

IAN A. O. MACMILLAN

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EDUCATION

California Institute of Technology, *Doctor of Philosophy*, Physics.....September 2019 – Present
Thesis: *Precision Control in Gravitational Physics: From LIGO to GQuEST*
Research Fields: Optimal Controls, Quantum Sensing, Laser Stabilization, Optical Cavities

California Institute of Technology, *Master of Science*, Physics.....June 2024
Research Fields: Digital Filtering, CCDs, Quantization Noise, Controls, SysID, Interferometry

Georgetown University, *Scientiae Baccalaureatum*, Physics August 2017 – May 2019
Thesis: *Brownian Thermal Noise in AlGaAs and Its Implications for LIGO's Sensitivity*
Research Fields: Optics, Thermal Coatings, Gravitational Waves, Advanced Interferometry

EXPERIENCE

Graduate Researcher, California Institute of Technology October 2019 – Present
The LIGO Lab & McCuller Quantum Optics Lab

- Designed, engineered, and implemented optimal \mathcal{H}_∞ bounded LQG control algorithms for LIGO, enhancing sensitivity and stability, lowering some noise by orders of magnitude.
- Built in-vacuum, high-finesse optical cavities for laser phase noise suppression and frequency stabilization via saturated absorption spectroscopy in rubidium vapor.
- Modeled, designed, and helped build a series of four coupled optical cavities targeting 60 dB of optical isolation with a stable pass band.
- Developed a novel organization-wide RAG agent (Python, SQL, custom vector DBs) enabling rapid access to institutional technical knowledge. ([ligolabrador.com](#))

Optics Researcher, American University October 2016 – August 2019
LIGO Optical Development Lab

- Characterized Brownian thermal noise in amorphous and crystalline optical coatings for next-generation interferometers using ringdown techniques, informing LIGO upgrade roadmap.
- Engineered material testing protocols using COMSOL Multiphysics finite element analysis to optimize coating performance and predict thermal noise across architectures.
- Achieved first decomposition of thermal loss angle in multilayer GaAs/AlGaAs coatings into principal components, advancing understanding of coating losses.
- Mentored junior students and supported outreach initiatives (NSF, LIGO education events).

Visiting Research Fellow, Harvard University April 2018 – September 2018

- Developed the Overall Sky Emission Line Observing and Tracking Spectrograph (OSELOTS), a rugged field-deployed instrument for the Vera Rubin Observatory.
- Architected full data acquisition, control, and analysis software stack to optimize spectrometer performance in harsh field conditions.
- Developed and deployed FITS image analysis pipeline for automated detection and interpretation of astronomical data.

AWARDS & FELLOWSHIPS

Joseph W. Serene Medal, Georgetown University June 2019
For Outstanding research accomplishments in physics

Research Grant, NASA DC Space Grant Consortium May 2017
Research in Gravitational Physics and Related Projects

First Place Poster Prize, LIGO Lab at Caltech March 2018
Distribution of Measured Q s and Implications for Thermal Noise Prediction

Outstanding Teaching Assistant, American University April 2017
For excellence in physics teaching

STEAM Scholar Medal , Portsmouth Department of Education	June 2015
<i>For academic achievement in science, technology, engineering, arts, and mathematics</i>	
Recognition of Achievement , RI Governor Gina M. Raimondo	May 2015
<i>For being the co-founder and president of a two-time state-winning cyber security team</i>	
Eagle Scout , Boy Scouts of America	April 2012

PUBLICATIONS

1. **Ian A. O. MacMillan** and Lee P. McCuller. *Robust Bilinear-Noise-Optimal Control for Gravitational Wave Detectors: A Mixed LQG/ \mathcal{H}_∞ Approach*. 2025.
2. Sander M. Vermeulen, Torrey Cullen, Daniel Grass, **Ian A. O. MacMillan**, et al. *Photon-Counting Interferometry to Detect Geotropic Space-Time Fluctuations with GQuEST*. *Phys. Rev. X*, 15:011034, Feb 2025.
3. **Ian A. O. MacMillan**, Gregory M. Harry, Andri M. Gretarsson, et al. *Experimental Uncertainty in Mechanical Quality Factor and Implications for LIGO Thermal Noise*. 2018.
4. Steven D. Penn, Maya M. Kinley-Hanlon, **Ian A. O. MacMillan**, et al. *Mechanical Ringdown Studies of Large-area Substrate-transferred GaAs/AlGaAs Crystalline Coatings*. *J. Opt. Soc. Am. B*, 36(4):C15–C21, Apr 2019.

POSTERS & PRESENTATIONS

Presentations

- **LIGO/Virgo Collaboration Meeting**, Melbourne, Australia March 2025
The State of Art in H-Norm Synthesis Optimal Controls
- **QuRIOUS Collaboration Meeting**, Pasadena, CA March 2024
Laser Noise and Its Mitigation in GQuEST
- **Caltech Candidacy**, Pasadena, CA February 2024
LIGO to GQuEST
- **LIGO/Virgo Collaboration Meeting**, Toyama, Japan September 2023
Beyond H-2 and H-infinity: Robust Optimal Controllers for LIGO
- **LIGO/Virgo Collaboration Meeting**, Evanston, IL March 2023
H-2, Infinity, and Beyond: Optimal Bilinear Noise in LIGO (Remote)
- **Microsoft**, Redmond, WA October 2021
Using Minecraft Education Edition as an Outreach tool for LIGO (Remote)
- **Russian Science Festival**, Moscow, Russia October 2020
LIGO and Astronomy (Remote)
- **LIGO/Virgo Collaboration Meeting**, Warsaw, Poland September 2019
Experimental Distribution of Mechanical Quality Factor
- **APS March Meeting**, Boston, MA March 2019
Experimental Distribution of Mechanical Quality Factor
- **APS Mid-Atlantic Section Meeting**, College Park, MD November 2018
Measurement and Analysis of Uncertainty in Mechanical Quality Factor and Implications for LIGO Thermal Noise Estimation
- **LIGO AlGaAs Workshop**, Washington, DC June 2018
FEA Modeling of Defects in AlGaAs Samples

Posters

- **APS March Meeting**, Las Vegas, NV March 2023
Optimal Bilinear Controls Noise for LIGO
- **LIGO/Virgo Collaboration Meeting**, Sonoma, CA March 2018
Quality Factor Analysis in Thermal Noise Experiments
- **Undergraduate Research Fair**, Washington, DC October 2018
Thermal Noise in LIGO

TEACHING

Quantum Hardware, Teaching Assistant, California Institute of Technology April 2023 - June 2023
Advanced Physics Lab, Teaching Assistant, California Institute of Technology ... January 2020 - March 2020
Statistical Mechanics, Teaching Assistant, Georgetown University January 2019 - May 2019
MCAT & Physics, Private Tutor, Georgetown University & Caltech January 2016 - Present
Principles of Physics I, Teaching Assistant, American University September 2016 - December 2016

OUTREACH

Public Outreach

- **Caltech Future Program**, Pasadena, CA September 2022, 2025
- **Watson Lecture Program**, Pasadena, CA November 2024
- **Optics Olympiad**, American University, Washington, DC February 2018, 2017
- **NSF Outreach Booth**, USA Science & Engineering Festival, Washington, DC April 2018

LIGO Outreach

- **Hamilton Elementary Science Night**, Pasadena, CA March 2024
- **Russian National Science Festival**, Moscow, Russia (Remote) October 2020
- **American Physical Society Meeting**, Washington, DC April 2018
- **American Astronomical Society Meeting**, Prince George’s County, MD January 2018
- **Astronomy on the Mall**, Washington, DC June 2017, 2018, 2019

TECHNICAL SKILLS

Coding Languages	Python, Java, MATLAB, Mathematica, Bash, HTML, SQL, \LaTeX
Software & Tools	COMSOL Multiphysics (FEA), SolidWorks, Inventor, Finesse, OptoCad, Inkscape, Photoshop, Lightroom, Final Cut Pro X
Controls	Optimal/State-Space Control, LQR/LQG, \mathcal{H}_∞ Bounded LQG, Riccati/Lyapunov Methods, PID, Frequency-Domain Weighting
Optics	Interferometers, Optical Cavities, Spectrometers, Micro-Resonators, Free Space/Fiber Optics, Optomechanics, HR/AR Coatings, CCD Cameras
Lab Equipment	FPGAs, RF Electronics, Signal Analyzers, Lock-in Amplifiers, Oscilloscopes, Low Noise Lasers, Additive Manufacturing
Machine Learning	TensorFlow, Scikit-learn, Pandas, Reinforcement Learning, Agent/RAG Development, Vector Datastores

PROFESSIONAL MEMBERSHIPS

QuRIOUS Collaboration 2017 - Present
LIGO Scientific Collaboration 2017 - Present
American Physical Society 2016 - Present
American Astronomical Society 2018 - Present
American Association of Physics Teachers 2016 - Present
National Geographic Society 2015 - Present