Karen V. Kheruntsyan

Curriculum Vitae

11 December 2023

CONTACT DEATAILS

Professor Karen V. Kheruntsyan
School of Mathematics and Physics
The University of Queensland
Brisbane, Queensland 4072
Australia

Phone: +61 (0)404 753 449 (mobile)
Fax: +61 (0)7 3365 1242
E-mail: karen.kheruntsyan@uq.edu.au
https://people.smp.uq.edu.au/KarenKheruntsyan/

EMPLOYMENT HISTORY

01/01/2018–present	***Professor,*** School of Mathematics and Physics (SMP), University of Queensland (UQ), Brisbane, Australia
01/01/2015–31/12/2017	***Associate Professor,*** SMP, UQ
01/01/2011–31/12/2014	***Australian Research Council (ARC) Future Fellow and UQ ResTeach Affiliate,*** SMP, UQ
01/01/2008–31/12/2010	***Senior Research Fellow and UQ ResTeach Affiliate,*** Chief Investigator in the ARC Centre of Excellence for Quantum-Atom Optics (ACQAO), UQ
01/01/2004–31/12/2007	***Senior Research Fellow,*** Chief Investigator, ACQAO, UQ.
01/01/2001–31/12/2003	***ARC Senior Research Associate***, UQ.
01/07/2000–31/12/2000	***Lecturer***, UQ.
01/01/2000–31/06/2000	***ARC Senior Research Associate***, UQ.
01/10/1997–31/09/1999	***UQ Postdoctoral Research Fellow***, UQ.
04/10/1996–31/09/1997	***ARC Research Associate***, UQ.
1992–1996	***Junior Research Scientist (with interruptions),*** Institute for Physical Research, National Academy of Science, Armenia

EDUCATION

1989–1992 *PhD studies*, Institute for Physical Research, National Academy of Science, Armenia

1983–1988 *Undergraduate/Postgraduate studies*, Yerevan State University, Yerevan, Armenia

DEGREES AWARDED

1993 *PhD in Physics*, Institute for Physical Research, National Academy of Science, Armenia

1988 *MSc*, Yerevan State University, Yerevan, Armenia

AWARDS / PRIZES / FELLOWSHIPS

2016 UQ Faculty of Science Teaching Excellence Award

2010 ARC Future Fellowship Award

2005 ARC Centre of Excellence Fellow

1997 UQ Postdoctoral Research Fellowship

1994 Finalist (winner in Physics) for the Young Scientists'94 award by the Pan-Armenian Fund "Hayastan"

1993 International Science Foundation Award – Individual Grants Program for the Scientists from the Former USSR, Institute for Physical Research, Armenia

1988 MSc Diploma with Excellence (*Cum Laude*), Yerevan State University, Yerevan, Armenia

COMPETITIVE RESEARCH AND TEACHING GRANTS RECEIVED

2024 **$304,031**, for 3 years (2024-2026), ARC Discovery Project grant "Hydrodynamics of quantum fluids". Chief Investigators: K. V. Kheruntsyan, E. Laird

2021 **$472,000**, UQ Research Infrastructure Investment grant "Atomic Scale Imaging Facility for Quantum and Organic Electronic Devices". P. Jacobson, W. Bowen, A. Federov, H. Rubinsztein-Dunlop, M. Davis, C. Williams, J. Clegg, B. Powel, R. McKenzie, I. McCulloch, K. V. Kheruntsyan, T. Stace

2019 **$291,000** for 3 years (2019-2021), ARC Discovery Project grant "Quantum Thermododynamics of Ultra-Cold Atoms". Chief Investigators: K. V. Kheruntsyan, I. P. McCulloch

2018 **$2,038** for 1 year, SMP Teaching and Learning grant "An online reading quiz module for PHYS2041- Quantum Physics".

2017 **$119,570** for 1 year (2017), UQ Major Equipment and Infrastructure Grant "Upgrading cryogenic characterisation facility for optoelectronic measurements in a full range of cryogenic temperatures"; Chief Investigators: E. Nambas, A. Fedorov, S. C. Lo, J. Clegg, B. Powell, W. Boswen, A. White, T. Stace, T. Plakhotnik, A. Rakic, K.V. Kheruntsyan.

2017 **$586,828** for 3 years (2017-2019), UQ Precision Sensing Initiative; Chief Investigators: W. Bowen, M. Bromley, M. Bruenig, J. Carpenter, M.J. Davis, A. Fedorov, K.V. Kheruntsyan, Y.-L. Lim, G. Milburn, E. Nambas, T. Niemenen, T. Plakhotnik, A. Rakic, H. Rubinsztein-Dunlop, T. Stace, A. White, S. Wilson.

2017 **$366,000** for 3 years (2017-2019), ARC Discovery Project grant "Quantum matter far-from-equilibrium", Chief Investigator: K. V. Kheruntsyan; Partner Investigator: J. Schmiedmayer

2015 **$161,229** for 1 year, UQ Major Equipment and Infrastructure Grant "Advanced superfluid physics facility". Chief Investigators: W. Bowen, M. Bromley, M. Davis, A. Fedorov, K.V. Kheruntsyan, I. McCulloch, L. Madsen, G. Milburn, E. Moore, E. Nambas, T. Plakhotnik, B. Powell, A. Rakic, M. Riley, H. Rubinsztein-Dunlop, T. Stace, A. White.

2015 **$3,271** for 1 year, SMP Teaching and Learning grant "Conceptual Checkpoints: an Interactive eLearning Module for PHYS3020 – Statistical Mechanics"

2014 **$330,000** for 3 years (2014-2016), ARC Discovery Project grant "Emergent physics in quantum transport with ultracold atoms". Chief Investigator: K.V. Kheruntsyan

2014 **$20,000** for 2 years (2014-2015), Group of Eight Australia – DAAD Germany Joint Research Cooperation Grant "Einstein-Podolsky-Rosen entanglement in ultracold atomic gases". Chief Investigator: K.V. Kheruntsyan; Partner Investigator: M. Oberthaler

2012 **$385,000** for 3 years (2012-2014), ARC Discovery Project Grant "Quantum nonlocality tests with untracold atoms". Chief Investigators: A.G. Truscott, K.V. Kheruntsyan, K.G. Baldwin. Partner Investigators: A. Aspect, C.I. Westbrook

2010 **$791,192** for 4 years (2010-2014, including salary), ARC Future Fellowship "Fundamental tests of quantum mechanics with ultracold atomic gases". Chief Investigator: K.V. Kheruntsyan

2011 **$405,000** for 3 years (2011-2013), ARC Discovery Project Grant "Quantum Equilibration". Chief Investigators: K.V. Kheruntsyan and M.J. Davis; Partner Investigators: G.V. Shlyapnikov, M. Rigol, J-S. Caux, and N.J. van Druten

2006 **$68,000** for 3 years (2007-2010), ARC Linkage International Award "Quantum correlations in ultra-cold Fermi gases". Chief Investigators: P.D. Drummond, X.-J. Liu, J.F. Corney, and K.V. Kheruntsyan.

2004 **$10,000** ARC Networks, "Quantum Many-Body Systems Network: Breakthrough Science and Frontier Technologies". Chief Investigators: D. Hannan, M. Gould, S. Bartlett, M.T. Batchelor, V. Bazhanov, P. Bouwknegt, A.J. Bracken, K. Burrage, A.L. Carey, M.Cowling, P.D. Drummond, O. Foda, P. Forrester, A. Guttmann, C.J. Hamer, P.D. Jarvis, D. Jayatilaka, I. Jensen, K. Kheruntsyan, J.R. Links, I. McArthur, R. McKenzie, G.J. Milburn, M. Nielsen, A. Owczarek, P.A. Pearce, K. Seaton, R.H. Street, Y.-Z. Zhang, H.-Q. Zhou.

2003 **$750,000** over 5 years (2003-2007), Queensland Government matching funds to the UQ Node of the ARC Centre of Excellence for Quantum-Atom Optics. Chief Investigators: P.D. Drummond, K. Kheruntsyan, J.F. Corney, M.J. Davis, M. Reid.

2003 **$16,950,000** over 8 years (2003-2010), ARC Centre of Excellence Grant – Australian Centre for Quantum-Atom Optics (UQ component: $2,554,000). Chief Investigators: H.A. Bachor, K.G. Baldwin, J.D. Close, J.J. Hope, Y.S. Kivshar, P.K. Lam, E.A. Ostrovskaya, C.M. Savage, A.G. Truscott, J.F. Corney, M.J. Davis, P.D. Drummond, K.V. Kheruntsyan, M.D. Reid, M.K. Olsen, B.J. Dalton, P. Hannaford, T.D. Kieu, R. McLean, W.J. Rowlands, A. Sidorov.

2002 **$25,000** - UQ Research Development Grant "Quantum correlations in degenerate Bose gases". Chief Investigators: P.D. Drummond, A. Bracken, M. Reid, M. Gould, K.V. Kheruntsyan and Y-Zh. Zhang.

2001 **$15,000** - UQ Early Career Researcher Grant "Prospects for superchemistry: Non-linear mater-wave optics with interacting atomic and molecular quantum gases". Chief Investigator: K.V. Kheruntsyan.

2000 **$18,000** - ARC Small Grant "Coherent bosonization in Fermi gases". Chief Investigators: P.D. Drummond and K.V. Kheruntsyan.

1999 **$19,350** - ARC Small Grant "Vortices and solitons in Bose-Einstein condensates". Chief Investigators: P.D. Drummond and K.V. Kheruntsyan.

1997 **$10,000** plus salary - UQ Postdoctoral Research Fellowship "Quantum optical solitons in higher dimensions". Chief Investigator: K.V. Kheruntsyan.

1995 Travel grant from the EC Action for Cooperation in Science and Technology with Central and Eastern European countries for attending the European Research Conference on Quantum Optics, Davos, Switzerland (23–28 September 1995).

1993 **US$500** - Grant from the International Science Foundation – Individual Grants Program for the Scientists from the Former USSR, Institute for Physical Research, National Academy of Science, Armenia. Chief Investigator: K.V. Kheruntsyan.

TEACHING AND STUDENT SUPERVISION

- UQ Faculty of Science Dean's Commendation for the Most Effective Teacher nominations:
  - Sem 2, 2021
  - Sem 2, 2020
  - Sem 1, 2019
  - Sem 2, 2018

- Courses taught:
  - PHYS2041 – 2nd year Quantum Physics, since 2017 (course coordinator, lecturer)
  - PHYS3020 – 3rd year Statistical Mechanics, since 2008-2019 (course coordinator, lecturer)
  - PHYS4030 – 4th year Condensed Matter Physics, since 2015 (lecturer)
  - PH341 – 3rd year Statistical Mechanics, 1998-2000 (lecturer)
  - PH454 – 4th year Quantum Optics, 1999 (lecturer)

- Student supervision:
  - 15 PhD students (13 completed, 2 current)
  - 13 Honours students (11 completed, 2 University Medalists)
  - 14 Summer Vacation and International Exchange Students (all completed)

PUBLICATIONS AND IMPACT

- Total number of publications in international refereed journals: 92

- total number of citations received: 3,305 (Web of Science)
- *h*-index: 33 (WoS); average number of citations per publication: 36 (WoS)
- >30% of publications in the last ten years are published in the discipline's leading journals Physical Review Letters, Nature Physics, and Nature Communications.
- Eight most highly cited papers received 311, 202, 198, 193, 135, 130, 120 & 100 citations, respectively
- Received more than 140 citations per year in the last 15 consecutive years
- For updated citation metrics, see www.researcherid.com/rid/A-1725-2010

- Co-Editor (with R.E. Robson and P.D. Drummond) of the *Proceedings of the Conference on Computational Physics 2000*, published as a Special Issue of the *Journal of Computer Physics Communications*, Vol. **142**, No. 1–3 (2001)

INVITED CONFERENCE TALKS AND VISITING POSITIONS

2019 International ICTP conference on Complex Quantum Systems out of Equilibrium in Many-Body Physics and Beyond, Yerevan, Armenia

2018 Workshop on Dynamics of Ultracold Systems with Embedded Highly-Excited Rydberg Atoms, Bhopal, India.

2016 Invited Talk, 25th Intern. Laser Physics Workshop (11–16 July 2016, Yerevan, Armenia)

2015 Invited Talk, Kangaroo Island Cold Atoms Workshop (26 - 29 November 2015, Kangaroo Island, SA, Australia)

2015 Invited Talk, International Workshop on Nonlinear Physics at the Nanoscale: A Cross-Fertilization on Stochastic Methods (2-6 February 2015, Rotorua, New Zealand)

2014 Invited Talk, International Workshop on Nonlinear Physics at the Nanoscale: A Cross-Fertilization on Stochastic Methods (12-16 May 2014, Dresden, Germany)

2009 Visiting Research Professor, Institut d'Optique, CNRS, Palaiseau, France

2008 Visiting Research Professor, Institut d'Optique, CNRS, Palaiseau, France

2008 Invited talk, ICO-21: 21st Congress of the International Commission for Optics (7-10 July 2008, Sydney, Australia)

2007 Invited Talk, International Workshop "Non-equilibrium behavior in superfluid gases at finite temperature" (10–13 June 2007, Sandbjerg, Denmark)

2007 Invited Talk, International Workshop "Quantum Engineering based on Atoms and Photons" (26 March–2 February 2007, Hannover, Germany)

2007 Participant, "Quantum Gases" Research Program, Institut Henri Poincare, Paris, France

2006 Invited Talk, 15th International Laser Physics Workshop (24–28 July 2006, Lausanne, Switzerland)

2004 Invited Talk, 13th Intern. Laser Physics Workshop (12–16 July 2004, Trieste, Italy)

2004 Participant, "Quantum Gases" Research Program, Kavli Institute for Theoretical Physics, University of California, Santa Barbara, USA

2003 Visiting Researcher, FOM-Instituut AMOLF, Amsterdam, Netherlands

2002 Participant, "Physics of Ultracold Dilute Atomic Gases" Research Program, Benasque Centre of Science, Spain

2001 Visiting Researcher, The University of Texas, Austin, USA

SERVICE

- Chair of the UQ School and Mathematics and Physics (SMP) Engagement Committee (2018-2021)
- Member of the SMP Executive Committee (2018-2021)
- Member of the UQ Faculty of Science Engagement and Advancement Committee (2018-2021)
- Acting Chair of the SMP Engagement Committee and Ex-officio member of the SMP Executive Committee (07-12/2018)
- Member of the SMP Engagement Committee (2015–current)

- Academic Supervisor of the UQ Science Demo Troupe (2015–current)
- Member of the Postgraduate Confirmation Committee for Physics (2011–current)
- Member of the SMP Curriculum Review Committee for Thermodynamics – Statistical Mechanics – Condensed Matter stream (2011, 2013)
- Chair of the Student-Staff Liaison Committee for Physics (2010-11)
- Expert of International Standing – referee for the Australian Research Council
- Member of the External Review Committee for the 2016 review of the Quantum Systems Unit of the Okinawa Institute of Science and Technology (OIST) Graduate University
- International Assessor for the Swiss National Science Foundation
- International Assessor for the Foundation for Polish Science
- International Assessor for the Austrian Science Fund
- International Assessor for the Laboratoire d'Excellence Physique: Atomes Lumiere Matière, France
- Member of the Australian Institute of Physics
- Member of the American Physics Society
- Referee for professional journals: *Nature Communications; Physical Review Letters; Physical Review A*; *Journal of Physics B: Atomic, Molecular and Optical Physics*, *Optics Communications, Journal of Modern Optics*
- Member of the Program Committee for the International Workshop "Quantum-Atom Optics Beyond Bells" (26-28 November 2008, Lorne, Australia)
- Member of the Organising Committee for the Australasian Workshop On Emergent Quantum Matter (24–28 November 2014, North Stradbroke Island, Queensland, Australia)
- Chair of the Program Committee for the International Workshop on Quantum Noise (14–18 May 2007, Caloundra, Australia)
- Member of the Program Committee and Deputy-Chair of the Organizing Committee for the Workshop on Bose-Einstein Condensation and Quantum Information (16–20 February 2003, Caloundra, Australia)
- Member of the Program Committee and Secretary-Treasurer of the Organizing Committee for the IUPAP Conference on Computational Physics 2000 (3–8 December 2000, Gold Coast, Australia)

MOST SIGNIFICANT CONTRIBUTIONS TO THE RESEARCH FIELD

A/Prof Kheruntsyan is recognised internationally for his pioneering contributions in theoretical quantum atom optics within the field of degenerate quantum gases, most notably: (i) in the theory of coherently coupled atomic-molecular Bose-Einstein condensates, (ii) theory of atom-atom correlations and thermodynamics of one-dimensional (1D) Bose gases, and (iii) foundational tests of quantum mechanical entanglement with mater waves. His work has often inspired breakthrough experiments in the leading laboratories worldwide and influenced subsequent trends in theory. More specifically, Kheruntsyan's most significant contributions are:

1. Theory of coherently coupled atomic-molecular Bose-Einstein condensates. In 1998 Kheruntsyan (with Drummond and He) introduced a new field-theoretic model for the description of coherently coupled atomic and molecular Bose-Einstein condensates (BECs) [*Phys. Rev. Lett.* **81**, 3055 (1998)]. This work, together with a follow-up groundbreaking proposal of "super-chemistry" [*Phys. Rev. Lett.* **84**, 5029 (2000)], has inspired the development of novel approaches to the creation of molecular condensates from atomic condensates, leading to the production of such condensates in more than 12 laboratories worldwide. Subsequent developments in the theory and experiments on coherently coupled atomic-molecular systems helped to solve a long-standing problem from condensed matter physics – "the BCS-BEC crossover" problem, which pertains to the understanding of the nature of the transition from the Bardeen–Cooper–Schrieffer (BCS) to Bose–Einstein condensate superfluidity.

2. Theory of atom-atom correlations and thermodynamics of one-dimensional (1D) Bose gases. In 2003, Kheruntsyan produced the world-first exact calculation of atom-atom pair correlations in a 1D Bose gas [*Phys. Rev. Lett.* **91**, 040403 (2003)]. The 1D Bose gas is of fundamental importance to quantum many-body physics as the underlying theoretical model belongs to an important class of exactly integrable models. By calculating the atom-atom correlation functions for arbitrary interaction strengths and temperatures, Kheruntsyan and co-workers (D. Gangardt, P. D. Drummond, and G. V. Shlyapnikov) have been able for the first time to map out the complete phase diagram of the system and to propose simple correlation measurements that could test the theoretical predictions experimentally. These predictions were confirmed in 2004 in the NIST group of Nobel laureate W. Phillips. In 2008, Kheruntsyan and the experimental group of N. van Druten (University of Amsterdam) published another high-impact paper on the thermodynamic properties of 1D Bose gases created on an atom chip [*Phys. Rev. Lett.* **100**, 090402 (2008)]. The team has succeeded in comparing the temperature and atom number density of the 1D quantum gas to the exact theory developed by C.N. Yang (Nobel 1957) and C.P. Yang back in 1969. Further insights into thermodynamic properties of 1D Bose gases came through Kheruntsyan's contribution to the interpretation of experimental measurements of density fluctuations [*Phys. Rev. Lett.* **106**, 230405 (2011), *Phys. Rev. Lett.* **105**, 230402 (2010)] performed in Dr I. Bouchoule's lab at the Institut d'Optique of France. This series of works probed one of cornerstone theorems of statistical mechanics – the fluctuation-dissipation theorem, in addition to proposing a new (higher-order) version of the theorem based on the measurements of the third-order moment of density fluctuations. The experimental and theoretical methods developed in these papers for measuring and describing atom-number fluctuations have now become a 'must-have' tool in many laboratories around the world, studying the phase diagrams of other important ultracold atom systems.

3. Foundational tests of quantum mechanical correlations and entanglement with massive particles. In the area of fundamental tests of quantum mechanical entanglement, Kheruntsyan (with Olsen and Drummond) has made a pioneering proposal for demonstrating the famous Einstein-Podolsky-Rosen (EPR) paradox using correlated atom-laser beams produced via coherent dissociation of a molecular condensate [*Phys. Rev. Lett.* **95**, 150405 (2005)]. This process is the atom-optics analog of parametric down-conversion with photons, which played a pivotal role in the advancement of quantum optics in the 1980s and led to the modern understanding of foundational principles of quantum mechanics with photons. Kheruntsyan has also established research collaboration with a world-renowned experimental group of Aspect and Westbrook (Institut d'Optique, France) aiming at an experimental demonstration of EPR entanglement and Bell inequality violation in a related ultracold atom system – colliding metastable helium condensates. To this end, the team has reported an observation and characterisation of two important precursors of such entanglement – reduction of atom number fluctuations below the Poissonian level [*Phys. Rev. Lett.* **105**, 190402 (2010] and violation of the classical Cauchy-Schwartz inequality [*Phys. Rev. Lett.* **108**, 260401 (2012)]. Kheruntsyan's most recent work in this area include novel theoretical proposals for demonstrating an atomic analog of the celebrated Hong-Ou-Mandel effect [*Nature Comms.* **5**, 3752 (2014)] and violating a motional-state Bell inequality with ultracold atoms [*Phys. Rev. A* **91**, 052114 (2015)].

4. Stochastic phase-space methods for simulating quantum many-body dynamics. Kheruntsyan is an internationally recognised expert in using stochastic phase-space methods for simulating the quantum dynamics of interacting Bose-Einstein condensates. He was the first to perform *ab initio* simulations of coherent dissociation of molecular condensates [*Phys. Rev. Lett.* **95**, 150405 (2005), *Phys. Rev. Lett.* **99**, 220404 (2007), *Phys. Rev. A* **74**, 033620 (2006)] and to provide the first accurate quantitative models of the experiments on collisions of metastable helium condensates [*New J. Phys.* **10**, 045021 (2008), *Phys. Rev. A* **79**, 021606 (2009)] using the positive-*P* representation. He is also a co-inventor (with P. D. Drummond and P. Deuar) of two new theoretical approaches to many-body simulations: (*i*) the 'stochastic gauge' approach [Phys. Rev. Lett. **92**, 040405 (2004)] for studying equilibrium properties of interacting many-body systems using 'imaginary-time' evolution, and (*ii*) the stochastic Bogoliubov approach [*Phys. Rev. Lett.* **104**, 150402 (2010); *Phys. Rev. Lett.* **108**, 260401 (2012)] for dynamical simulations using the linearized treatment of quantum fluctuations [*Phys. Rev. Lett.* **105**, 190402 (2010); *Nature Comms.* **5**, 3752 (2014); *Phys. Rev. A* **90**, 033613 (2014)], which is an alternative to the standard (but often numerically intractable) Bogoliubov-de Genes approach.

5. Quantum many-body physics, hydrodynamics, and quantum thermodynamics. Kheruntsyan's more recent significant contributions are in the area of many-body physics and nonequilibrium dynamics of many-particle systems. In Refs. [*Phys. Rev. Lett.* **118**, 240402 (2017); *Nature Physics* **9**, 341 (2013)], which is a theory-experiment collaboration with Prof A. Truscott's helium BEC lab at the ANU, Kheruntsyan demonstrated a textbook paradigm of fully characterising a quantum many-body system via the measurement of higher-order (many-particle) correlations between particles in the system. In Ref. [*Phys. Rev. A* **94**, 051602(R) (2016)], he developed a finite temperature hydrodynamic theory for one-dimensional Bose gases and found analytic scaling solutions to characterise the breathing-mode dynamics of harmonically trapped 1D quasicondensates. Other notable contributions in this area include development of new exact methods (based on a Fredholm determinant approach and the coordinate Bethe ansatz) for the calculations of equilibrium and nonequilibrium properties of 1D Bose gases following a confinement or interaction-induced quantum quench, and uncovering the mechanism behind dispersive quantum shock waves in the 1D Bose gas [*Phys. Rev. Lett.* **125**, 180401 (2020)]. The Fredholm determinant approach was recently further exploited in Ref. [*Phys. Rev. A* **102**, 043312 (2020)] to construct the first exact nonequilibrium quantum thermodynamics of a strongly interacting Tonks-Girardeau gas.