Alexander R. H. Smith

Junior Fellow, Society of Fellows
NSERC Postdoctoral Fellow

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Research Interests

Quantum information science: resource theories (quantum reference frames), continuous variable quantum information, quantum metrology, and open system dynamics

Relativistic quantum information: interferometric tests of general relativity with satellites, information processing in curved spacetime, and operational probes of vacuum entanglement

Quantum gravity: the problem of time (conditional probability interpretation), relational quantum mechanics, and gravitationally induced decoherence

Education

Doctorate of Philosophy in Theoretical Physics 2012 - 2017
University of Waterloo, Waterloo, Canada and Macquarie University, Sydney, Australia

Thesis title: Detectors, Reference Frames, and Time

- Published in Springer Thesis series and runner-up in the 2018 Canadian Association of Physicists Thesis Competition

Master of Science in Theoretical Physics 2011 - 2012
University of Toronto, Toronto, Canada

Thesis title: Black Holes and the Kodama Vector Field

Honours Bachelor of Science (Co-op) in Physics, Deans Honour List 2006 - 2011
University of Waterloo, Waterloo, Canada

Thesis title: Persistence of Tripartite Nonlocality for Non-inertial Observers
Specialization: Astrophysics and Applied Physics

Summary of Qualifications

9 years of research experience in theoretical physics, with a focus on quantum information science, black hole physics, and quantum field theory on curved spacetime.

9 publications in international peer reviewed journals, including Physical Review A, Physical Review D, and a highlighted article and letter in Classical and Quantum Gravity. 4 soon to be published preprints available on the arXiv.

Received funding to date: $381,875, from competitive scholarships, awards, and grants.

Designed and taught a new course in the Dartmouth physics and astronomy department titled "Introductory Mathematical Methods for Physicists". Experience with undergraduate research supervision.

Industry research experience at a large private lab (Xerox Research Centre of Canada) and a small solar start-up company (Morgan Solar Inc.), along with field experience in geophysics (WorlyParsons).

Publications

1. Laura J. Henderson, Robie A. Hennigar, Robert B. Mann, **Alexander R. H. Smith**, and Jialin Zhang, *Harvesting Entanglement from the Black Hole Vacuum*, Classical and Quantum Gravity Letters 35, 21LT02 (2018)
DOI: 10.1088/1361-6382/aae27e

2. Filip Kiałka, **Alexander R. H. Smith**, Mehdi Ahmadi, and Andrzej Dragan, *Massive Unruh particles cannot be directly observed*, Physical Review D 97, 065010 (2018)
DOI: 10.1103/PhysRevD.97.065010

   - Featured in $N+1$ internet publication (2018)

3. **Alexander R. H. Smith**, Marco Piani, and Robert B. Mann, *Quantum reference frames associated with noncompact groups: the case of translations and boosts, and the role of mass*, Physical Review A 94, 012333 (2016)
DOI: 10.1103/PhysRevA.94.012333

4. Mehdi Ahmadi, Krzysztof Lorek, Agata Chęcińska, **Alexander R. H. Smith**, Robert B. Mann, and Andrzej Dragan, *Effect of gravity on localized two-mode Gaussian quantum states*, Physical Review D 92, 124031 (2016)
DOI: 10.1103/PhysRevD.93.124031

5. Eduardo Martín-Martínez, **Alexander R. H. Smith**, and Daniel R. Terno, *Spacetime structure and vacuum entanglement*, Physical Review D 93, 044001 (2016)
DOI: 10.1103/PhysRevD.93.044001

   *Note alphabetical order of authors; A. R. H. Smith was the lead investigator.

6. Mehdi Ahmadi, **Alexander R. H. Smith**, and Andrzej Dragan, *Communication between inertial observers with partially correlated reference frames*, Physical Review A 92, 062319 (2015)
DOI: 10.1103/PhysRevA.92.062319

7. Aharon Brodutch, Alexei Gilchrist, Thomas Guff, **Alexander R. H. Smith**, and Daniel R. Terno, *Post-Newtonian gravitational effects in optical interferometry*, Physical Review D 91, 064041 (2015)
DOI: 10.1103/PhysRevD.91.064041

   *Note alphabetical order of authors; A. R. H. Smith and D. R. Terno were the lead investigators.

8. **Alexander R. H. Smith** and Robert B. Mann, *Looking Inside a Black Hole*, Classical and Quantum Gravity 31, 082001 (2014)
DOI: 10.1088/0264-9381/31/8/082001

   - International media coverage in Spektrum, *Hinterm Horizont geht's weiter?* (2016)

   - Featured in Classical and Quantum Gravity Plus, *Black hole voyeurism* (2014)

9. **Alexander R. H. Smith** and Robert B. Mann, *Persistence of Tripartite Nonlocality for Non-inertial Observers*, Physical Review A 86, 012306 (2012)
DOI: 10.1103/PhysRevA.86.012306

Preprints

1. **Alexander R. H. Smith**, *Communicating without shared reference frames*, arXiv:1811.04835 [gr-qc] (2018) - Submitted to Quantum Physical Review A on Dec 15, 2017, Manuscript ID: 524460

2. Daniel R. Terno, Francesco Vedovato, Matteo Schiavon, **Alexander R. H. Smith**, Piergiovanni Magnani, Giuseppe Vallone, Paolo Villoresi, *Proposal for an Optical Test of the Einstein Equivalence Principle*, arXiv:1812.08053 [quant-ph] (2018)

3. Laura J. Henderson, Robie A. Hennigar, Robert B. Mann, **Alexander R. H. Smith**, and Jialin Zhang, *Entangling detectors in anti-de Sitter space*, arXiv:1809.06862 [quant-ph] (2018)

4. **Alexander R. H. Smith** and Mehdi Ahmadi, *Quantizing time: Interacting clocks and systems*, arXiv:1711.05179 [quant-ph] (2017)

Other articles

Jack Davis, Robert B. Mann, and **Alexander R. H. Smith**, *Decoherence resulting from the gravitational interaction between two quantum objects*, Physics in Canada Magazine 73, 4 (2017)

Presentations

Conference presentations

1. *Quantum Clocks: Gravitation and Relativity*, American Physical Society March Meeting, Boston, USA (2019)

2. *Quantizing Time: Interacting Clocks and Systems*, International Relativistic Quantum Information - North, University of Vienna, Vienna, Austria (2018)

3. *How spacetime structure affects field entanglement*, International YQIS, University of Vienna, Vienna, Austria (2018)

4. *Quantizing Time: Interacting Clocks and Systems*, Foundations 2018, Utrecht University, Utrecht, Netherlands (2018)

5. *Time from Quantum Correlations*, Gravity in the Quantum Regime, Dartmouth College, Hanover, USA (2018)

6. *Interacting Clocks within the Conditional Probability Interpretation of Time*, 27th Midwest General Relativity Meeting, University of Michigan, Ann Arbor, United States (2017)

7. *Spacetime Structure and Vacuum Entanglement*, 26th Midwest General Relativity Meeting, Perimeter Institute for Theoretical Physics, Waterloo, Canada (2016)

8. *Time in Quantum Mechanics*, "Gong Show" at the It from Qubit Workshop, Perimeter Institute for Theoretical Physics, Waterloo, Canada (2016)

9. *Tools for relativistic quantum reference frames*, Relativistic Quantum Information - North Conference, Institute of Quantum Computing, Waterloo, Canada (2016)

10. *Tools for relativistic quantum reference frames*, Canadian Association of Physicists Congress, University of Ottawa, Ottawa, Canada (2016)

11. *Quantum frames of reference and relativity*, Rethinking Foundations of Physics Workshop, Dorfgastein, Austria (2016)

12. *Quantum reference frames*, 9th Relativistic Quantum Information Workshop, Customs House, Brisbane, Australia (2015)

13. *Spacetime structure and vacuum entanglement*, International Relativistic Quantum Information - North conference, Dartmouth College, Hanover, USA (2015)

14. *Inside a black hole: detectors as topological probes*, International Relativistic Quantum Information - North conference, University of Seoul, Seoul, Korea (2014)

15. *Detectors as topological probes*, Canadian Association of Physicists Congress, University, Sudbury, Canada (2014)

16. *Modelling 2D illumination patterns on a triple junction solar cell*, Canadian Undergraduate Physics Conference, University of Dalhousie, Halifax, Canada (2010)

Invited talks

1. *The structure of reality: information, relativity, and the quantum*, Society of Fellows, Dartmouth College, Hanover, USA (2018)
2. *Quantizing time*, Physics & Astronomy Colloquium, Dartmouth College, Hanover USA (2018)
3. *Quantizing time: General total Hamiltonians in the conditional probability interpretation of time*, University of Warsaw, Warsaw, Poland (2017)
4. *Quantizing time: General total Hamiltonians in the conditional probability interpretation of time*, University of Strathclyde, Glasgow, Scotland (2017)
5. *Tools for relativistic quantum reference frames*, University of Calgary, Calgary, Canada (2016)
6. *Relativistic quantum reference frames*, University of Vienna, Vienna, Austria (2016)
7. *Relativistic quantum reference frames*, University of Strathclyde, Glasgow, Scotland (2016)
8. *Spacetime topology and quantum field theory*, University of Warsaw, Warsaw, Poland (2015)

Other presentations

1. *Panel discussion on graduate studies in physics* with Carolyn Earnest, Ali Ramadha, Jennifer Reid, Allison Sachs, and Paulina Ugalde , University of Waterloo, Waterloo, Canada (2016)
2. *Relativistic quantum information*, Macquarie Physics Department Jam Session, Macquarie University, Sydney, Australia (2015)
3. *Vacuum entanglement and spacetime structure*, Poster presentation, QSciTech board meeting, Macquarie University, Sydney, Australia (2015)
4. *Inside a black hole*, Faculty winner and University finalist in the 3 Minute Thesis (3MT) competition, University of Waterloo, Waterloo, Canada (2014)
5. *Entanglement in non-inertial reference frames*, Poster presentation, University of Waterloo, Waterloo, Canada (2012)

Research Experience

Junior Fellow, Society of Fellows, Dartmouth College, Hanover, USA — 2017 - Present

NSERC Postdoctoral Fellow, Dartmouth College, Hanover, USA — 2017 - Present

Research in quantum information science and relativistic quantum information.

Doctoral Researcher, University of Waterloo, Waterloo, Canada — 2012 - 2017

Quantified how the behaviour of quantum systems (Unruh-DeWitt detectors) interacting with a quantum field differ in black hole spacetimes with identical local geometry but differing global topology.

Extended the theory of quantum reference frames to include reference frames associated with the noncompact groups of translations and Galilean boosts.

Applied techniques from quantum metrology to study communication between observers in different Lorentz frames who have partial information about the relation between their reference frames.

Employed the theory of Gaussian quantum information to study how localized modes of a quantum field differ when viewed from an inertial versus non-inertial reference frame.

Doctoral Researcher, Macquarie University, Sydney, Australia 2014 - 2015

Investigated general optical interferometry in stationary spacetimes focusing on experiments in near-Earth environments. Provided a rigorous derivation of the gravitationally induced phase difference in interferometry experiments and adapted the parametrized post-Newtonian formalism to study polarization rotation.

Generalized the entanglement harvesting protocol (swapping of correlations from a quantum field to a bipartite quantum system) to arbitrary static spacetimes and demonstrated that this protocol can be used as a probe of spacetime topology.

Masters Researcher, University of Toronto, Toronto, Canada 2011 - 2012

Studied black hole mechanics in dynamical spherically symmetric spacetimes and the possible role the Kodama vector field (similar to a timelike Killing field) can play in black hole thermodynamics.

Undergraduate Researcher, University of Waterloo, Waterloo, Canada 2010 - 2011

Quantified the degradation of tripartite entanglement for accelerated observers and demonstrated qualitatively different behaviour of tripartite versus bipartite nonlocality in non-inertial reference frames.

Teaching Experience

Course instructor, Dartmouth College, Hanover, USA 2019

Designed and taught a new course in the Dartmouth physics and astronomy department tiled "Introductory Mathematical Methods for Physicists". This course introduced undergraduate students to linear algebra and the study of differential equations from the perspective of a physicist with a focus on applications.

Undergraduate research supervision, Dartmouth College, Hanover, USA 2019

Supervising an undergraduate researcher in the completion of a project in the area of relativistic quantum information.

Co-Supervisor of Undergraduate Researcher, University of Waterloo, Waterloo, Canada 2016 - 2017

Co-supervising, along with Professor Robert B. Mann, an undergraduate researcher in completion of their undergraduate thesis titled: *Quantum Reference Frames and the Three Body Problem.*

Teaching Assistant, University of Waterloo, Waterloo, Canada 2013 - 2014, 2016 - 2017

Courses: Physics for Engineers, Quantum Mechanics I, and Quantum Mechanics II.
Responsibilities: leading tutorials, marking assignments, and proctoring and marking exams.

Co-Supervisor of Undergraduate Researcher, University of Waterloo, Waterloo, Canada 2013 - 2014

Co-supervised, along with Professor Robert B. Mann, an undergraduate reseracher in completion of thier undergraduate thesis titled: *An Unruh-Dewitt detector orbiting around a stationary BTZ black hole.*

Lab Instructor, University of Waterloo, Waterloo, Canada 2012 - 2013

Ran first year physics labs for physics students, which included giving a 30 minute weekly lecture, supervising student experiments, and marking lab reports.

Lab Instructor, University of Toronto, Toronto, Canada 2011 - 2012

Led a two hour tutorial twice a week for first year physics and engineering students. My weekly responsibilities included: two 40 minute lectures, supervising student experiments, and marking lab reports.

Worked in the physics drop in center assisting students with their coursework.

Mathematics Teaching Assistant and Resident Don, St Andrews College, Aurora, Canada 2008

Instructed students in mathematics from grade 9 to advanced placement calculus. Organized both a junior and senior mathematics club.

Industry Experience

Junior Scientist, Morgan Solar Inc., Toronto, Canada 04/2010 - 08/2010

Created a computational model of a triple junction solar cell, which has been used as an important design tool at Morgan Solar Inc.

Presented research in these regards at the Canadian Undergraduate Physics Conference hosted by Dalhousie University on October 23, 2010.

Nuclear Theory Research Assistant, TRIUMF National Lab, Vancouver, Canada 08/2009 - 12/2009

Applied chiral effective field theory to study the half-life of the triton nucleus, which required the use of numerical integration methods implemented in Fortran 95.

Geophysics Technician, WorleyParsons Ltd, Calgary, Canada 01/2009 - 04/2009

Implemented various geophysical techniques for the exploration of different resources, including gravel and oil deposits.

Developed an 8-cable electrical resistance tomography (ERT) system to measure the resistivity of the ground at deeper depths and higher resolutions.

Research Assistant, Xerox Research Centre of Canada, Mississauga, Canada 09/2008 - 12/2008

Investigated the fusing performance of the next generation fuser materials and toners for various colour printers using a wide variety of analytic techniques and instruments.

Designed, programmed, built, and operated a robotic arm to distribute a solvent based film onto fuser rolls for high speed printing presses (iGen3).

Awards, Scholarships, and Grants

Major awards

$167,000	Junior Fellowship in the Society of Fellows, Dartmouth College Awarded by Dartmouth College	09/2017 - 06/2020
$90,000	NSERC Postdoctoral Fellowship Awarded by the Canadian Government based on research performance and leadership	11/2017 - 10/2019
$15,000	Ontario Graduate Scholarship Awarded by the Ontario provincial government based on research performance	09/2016 - 08/2017
$25,400	International Macquarie University Research Excellence Scholarship Awarded internationally by Macquarie University based on research and academic performance	10/2014 - 12/2015
$15,000	Ontario Graduate Scholarship Awarded by the Ontario provincial government based on research performance	09/2012 - 08/2013
$10,000	President's Graduate Scholarship Awarded by the University of Waterloo based on research performance	09/2012 - 08/2013
$20,000	University of Toronto Research Grant Awarded by the University of Toronto based on research performance	09/2011 - 08/2012

Minor awards

$500	Springer Theses, Recognizing Outstanding Ph.D. Research Awarded by Springer Publishing upon publication of PhD thesis	2019
$2,500	International Experience Award Awarded by the University of Waterloo to students who are traveling internationally based on academic and research performance	01/2017 - 04/2017
$5,000	President's Graduate Scholarship Awarded by the University of Waterloo based on research performance	09/2016 - 08/2017
$2,600	Marie Curie Graduate Student Award Awarded by the University of Waterloo Department of Physics & Astronomy based on research performance	01/2016 - 08/2016
$3,750	UW Graduate Scholarship Awarded by the University of Waterloo based on academic and research performance	01/2016 - 04/2016
$3,750	Post Graduate Research Award Awarded by Macquarie University based on research performance	07/2015 - 12/2015

$2,500	Governor General David Johnson International Experience Award Awarded by the University of Waterloo to students who are studying internationally based on academic and research performance	09/2014 - 12/2014
$5,600	Marie Curie Graduate Student Award Awarded by the University of Waterloo Department of Physics & Astronomy based on research performance	09/2013 - 08/2014
$6,275	Science Graduate Experience Award Awarded by the University of Waterloo Faculty of Science based on teaching responsibility	09/2012 - 12/2013
$3,000	University of Waterloo Graduate Entrance Scholarship Awarded by the University of Waterloo based on academic performance	09/2012 - 08/2013
$3,000	University of Toronto Admission Award Awarded by the University of Toronto based on academic performance	09/2011 - 08/2012
$1,000	University of Waterloo Merit Scholarship Awarded by the University of Waterloo based on academic performance	09/2006 - 08/2007

Other awards

Runner-up in the Canadian Association of Physicists, Division of Theoretical Physics, Thesis Competition — 2018

Nominated for the Governor General's Gold Medal, University of Waterloo on behalf of the Government of Canada — 2017

Nominated for the W.B. Pearson Medal for best PhD Thesis, University of Waterloo — 2017

2nd place in the theory division of the Canadian Association of Physicists student oral presentation competition, Canadian Association of Physics Congress, Ottawa, Canada — 2016

3 Minute Thesis (3MT) Science Faculty winner and University of Waterloo finalist — 2014

Deans Honour List at the University of Waterloo; awarded based on academic performance — 2006 - 2011

Service and Leadership

Conference organization

Gravity in the Quantum Regime, Dartmouth College, USA — 2018

Organizer of the Gravity in the Quantum Regime workshop, which focused on conceptual technical issues at the intersection of quantum theory and gravitational physics.

Quantum Frontiers, Dartmouth College, USA — 2018

Organizer of the Quantum Frontiers workshop, which brought together a group of researchers working on wide range of topics in quantum information science.

Spacetime and Information Workshop, Manitoulin Island, Canada 2017

Co-organizer of the international Spacetime and Information Workshop, which brought together young researchers from around the world (Canada, USA, Australia, Austria, United Kingdom, and China) working on relativistic quantum information, and related areas, to discuss recent developments in the field and work on open problems.

- Media coverage: Sandfield plays host to theoretical physics conference

International Relativistic Quantum Information - North Conference, University of Waterloo 2016

Member of the organizing committee for 2016 International Relativistic Quantum Information - North Conference, held at the Institute for Quantum Computing, Waterloo, Canada.

Seminar and group organization

Reading group, University of Waterloo, Waterloo, Canada 2016 - 2017

Founded a pedagogical reading group for senior graduate students and professors focused on topics in canonical quantum gravity.

Journal club, University of Toronto, Toronto, Canada 2011 - 2012

Founded a journal club focusing on articles addressing quantum foundations and the philosophy of science.

Referee duites

Served as as a referee for the following journals:

Foundations of Physics, Springer Nature	2018 - Present
Nature Communications, Springer Nature	2018 - Present
Quantum Information Processing, Springer	2017 - Present
Canadian Journal of Physics	2017 - Present
Diacritics	2018 - Present

Scientific Outreach

Public lecture host, Dartmouth College, Hanover, USA 2018

Organized and hosted a public lecture given by Professor Andrzej Dragan from the University of Warsaw titled: Quantum Theory versus Common Sense.

Participant in panel discussion, University of Waterloo, Waterloo, Canada 2016

Discussed the realities of pursuing graduate studies in physics with several other graduate students for an audience of undergraduate students.

Science fair judge, Waterloo-Wellington Science and Engineering Fair, Waterloo, Canada 2014, 2016

Judged and provided constructive feedback for both elementary and high school student science fair projects.

Presenter, Macquarie University Physics Jam, Sydney, Australia 2015

Presented my current research with the aim of showcasing the research interests of the Macquarie University Physics and Astronomy Department to prospective graduate students.

Volunteer scientist, BrainSTEM exhibition , Perimeter Institute, Waterloo, Canada 2013

Explained the science behind new and novel technologies to the public at the BrainSTEM exhibition held at the Perimeter Institute for Theoretical Physics.

Mentor, International Summer School for Young Physicists, Perimeter Institute, Waterloo, Canada 2013

Mentored high school students from around the world who came to the Perimeter Institute for Theoretical Physics for an intensive two week summer camp focused on physics.

Professional Development

Kresge's Writer's Retreat, Dartmouth College, Hanover, USA 2018

DCAL Future Faculty Program, Dartmouth College, Hanover, USA 2018

Fundamentals of University Teaching Program, University of Waterloo, Waterloo, Canada 2017

It from Qubit Summer School, Perimeter Institute, Waterloo, Canada 2016

Writing Research Proposals Workshop, Macquarie University, Sydney, Australia 2015

Physics Teaching Assistant Workshop, University of Waterloo, Waterloo, Canada 2012

Academic Integrity Workshop, University of Waterloo, Waterloo, Canada 2012

Physics Undergraduate Teaching Workshop, University of Toronto, Toronto, Canada 2011

Professional Affiliations

Member, American Physical Society, USA 2018 - Present

Member, Canadian Association of Physicists, Canada 2010 - 2011; 2016 - Present

Member, Basic Research Community for Physics, Germany 2016 - Present