Andreas Winter – Curriculum Vitae (8 December 2025)

Personal details

Birth date:	14 June 1971 (Mühldorf am Inn, Germany)
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Present and previous employment

since 4/2025	Humboldt-Professor for Quantum Information and Computation Department Mathematik/Informatik—Abteilung Informatik Universität zu Köln, Germany
10/2012-3/2025	ICREA Research Professor, affiliated with Departament de Física, Universitat Autònoma de Barcelona, Spain
10/2006-9/2012	Professor of the Physics of Information Department of Mathematics, University of Bristol, U.K. (2008-2012 in addition Visiting Research Professor with the Centre for Quantum Technologies, National University of Singapore)
9/2003-9/2006	Lecturer in Mathematics Department of Mathematics, University of Bristol, U.K.
5/2001-8/2003	Research Associate with Prof. Richard Jozsa Department of Computer Science, University of Bristol, U.K.
7/1999-4/2001	Research Associate with Prof. Rudolf Ahlswede Department of Mathematics, Universität Bielefeld, Germany.

Academic qualifications

1/7/1999	PhD (Dr. math.) from Universität Bielefeld, Germany. Thesis: *Coding Theorems of Quantum Information Theory* Advisor: Prof. Rudolf Ahlswede (Zweitgutachter: Prof. Friedrich Götze)
11/7/1997	Diploma (Dipl. math.) from Freie Universität Berlin, Germany
4/1994-8/1997	Undergraduate studies of mathematics at Freie Universität Berlin, Germany
10/1991-3/1994	Undergraduate studies of mathematics at Universität Konstanz, Germany

Knowledge of languages

German	*native speaker*		
English	*fluent*	Spanish	*proficient*
Italian	*fluent*	Catalan	*basic*

Grants and prizes

German Research Council Emmy Noether fellowship		
Information and Quantum Physics	2001	(not taken up)
University of Bristol Research Fellowship		
Transmission of partial quantum information	2005-2006	£10,000
U.K. EPSRC Advanced Research Fellowship		
Random and Nonrandom Coding for Quantum Information	2006-2011	£450,000
Royal Society International Joint Project		
Noise as a Resource in Cryptography	2006-2008	£8,000
Wolfson Research Merit Award		
Mathematical Studies in the Physics of Information	2007-2012	£100,000
ERC Advanced Grant “IRQUAT”		
Information and Randomness in Quantum Theory	2011-2017	€1,440,119
Co-PI in MINECO project FIS2016-86681-P		
Quantum Learning and Non-Classicality	2017-2020	€153,000
Research collaboration with Baidu Ltd.		
Learning of Quantum Hidden Markov Chains	2019-2021	€152,532
PI (from 9/2025 co-PI) of MICIN project PID2022-141283NB-I00		
Exploring Structure and Quantum Advantage in Complex Systems	2023-2027	€286,758
Alexander von Humboldt Professorship at University of Cologne		
Chair of Quantum Information and Computation	2025-2030	€5,000,000

Participant in EC collaborative network “RESQ”		
Resources in Quantum Information Processing	2003-2006	€140,000
Participant in U.K. EPSRC “QIP IRC” (Large U.K.-wide		
collaboration; Bristol group with separate theory grant)	2004-2010	£525,000
Participant and node leader in EC integrated project “QAP”		
Qubit Applications	2006-2010	€150,000
Participant in EC integrated project “QESSENCE”		
Quantum Interfaces, Sensors and Communication based on Entanglement	2010-2013	€75,000
Participant in EC STREP project “QICS”		
Foundational Structures for Quantum Information and Computation	2007-2010	€150,000
Participant in EC STREP project “QCS”		
Quantum Computer Science	2010-2013	€150,000
Participant in Templeton Foundation project (Bristol)		
Why is Nature Not More Non-local?	2011-2013	£145,000
Participant in ARC Discovery project *Towards a quantum zero-error*		
information theory (Prof. Runyao Duan, UTS, Sydney)	2011-2013	–
Participant in EC STREP project “RAQUEL”		
Randomness and Quantum Entanglement	2013-2016	€200,000
Participant in MINECO project FIS2013-40627-P		
Recursos y Restricciones en el Procesado de Información Cuántica	2013-2016	€175,000
Participant in MINECO project PID2019-107609GB-100		
Dynamical Resources in Quantum Information	2020-2022	€112,125
Participant in EC Quantera project “ExTRaQT”		
Experiment and Theory of Resources in Quantum Technologies	2022-2025	€115,000

Philip Leverhulme Prize *Quantum Information*	2009	£70,000
Whitehead Prize of the London Mathematical Society	2012	£1,000
Paper Award of the Information Theory Society for *Ref. 129*	2017	US$400
Alexander von Humboldt Foundation Research Prize	2022	€65,000
TUM IAS Hans Fischer Senior Fellowship	2022	€320,000
QCMC International Quantum Award	2022	US$2,500

Other indicators of academic leadership

I am considered one of the internationally leading figures in mathematical/theoretical quantum information science, and my scientific advice is being sought consistently. I have been consulted regularly since 2005 by the U.K. EPSRC, the European Commission, and Austrian, Canadian, German and Japanese funding bodies on future research directions and grant proposal evaluation. Despite not being a member, I have also been involved with the Information Theory Society, on whose Paper Award Committee I have served six times, 2006, 2008, 2013, 2014, 2024 and 2025.

2008-2012 my role in shaping the then newly founded Centre for Quantum Technologies (CQT) in Singapore (`http://www.quantumlah.org`) was being honoured with a visiting research professorship there. As a principal investigator within CQT, I was responsible for a research budget of ca. S$ 2M, to manage a group of around five RAs, aided by a Senior RA.

Invited lectures at international conferences

From the beginning of my career I have been invited to international conferences to speak about my work. Every year I accept 3-6 such invitations, from specialist workshops to major international events. In the following I list only the most visible such invitations.

- Invited speaker at the 2nd "ESF Quantum Information Theory Conference", Gdańsk, 2001.
- Invited speaker at "Quantum Information Processing" 2002, IBM, Yorktown Heights, NY; 2003, MSRI, Berkeley; 2004, Perimeter Institute, Waterloo; 2005, MIT, Cambridge MA; 2007, University of Queensland, Brisbane; 2014, Barcelona, Spain.
- Invited speaker at the "Von Neumann centennial conference", Alfred Rényi Institute, Budapest, 2003.
- Invited speaker at "Asian Quantum Information Science" 2005, Tokyo; 2011, Busan (Korea); tutorial speaker at AQIS 2013, IMSc Chennai (India).
- Plenary speaker at "13th International Congress of Mathematical Physics", Rio de Janeiro, 2006.
- Invited speaker at "Phenomena in High Dimension", Sevilla, 2008.
- Invited speaker at "5th European Congress of Mathematics", Amsterdam, 2008.
- Invited speaker at a topical symposium of the 2014 Spring meeting of the German Physical Society (DPG), Berlin; and 2018, Erlangen.
- Hearne Eminent Lecture at LSU, Baton Rouge, March 2017.
- Plenary speaker at the 2017 International Symposium on Information Theory (ISIT), Aachen, Germany, 2017.
- Plenary speaker at "Rényi centennial conference", Hungarian Academy of Sciences, Budapest, 2021 (moved to 2022).
- Invited participant at extended topical programmes on quantum information: MSRI (Berkeley), Isaac Newton Institute (Cambridge), Institut Henri Poincaré (Paris), Fields Institute (Toronto), Centro de Ciencias "Pedro Pascual" (Benasque) and KITP (Santa Barbara).

Organisation of conferences

- Member of the Steering Committee of the "Quantum Information Processing" conference series, 2007-2012. `http://qipworkshop.org/`
- Member of the Steering Committee of the "Central European Quantum Information Processing" conference series, since 2011. `http://ceqip.eu/`
- Member of the Steering Committee of the "Asian Quantum Information Science" conference series, 2012-2014.
- Member of technical programme committee of the "Theory of Quantum Computing" conference 2011.

- Member of technical programme committee of the "Quantum Information Processing" conference 2006, 2007, 2015 and 2018.
- Member of technical programme committee of the "Asian Quantum Information Science" conference 2005, 2006, 2008, 2009, 2010, 2012, 2013, 2014 (chair) and 2017.
- Member of technical programme committee of the "International Symposium on Information Theory", 2013, 2014, 2016, 2017, 2019 and 2021 and 2024 and 2025???
- Co-chair (with Emina Soljanin) of the technical programme committee of the Information Theory Workshop of the Information Theory Society, Porto, 5-9 May 2008.
`http://www.dcc.fc.up.pt/itw08/`
- Co-organiser (with Matthias Christandl and Heinz Siedentopp) of a topical semester "Complex Quantum Systems" at the Institute for Mathematical Sciences, National University of Singapore, 15 February-27 March 2010. `http://www.ims.nus.edu.sg/Programs/010quantum/`
- Co-organiser (with Alexander S. Holevo, Mary-Beth Ruskai, Erling Størmer and Michael M. Wolf) of the topical semester "Quantum Information Theory" at Institut Mittag-Leffler, Stockholm, 1 September-15 December 2010.
`https://www.mittag-leffler.se/activities/quantum-information-theory/`
- Local organiser of the 14th "Quantum Information Processing" conference, 10-14 January 2011, Singapore. `http://qip2011.quantumlah.org/`
- Co-organiser (with Richard Jozsa, Noah Linden and Peter Shor) of the topical semester "Mathematical Challenges of Quantum Information" at the Isaac Newton Institute, Cambridge, 27 August-20 December 2013. `http://www.newton.ac.uk/programmes/MQI/`
- Co-organiser (with Stefano Mancini and Maciej Lewenstein) of the conference "Noise Information and Complexity at Quantum Scale", Ettore Majorana Centre for Scientific Culture, Erice (TP), Italy, 6-11 October 2013.
- Co-organiser (with Stefano Mancini) of of the workshop "New Frontiers in Quantum Information Theory", Ascoli Piceno (AP), Italy, Palazzo dei Capitani del Popolo, 7-11 July 2014.
- Co-organiser (with Nilanjana Datta, Renato Renner and Mark Wilde) of the workshop "Beyond IID in Information Theory 3", Banff (AB), Canada, 5-10 July 2015.
`https://www.birs.ca/events/2015/5-day-workshops/15w5120`
- Co-organiser (with Holger Boche, Albert Guillén i Fabregas, Alfonso Martinez and Mark Wilde) of the workshop "Beyond IID in Information Theory 4", Barcelona, Spain, Institut d'Estudis Catalans, 18-22 July 2016. `https://sites.google.com/site/beyondiid4/`
- Co-organiser (with Nilanjana Datta and Jossy Sayir) of the workshop "Beyond IID in Information Theory 6", Isaac Newton Institute, Cambridge, U.K., 23-27 July 2018.
`https://www.newton.ac.uk/event/mqiw05`
- Co-organiser (with Dominic Verdon) of the focused research group "Non-commutative mathematics and quantum information", Heilbronn Institute for Mathematical Research, Bristol, U.K., 8-10 August 2019.
- Co-organiser (with Ivan G. Todorov, Monique Laurent and Simone Severini) of the workshop "Analytical and combinatorial aspects of quantum information theory", International Centre for Mathematical Sciences, Edinburgh, U.K., 9-13 September 2019.
- Co-organiser (with Ivan G. Todorov, Gemma De las Cuevas and Hamza Fawzi) of the workshop "Analytical and combinatorial methods in quantum information theory", International Centre for Mathematical Sciences, Edinburgh, U.K., 24-28 July 2023.
- Co-organiser (with Ángela Capel, Nilanjana Datta and Ludovico Lami) of the BIRS workshop "Towards infinite dimension and beyond in quantum information", IMAG, Granada, Spain, 5-10 May 2024.
- Organiser (with Holger Boche, Barbara Kraus, Janis Nötzel and Simone Warzel) of the "13th Beyond IID in Information Theory" workshop, IAS, Technical University of Munich, 14-18 July 2025.

- Co-organiser (with Laura Mančinska, Ivan G. Todorov and Lyudmila Turowska) of the topical semester “Operator Algebras and Quantum Information” at Institut Mittag-Leffler, Stockholm, 11 February-22 May 2026.
  `https://www.mittag-leffler.se/activities/operator-algebras-and-quantum-information/`

Editorial activity

- Associate editor for Quantum Information with IEEE Transactions on Information Theory, 2005-2008.
- Editorial board member of Communications in Mathematical Physics, 12/2012-3/2020.
- Steering board member of Quantum, since its foundation 6/2016.
- Editorial board member of Journal of Mathematical Physics, since 4/2011.
- Senior editor of Journal on Selected Areas of Information Theory, since 7/2019.
- Area (Executive) Editor for Quantum topics with IEEE Transactions on Information Theory, 7/2021-10/2025.

Mentoring

I have supervised or co-supervised 23 PhD students, 8 of whom are currently in progress. Several among them have gone on to outstanding careers in and outside academia. Cecilia Lancien (Grenoble), Ludovico Lami (Scuola Normale Superiore Pisa) and María García-Díaz (Universidad Politécnica de Madrid), as well as Kun Fang (Chinese University of Hong Kong, Shenzhen) and Xin Wang (Hong Kong University of Science and Technology, Guangzhou), are now permanent faculty; Luis Pedro García-Pintos (Los Alamos National Labs) is a senior researcher and group leader; and after outstanding postdoctoral careers, Stefan Bäuml, Zahra Khanian and Farzin Salek are poised to soon obtain faculty positions.

Furthermore, I have served as mentor to four Marie Curie fellows (Aram Harrow, Milan Mosonyi and Marcus Huber, all in Bristol; and Matteo Rosati in Barcelona), five Juan de la Cierva fellows (Marcus Huber, Michalis Skotiniotis, Philipp Strasberg, Matteo Rosati, and Marco Fanizza), one Beatriu de Pinós fellow (Joseph Schindler), one JSPS postdoctoral fellow (Yoshifumi Nakata), and three DFG Walter Benjamin postdoctoral fellows (Janis Nötzel, Philipp Strasberg and Minglai Cai), all in Barcelona. Of these, Aram Harrow (MIT), Milan Mosonyi (Budapest), Marcus Huber (TU Wien) and Yoshifumi Nakata (Kyoto University) have become full professors; Janis Nötzel is a Junior Professor at TU Munich, and Matteo Rosati (Università di Roma) similarly fixed-term faculty; Michalis Skotiniotis (Granada) and Philipp Strasberg (Santander) are Ramon y Cajal Fellows on tenure track.

A fair number of other postdocs are having excellent careers, too, such as Graeme Smith (University of Waterloo), Ke Li (Harbin Institute of Technology), Mark Wilde (Cornell), Dong Yang (SUSTECH Shenzhen), Lin Chen (Beihan University Beijing), Giannicola Scarpa (Universidad Politécnica de Madrid) and Markus Grassl (University of Gdańsk) are all faculty of various seniority at their respective institutions; Krishnakumar Sabapathy (Bangalore) is senior scientist at Fujitsu Quantum.

This continuing mentoring of former postdocs and students, even those having done mere Bachelor or Master theses, is an important part of my approach to research and education. I always follow their progress well into their careers, and continue to discuss career and life with them. I am happy to say that with most of my former students and postdocs we are enjoying an ongoing scientific exchange and collaborations.

Publications

During the 25 years of my research career in quantum information science, I have written 280 papers as preprints or in refereed journals and proceedings, in part as the sole author, but many in collaboration: to-date I have more than 150 collaborators on papers, including C. H. Bennett, M. Hayashi, K., M. and P. Horodecki, R. Jozsa, M. Lewenstein, R. Renner, M.-B. Ruskai, P. W. Shor, V. Vedral, F. Verstraete, M. M. Wilde, etc, but also many younger colleagues, the interaction with whom remains extremely important to me.

1. "Coding theorem and strong converse for quantum channels", IEEE Trans. Inf. Theory **45**(7):2481-2485, 1999; doi:10.1109/18.796385; e-print `arXiv[quant-ph]:1409.2536`.
2. "Another algebraic proof of Bondy's theorem on induced subsets", J. Combin. Theory Ser. A **89**(1):145-147, 2000; doi:10.1006/jcta.1999.3013.
3. (with H. Barnum, P. Hayden and R. Jozsa) "On the reversible extraction of classical information from a quantum source", Proc. Roy. Soc. Lond. A: Math. Phys. Eng. Sci. **457**(2012):2019-2039, 2001; doi:10.1098/rspa.2001.0816; e-print `arXiv/quant-ph:0011072`.
4. (with S. Massar) "Compression of quantum-measurement operations", Phys. Rev. A **63**:012311, 2001; doi:10.1103/PhysRevA.64.012311; e-print `arXiv:quant-ph/0012128`.
5. "On the fidelity of two pure states", J. Phys. A: Math. Gen. **34**(35):7095-7101, 2001; doi:10.1088/0305-4470/34/35/333; e-print `arXiv:quant-ph/0011053`.
6. "The capacity of the quantum multiple-access channel", IEEE Trans. Inf. Theory **47**(7):3059-3065, 2001; doi: 10.1109/18.959287; e-print `arXiv:quant-ph/9807019`.
7. (with R. Freivalds) "Quantum Finite State Transducers", in Proc. of SOFSEM 2001, Piešt'any, Slovakia, 24 November-1 December 2001, LNCS 2234, pp. 233-242, Springer Verlag, Berlin 2001. Full version: e-print `arXiv:quant-ph/0011052`.
8. (with R. Ahlswede) "Strong converse for identification via quantum channels", IEEE Trans. Inf. Theory **48**(3):569-579, 2002; doi:10.1109/18.985947; e-print `arXiv:quant-ph/0012127`. Addendum: IEEE Trans. Inf. Theory **49**(1):346, 2003.
9. "Scalable programmable quantum gates and a new aspect of the additivity problem for the classical capacity of quantum channels", J. Math. Phys. **43**(9):4341-4352, e-print `arXiv:quant-ph/0108066`.
10. (with P. Hayden and R. Jozsa) "Trading quantum for classical resources in quantum data compression", J. Math. Phys. **43**(9):4404-4444, 2002; e-print `arXiv:quant-ph/0204038`
11. "The Reverse Shannon Theorem in Classical and Quantum Information Theory: a New Unifying Principle", Proc. ICSF 2002, Waseda University, Tokyo, Japan, 27-28 March 2002, pp. S6.12-17.
12. "Scalable programmable quantum gates and a new aspect of the additivity problem for the classical capacity of quantum channels", in Proc. ISIT, Lausanne, Switzerland, 1-5 July 2002, p. 70.
13. "Compression of sources of probability distributions and density operators", e-print `arXiv:quant-ph/0208131`, 2002.
14. (with P. Hayden) "Communication cost of entanglement transformations", Phys. Rev. A **67**:012326, 2003; e-print `arXiv:quant-ph/0204092`.
15. (with M. Hayashi, M. Koashi, K. Matsumoto and F. Morikoshi) "Error exponents for entanglement concentration", J. Phys. A: Math. Gen. **36**(2):527-553, 2003; e-print `arXiv:quant-ph/0206097`.
16. (with I. Devetak) "Classical data compression with quantum side information", Phys. Rev. A **68**:042301, 2003; e-print `arXiv:quant-ph/0209029`.
17. (with R. Jozsa, M. Koashi, N. Linden, S. Popescu, S. Presnell and D. Shepherd) "Entanglement cost of generalised measurements", Quantum Inf. Comput. **3**(5):405-422, 2003; doi:10.26421/QIC3.5-2; e-print `arXiv:quant- ph/0303167`.
18. (with I. Devetak) "Distilling common randomness from bipartite quantum states", in Proc. ISIT, Yokohama, Japan, 29 June-4 July 2003, p. 403.
19. (with A. C. A. Nascimento and H. Imai) "Commitment Capacity of Noisy Channels", in Proc. 9th IMA Intl. Conference on Cryptography and Coding, Cirencester, U.K., 16-18 December 2003, LNCS 2898, Springer Verlag, Berlin 2003, pp. 35-51. Full version e-print `arXiv:cs.CR/0304014`.
20. "'Extrinsic' and 'intrinsic' data in quantum measurements: asymptotic convex decomposition of positive operator valued measures", Commun. Math. Phys. **244**:157-185, 2004; e-print `arXiv:quant-ph/0109050`.

21. (with K. Matsumoto and T. Shimono) "Remarks on additivity of the Holevo channel capacity and of the entanglement of formation", Commun. Math. Phys. **246**:427-442, 2004; e-print `arXiv:quant-ph/0206148`.
22. "Quantum and Classical Message Identification via Quantum Channels", in *Quantum Information, Statistics, Probability* (festschrift on the occasion of A. S. Holevo's 60th birthday), (O. Hirota, ed.), pp. 172-189, Rinton Press, 2004. Reprinted in Quantum Inf. Comput. **4**(6&7):563-578, 2004; doi:10.26421/QIC4.6-7-14; e-print `arXiv:quant-ph/0401060`.
23. (with P. Hayden, R. Jozsa and D. Petz) "Structure of states satisfying strong subadditivity of quantum entropy with equality", Commun. Math. Phys. **246**:359-374, 2004; e-print `arXiv:quant-ph/0304007`.
24. (with K. M. R. Audenaert, C. A. Fuchs and C. King) "Multiplicativity of Accessible Fidelity and Quantumness for Sets of Quantum States", Quantum Inf. Comput. **4**(1):1-11, 2004; doi:10.26421/QIC4.1-1; e-print `arXiv:quant-ph/0308120`.
25. (with N. Cai and R. W. Yeung) "Quantum Privacy and Quantum Wiretap Channels", Probl. Inf. Transm. **40**(4):318-336, 2004; doi:10.1007/s11122-005-0002-x.
26. (with I. Devetak) "Relating quantum privacy and quantum coherence: an operational approach", Phys. Rev. Lett. **93**(8):080501, 2004; e-print `arXiv:quant-ph/0307053`.
27. (with P. Hayden, D. W. Leung and P. W. Shor), "Randomizing quantum states: Constructions and applications", Commun. Math. Phys. **250**:371-391, 2004; e-print `arXiv:quant-ph/0307104`.
28. (with A. Chefles and R. Jozsa) "On the existence of physical transformations between sets of quantum states", Int. J. Quantum Inf. **2**(1):11-21, 2004; e-print `arXiv:quant-ph/0307227`.
29. (with M. S. Leifer and N. Linden) "Measuring Polynomial Invariants of Multi-Party Quantum States", Phys. Rev. A **68**:052304, 2004; e-print `arXiv:quant-ph/0308008`.
30. (with M. Christandl) "'Squashed Entanglement' - An Additive Entanglement Measure", J. Math. Phys. **45**(3):829-840, 2004; e-print `arXiv:quant-ph/0308088`.
31. (with M. Koashi) "Monogamy of entanglement and other correlations", Phys. Rev. A **69**:022309, 2004; e-print `arXiv:quant-ph/0310037`.
32. (with I. Devetak) "Distilling common randomness from bipartite quantum states", IEEE Trans. Inf. Theory **50**(12):3183-3196, 2004; e-print `arXiv:quant-ph/0304196`.
33. (with A. W. Harrow and I. Devetak) "A Family of Quantum Protocols", in Proc. ISIT, Chicago, IL, 27 June-2 July 2004, p. 134.
34. (with H. Imai, J. Müller-Quade and A. C. A. Nascimento) "Rates for Bit Commitment and Coin Tossing from Noisy Correlation", in Proc. ISIT, Chicago, IL, 27 June-2 July 2004, p. 47.
35. (with G. Hanaoka, H. Imai, J. Müller-Quade, A. C. A. Nascimento and A. Otsuka) "Information Theoretically Secure Oblivious Polynomial Evaluation: Model, Bounds, and Constructions", in Proc. 9th Australasian Conference on Information Security and Privacy, LNCS 3108, Springer Verlag, Berlin 2004, pp. 62-73.
36. (with I. Devetak) "Distillation of secret key and entanglement from quantum states", Proc. Roy. Soc. Lond. **461**:207-235, 2005; e-print `arXiv:quant-ph/0306078`.
37. (with C. H. Bennett, P. Hayden, D. W. Leung and P. W. Shor) "Remote preparation of quantum states", IEEE Trans. Inf. Theory **51**(1):56-74, 2005; e-print `arXiv:quant-ph/0307100`.
38. (with I. Devetak and A. W. Harrow) "A family of quantum protocols", Phys. Rev. Lett. **93**:230504, 2004; e-print `arXiv:quant-ph/0308044`.
39. (with H. Imai, J. Müller-Quade, A. C. A. Nascimento and P. Tuyls) "An information theoretical model for quantum secret sharing schemes", Quantum Inf. Comput. **5**(1):69-80, 2005; doi:10.26421/QIC5.1-7; e-print `arXiv:quant-ph/0311136`.
40. (with N. Linden) "A new inequality for the von Neumann entropy", Commun. Math. Phys. **259**(1):129-138, 2005; e-print `arXiv:quant-ph/0406162`.
41. (with M. Horodecki and J. Oppenheim) "Partial quantum information", Nature **436**:673-676, 2005; e-print `arXiv:quant-ph/0505062`.
42. (with M. Christandl), "Uncertainty, Monogamy, and Locking of Quantum Correlations", IEEE Trans. Inf. Theory **51**(9):3159-3165, 2005; e-print `arXiv:quant-ph/0308088`.
43. (with B. Groisman and S. Popescu) "On the quantum, classical and total amount of correlations in a quantum state", Phys. Rev. A **72**(3):032317, 2005; e-print `arXiv:quant-ph/0410091`.
44. (with J. A. Smolin and F. Verstraete) "Entanglement of assistance and multipartite state distillation", Phys. Rev. A **72**(5):052317, 2005; e-print `arXiv:quant-ph/0505038`.
45. (with M. Christandl) "Uncertainty, Monogamy, and Locking of Quantum Correlations", in Proc. ISIT, Adelaide, 5-9 September 2005, pp. 879-883.
46. "Secret, Public, and Quantum Correlation Cost of Triples of Random Variables", in Proc. ISIT, Adelaide, 5-9 September 2005, pp. 2270-2274.

47. (with P. Zoller *et al.*) "Quantum information processing and communication: Strategic report on current status, visions and goals for research in Europe", Eur. Phys. J. D **36**:203-228, 2005: doi:10.1140/epjd/e2005-00251-1.
48. (with G. V. Klimovitch) "Classical Capacity of Quantum Binary Adder Channels", e-print arXiv:quant-ph/0507045, 2005.
49. (with J. Oppenheim) "Uncommon information", e-print arXiv:quant-ph/0511082, 2005.
50. (with J. Oppenheim and R. W. Spekkens) "A classical analogue of negative information", e-print arXiv:quant-ph/0511247, 2005.
51. "Identification via Quantum Channels in the Presence of Prior Correlation and Feedback", in *General Theory of Information Transfer and Combinatorics* (R. Ahlswede, L. Bäumer, N. Cai, H. K. Aydinian, V. Blinovsky, C. Deppe and H. Mashurian, eds.), Springer LNCS, vol. 4123, pp. 486-504, 2006; doi:10.1007/11889342_27; e-print arXiv:quant-ph/0403203.
52. (with C. Ahn, A. Doherty and P. Hayden) "On the distributed compression of quantum information", IEEE Trans. Inf. Theory **52**(10):4349-4357, 2006; e-print arXiv:quant-ph/0403042.
53. (with P. Hayden and D. W. Leung) "Aspects of generic entanglement", Commun. Math. Phys. **265**(1):95-117, 2006; e-print arXiv:quant-ph/0407049.
54. (with A. Abeyesinghe, P. Hayden and G. Smith) "Optimal superdense coding of entangled states", IEEE Trans. Inf. Theory **52**(8):3635-3641, 2006; e-print arXiv:quant-ph/0407061.
55. (with B. Ibinson and N. Linden) "All Inequalities for the Relative Entropy", in Proc. ISIT, Seattle, WA, 9-14 July 2006, pp. 237-241.
56. (with H. Imai, K. Morozov and A. C. A. Nascimento) "Efficient Protocols Achieving the Commitment Capacity of Noisy Correlations", in Proc. ISIT, Seattle, WA, 9-14 July 2006, pp. 1432-1436.
57. (with A. C. A. Nascimento) "On the Oblivious Transfer Capacity of Noisy Correlations", in Proc. ISIT, Seattle, WA, 9-14 July 2006, pp. 1871-1875.
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284. (with J. Ahiable) "Certifying bipartite entangled states with few local measurements: from separable stabilizers to applications", e-print `arXiv[quant-ph]:2509.13082`, 2025.
285. (with L. Rossetti, S. Mancini and J. Schindler) "Observational entropy of quantum correlations and entanglement", e-print `arXiv[quant-ph]:2510.10058`, 2025.
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290. (with J. Ahiable and N. B. T. Kothakonda) "Geometry of absolute separability and other convex matrix properties from spectrum", to appear.
291. (with F. D. Cunden and P. Facchi) "From random matrices to mixtures of random tensors", to appear.
292. (with T. Biswas) "Representation Theoretic Proof of the Asymptotic Equivalence Theorem for Commuting Observables", to appear.
293. (with Hari Krishnan S. V.) "Robust Device-Independent Quantum Key Distribution Arbitrarily Close to Local Correlations", in preparation.
294. (with M. Cerdà Ramon) "Quantum advantage for Bayesian games from quantum pseudo-telepathy", in preparation.
295. (with Y. X. Wang and G. Scarpa) "Playing Bayesian games better with separable quantum states than with any classical correlation", in preparation.

Research statement

Research and most significant contributions. My research is centred around quantum information theory, its core being quantum Shannon theory, which is concerned with operational questions of the type "how to communicate most efficiently through a noisy channel?", and abstractions thereof. However, I also work on classical information theory and cryptography; coding theory and discrete mathematics; quantum thermodynamics and statistical mechanics; quantum entanglement, Bell non-locality and contextuality; quantum resource theories; mathematical physics.

I have contributed fundamentally to quantum information science, by focusing on the mathematical structures behind the information coding problems, and I am especially fascinated by probabilistic and geometric methods applied to information. My own work contributes to the development of the mathematical foundation of quantum information in three ways. First, through the creation of new mathematical tools and concepts to approach information theory problems; in the past, this has ranged from combinatorial ideas, to new large deviation bounds for operator valued random variables, and to new inequalities for the quantum entropy, including entropic uncertainty relations. Secondly, by importing tools from other disciplines – an example is the extremely fruitful use of probabilistic-geometric measure concentration in quantum coding and in the construction of exotic quantum states, or most prominently of quantum channels violating certain so-called additivity conjectures. Thirdly, by applying the new techniques to other areas, for example in my work on the foundations of statistical mechanics.

1. **Partial quantum information.** In my work on negative quantum information [with M. Horodecki and J. Oppenheim, *Nature* **436**:673-676 (2005) and *Commun. Math. Phys.* **269**:107-136 (2007)], the fundamental new concept of quantum state merging is introduced, giving operational meaning to the sometimes negative values of the quantum conditional entropy. It profoundly changed the community's view of the subjects of quantum error correction, channel coding and capacities. In particular, we showed a deep duality between quantum (distributed) data compression and channel coding, known in different form in classical information theory. This new viewpoint has resulted in a whole series of papers re-organising the foundations of quantum Shannon theory, spearheaded by my work with A. Abeyesinghe, I. Devetak and P. Hayden [*Proc. Roy. Soc. London A* **465**:2537-2563 (2009)]. I recently returned to state merging in the multipartite setting, where we solved the one-shot version of the problem, and consequently resolving merging under source uncertainty [with P. Colomer, *Commun. Math. Phys.* **405**:281 (2024)].
2. **Statistical mechanics.** Together with N. Linden, S. Popescu and A. J. Short, we proposed an approach to establish the foundations of statistical mechanics on quantum theoretical grounds. Our initial paper on this subject [with S. Popescu and A. J. Short, *Nature Physics* **2**:754-758 (2006)] showed that the equilibrium state consistent with the postulate of equal probabilities can be generically explained by a pure state of system and bath, in the most general of physical situations. It is developed further to cover Hamiltonian dynamics in [N. Linden *et al.*, *Phys. Rev. E* **79**:061103 (2009) and *New J. Phys.* **12**:055021 (2010)], and we continued carrying out the ambitious "roadmap" laid out there in [L. P. García-Pintos *et al.*, *Phys. Rev. X* **7**:031027 (2017)]. With N. Yunger Halpern, Ph. Faist and J. Oppenheim [*Nature Comm.* **7**:12051 (2016)] we used information theoretic ideas to justify grand canonical equilibrium states as the unique "completely passive" states for work extraction, under arbitrary extensive conserved quantities, even if they do not commute; the crucial concept we developed here is that of an "approximately microcanonical subspace" in the composition of many copies of the system. Subsequently we refined this approach in [Z. B. Khanian *et al.*, *Ann. Henri Poincaré* **24**(5):1725-1777 (2023)], and in work with T. Biswas [to appear] we give a new, representation theoretic proof of the fundamental asymptotic equivalence theorem in the commuting case.
3. **Zero-error quantum information.** In collaboration with R. Duan and S. Severini [*IEEE Trans. Inf. Theory* **59**(2):1164-1174 (2013)], we have not only introduced a quantum generalisation of Lovász' famous ϑ function [*IEEE Trans. Inf. Theory* **25**(1):1-7 (1979)], and proved that it bounds the zero-error capacity of a quantum channel, but have shown that much of graph theory can be recast in the algebraic language of Hilbert modules and operator systems, motivating the generalisation

to *non-commutative graphs*, a theory that is ideally adapted to reason about error-free information transmission via channels, and which we expect to have many further applications, in quantum Shannon theory and combinatorics. With R. Duan [*IEEE Trans. Inf. Theory* **62**(2):891-914 (2016)] we showed subsequently that the Lovász number of a graph is actually equal to the no-signalling assisted capacity of classical-quantum channels, the first such information theoretic interpretation of $\vartheta(G)$. The zero-error information theory of Lovász numbers and their relatives is explored further in [T. S. Cubitt *et al.*, *IEEE Trans. Inf. Theory* **60**(11):7330-7344 (2014)] and [A. Acín *et al.*, *Discr. Appl. Math.* **216**:489-501 (2017)]. More recently [with G. Boreland and I. G. Todorov, *J. Comb. Theory A* **177**:105302 (2021)] we return to information theoretic basics to propose yet another definition of a quantum Lovász number of a non-commutative graph.

4. **Additivity conjectures.** I initiated much of the conceptual and mathematical progress on the "additivity problem" of quantum communication theory. In work with K. Matsumoto and T. Shimono [*Commun. Math. Phys.* **246**:427-442 (2004)] we provided the first link of the additivity of the so-called Holevo capacity to other additivity conjectures; this was subsequently developed into a full equivalence of several additivity conjectures by Shor [*Commun. Math. Phys.* **246**:453-472 (2004)]. The equivalences were the basis for my recent work [with P. Hayden, *Commun. Math. Phys.* **284**:263-280 (2008); and with T. S. Cubitt *et al.*, *Commun. Math. Phys.* **284**:281-290 (2008)] on counterexamples to a set of stronger additivity properties; the ideas of these papers were essential to Hastings' subsequent disproof of the original additivity conjectures [*Nature Physics* **5**:255-258 (2009)]. With J. Chen [arXiv:1206.1307], we have shown, using information theoretic and numerical methods, that another correlation measure, the entanglement of purification, is not additive. In [K. Li *et al.*, *Phys. Rev. Lett.* **103**:120501 (2009)], we show nonadditivity of the private capacity of a quantum channel.
5. **Operator-valued random variables.** My paper with R. Ahlswede [*IEEE Trans. Inf. Theory* **48**(3):569-579 (2002)] lays the foundations of a theory of operator valued random variables and their large deviations and tail bounds, developed to solve a specific problem in quantum identification theory. The theory is so beautiful and versatile that it started having further applications instantly, at first in quantum Shannon theory, then further afield, e.g. a new, shorter and more efficient proof of the Alon-Roichman theorem on random Cayley graphs being expanders [Z. Landau and A. Russell, *Electr. J. Comb.* **11**:62 (2004); D. Christofides and K. Markström, *Rand. Struct. Alg.* **32**(1):88-100 (2007); A. Wigderson and D. Xiao, Proc. FOCS 2005 & 2009], or a much simplified approach to matrix completion [E. J. Candés and T. Tao, arXiv:0903.1476; D. Gross *et al.*, arXiv:0909.3304 and arXiv:0910.1879]. Many researchers have subsequently contributed to the development of matrix tail bounds, see [J. Tropp, *Found. Trends ML* **8**:1-230 (2015)].
6. **Random states.** My paper on generic entanglement [with P. Hayden and D. Leung, *Commun. Math. Phys.* **265**(1):95-117 (2006)], was the very first exploration of a fully quantum version of the probabilistic method, yielding not examples but the existence of states and quantum channels with exotic or even paradoxical properties. Among later applications of this are the above-mentioned ground-breaking results concerning statistical mechanics and the additivity conjectures. These investigations are very much related to random matrix theory, and with F. D. Cunden and P. Facchi [to appear] we show that the famous Marchenko-Pastur law of the spectrum of random covariance matrices is a phenomenon arising for several seemingly unrelated ensembles.
7. **Applications of entropies.** In the paper with P. Hayden [*Phys. Rev. A* **67**:012326 (2003)], Rényi entropies, and more importantly *smooth* Rényi entropies, are used for the first time in quantum information to solve the problem of reversibility in the theory of pure state entanglement. R. Renner [PhD thesis, ETH Zürich 2005] and his followers have systematically developed this tool as a foundation of information theory, putting at the centre of the theory smoothed (conditional) min-entropies. In work with C. Morgan [*IEEE Trans. Inf. Theory* **60**(1):317-333 (2014)], this formalism was used to show a "pretty strong" converse for the quantum capacity of certain channels. Finally, in a preprint with M. M. Wilde and D. Yang [*Commun. Math. Phys.* **331**(2):593-622 (2014)] a new, "sandwiched", Rényi relative entropy was defined and shown to be useful for proving strong converses for the classical capacity of entanglement-breaking and Hadamard channels; the latter papers have sparked considerable interest in the new functional and its properties, which now is among the

best-understood entropies.

8. **Entropy inequalities.** Finally, inequalities relating quantum entropies are among the fundamental tools in information theory. In my work with N. Linden [*Commun. Math. Phys.* **259**:129-138 (2005)], we provided the first evidence of a new inequality for the von Neumann entropy in more than 30 years since the proof of strong subadditivity [E. H. Lieb, M.-B. Ruskai, *J. Math. Phys.* **44**(12):1938-1941 (1973)], by building on my own work regarding the equality conditions of the latter [with P. Hayden, R. Jozsa and D. Petz, *Commun. Math. Phys.* **246**:359-374 (2004)], and bringing to bear information theoretic ideas. More such inequalities were found in work with J. Cadney and N. Linden [*IEEE Trans. Inf. Theory* **58**(6):3657-3663, 2012]. With N. Linden and M. Mosonyi [*Proc. Roy. Soc. London A* **469**(2158):20120737 (2013)], we showed that Rényi entropies in contrast cannot obey any nontrivial inequalities. The exception is the limiting case of $\alpha \to 0$, which corresponds to the rank of the density matrix: with J. Cadney, M. Huber and N. Linden [*Lin. Algebra Appl.* **452**:153-171, 2014] we showed that there is an interesting structure of inequalities constraining the ranks of reduced states. Finally, in work with K. Li [*Found. Phys.* **48**(8):910-924 (2018)], we conjectured a strengthening of strong subadditivity and the monotonicity of the quantum relative entropy by introducing a new term in the inequality, relating to approximate recoverability (aka sufficiency), and with applications throughout quantum information theory. It was subsequently proved by Fawzi and Renner in a breakthrough paper, and with M. Junge, R. Renner, D. Sutter and M. M. Wilde [*Ann. Henri Poincaré* **19**(10):2955-2978 (2018)], we were able to give an explicit form of the recovery map.
9. **Distrustful cryptography.** In cryptography, my work with A. C. A. Nascimento and H. Imai [*Proc. 9th IMA Intl. Conference on Cryptography and Coding*, LNCS 2898, Springer Verlag, Berlin 2003, pp. 35-51] has shown that every noisy channel can be used to implement the cryptographic primitive, bit commitment, and indeed we found a simple formula for the precise capacity of committing to a long string. This is the first result of its kind in distrustful cryptography; subsequently we managed to extend this work to a capacity theorem for the more powerful task of oblivious transfer [with A. C. A. Nascimento, *IEEE Trans. Inf. Theory* **54**(6):2572-2581 (2008)], whereupon Ahlswede and Csiszár addressed one of our conjectures. Motivated by the modular code construction of bit string commitment, more recently, in a string of papers with P. Colomer, C. Deppe and H. Boche [most importantly *IEEE Trans. Inf. Theory* **71**(5):3373-3396 (2025)], we turned our attention to the subtask of “deterministic identification” for general classical and quantum channels, where not only did we find an unusual linearithmic (rather than linear) growth of message length, but surprising capacity formulas involving the fractal dimension of certain point sets.
10. **Stochastic processes.** In two papers [with A. Monràs, *J. Math. Phys.* **57**:015219 (2016), and with M. Fanizza and J. Lumbreras, *Commun. Math. Phys.* **405**:50 (2024)], we developed new methods to classify hidden Markov processes, and their generalisations hidden quantum Markov processes and finitely correlated states: using vector space and matrix orders associated to each process, we constructed processes that have hidden quantum Markov models, but not hidden Markov model, and processes that are presented as finitely correlated states but not as hidden quantum Markov models, answering in the negative a question by Fannes, Nachtergaele and Werner [*Commun. Math. Phys.* **144**(3):443-490 (1992)]. In the hypothesis testing of quantum channels, hidden quantum Markov models appear interpreted as channels with memory, as strategies to adaptively distinguish two channels given as black boxes. With M. Hayashi and F. Salek [*Phys. Rev. A* **105**:022419 (2022)] we showed that for quantum channels, adaptiveness impacts the exponent of asymptotic discrimination, unlike for classical channels.

Concept. At the Universität zu Köln, using the funds of my Humboldt Professorship, I have started to build up a group dedicated to furthering my multi-faceted research along the lines described above.

Our activities can be ordered under four major themes, (1) “Entropy and entropy inequalities”, (2) “Information-theoretic constructions and limitations of codes”, (3) “Resource theory and information”, and (4) “Information theory of generalised state spaces”.

1. **Entropy and entropy inequalities** unites the quests for new inequalities and continuity relations governing the von Neumann and Rényi entropies, for the observational entropy and for new additivity

and non-additivity results of information quantities. One beacon problem in particular is the proof of the conjecture that all linear entropy inequalities for the Shannon entropy (of which there are infinitely many) hold in fact for the von Neumann entropy of separable multipartite states.

2. **Information-theoretic constructions and limitations of codes** concerns the use of information theoretic methods to construct and leverage new quantum Lovász numbers bounding the size of quantum error correcting codes, and the development of Rényi entropic and hypothesis testing methods towards the construction and limitations of multi-user quantum information protocols.

3. **Resource theory and information** aims to transport information theoretic ideas to broader classes of problems in mathematical physics, which can be cast within resource theories (such as thermodynamics, entanglement, magic, coherence, etc). In particular, we are interested in (quantum) channels as resources, in their entropic characteristics, and in the extension of the known results regarding parallel and adaptive hypothesis testing to so-called non-causal strategies.

4. **Information theory of generalised state spaces** is motivated by my previous work on hidden Markov models and finitely correlated states, and here we want to flesh out some of the structures encountered there, in particular to which extent matrix orders support basic (one-shot) information theory, and if this can be leveraged to prove certain common conjectures about the decay of correlations in finitely correlated states.

Teaching statement

Teaching experience. For an academic at my stage of the career, I have taught relatively little and quite selectively. I begin with a short resume of my past teaching activity:

At the University of Bristol, I was relieved of teaching for long periods of time due to a couple of important grants I had brought in. Nevertheless, I taught several courses, including *Advanced Optimisation* in 2003 and 2004. Afterwards, I designed a new course *Information Theory* and delivered it from 2006, first fully, subsequently in cooperation with other lecturers, until my departure in 2012. I participated in the Graduate Taught Course Centre in collaboration between the Universities of Bristol, Bath, Warwick, Oxford and Imperial College, by covering for several years part of a successful unit *Quantum Information and Computing*. Furthermore, I supervised and evaluated final year projects in the Mathematics Department.

At the Universitat Autònoma de Barcelona, my position was defined as a research appointment (as an ICREA Professor), but I did contribute to advanced courses on different levels: every year I covered a couple of lectures in the undergraduate course on *Quantum Information Theory*, delivered by our group; since 2019/20 I contributed to a course on *Quantum Information* offered by the Physics department in the context of a Data Science degree in Mathematics; since 2021/22 I contributed to the new Barcelona Master in Quantum Science and Technology with a course *Advanced Quantum Information Theory* designed by me, and by supervising Master theses. In 2015 I taught a graduate course in *Information Theory* (jointly with Albert Guillén i Fabregas, UPF) at the Barcelona Graduate School of Mathematics. Furthermore, I supervised on average one final-year project (treball de fi de grau) per year in the Physics department.

Concept. I care deeply about teaching the next generation in mathematical sciences. Due to my upbringing in mathematics and long work experience in mathematical physics, I would be able to teach right away any of the fundamental mathematics units. In addition basic and advanced level of probability theory, functional analysis, information theory, quantum information, discrete mathematics (such as graph theory, combinatorics, or coding theory); furthermore topics in mathematical physics, such as analytical mechanics and quantum mechanics.

Concretely, I would like to propose courses and/or seminars on the following topics, either at undergraduate or graduate level:

1. **Information theory.** This is a field as much rooted in probability theory (for example the Shannon-McMillan theorem providing a refinement of the law of large numbers), discrete mathematics (the basic tasks always are measured by counting something), computer science (inasmuch information theory is about well-defined tasks and their asymptotic optimal performance), and analysis (especially the convex variety, seeing as almost everything worth knowing about the entropy is a consequence of the concavity of the log). It can be taught at a basic level using only elementary probability theory, but a more sophisticated probability background can be used to go to information theory of continuous alphabets, entropy-power inequality, etc.

2. **Quantum information theory** injects information theory with quantum physics, and shows how to treat quantum states, entanglement, and other resources with information theoretic methods. For students who know their information theory, the course could cover the necessary mathematical physics (Hilbert space, Banach spaces of operators) and convex analysis (in particular semidefinite programming) to go over some of the most important information protocols and capacity theorems, all the way to Rényi and one-shot entropies for quantum information processing.

3. **Matrix and trace inequalities.** Inequalities are a fascinating topic, usually indicating that a problem is to hard for identities, moving to simplify by comparing. On the other hand, they are difficult because there are few methods to obtain them, and even their "tightness" is not an entirely defined notion. Matrix inequalities concern the functional calculus and more general the non-commutative algebra of matrices, and its relation to the semidefinite (Löwner) order. Trace inequalities arose when it was noticed that certain identities for real numbers not just fail for Hermitian matrices, but turn into systematic inequalities. The course would start by recalling the spectral theorem for Hermitians and some basic facts on tensor products, and proceeds to the theory of matrix monotone and matrix convex functions, Lieb's concavity, Lieb-Thirring and related inequalities, etc.

4. The **probabilistic method** is of central importance in graph theory (for instance Ramsey theory), information theory (Shannon's random codes) and even geometry (Milman's proof of Dvoretzky's theorem on almost-Euclidean subspaces of normed spaces). The lecture course would address a range of famous problems and the probabilistic methods developed to approach them. A central role would be played by the analysis of the fundamental ensembles using symmetry and independence, and how to derive measure concentration from these characteristics.

5. **Game theory.** In the theory of zero-sum games of von Neumann and Morgenstern, and more generally in Nash's theory of multi-player games, the central concept of game equilibrium requires mixed strategies, i.e. players' behaviour is described by random variables; this is subsequently generalised to Aumann's correlated equilibria (and more recently to quantum correlated equilibria). In this topic, which is perhaps best suited for a seminar, students will learn or revisit notions from probability, analysis and convex geometry to model and analyse games, and they will learn about notions of equilibrium, robustness, and economic rationality.