwer, 1996), p. 239–248

Software:

MPSpack (coauthor T. Betcke, Reading, UK). A MATLAB toolbox to solve Helmholtz and scattering problems with particular solutions and integral equations. Version 1.0 released September 2009 (tutorial 35 pages, manual 37 pages); downloaded at least 200 times. Freely available at <http://code.google.com/p/mpspack>

Other codes for numerical solution of PDEs freely available at <http://math.dartmouth.edu/~ahb/software>

Partial list of researchers using these codes: B. Osting (UCLA), N. Nigam (SFU), M. Ganesh (Colorado Mines), D. Boas (Harvard), M. Porter (Oxford), M. Wright (ISVR, UK), P. Doyle (Dartmouth)

Publicity / outreach / education:

Computed eigenmodes for integrable and chaotic billiards, appearing in: P. Sarnak, “Recent progress on QUE” (2009); D. Mackenzie, *What’s Happening in the Mathematical Sciences, Volume 8* (AMS, 2011); S.-Y. Koyama, *From primes and zetas to arithmetic quantum chaos* (Nihon Hyoronsha, 2010); and S.-Y. Koyama, “Arithmetic quantum chaos and zeta functions”, *Suurikagaku*, **571** (2011)

“convolution: *son et lumière*”, A. H. Barnett, *in press*, issue 01 of *Convolution. A journal for experimental criticism*, 4 pages (Oct 2009).

Cover of *Notices of the American Mathematical Society*, January 2008. I created all images (modes 1, 10, 10², 10³, 10⁴, 10⁵ of a planar chaotic cavity), and eigenvalue data for article “Quantum Chaos” by Z. Rudnick.

Quantum chaos research featured in “A Decade of Science at Dartmouth”, W. Schpero and C. Chiang, *Dartmouth Undergraduate Journal of Science*, Spring 2008.

INVITED RESEARCH TALKS

Oberwolfach Workshop on Computational Electromagnetism and Acoustics. MFO, Germany	January 2013.
<i>Applications of Integral Equation Methods</i> , minisymposium, SIAM Annual Meeting, Minneapolis	July 2012
Workshop on <i>Geometry of eigenvalues and eigenfunctions</i> , CRM, Univ. de Montréal	June 2012
<i>Challenges in Geometry, Analysis, and Computation</i> , Yale University, (not speaker)	June 2012
Frontiers in Computational and Applied Mathematics, NJIT, Newark, NJ	May 2012
Analysis/PDE Seminar, UNC Chapel Hill	April 2012
Mathematical Physics and Harmonic Analysis Seminar, Texas A&M University	February 2012
<i>Modern Numerical Methods for Waves: Periodic Geometries</i> , ICIAM, Vancouver	July 2011
WAVES2011, Vancouver (contributed talk)	July 2011
Applied and Computational Mathematics Seminar, Dartmouth	May 2011; January 2012; February 2012
New England Numerical Analysis Day, UMass Dartmouth	April 2011
CSC Seminar, Simon Fraser University, Vancouver, BC	March 2011
Numerical Analysis and Scientific Computing Seminar, Courant Institute, NYU	January 2011
Applied Mathematics and Computational Science Colloquium, U. Penn	January 2011
Conference in honor of 65th birthday of Eric Heller, ITAMP, Harvard	October 2010
<i>Integral Equation Methods, Fast Algorithms and Applications</i> , IMA workshop, Minnesota	August 2010
Frontiers in Computational and Applied Mathematics, NJIT, Newark, NJ	May 2010
<i>Numerical solution of the Painlevé equations</i> , ICMS, Edinburgh, UK	May 2010
Applied Analysis Seminar, Louisiana State University	March 2009
Dartmouth Mathematics Colloquium	November 2009
MIT Applied Mathematics Colloquium	November 2009
Computational Optical Sensing and Imaging Seminar, CU Boulder	September 2009
<i>Topological Complexity of Random Sets</i> , AIM workshop, Palo Alto	August 2009
WAVES2009, Pau, France (contributed talk)	June 2009
Colloquium & PDE/Analysis Seminar (two separate talks), ANU, Canberra, Australia	February 2009
<i>Laplacian Eigenvalues & Eigenfunctions: Theory, Computation, Application</i> , IPAM, UCLA	February 2009
<i>Workshop on Numerical and Analytical Methods for Wave Scattering</i> , Manchester, UK	June 2008
Workshop on quantum chaos, CRM (Univ. de Montréal)	June 2008
Frontiers in Computational and Applied Mathematics, NJIT, Newark, NJ (contributed poster)	May 2008
McGill Applied Mathematics Seminar, Montreal	March 2008
Applied Mathematics Seminar, U. Delaware	November 2007
Numerical analysis seminar, Manchester, UK	July 2007
Three separate mini-symposium talks, ICIAM, Zurich	July 2007
PDE/Analysis Seminar, ANU, Canberra, Australia	February 2007
Heller Group Seminar, Physics Department, Harvard	December 2006
Applied Mathematics Seminar, UMass Amherst, MA	November 2006

Dartmouth Physics Colloquium	October 2006
SIAM Annual Meeting, Boston (contributed talk)	July 2006
Joint MIT/Harvard Analysis Seminar	March 2006
Computations in Science Seminar, U. Chicago	November 2005
Institute of Sound and Vibration Research, Southampton University, UK	June 2005
Computational Mathematics and Applications Seminar, Computing Laboratory, Oxford, UK	June 2005
Numerical Analysis and Scientific Computing Seminar, Courant Institute, NYU	December 2004
Applied Mathematics Colloquium, Columbia University	October 2004
<i>Workshop on Semi-classical Theory of Eigenfunctions and PDEs</i> , CRM (Univ. de Montréal)	June 2004
Applied Mathematics Seminar, Yale University	March 2004
Applied Mathematics Laboratory Seminar, Courant Institute, NYU	February 2004
European Conference on Biomedical Optics, Munich, Germany (contributed talk)	June 2003
Theoretical & Computational Biology Seminar Series, Mount Sinai School of Medicine, NY	May 2003
Applied Mathematics Seminar, Courant Institute, NYU	November 2002
Photon Migration Imaging Seminar, Harvard Medical School	May 2002
Applied Mathematics Laboratory Seminar, Courant Institute, NYU	December 2001
Statistics Seminar, University of Toronto	September 2001
Pan-American Advanced Study Institute on Quantum Chaos, Ushuaia, Argentina	October 2000
<i>14th Maximum Entropy Workshop (MAXENT94)</i> , St John's College, Cambridge, England	June 1994

TEACHING

Dartmouth College *(the four new courses I created in the period 2006–2008 are shown by asterisks)*

- Math 53: Chaos! (dynamical systems)* Fall 2007, 2009, 2011
- Math 5: The Mathematics of Music and Sound (for non-majors)* Spring 2007, Fall 2008, 2010, 2011
- Math 46: Introduction to Applied Mathematics (for majors)* Spring 2007, 2008, 2009, 2011
- Math 22: Linear Algebra with Applications Summer 2006
- Math 11: Multivariable Calculus Fall 2010
- Math 116/126: Numerical PDEs and Waves (graduate level)* Winter 2006, Fall 2008, Winter 2012
- Math 50: Probability and Statistical Inference Winter 2006
- Math 23: Differential Equations Fall 2005, 2007
- Math 147: Graduate Teaching Seminar Summer 2012

New York University

- Business Calculus Fall 2004
- Mathematical Wave Dynamics (new honors VIGRE course, with O. Bühler) Spring 2004
- Linear Algebra Fall 2003
- Multivariable Calculus Spring 2003
- Undergraduate Math Lab (new honors VIGRE course, with P. Sarnak) Fall 2002

Harvard University

- Laboratory Electronics (TA) Fall 2001
- The Physics of Music and Sound (head TA, created labs and content) Spring 2001
- Advanced Quantum Mechanics (TA, graduate course) Fall 1998
- *Microteaching Facilitator* for the Derek Bok Center Fall 1997
- Mechanics (TA) Fall 1996, 1997
- Principles of Physics (TA) Summer 1996

- Introductory Mechanics and Relativity (TA)
- Mechanics and Special Relativity (TA)

Spring 1996
Fall 1995

MENTORING

Postdoctoral:

Adrianna Gillman (JWY Instructor) July 2011–present

Graduate students:

Matt Mahoney (Ph. D. '09) July 2006–July 2007
Global numerical methods for eigenmodes with gravity

Undergraduate students:

Bradley Nelson '13 (supported by a \$4000 grant, Paul K. Richter and Evalyn E. Cook Richter Memorial Fund) March–May 2012

Integral equations for waves in variable-index media

Hahn Nguyen '14 (first-year WISP intern, Women in Science Program) January–June 2011

Accurate evaluation of layer potentials up to the boundary

Kyle Konrad '12 (senior thesis, Neukom Scholar) March 2011–June 2012

Nodal domain counts of chaotic eigenfunctions

Vipul Kakkad '13 (Presidential Scholar) January–March 2012

Optimization of tubular bell mode frequencies

Taylor Sipple '13 (Presidential Scholar) June–December 2011

Method of particular solutions for polygon and Dirichlet-Neumann eigenmodes

Kathleen Champion '11 (Presidential Scholar and senior thesis, co-supervisor Amy Gladfelter, Biology) January 2010–May 2011

Three-dimensional tracking of nuclear mitosis

Zoe Lawrence '10 (senior thesis, with 'high honors', co-supervisor Dorothy Wallace) Spring 2010

The spatiotemporal dynamics of African Cassava Mosaic Disease

Emmanuel Mensah '09 (independent study) Spring 2009

The inverse source problem in medical imaging (published in DUJS, November 2009)

Yong Su '09 (senior thesis, with 'high honors'; Neukom Scholar) September 2008–March 2009

Computing the capacitance of the unit cube

Evan Tice '09 (computer science major, co-supervisor Amy Gladfelter, Biology) January 2008–June 2009

Automated image tracking of cell movement and division (awarded Kemeny Prize, 2008)

Chetan Mehta '08 (senior thesis, with 'high honors') June 2007–May 2008

Optimal optode location in Diffuse Optical Tomography

Chor Lam '08 (Presidential Scholar) January–June 2008

Chaos in billiards

Vissuta Jiwariyavej '09 (sophomore WISP intern, Women in Science Program) January–June 2007

A clap can chirp: waves and echoes in the racquetball court

William A. Webb (Caltech, co-advisor Mason Porter) Summer 2006

A computational study of the quantization of billiards with mixed dynamics

SERVICE TO DEPARTMENT AND COLLEGE

Conference organizer:

Organizer (one of four), *International Conference on Spectral Geometry*, Dartmouth College July 2010

Seminar organizer:

Applied and Computational Mathematics Seminar, Dartmouth (hosted 49 talks so far) May 2006–present

Mathematics education:

Interactive Learning in the Sciences, session given at Dartmouth Center for the Advancement of Learning October 2007

Cross-disciplinary classroom visits by professional musicians to Math 5, 53 2007–2011
 Committee member, Applied Mathematics Qualifying Examination, Katherine Kinnaird Spring 2010
The Mathematical Overtones of Music, lecture, JHU Center for Talented Youth, Odyssey Series May 2011

Outreach:

Advisory Committee, Leslie Center for the Humanities Winter 2011–present
 Faculty Advisory Board, Dartmouth Undergraduate Journal of Science (DUJS) Fall 2007–present
 Affiliated faculty, Electro-Acoustic Music Program, Dartmouth 2007–present
 Research talks for Dartmouth Graduate Recruiting Open House 2006, 2007, 2009, 2011
 Research talks for Dartmouth Mathematics Society 2006, 2008, 2009, 2010
 Mathematical model building, Dartmouth Mathematics Society October 2006
 First-year advising Fall 2007, 2008, 2010
 Guest lecturer, Music 3 (Music and Technology), Dartmouth November 2006

College committees:

Committee on Student Life 2011–2011

Department committees:

Undergraduate Program Committee 2005, 2008–2010
 Recruiting Committee 2007–2008, 2010–2011
 Equipment Committee 2007–2008
 Graduate Program Committee 2006–2007
 Mirkil Book Committee 2006–2007
 Graduate Admissions Committee 2005, 2006, 2011
 Computing Committee 2005–2006

OTHER PROFESSIONAL ACTIVITIES

Conferences & seminar organizer, outreach:

Organizer (one of five), *Integral Equations Methods: Fast Algorithms and Applications*, BIRS Dec 2013
 Scientific Committee, *International Conference on Mathematical and Numerical Aspects of Wave Propagation (WAVES)*, Vancouver, BC July 2011
 Organizer (with L. Demanet), two minisymposia on numerical waves, ICIAM, Vancouver, BC July 2011
 Organizer (with J. Zhang), Applied Mathematics Laboratory Seminar, Courant Institute, NYU 2002–2003
 Organizer, Creating Careers in Physics series, Harvard Physics Department 1999–2000
 Co-organiser, Boston Area Undergraduate Physics Competition 1998–2001

Referee, review panels:

SIAM Journal on Scientific Computing, SIAM Journal on Applied Mathematics, Journal of Computational Physics, Notices of the AMS, Communications in Mathematical Physics, Journal of Mathematical Analysis and Applications, Inverse Problems, Proceedings of the Royal Society of London A, Journal of Physics A, Engineering Analysis with Boundary Elements, Numerical Functional Analysis and Optimization, Experimental Mathematics, Applied Optics, Waves in Random and Complex Media, NeuroImage, Journal of Electronic Imaging, Physics in Medicine and Biology, Transactions on Medical Imaging, Journal of the Optical Society of America A, Nonlinear Dynamics, Canadian Journal of Physics, New Journal of Physics, AMS Mathematical Reviews; National Science Foundation.

Member: Society for Industrial and Applied Mathematics, Optical Society of America.