

## Personal details and date of CV

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- Date of CV: 10 November 2025
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## Degree

- Date: 2019 (awarded March 2019), PhD (Physics), King's College London, London, UK. (Contact: King's College London, Strand, London, WC2R 2LS, UK)
- Date: 2015 (graduated July 2015), MRes (Non-Equilibrium Systems: Theoretical Modelling, Simulation and Data Analysis), King's College London, London, UK. (Distinction)
- Date: 2013 (graduated July 2013), MPhys (Physics), University of Warwick, Coventry, UK. (First)

## Current employment

- Start and end date: 2024–Present
- Job title: PDRA for the QRC-4-ESP project
- Employer and place of work: Loughborough University, Loughborough, UK
- Stage of academic research career: II/III

## Previous work experience

- Start and end date: 2021–2024, Job position: W.M. Keck Fellow, Employer: Tulane University, New Orleans, USA
- Start and end date: 2019–2021, Job position: Postdoctoral Fellow, Employer: Tulane University, New Orleans, USA
- Start and end date: 2013–2014, Job position: IB and IGCSE maths and physics teacher, Employer: Qidong Middle School, Jiangsu, China

## Research funding and grants

I have a track record of securing funding supporting impactful publications (\$3000), as well as research visits to institutes including Princeton (Jan-April 2018), Ulm (May-June 2023) and ELTE (Jan 2025) universities, plus Sandia National Lab (August 2023) (collectively  $\sim$  \$15000). In addition to multiple postdoctoral conference travel awards, in June 2023 I was co-PI on Army Research Office (ARO) grant # W911NF-23-1-0288 ( \$450,000).

## Research output

Here I list ten of the most relevant outputs in reverse chronological order, using **Corresponding Author**:\* and **Equal Contribution**:†. Unless otherwise stated, in all outputs I led both theoretical analysis and manuscript drafting, and in the majority of instances also developed the numerical implementation. A short description is included for those publications most relevant to the proposal.

- ["Free Snacks in Quantum Complexity"](#) Gerard McCaul\*, arxiv:2509.04618 (2025) A theoretical investigation of the ITQDE methodology from the perspective of complexity theory. Using a quadrature-based formulation, I derive scaling and stability criteria that diagnose when its estimates are reliable, and introduce a controlled smoothing that yields a principled bias-variance trade off. The resulting picture preserves the hardness of exact eigenvalue resolution but reveals a practical regime - a "free snack" - where coarse-grained spectral information is obtainable with only polynomial resources. By recasting sampling costs as explicit bounds on resolvable bandwidths, an intermediate regime between trivial and intractable complexity becomes targetable.
- ["Unwrapping Photonic Reservoirs: Enhanced Expressivity via Random Fourier Encoding over Stretched Domains"](#) Gerard McCaul, Girish Tripathy, Giulia Marcucci, Juan Sebastian Toterogongora\*, Chaos **35**, 093129 (2025) **Featured article**

- [“Observables in Motion: A Guide to Simulating Classical and Quantum Dynamics”](#) Denys I. Bondar, **Gerard McCaul**, Andrii Sotnikov, arxiv:2509.20403 (2025)  
Version zero of a textbook detailing the theory and implementation of Hilbert space representations of dynamics. Besides editing across chapters, my main contributions have been the introductory chapters, and the extension to open systems. In-progress contributions include adaptations of the quantum-classical mappings outlined in J. Phys. A 55, 434003 (2022) and Eur. Phys. J. Spec. Top. 230, 733-754, (2021)
- [“Minimal Quantum Reservoirs with Hamiltonian Encoding”](#) **Gerard McCaul\***, Juan Sebastian Toterogongora, Wendy Otieno, Sergey Savelev, Alexandre Zagoskin, Alexander G. Balanov, Chaos 35, 093135 (2025)
- [“Dynamical Learning and Quantum Memory with Non-Hermitian Many-Body Systems”](#) Moein N. Ivaki\*, Austin J. Szuminsky, Achilleas Lazarides, Alexandre Zagoskin, **Gerard McCaul**, Tapio Ala-Nissila, arxiv:2506.07676 (2025). Here the relationship between a reservoir’s learning capacity and the underlying dynamics driving it is investigated. Using the example of an interacting Non-Hermitian spin system defined on random graphs, we show that the onset of the first exceptional point - marking the real-to-complex spectral transition - also corresponds to an abrupt change in the system’s learning capacity. My main contribution to this work was to develop a scheme by which the proposed Non-Hermitian dynamics could be controllably realised, as well as assistance in manuscript drafting and result interpretation.
- [“Quantum Dynamical Emulation of Imaginary Time Evolution”](#) Jacob Leamer, Alicia Magann, Denys I. Bondar, **Gerard McCaul\***, arxiv:2403.03350 (2024). Here I propose a constructive method for simulating non-unitary – e.g. non-Hermitian or Lindbladian – dynamics via weighted ensembles of unitary evolutions. From this the Imaginary Time QDE (ITQDE) protocol was developed. This enables both spectral estimation and thermal state preparation on quantum hardware, and was successfully implemented in existing quantum processors. I conceived the method, derived the mathematical formalism and wrote the initial numerical implementation.
- [“Superoscillations Deliver Superspectroscopy”](#) **Gerard McCaul\*<sup>†</sup>**, Peisong Peng<sup>†</sup>, Monica Ortiz Martinez, Dustin Lindberg, Diyar Talbayev and Denys I. Bondar, Phys. Rev. Lett. 131, 153803 (2023)
- [“The Waveoperator Representation of Quantum and Classical Dynamics”](#) **Gerard McCaul\***, Dmitry V. Zhdanov and Denys I. Bondar, Phys. Rev. A 108, 052208 (2023). This work introduces a purified square-root representation of the density matrix termed the waveoperator. This formalism provides a natural bridge between Hilbert and phase-space, with which it is possible to construct a systematic, singularity-free procedure for taking the classical limit of both real- and imaginary-time quantum dynamics. I was co-developer of the formalism, performed the theoretical and numerical analysis, and served as lead author in the manuscript draft.
- [“Towards Single Atom Computing via High Harmonic Generation”](#) **Gerard McCaul\***, Kurt Jacobs and Denys I. Bondar, Eur. Phys. J. Plus (2023) 138: 123 - [Journal Highlight](#)
- [“Fast Computation of Dissipative Quantum Systems with Ensemble Rank Truncation”](#) **Gerard McCaul\***, Kurt Jacobs and Denys I. Bondar, Phys. Rev. Research 3, 013017, (2021)

#### Research supervision and leadership experience

- Supervised multiple postgraduate, undergraduate and school students, resulting in five published papers.
- Principal supervisor for an MSc thesis: "Numerical investigation of minimal quantum reservoirs" (Roland Weismuller, ELTE university, June 2025).

#### Teaching merits

- Lecturer for General Physics II (calculus-based freshman physics) at Tulane University (January 2022 – May 2022). Designed course covering electrostatics, circuits, EM waves & optics

- Mentored one student from this class for a successful Goldwater fellowship application.
- Teaching assistant for KCL physics modules (Mathematics for Physicists II and III) (September 2015 – September 2018). Delivered full lectures in the final year.
- Teacher (Physics and Mechanics, IGCSE and A-level) at Qidong Middle School International Department, Jiangsu, China (August 2013 – July 2014).

#### Awards and honours

- Five of my papers have been selected as either [journal highlights](#) [EPJ Plus **138**: 123 (2023)], [featured articles](#) [Chaos **35**, 093129 (2025), Physics of Fluids **33**, 031801 (2021)], or [editor's suggestions](#) [Phys. Rev. Lett. **124**, 183201 (2020), Phys. Rev. A **101**, (2020)]. My work has also been covered in outlets including [Physics](#), [Physics World](#), [Chemistry World](#), [Nature Materials](#) and [Quanta](#).
- [2024 Tulane School of Science and Engineering's full-time researcher award](#) for "significant research accomplishments at Tulane", relating to my work on quantum control.
- Runner-up in the university of Maryland's 2023 [quantum thermodynamics hub short story contest](#), for my entry 'Doctor Up and Mister Down' (\$1000)
- IOP trusted reviewer (2022)

#### Selected invited international lectures:

- [Chapman Institute of Quantum Studies](#) - Oct 2025 - *Free Snacks in Quantum Complexity*
- [Aalto Summer School on New Directions in Quantum and Quantum Reservoir Computing, Quantum Devices and Related Technologies](#) - Aug 2025 - *Computation as Dynamics*
- [Kharkiv Quantum Seminar](#) - Feb 2025 - *Quantum Dynamical Emulation*
- [Frontiers of Quantum and Mesoscopic Thermodynamics](#) - July 2024 - *Generating thermal states in quantum circuits* (also invited speaker for 2026 session)
- [Superoscillations in Cetraro III](#) - June 2024 - *Superoscillations Deliver Superspectroscopy*
- [IQST early career researchers retreat](#) - May 2024 - *Superoscillations and Non-Linear Optical Response*
- [Ohio State University Institute for Optical Science](#) - November 2023 - *Malleable Light: From Single Atom Computing to Superspectroscopy*

#### Scientific conferences organised:

- Micro March Meeting - Denver, Colorado (March 2020). (Organised at short notice after APS March meeting cancellation due to COVID-19. Approx. 30 attendees, 12 talks).
- Workshop on Localisation in Quantum Systems - London (June 2017). (Organised with other CDT students. 4 speakers, 40 attendees).

#### Referee for scientific publications:

- 25+ reviews across journals including Nature Communications, Physical Review Letters/A/B/Research, New Journal of Physics, European Journal of Physics B/Plus, Journal of Physics A, Entropy.

#### Scientific and societal impact

- Pint of Science talk: "[Linear algebra ruined your life](#)" (May 2025).
- Interviewed for popular summaries of my work (e.g., journal highlights on single-atom computing, Quanta magazine article "Alchemy Arrives in a Burst of Light").
- Lecture series delivered to AP mathematics students at Benjamin Franklin High School on vector spaces (New Orleans, December 2022–January 2023).
- Mentor for US Army Educational Outreach Program (AEOP) Apprenticeships (2020–2023).
- GNOSEF judge - Tulane University, New Orleans (February 2020–2023).
- FIRST Lego League judge - Jesuit High School, New Orleans (January 2020–2023).

#### Other

- Hanyu Shuiping Kaoshi (HSK) 2 Mandarin qualification.
- Computing experience with Python, Maple, MATLAB, Mathematica, TikZ and  $\LaTeX$ .
- Dreadful guitarist.