

# CV: Matthew J. Colbrook

## Work Address

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## Personal Information

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## Education

- ◇ October 2016 – September 2020: **University of Cambridge**, St John's College, UK  
PhD, Mathematics, Cambridge Centre for Analysis (CDT, Supervisor: Dr A. Hansen)  
Thesis: *The Foundations of Infinite-Dimensional Spectral Computations*
- ◇ Academic year 2015 – 2016: **University of Cambridge**, St John's College, UK  
MMath, Mathematics. Grade: Distinction.  
(Ranked 3rd in year (out of > 200) and top in the Department of Applied Mathematics and Theoretical Physics)
- ◇ Summer 2015 (10 weeks): **Caltech**, USA  
Summer Undergraduate Research Fellowship  
(Supervisor: Prof. P. Hopkins, Outcome: Published article in Monthly Notices of the Royal Astronomical Society)
- ◇ October 2012 – July 2015: **University of Cambridge**, St John's College, UK  
BA (Hons), Mathematics. Grade: 1st every year.

## Academic Positions

- ◇ October 2020 – present: **Junior Research Fellow, Trinity College, University of Cambridge, UK**

## Main Academic Prizes/Awards

- ◇ IMA Lighthill–Thwaites Prize Winner 2021 (£1000) (+ Finalist in 2019)  
(biannual international prize given by IMA to top early career applied mathematicians)
- ◇ Cecil King Travel Scholarship 2020 (£6000)  
(annual early career prize of the London Mathematical Society “to a young mathematician of outstanding promise”)
- ◇ Grade 1 Smith–Knight/Rayleigh–Knight Prize 2018 (£750)  
(annual prize for best graduate piece of research in the mathematics department at the University of Cambridge)
- ◇ Mayhew Prize 2016 (£600)  
(annual prize given to best DAMTP MMath degree at the University of Cambridge)
- ◇ LMS Travel Grant for Early Career Researchers 2020 (£500)
- ◇ Caltech SURF Scholarship 2015 (\$6000)
- ◇ Cambridge Summer Research in Mathematics 2014 (£800) (grant for undergraduate academic research project)
- ◇ Baylis Scholarship for Mathematics 2013–2016
- ◇ Various named College Prizes for exceptional exam results 2013–2016

## Research interests

- ◇ Computational spectral theory and linear algebra in infinite dimensions.
- ◇ Deep learning and its mathematical foundations.
- ◇ Computational methods for PDEs including spectral/pseudospectral methods.
- ◇ Analysis and numerical solutions of initial boundary value problems.
- ◇ Computational methods for fluid mechanics and acoustic scattering problems.

## Publications (\* denotes articles which are predominantly my work and where I am the lead author)

### Peer-reviewed journal articles

1. M.J. Colbrook, A. Horning, A. Townsend, *Computing spectral measures of self-adjoint operators*, **SIAM Review**, to appear.
2. M.J. Colbrook\*, *Computing spectral measures and spectral types*, **Communications in Mathematical Physics**, to appear.
3. M.J. Colbrook\*, B. Roman, A.C. Hansen, *How to compute spectra with error control*, **Physical Review Letters**, 2019.  
(Cover highlight for issue)
4. M.J. Colbrook\*, A.C. Hansen, *On the infinite-dimensional QR algorithm*, **Numerische Mathematik**, 2019.
5. M.J. Colbrook\*, *Pseudoergodic operators and periodic boundary conditions*, **Mathematics of Computation**, 2019.
6. M.J. Colbrook\*, A. Kisil, *A Mathieu function boundary spectral method for diffraction by multiple variable poro-elastic plates, with applications to metamaterials and acoustics*, **Proceedings of the Royal Society A**, 2020.
7. M.J. Colbrook\*, L.J. Ayton, A.S. Fokas, *The unified transform for mixed boundary condition problems in unbounded domains*, **Proceedings of the Royal Society A**, 2019.

8. M.J. Colbrook\*, *Extending the unified transform: curvilinear polygons and variable coefficient PDEs*, **IMA Journal of Numerical Analysis**, 2018.
9. M.J. Colbrook\*, A.S. Fokas, P. Hashemzadeh, *A hybrid analytical-numerical technique for elliptic PDEs*, **SIAM Journal on Scientific Computing**, 2019.
10. M.J. Colbrook\*, N. Flyer, B. Fornberg, *On the Fokas method for the solution of elliptic problems in both convex and non-convex polygonal domains*, **Journal of Computational Physics**, 2018.
11. M.J. Colbrook\*, L.J. Ayton, *Do we need non-linear corrections? On the boundary Forchheimer equation in acoustic scattering*, **Journal of Sound and Vibration**, 2021.
12. L.J. Ayton, M.J. Colbrook, T. Geyer, P. Chaitanya, E. Sarradj, *Reducing aerofoil-turbulence interaction noise through chordwise-varying porosity*, **Journal of Fluid Mechanics**, 2021.
13. M.J. Colbrook, M.J. Priddin, *Fast and spectrally accurate numerical methods for perforated screens (with applications to Robin boundary conditions)*, **IMA Journal of Applied Mathematics**, 2020.
14. M.J. Colbrook\*, L.J. Ayton, *A spectral collocation method for acoustic scattering by multiple elastic plates*, **Journal of Sound and Vibration**, 2019.
15. M.J. Colbrook\*, Z.I. Botev, K. Kuritz, S. MacNamara, *Kernel density estimation with linked boundary conditions*, **Studies in Applied Mathematics**, 2020.
16. M.J. Colbrook\*, X. Ma, P. Hopkins, J. Squire, *Scaling laws of passive-scalar diffusion in the interstellar medium*, **Monthly Notices of the Royal Astronomical Society**, 2017.
17. F. de Barros, M.J. Colbrook, A.S. Fokas, *A hybrid analytical-numerical method for solving advection-dispersion problems on a half-line*, **International Journal of Heat and Mass Transfer**, 2019.

#### Peer-reviewed conference articles

- C1. L.J. Ayton, M.J. Colbrook, A.S. Fokas, *The unified transform: a spectral collocation method for acoustic scattering*, **AIAA/CEAS Aeroacoustics**, 2019.
- C2. M.J. Colbrook\*, V. Antun, A.C. Hansen, *On the existence of stable and accurate neural networks for image reconstruction*, **SPARS**, 2019.

#### Submitted articles and preprints (available on the arXiv or on my website)

- S1. M.J. Colbrook\*, A.C. Hansen, *The foundations of spectral computations via the solvability complexity index hierarchy: Part 1*.
- S2. M.J. Colbrook\*, *On the computation of geometric features of spectra of linear operators on Hilbert spaces*.
- S3. J. Ben-Artzi, M.J. Colbrook, A.C. Hansen, O. Nevanlinna, M. Seidel, *On the solvability complexity index hierarchy and towers of algorithms*.
- S4. M.J. Colbrook\*, V. Antun\*, A.C. Hansen, *Can stable and accurate neural networks be computed? - On the barriers of deep learning and Smale's 18th problem*.
- S5. M.J. Colbrook\*, *Computing semigroups with error control*.
- S6. T. Loss, M.J. Colbrook, A.C. Hansen, *Stratified sampling based compressed sensing for structured signals*.

#### **Selected lectures, and talks/papers at conferences/workshops**

- ◇ “*Diagonalising the infinite: How to compute spectra with error control*,” British Mathematical Colloquium and British Applied Mathematics Colloquium, Glasgow, UK, April 2021.
  - ◇ “*Diagonalising the infinite: How to compute spectra with error control*,” Early Career Applied Mathematics Meeting (Online Seminar Series), March 2021.
  - ◇ “*On the barriers of AI and the trade-off between stability and accuracy in deep learning*,” lectures given at the 21st Geilo Winter School in eScience, January 2021.
  - ◇ “*Diagonalising Infinite-Dimensional Operators: Computing spectral measures of self-adjoint operators*,” Annual Meeting of the Australian Mathematical Society, December 2020.
  - ◇ “*A Mathieu function boundary spectral method for acoustic scattering*,” Canadian Mathematical Society Winter Meeting, December 2020.
  - ◇ “*Diagonalising Infinite-Dimensional Operators: Computing spectral measures of self-adjoint operators*,” Communications in NLA (Online Seminar Series), October 2020.
  - ◇ “*How To Compute Spectra With Error Control: On The Foundations of Infinite-Dimensional Spectral Computations*,” Computational Techniques & Applications Conference, University of New South Wales, Australia, September 2020.
- Student prize:** Selected as highly commended.
- ◇ “*The Foundations of Infinite-Dimensional Spectral Computations*,” British Early Career Mathematicians’ Colloquium, Birmingham, UK, July 2020.
  - ◇ “*Scattering, Acoustic Black Holes and Mathieu Functions: A boundary spectral method for diffraction by multiple variable poro-elastic plates*,” Waves in Complex Continua, International Centre for Mathematical Sciences, May 2020.
  - ◇ “*The Foundations of Infinite-Dimensional Spectral Computations*,” Isaac Newton Institute Workshop on complex analysis, Cambridge, UK, December 2019.

- ◇ “*Solving Wiener–Hopf problems numerically: a spectral method approach*,” Isaac Newton Institute Workshop on Wiener–Hopf technique, Cambridge, UK, August 2019.
- ◇ “*Do stable networks with recovery guarantees exist?*” Applied Inverse Problems Conference, Grenoble, France, July 2019.
- ◇ “*Spectral analysis and new resolvent based methods*”, 28th Biennial Numerical Analysis Conference, Glasgow, UK, June 2019.
- ◇ “*On Instabilities of Deep Learning in Image Reconstruction*”, The Mathematics of Deep Learning and Data Science, Isaac Newton Institute, Cambridge, UK, May 2019.
- ◇ “*The Unified Transform: A New Tool for Scattering Problems*”, British Applied Mathematics Colloquium 2019, Bath, UK, April 2019.
- ◇ “*On the solvability complexity index hierarchy, the computational spectral problem and computer-assisted proofs*,” Measuring the Complexity of Computational Content: From Combinatorial Problems to Analysis, Dagstuhl, Germany, September 2018.

### Selected upcoming future talks

- ◇ **Plenary Speaker:** “*The Foundations of Infinite-Dimensional Spectral Computations*,” Bedlewo Acta Numerica Conference (celebrating 30 years of Acta Numerica), June 2021 (delayed until 2022 due to COVID-19).
- ◇ “*Can stable and accurate neural networks be computed? - On the barriers of deep learning and Smale’s 18th problem*,” SIAM Annual Meeting, July 2021.

### Selected invited seminar talks

Over 10 invited seminar talks over the last few years including at: Cornell University (Scientific Computing and Numerics Seminar, Mechanics Seminar), Imperial College London (Imperial–UCL Numerics Seminar), University of Bath (Applied and Interdisciplinary Mathematics Seminar & Numerical Analysis Seminar), UC Berkeley (Analysis Seminar, Applied Mathematics Seminar), UC Irvine (Applied and Computational Mathematics Seminar), University of Oxford (Oxford–Cambridge Applied Mathematics Meeting), University of Strathclyde (Quantum Optics and Quantum Many-body Systems Seminar), University of Washington (Applied PDE Seminar), École Normale Supérieure (Laplace Seminar Series) and École Polytechnique Fédérale de Lausanne (Biomedical Imaging Seminar).

### Lecturing, teaching and administrative roles

- ◇ January 2021: Lecturer on machine learning at the 21st Geilo Winter School.
- ◇ Supervised Cambridge undergraduate courses on numerical analysis, mathematical methods, machine learning, analysis, statistics and linear algebra.
- ◇ Taught exam revision lectures for University of Cambridge MMath degree courses.
- ◇ Undergraduate admissions interviews for mathematics at Homerton College, Cambridge.
- ◇ 2018: Supervised a student intern research project on the unified transform.
- ◇ 2018: Ran the Cambridge Analysts’ Knowledge Exchange seminar series.
- ◇ 2019/2020: Ran a joint PhD seminar series between the Cambridge and Imperial numerical analysis groups.
- ◇ Summer 2020: Supervised mathematics students for Cornell’s Research Experience for Undergraduates (REU) projects.

### Refereeing

Applied Mathematics Letters, Foundations of Computational Mathematics, IEEE Transactions on Knowledge and Data Engineering, IEEE Transactions on Pattern Analysis and Machine Intelligence, IEEE Transactions on Signal Processing, IMA Journal of Numerical Analysis, Journal of Aerospace Engineering, Journal of Applied Analysis and Computation, Journal of Computational Physics, Journal of Fourier Analysis and Applications, Journal of Scientific Computing, Nature Scientific Reports, Numerical Algorithms, Proceedings of the Royal Society A, SIAM Journal on Applied Mathematics, Studies in Applied Mathematics, Zeitschrift für Naturforschung A, Cambridge University Press (book).