

Brendon L. Higgins

Curriculum Vitae

Institute for Quantum Computing
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Education

- 2007–2010 **Doctor of Philosophy**, *Griffith University*, Brisbane, Australia.
Quantum physics
- 2006 **Bachelor of Science (Hons)**, *Griffith University*.
Majoring in Physics
- 2002–2005 **Bachelor of Science**, *Griffith University*.
With Advanced Studies, dual-majors in Physics and Applied Mathematics
Bachelor of Information Technology, *Griffith University*.
Majoring in Computer Science

Awards, Scholarships, and Memberships

- 2011– Member, Australian Institute of Physics
- 2011–2013 Banting Postdoctoral Fellowship (Canada)
- 2011 Queensland state nominee for the Australian Institute of Physics Bragg Gold Medal for Excellence in Physics
- 2010 Chancellor's Medal, best PhD thesis in the Science, Environment, Engineering and Technology Group, Griffith University
- 2007–2010 Australian Postgraduate Award
- 2006–2010 Secretary, Griffith University Maths and Physics Association (student organisation)
- 2006 Honours 1st Class, Griffith University
University Medal, Griffith University
Griffith Award For Academic Excellence
- 2005 Griffith University School of Computing and Information Technology combined academic program Information Technology Award
Information Technology Medal, Griffith University
- 2004 Griffith Award For Academic Excellence
- 2003– Member, Golden Key International Honour Society
- 2003 Griffith Award For Academic Excellence
- 2002 Griffith Award For Academic Excellence

Skills and Interests

Physics, computation and computer systems, and general science and technology

Quantum information, algorithms, and complexity

Quantum control and adaptive quantum measurement

Numerical simulation and data processing

Experimental implementations in photonics

Optical circuit construction, devices, and device drivers

Computer programming paradigms and languages: C/C++, C#, Python, Matlab, Haskell, VHDL, LabVIEW, and others

Unix system administration; Linux and open-source software

Computer networks and communications systems

Misc. computer skills, media creation, mark-up languages such as HTML and L^AT_EX

Project management and communication skills

Laboratory and Research Experience

2011– **Quantum Space: Research at the Institute for Quantum Computing.**

Post-doctoral research in the Quantum Photonics Laboratory of Assoc. Prof. Thomas Jennewein, University of Waterloo.

Studies and experiments towards global quantum key distribution through implementations between ground locations and orbiting satellites. I investigate solutions to practical issues of high-loss, restricted processing capacity, and high-precision timing and polarization reference frame alignment, with focus on applications to satellite uplinks for quantum communications protocols. I also develop systems to support the experimental laboratory and field demonstrations, including data collection and processing, and stage motion control. My work, largely centered around development of the Quantum Encryption and Science Satellite (QEYSSat) and related projects, is done in collaboration with governmental and industry partners, including the Canadian Space Agency, Neptec, Honeywell (formerly COM DEV), INO, Xiphos, and others. I also contributed to experimental demonstrations of violations of three-partite Bell-like inequalities, performing spacetime analysis to ensure strict separation of all relevant source and measurement choice events.

2007–2010 **Quantum Measurement: Concepts, Algorithms, and Experiments in Photonic Quantum Information Science.**

PhD research in the Quantum Optics and Information Laboratory. Advisers: Prof. Geoff Pryde, Prof. Howard Wiseman, Griffith University.

Experiments with a central theme of photonic implementations of quantum-enhanced measurement. I conducted the first demonstrations of unbiased phase measurement schemes with precision scaling at the fundamental limit, both with and without the use of adaptive feedback. I also constructed and experimentally demonstrated multiple-copy nonorthogonal quantum state discrimination schemes, employing local measurements and adaptive feedback, that are optimally robust in the presence of depolarising noise. Finally, I experimentally demonstrated weak measurements of two-photon entangled states, deriving negative so-called “weak” probabilities of joint outcomes of conjugate measurements in the context of a Bell-like measurement.

2006 **Advanced Photonic Measurements for Quantum Information.**

Bachelor of Science (Hons) project. Adviser: Prof. Geoff Pryde, Griffith University. (Experiments primarily conducted in the Quantum Technology Laboratory of Prof. Andrew White at the University of Queensland.)

The photonic implementation of an entangling nonprojective quantum measurement scheme. I constructed a quantum nondemolition measurement device based on a nondeterministic controlled-NOT gate employing polarising beam displacers, and a quantum circuit which unambiguously discriminates nonorthogonal polarisation states. I then studied the outcomes of the combination of these two circuits towards developing a nondemolishing unambiguous state discriminator.

2004 **Using Wavelet Transforms to Assist the Solution of van der Waals Forces.**

Bachelor of Science Advanced Studies project. Adviser: Prof. John Dobson, Griffith University.

A theoretical investigation into the usefulness of two-dimensional wavelet transformations of processing matrices describing long-ranged van der Waals interactions. I showed that wavelet transformations are likely good candidates to assist the efficient solution of electronic ground state energy in a simple model material known as a “jellium slab” using the random phase approximation procedure.

Teaching and Other Work Experience

- 2017– Referee for EPJ Quantum Technology
- 2015– Referee for NPJ Quantum Information
Referee for Quantum Information Processing
- 2014– Referee for Nature Communications
- 2011– Supervision of undergraduate and graduate students (>10) taking part in research projects at the Institute for Quantum Computing, University of Waterloo
Referee for Physical Review Letters
- 2011–2016 Adjunct member, Centre for Quantum Dynamics, Griffith University
- 2011 Poster Presentation Judge, Graduate Student Research Conference, University of Waterloo
- 2009– Referee for Physical Review A
- 2009 Laboratory demonstrator, 3rd-year undergraduate physics, Griffith University
- 2007 Laboratory demonstrator, 1st-year undergraduate physics, Griffith University
- 2005, 2006 Student Ambassador for Griffith University, “Mythbusters” events and Open Day (2006)

Publications

Refereed Publications

- 18. J. G. Lim, E. Anisimova, B. L. Higgins, J.-P. Bourgoin, T. Jennewein, and V. Makarov. *Laser annealing heals radiation damage in avalanche photodiodes*, **EPJ Quantum Technol.** **4**, 11 (2017)
- 17. C. J. Pugh, S. Kaiser, J.-P. Bourgoin, J. Jin, N. Sultana, S. Agne, E. Anisimova, V. Makarov, E. Choi, B. L. Higgins, and T. Jennewein. *Airborne demonstration of a quantum key distribution receiver payload*, **Quantum Sci. Technol.** **2**, 024009 (2017)

16. E. Anisimova, B. L. Higgins, J.-P. Bourgoin, M. Cranmer, E. Choi, D. Hudson, L. P. Piche, A. Scott, V. Makarov, and T. Jennewein. *Mitigating radiation damage of single photon detectors for space applications*, ***EPJ Quantum Technol.*** **4**, 10 (2017)
15. J.-P. Bourgoin, B. L. Higgins, N. Gigov, C. Holloway, C. J. Pugh, S. Kaiser, M. Cranmer, and T. Jennewein. *Free-space quantum key distribution to a moving receiver*, ***Optics Express*** **21**, 33437–47 (2015)
14. J.-P. Bourgoin, N. Gigov, B. L. Higgins, Z. Yan, E. Meyer-Scott, A. K. Khandani, N. Lütkenhaus, and T. Jennewein. *Experimental quantum key distribution with simulated ground-to-satellite photon losses and processing limitations*, ***Phys. Rev. A*** **92**, 052339 (2015)
13. B. L. Higgins, M. S. Palsson, G. Y. Xiang, H. M. Wiseman, and G. J. Pryde. *Using weak values to experimentally determine “negative probabilities” in a two-photon state with Bell correlations*, ***Phys. Rev. A*** **91**, 012113 (2015)
12. C. Erven, E. Meyer-Scott, K. Fisher, J. Lavoie, B. L. Higgins, Z. Yan, C. J. Pugh, J.-P. Bourgoin, R. Prevedel, L. K. Shalm, L. Richards, N. Gigov, R. Laflamme, G. Weihs, T. Jennewein, and K. J. Resch. *Experimental Three-Photon Quantum Nonlocality under Strict Locality Conditions*, ***Nature Photonics*** **8**, 292–6 (2014)
11. E. Meyer-Scott, V. Roy, J.-P. Bourgoin, B. L. Higgins, L. K. Shalm, and T. Jennewein. *Generating Polarization-Entangled Photon Pairs Using Cross-Spliced Birefringent Fibers*, ***Optics Express*** **21**, 6205–12 (2013)
10. Z. Yan, E. Meyer-Scott, J.-P. Bourgoin, B. L. Higgins, N. Gigov, A. MacDonald, H. Hübel, and T. Jennewein. *Novel High-Speed Polarization Source for Decoy-State BB84 Quantum Key Distribution Over Free Space and Satellite Links*, ***J. Lightwave Tech.*** **31**, 1399–408 (2013)
9. J.-P. Bourgoin, E. Meyer-Scott, B. L. Higgins, B. Helou, C. Erven, H. Hübel, B. Kumar, D. Hudson, I. D’Souza, R. Girard, R. Laflamme, and T. Jennewein. *A comprehensive design and performance analysis of low Earth orbit satellite quantum communication*, ***New J. Phys.*** **15**, 023006 (2013)
8. D. Rideout, T. Jennewein, G. Amelino-Camelia, T. F. Demarie, B. L. Higgins, A. Kempf, A. Kent, R. Laflamme, X. Ma, R. B. Mann, E. Martin-Martinez, N. C. Menicucci, J. Moffat, C. Simon, R. Sorkin, L. Smolin, and D. R. Terno. *Fundamental quantum optics experiments conceivable with satellites—reaching relativistic distances and velocities*, ***Class. Quantum Grav.*** **29**, 224011 (2012)
7. B. L. Higgins, A. C. Doherty, S. D. Bartlett, G. J. Pryde, and H. M. Wiseman. *Multiple-copy state discrimination: Thinking globally, acting locally*, ***Phys. Rev. A*** **83**, 052314 (2011)
6. G. Y. Xiang, B. L. Higgins, D. W. Berry, H. M. Wiseman, and G. J. Pryde. *Entanglement-enhanced measurement of a completely unknown optical phase*, ***Nature Photonics*** **5**, 43–7 (2011)
5. B. L. Higgins, B. M. Booth, A. C. Doherty, S. D. Bartlett, H. M. Wiseman, and G. J. Pryde. *Mixed state discrimination using optimal control*, ***Phys. Rev. Lett.*** **103**, 220503 (2009)
4. D. W. Berry, B. L. Higgins, S. D. Bartlett, M. W. Mitchell, G. J. Pryde, and H. M. Wiseman. *How to perform the most accurate possible phase measurements*, ***Phys. Rev. A*** **80**, 052114 (2009)

3. H. M. Wiseman, D. W. Berry, S. D. Bartlett, B. L. Higgins, and G. J. Pryde. *Adaptive Measurements in the Optical Quantum Information Laboratory*, **IEEE J. Sel. Top. Quantum Electron.** **15**, 1661–72 (2009)
2. B. L. Higgins, D. W. Berry, S. D. Bartlett, M. W. Mitchell, H. M. Wiseman, and G. J. Pryde. *Demonstrating Heisenberg-limited unambiguous phase estimation without adaptive measurements*, **New J. Phys.** **11**, 073023 (2009)
1. B. L. Higgins, D. W. Berry, S. D. Bartlett, H. M. Wiseman, and G. J. Pryde. *Entanglement-free Heisenberg-limited phase estimation*, **Nature** **450**, 393–6 (2007)

Preprints and In-preparation

J.-F. Lavigne, C. J. Pugh, J.-P. Bourgoin, B. L. Higgins, and T. Jennewein. *Adaptive Optics for Quantum Key Distribution between an Earth station and a Satellite*, in preparation (2017)

B. L. Higgins, J.-P. Bourgoin, and T. Jennewein. *Practical polarization-frame alignment for quantum key distribution without classical references*, in preparation (2017)

Articles

T. Jennewein, C. Grant, E. Choi, C. Pugh, C. Holloway, J.-P. Bourgoin, H. Hakima, B. Higgins, and R. Zee. *The NanoQEY mission: ground to space quantum key and entanglement distribution using a nanosatellite*, **Proc. SPIE** **9254**, 925402 (2014)

T. Jennewein, J.-P. Bourgoin, B. Higgins, C. Holloway, E. Meyer-Scott, C. Erven, B. Heim, Z. Yan, H. Hübel, G. Weihs, E. Choi, I. D’Souza, D. Hudson, and R. Laflamme. *QEYSSAT: a mission proposal for a quantum receiver in space*, **Proc. SPIE** **8997**, 89970A (2014)

Thomas Jennewein, Brendon Higgins, and Eric Choi. *Progress toward a quantum communication satellite*, **SPIE Newsroom** **1 May 2014**

Thomas Jennewein and Brendon Higgins. *The quantum space race*, **Physics World** **March 2013**, pp52–6

Media Coverage

P. Daukantas. *Quantum Key Distribution Takes Flight*, **Optics & Photonics News** **2017-06-15**.

S. Chen. *Physicists, Lasers, and an Airplane: Taking Aim at Quantum Cryptography*, **Wired** **2017-02-02**.

I. Semeniuk. *Canadians solve key puzzle for future of encryption*, **The Globe and Mail** **2016-12-20** (online), **2016-12-21**, p1 and A14 (print). Reprinted in **The Record** **2016-12-22**, p1–2.

IQC Researchers Successfully Conduct Airborne Demonstration of Quantum Key Distribution, **CASI Toronto Flyer** **November 2016**, p5–6.

G. J. Pryde. *Entanglement à trois*, **Nature Photonics** **8**, 275–6 (2014)

Quantum Communication Finds Many Paths to Commercialization, **Photonics Spectra** **February 2014**, 42–5

Cryptography: The solace of quantum, **The Economist** **2013-05-25**

Quantum physics rules, Outcomes: Results of research in the real world '08, Australian Research Council inaugural publication, p60 (2008)

World's Most Precise Ruler Created, ***Australasian Science*** April 2008, p13

J. L. O'Brien. *Precision Without Entanglement*, ***Science*** **318**, 1393–4 (2007)

S. Trad. *No size too tiny to gauge*, ***The Australian*** 2007-22-21, p26

J. P. Dowling. *Kittens catch phase*, ***Nature*** **450**, 362–3 (2007)

P. Ball. *The most accurate measurement ever made*, ***Nature News*** 2007-11-14

Presentations

J.-P. Bourgoïn, B. Higgins, N. Gigov, C. Holloway, C. Pugh, S. Kaiser, M. Cranmer, and **T. Jennewein**. *Towards QEYSSat: Free-space quantum key distribution to a moving receiver*, (poster) QCRYPT: Conference on Quantum Cryptography, Tokyo, September 2015

E. Anisimova, B. Higgins, J.-P. Bourgoïn, M. Cranmer, E. Choi, D. Hudson, L. Piche, A. Scott, V. Makarov, and T. Jennewein. *Demonstration of suitability of avalanche photodiodes for quantum communications in the low-Earth-orbit radiation environment*, (poster) QCRYPT: Conference on Quantum Cryptography, Tokyo, September 2015

C. Pugh, T. D. Jennewein, C. Grant, J.-P. Bourgoïn, B. L. Higgins, and H. Hakima. *NanoQEY Quantum Key Distribution Satellite*, Canadian Association of Physicists Congress, Edmonton, June 2015

T. D. Jennewein, E. Choi, C. Pugh, C. Holloway, J.-P. Bourgoïn, B. L. Higgins, and R. Zee. *The NanoQEY Mission: Ground to Space Quantum Key and Entanglement Distribution Using a Nanosatellite*, SPIE Security + Defence, Amsterdam, September 2014

B. L. Higgins, J.-P. Bourgoïn, N. Gigov, E. Meyer-Scott, Z. Yan, and T. Jennewein. *Pushing Quantum Optical Receiver Technology Towards Satellite-Mediated Global Quantum Key Distribution*, (poster) QCRYPT: Conference on Quantum Cryptography, Waterloo, August 2013

E. Meyer-Scott, V. Roy, J.-P. Bourgoïn, **B. L. Higgins**, L. K. Shalm, and T. Jennewein. *A Collinear Nondegenerate Source of Entangled Photon Pairs in PM Fiber*, (poster) OFC/NFOEC, Anaheim, March 2013

E. Meyer-Scott, J.-P. Bourgoïn, L. K. Shalm, B. Higgins, V. Roy, and T. Jennewein. *A New 'Sausage' Source of Entangled Photon Pairs in Polarization-Maintaining Fiber*, Frontiers in Optics, Rochester, October 2012

J.-P. Bourgoïn, **B. L. Higgins**, N. Gigov, E. Meyer-Scott, Z. Yan, T. Jennewein, J.-F. Lavigne, V. Roy, P. Deladurantaye, and A. Fourgères. *Technological Developments Towards a Canadian Quantum Encryption and Science Satellite — QEYSSAT*, (poster) QCRYPT: Conference on Quantum Cryptography, Singapore, September 2012

B. L. Higgins, **J.-P. Bourgoïn**, N. Gigov, E. Meyer-Scott, Z. Yan, and T. Jennewein. *Detailed Performance Analysis of the Proposed QEYSSAT Quantum Receiver Satellite*, (poster) Quantum Communication, Measurement and Computing, Vienna, July 2012

- B. L. Higgins**, J.-P. Bourgoïn, N. Gïgov, E. Meyer-Scott, Z. Yan, and T. Jennewein. *Detailed Performance Analysis of the Proposed QEYSSAT Quantum Receiver Satellite*, (poster) CLEO: QELS – Fundamental Science, San Jose, May 2012
- B. L. Higgins**, A. C. Doherty, S. D. Bartlett, G. J. Pryde, and H. M. Wiseman. *Multiple-copy state discrimination: Thinking globally, acting locally*, Conference on Quantum Information and Quantum Control, Toronto, August 2011
- G. J. Pryde**, G. Y. Xiang, B. L. Higgins, H. M. Wiseman, H. F. Hofmann, and D. W. Berry. *Optimal multi-photon phase sensing with a single interference fringe*, Photonics West, San Francisco, January 2011
- G. J. Pryde**, G. Y. Xiang, B. L. Higgins, H. F. Hofmann, D. W. Berry, and H. M. Wiseman. *Optimal multi-photon phase sensing with a single interference fringe*, Australian Institute of Physics Congress, Melbourne, December 2010
- M. S. Palsson**, B. L. Higgins, G. Y. Xiang, and G. J. Pryde. *Bell Inequalities and Weak Values*, Australian Institute of Physics Congress, Melbourne, December 2010
- B. L. Higgins**, G. Y. Xiang, D. W. Berry, H. M. Wiseman, and G. J. Pryde. *Entanglement-enhanced measurement of a completely unknown phase*, SPIE Optics + Photonics, San Diego, August 2010
- B. L. Higgins**, G. Y. Xiang, D. W. Berry, H. M. Wiseman, and G. J. Pryde. *Entanglement-enhanced measurement of a completely unknown phase*, (poster) Quantum Communication, Measurement and Computing, Brisbane, July 2010
- G. Y. Xiang**, B. L. Higgins, H. F. Hofmann, and G. J. Pryde. *Phase estimation using four- and six-photon Holland-Burnett states*, (poster) Quantum Communication, Measurement and Computing, Brisbane, July 2010
- B. L. Higgins**, D. W. Berry, B. M. Booth, M. W. Mitchell, A. C. Doherty, S. D. Bartlett, H. M. Wiseman, and G. J. Pryde. *Demonstrations of Adaptive Quantum Measurements in Optics*, Australasian Conference on Optics, Lasers and Spectroscopy, Adelaide, December 2009
- D. W. Berry**, B. L. Higgins, H. M. Wiseman, S. D. Bartlett, M. W. Mitchell, and G. J. Pryde. *Phase Measurements at the Theoretical Limit*, DEX-SMI Workshop on Quantum Statistical Inference, Tokyo, March 2009
- D. W. Berry, **H. M. Wiseman**, B. L. Higgins, S. D. Bartlett, M. W. Mitchell, and G. J. Pryde. *Theory for Heisenberg Limited Phase Measurement*, Australian Institute of Physics Congress, Adelaide, November 2008
- B. L. Higgins**, B. M. Booth, A. C. Doherty, S. D. Bartlett, H. M. Wiseman, and G. J. Pryde. *Adaptive State Discrimination*, Australian Institute of Physics Congress, Adelaide, November 2008
- G. J. Pryde**, B. L. Higgins, D. W. Berry, B. M. Booth, A. C. Doherty, S. D. Bartlett, and H. M. Wiseman. *Quantum Information, Quantum Control, and Precision Measurement*, Australian Institute of Physics Congress, Adelaide, November 2008
- G. J. Pryde**, B. L. Higgins, D. W. Berry, S. D. Bartlett, and H. M. Wiseman. *Entanglement-free, Heisenberg-limited Phase Measurement*, Quantum Communication, Measurement and Computing, Calgary, August 2008

- B. L. Higgins**, B. M. Booth, A. C. Doherty, S. D. Bartlett, H. M. Wiseman, and G. J. Pryde. *Globally Optimal Quantum Control In State Discrimination*, (poster) Quantum Communication, Measurement and Computing, Calgary, August 2008
- G. J. Pryde**, B. L. Higgins, B. M. Booth, A. C. Doherty, S. D. Bartlett, and H. M. Wiseman. *Adaptive State Discrimination*, SPIE Optics + Photonics, San Diego, August 2008
- B. L. Higgins, H. M. Wiseman, **G. J. Pryde**, D. W. Berry, and S. D. Bartlett. *Entanglement-Free Heisenberg-Limited Phase Measurement*, CLEO/QELS and PhAST, San Jose, May 2008
- D. W. Berry**, B. L. Higgins, S. D. Bartlett, H. M. Wiseman, and G. J. Pryde. *Entanglement-free Heisenberg-limited phase estimation*, Noise Information & Complexity @ Quantum Scale, Erice, November 2007
- G. J. Pryde**, B. L. Higgins, D. W. Berry, S. D. Bartlett, and H. M. Wiseman. *Quantum-enhanced phase estimation without entanglement*, SPIE Optics + Photonics, San Diego, August 2007
- B. L. Higgins, D. W. Berry, S. D. Bartlett, H. M. Wiseman, and **G. J. Pryde**. *Entanglement-free Heisenberg-limited phase estimation*, (poster) IARPA Quantum Computing Program Review, August 2007
- G. J. Pryde**, B. L. Higgins, D. W. Berry, S. D. Bartlett, H. M. Wiseman. *Experimental entanglement-free Heisenberg-limited phase estimation*, PRACQSYS, Sydney, July 2007
- B. L. Higgins, **D. W. Berry**, S. D. Bartlett, H. M. Wiseman, and G. J. Pryde. *Theory of entanglement-free Heisenberg-limited phase estimation*, PRACQSYS, Sydney, July 2007