

BIOGRAPHICAL SKETCH

Bruno Nachtergaele

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Professional Preparation

UG Inst.:	University of Leuven	Physics	Licenciaat 1984
G Inst.:	University of Leuven	Theoretical Physics	Ph.D. 1987
P Inst.:	Princeton University	Mathematical Physics	09/01/1991–06/30/1993

Appointments

2007–2010	Department Chair of Mathematics, University of California, Davis.
2000–	Professor of Mathematics, University of California, Davis.
1996–2000	Associate Professor of Mathematics, University of California, Davis.
1993–1996	Assistant Professor of Physics, Princeton University.
1991–1993	Instructor, Department of Physics, Princeton University.
1991	Research Associate, Physics Department, K.U. Leuven, Belgium.
1989–1990	Research Associate, Depto de Física, U. de Chile, Santiago de Chile.
1984–1988	Researcher I.I.K.W., Physics Department, K.U. Leuven, Belgium.

Synergistic Activities

1) Graduate Group in Applied Mathematics, UC Davis, member (10/1996–present), chair (07/2001–07/2004). 2) UC Davis Academic Senate Committee on Research, chair (08/1999–08/2001). 3) UC Davis Academic Senate Committee on Planning and Budget, chair (2006–07 and 2008–09). 4) UC Davis Academic Senate, vice-chair (2011–12) and chair (2012–14). 5) The arXiv: moderator math-ph/math.MP section (05/1998–02/2014, member of Physics Advisory Board (04/2005–present). 6) International Association of Mathematical Physics, member Executive Committee (01/2006–2011); Vice-President (2009–11).

Editorial Activities

1) Journal of Mathematical Physics, Editor, 01/01/2006–present. 2) Reviews in Mathematical Physics, Associate Editor, 01/01/2004–present. 3) Mathematical Physics Electronic Journal, Editorial Board, 03/01/2002–present.

Short Stays

Newton Institute, Cambridge, UK (July 4 – 16, 1993). CNRS Luminy, France (May 15 – August 15, 1995). Erwin Schrödinger Institute, Vienna, Austria (August 26 – September 8, 1995). EPFL, Lausanne (October 4–25, 1998). ETH, Zurich (October 26–31, 1998). CPT, University of Marseille (July 1999). Courant Institute, New York University (14–23 October 2000, 28 March – 6 April 2001, 4–15 September 2001). Department of Mathematics, University of Bologna (June 2–15, 2001). Erwin Schrödinger Institute for Mathematical Physics, Vienna (Fall 2004, Spring 2011). Université de Marseille (April 2005). Institut

Mittag-Leffler, Djursholm, Sweden (Fall 2010). Université de Cergy-Pontoise (June 2015). Technical University Munich (April-June 2016).

Funding history

1) Fundación Nacional de Desarrollo Científico y Tecnológico, Chile: one year (1990). 2) National Science Foundation: 1996 - present, including a Vertical Integration of Graduate Research and Education (VIGRE) training grant, July 2002- June 2007, and a Focused Research Group on Quantum Spin Systems: Theory and Applications in Quantum Computation, July 2008 - June 2011. 3) Department of Education: Graduate Assistance in Areas of National Need (co-PI);, 2000 - 2010.

Honors

International Congress of Mathematicians, Beijing, 2002, invited lecture.
Fellow of the American Association for the Advancement of Science, 2007.
Senior Research Fellow, Erwin Schrödinger Institute for Mathematical Physics, Spring 2011.
Fellow of the American Mathematical Society (Inaugural Class), 2012.
John von Neumann Guest Professor, Technical University Munich, Spring 2016.

Thesis Advisor and Postgraduate-Scholar Sponsor

Thesis Advisor: Shannon Starr (U Alabama at Birmingham), Justin Abbott (Northrop Corporation), Li Lei, Nigie Shi, Austin Calder (National Security Agency), Jeremy Clark (U Mississippi), Spyridon Michalakis (Caltech), Hillel Raz (U Cardiff), Katy Marchand, Jaideep Mulherkar (Dhirubhai Ambani Institute of Information and Communication Technology), Stephen Ng (U Rochester), Anna Vershynina (TU Munich), Amanda Young (UC Davis), Matthew Cha(UC Davis).

Postgraduate-Scholar Sponsor: Oscar Bolina (Kaplan-China.), Jean-Bernard Bru (University of the Basque Country), Pierluigi Contucci (U. Bologna), Wolfgang Spitzer (Fern-Universität Hagen), Daniel Ueltschi (U Warwick), Tom Michoel (Roslin Institute, U Edingurgh), Robert Sims (U Arizona), Yoshiko Ogata (U of Tokyo), Motohisa Fukuda (TU Munich), Sven Bachmann (LMU, Munich), Jogia Bandyopadhyay, Michael Bishop (UC Davis), Dirk-André Deckert (LMU, Munich), Pieter Naaijken (RWTH Aachen U).

Selected Publications

1. M. Fannes, B. Nachtergaele, and A. Verbeure, *The equilibrium states of the Spin-Boson model*, Comm. Math. Phys., **114**, 537-548 (1988)
2. M. Fannes, B. Nachtergaele, and R.F. Werner, *Finitely Correlated States on Quantum Spin Chains*, Comm. Math. Phys. **144**, 443-490 (1992)
3. M. Aizenman and B. Nachtergaele, *Geometric Aspects of Quantum Spin States*, Commun. Math. Phys., **164**, 17-63 (1994)
4. E.H. Lieb and B. Nachtergaele, *The Stability of the Peierls Instability for Ring-Shaped Molecules*, Phys. Rev. B, **51**, 4777-4791 (1995)
5. B. Nachtergaele, *The spectral gap for some quantum spin chains with discrete symmetry breaking*, Commun. Math. Phys., **175**, 565-606 (1996)
6. B. Nachtergaele and H.-T. Yau, *Derivation of the Euler equations from quantum dynamics*, Commun. Math. Phys., **243**, 485-540 (2003) arXiv:math-ph/0209027.

7. B. Nachtergaele and S. Starr, *Ferromagnetic Lieb-Mattis Theorem*, Phys. Rev. Lett., **94**, 057206 (2005) arXiv:math-ph/0210017.
8. B. Nachtergaele and R. Sims, *Lieb-Robinson Bounds and the Exponential Clustering Theorem*, Commun. Math. Phys., **265**, 119-130 (2006), arXiv:math-ph/0506030.
9. S. Bachmann, S. Michalakis, B. Nachtergaele and R. Sims, *Automorphic Equivalence within Gapped Phases of Quantum Lattice Systems*, Commun. Math. Phys. **309**, 835–871 (2012) arXiv:1102.0842
10. S. Bachmann, and B. Nachtergaele, *Product vacua with boundary states and the classification of gapped phases*, Commun. Math. Phys., **329**, 509-544 (2014), arXiv:1212.3718.

Invited Talks at Conferences:

- Workshop on Mathematical Methods in Statistical Mechanics, Leuven, June 1988, invited lecture: *The Mathematical Structure of Spin-Boson Models*.
- Workshop on Phase Transitions, São Paulo, July 1989, invited talk: *Exact Ground States for a class of Quantum Antiferromagnets*.
- Third International Workshop on Instabilities and Non-Equilibrium Structures, Valparaiso, December 1989, invited talk: *Quantum Spin Chains with Residual Entropy*.
- Sixth Vilnius Conference on Probability Theory and Mathematical Statistics, Vilnius, 28 June - 3 July, 1993, invited lecture: *Quasi-state decompositions for quantum spin systems*.
- *Stochastic geometric aspects of some quantum spin chains*, NATO Advanced Research Workshop *Micro, meso and macro approaches in Physics*, Leuven, 19-24 July, 1993, invited lecture: *Stochastic geometric aspects of some quantum spin chains*.
- Hard Problems in Mathematical Physics - A meeting to celebrate the sixtieth birthday of Paul Federbush, Ann Arbor, Michigan, 2-4 May 1994, invited lecture: *Dimerization in Ring-Shaped Molecules*.
- The XIth International Congress of Mathematical Physics, Paris, 18-23 July 1994, invited speaker for the session on “Equilibrium statistical mechanics, random media and disordered systems, constructive field theory methods, and condensed matter”: *Dimerization in ring-shaped molecules: the stability of the Peierls instability*.
- Electron-Phonon Workshop, 5-16 September 1994, Mathematics Research Centre, University of Warwick, invited lecture: *The stability of the Peierls instability and dimerization in annulene molecules*.
- Disordered Systems and Statistical Physics: Rigorous Results, 21-26 August 1995, Budapest. Invited lecture: *Interface Ground States in the XXZ Ferromagnet*.

- Workshop on the Hubbard and Heisenberg Models, in the special semester on “Condensed Matter Physics — Dynamics, Geometry, and Spectral Theory”, August 27 - September 9, 1995, Erwin Schrödinger Institute, Vienna: *Review on the Heisenberg model*, four lectures jointly with Tom Kennedy.
- Joint Meeting of the American Mathematical Society, Orlando, January 10-13, 1996, invited talk in the Special Session on Mathematical Physics: *Low-Lying Spectrum of Quantum Interfaces*.
- 16th Annual Western States Mathematical Physics Meeting, February 24-25, 1997, California Institute of Technology, Pasadena. Invited talk on *Quantum Interfaces*.
- Workshop on *Quantum Probability (QP97)*, Gdańsk, 1-6 July 1997. Invited Talk on *Quantum Interfaces*.
- Workshop on *Recent Trends in Infinite-Dimensional Non-Commutative Analysis*, Research Institute for Mathematical Sciences, Kyoto University, 15-17 October 1997. Title: *The ground state problem of quantum spin chains*.
- Workshop on “Infinite-Dimensional Analysis and Quantum Probability” Nagoya University, 20-22 October 1997. Series of three lectures on *Quantum Markov Chains*.
- Workshop on *Systems with Strong Quantum Fluctuations*, 11-13 December 1997, University of California, Santa Cruz. Title : *On the complete set of ground states for quantum spin chains*.
- STATPHYS 20 Satellite Colloquium on *Mathematical Results in Statistical Mechanics*, 27-31 July 1998, University of Marseille. Title: *Interface states of quantum spin systems*.
- AMS Meeting, 13-15 November 1998, University of Arizona. Title: *Edge States of Quantum Spin Chains*.
- 1999 UAB-GIT International Conference on Differential Equations and Mathematical Physics, Birmingham, Alabama, 16-20 March, 1999 Title: *Interface states of quantum lattice models*.
- Symposium on Mathematical Physics and Quantum Field Theory, Celebrating the Seventieth Birthday of Eyvind H. Wichmann, Berkeley, 11-13 June, 1999 Title: *Quantum interfaces as examples of ground state selection*.
- $M \cup \Phi$ VII, Mathematical Physics Days, on the occasion of the 60th anniversary of André Verbeure, Leuven, 18-19 May, 2000. Title: *Derivation of the Euler equations from quantum dynamics*.
- International Conference on Mathematical Physics, London, 17-22 July, 2000 Title: *Interfaces and their excitations in quantum lattice models*.

- Joint meeting of the American Mathematical Society and the Sociedad Matemática Mexicana, 23-26 May 2001, Morelia, Mexico. Title: *From Schrödinger Dynamics to the Euler Equations*
- International Symposium on topics in Mathematical Physics, May 28-30, 2001, Guanajuato, Mexico. Title: *The Low-Lying Spectrum of the XXZ Heisenberg Model*.
- Quantum Markov chains and their applications in physics and quantum information, 14-20 December, 2001, Trento. Title: *Quantum Spin Systems and Finitely Correlated States*.
- 2002 UAB International Conference on Differential Equations and Mathematical Physics, Birmingham, Alabama, March 26-30, 2002. Title: *From Schrödinger dynamics to the Euler equations*.
- Frontiers of Non-Commutative Analysis and Mathematical Quantum Theory, on the occasion of H. Araki's 70th birthday, 7-11 August, 2002, Fukuoka. Title: *Derivation of the Euler equations from many-body quantum mechanics*.
- International Congress of Mathematicians 2002, 18-28 August, 2002, Beijing. Title: *Derivation of the Euler Equations from many-body quantum mechanics*.
- Mathematical Analysis of Quantum Systems, 19-21 September, 2002, DIAS, Dublin, Ireland. Title: *Recent results and conjectures on the low-lying spectrum of some XXZ Heisenberg models*.
- Inhomogeneous Random Systems, 28-29 January, 2003, Cergy-Pontoise. Title: *Interfaces and Droplets in the XXZ Heisenberg Model*.
- Classical and quantum phase transitions, crystal formation and Bose-Einstein condensation, 17-28 March, 2003, Luminy-Marseille. Titles: *Interfaces in quantum spin systems*. *Derivation of the Euler equations from many-body quantum mechanics* and *Some recent results on the XXZ Heisenberg model*.
- Percolation, Particle Systems and Random Media, 12-17 January 2004, Santiago de Chile. Title: *Particle dynamics, quantum spin models, and quantum computation*.
- QMATH9, 12-16 September 2004, Giens, France. Title: *Ordering of Energy Levels in Heisenberg Models and Applications*.
- Leuven Mathematical Physics Days, 20-22 September 2004, Leuven, Belgium. Title: *Ordering of Energy Levels in Heisenberg models*.
- Mathematical Analysis of Quantum Systems, 28 September - 2 October, 2004, DIAS, Dublin, Ireland. Title: *Ferromagnetic Ordering of Energy Levels and Applications*.
- Progress in mathematical many-body quantum theory, 1-4 December 2004, ESI, Vienna, Austria. Title: *A Ferromagnetic Lieb-Mattis Theorem*.

- Workshop on Quantum Lattice Models, 15-16 March 2005, Warwick, England. Title: *Ferromagnetic Ordering of Energy Levels and Applications*.
- Conference to honour the memory of the late J. T. Lewis, his contributions to mathematics and its applications, Dublin, 14-17 June 2005. Title: *What's new in quantum spin systems?*
- Leuven Mathematical Physics Days, 12-14 September 2005, Leuven, Belgium. Title: *A To-Do List of Problems in Quantum Spin Systems*
- International Congress on the Applications of Mathematics, 13-17 March 2006, Santiago de Chile. Title: *The Exponential Clustering Theorem and Related New Results in Quantum Spin Systems*.
- Statistical Mechanics, Rutgers, 7-9 May 2006. Title: *Propagation of Correlations, Exponential Clustering, and Related New Results*.
- Complex quantum and classical systems and effective equations, June 2006, ESI, Vienna, Austria. Title: *Entanglement in Finitely Correlated States*.
- Statistical Mechanics and Quantum Field Theory, Sao Paulo, 1-4 August 2006. Title: *Finite Speed of Propagation in Quantum Spin Systems and Applications*.
- BIRS Workshop on Operator Structures in Quantum Information Theory, 12-16 February 2007, Banff, Canada. Title: *Lieb-Robinson Bounds and Their Applications in Quantum Information Theory*.
- Workshop on Lieb-Robinson Bounds, 20-24 February 2007, ESI, Vienna, Austria. Title: *Lieb-Robinson bounds and the Lieb-Schultz-Mattis Theorem*.
- Mathematical Analysis of Quantum Systems, 2-4 April, 2007, DIAS, Dublin, Ireland. Title: *New applications of Lieb-Robinson bounds*.
- Meeting on Large Quantum Systems, 11-15 June 2007, Warwick, UK. Title: *A Multi-Dimensional Lieb-Schultz-Mattis Theorem*.
- Computational Complexity of Quantum Hamiltonian Systems, 23-27 July 2007, Lorentz Center, Leiden, The Netherlands. Title: *Locality in Quantum Dynamics and Applications*.
- First Joint International Meeting between the American Mathematical Society and the Polish Mathematical Society, 31 July - 3 August 2007, Warsaw, Poland. Title: *Locality in Quantum Dynamics and Applications*.
- ESF Conference on Operator Theory, Analysis and Mathematical Physics - OTAMP2008, 15-22 June 2008, Bedlewo, Poland. Title: *Quasi-Locality of Quantum Lattice Dynamics*.

- Workshop on Integrable Quantum Systems and Solvable Statistical Models, 29 June - 5 July 2008, CRM Montreal, Canada. Title: *A Lieb-Schultz-Mattis Theorem in d Dimensions*.
- Summer School on Current Topics in Mathematical Physics, July 21-31, ESI Vienna, Austria. Mini-course on *Quantum Spin Dynamics and Applications to Quantum Information and Computation*.
- Workshop on Mathematical Approaches to Collective Phenomena in Large Quantum Systems, 30 August - 5 September 2008, MFO Oberwolfach, Germany. Overview talk on *Lieb-Robinson Bounds and Applications*.
- Workshop on Quantum Many-Body Systems and Bose-Einstein Condensation, 28 September - 4 October 2008, CRM Montreal, Canada. Title: *New Results for the XXZ Chain*.
- Entropy and the Quantum. A school on analytic and functional inequalities with applications Tucson, Arizona, March 16-20, 2009. Minicourse on *Quantum Entropy in Condensed Matter and Information Theory*.
- 101st Statistical Mechanics Meeting, Rutgers University, May 10-12, 2009. Title: *Applications of Lieb-Robinson Bounds*.
- 1st Pacific Rim Mathematical Association (PRIMA) Congress, University of New South Wales, Sydney, Australia, July 6-10, 2009. Title: *Lieb-Robinson bounds for quantum lattice systems and applications*.
- XVIth International Congress on Mathematical Physics, Prague, August 3-8, 2009. Title: *Lieb-Robinson bounds and the existence of infinite-system dynamics*.
- CAIMS*SCMAI-2010, annual meeting of the Canadian Applied and Industrial Mathematics Society, Memorial University of Newfoundland, Canada, July 17–20, 2010. Plenary Talk. Title: *Propagation bounds for quantum dynamics and applications*.
- International Conference on: Operator Theory, Analysis and Mathematical Physics, Bedlewo, Poland, August 5–12, 2010. Title: *Propagation bounds for quantum dynamics and applications*.
- Satellite conference of ICM 2010 on "Quantum Systems", Chennai, India, 14-18 August 2010. Title: *Propagation bounds for quantum dynamics and applications*.
- 29th Annual Western States Mathematical Physics Meeting, Caltech, February 21–22, 2011. Title: *Frustration-free Ground States of Quantum Spin Systems*.
- FRG Workshop on *Quantum Spin Systems. Theory and Applications in Quantum Computation*, Harvard University, 16-20 May 2011. Title: *Frustration-free Ground States of Quantum Spin Systems*.
- Summer school on "Non-equilibrium statistical mechanics, Centre de recherches mathématiques (CRM), Montreal, Canada, July 1-29, 2011. Title: *Ground state phases of quantum spin systems*.

- Workshop on Correlations and Interactions in Random Quantum Systems, Oberwolfach, October 23-2, 2011. Title: *What is a gapped ground state phase?*
- Jean Bricmont 60th Anniversary's Conference on *Stochastic Models*, Brussels, April 10-11, 2012. Title: *What is a Quantum Ground State Phase?*
- 107th Statistical Mechanics Conference, Rutgers University, May 6-8, 2012. Title: *Five Generalizations of the AKLT Model.*
- Conference on *Networking tensor networks: many-body systems and simulations*, Benasque, Spain, May 6-19, 2012. Title: *On the classification of gapped ground state phases.*
- Conference on Mathematics of Many-Particle Systems (in honor of Elliott Lieb), Technical University of Berlin, Germany, July 14, 2012. Title: *On the classification of gapped ground state phases.*
- IX International Conference of Mathematical Physics in Armenia, Yerevan, Armenia, September 2012. Title: *On the classification of gapped ground state phases.*
- Conference on Recent Developments in the Mathematical Analysis of Large Systems (Herbert Spohn's 66th Birthday), Erwin Schrödinger International Institute for Mathematical Physics, Vienna, October 4, 2012. Title: *Quantum harmonic oscillator systems with disorder, Invited Speaker.*
- Winter School on Probability: Mécanique statistique de l'équilibre, February 4-9, 2013, CIRM, Marseille. Title: *On the classification of gapped ground state phases.*
- Conference on *Mathematical Statistical Physics*, a satellite meeting of STATPHYS 25 (2013) and a YITP workshop, Kyoto, July 29 - August 3, 2013. Title: *Gapped Ground State Phases of Quantum Lattice Systems.*
- Mathematical Congress of the Americas, Guanajuato, August 4-8, 2013. Invited session talk in Mathematical Physics. Title: *Structure of Gapped Ground States of Quantum Lattice Systems.*
- Mathematical Horizons for Quantum Physics 2, Institute for Mathematical Sciences, National University of Singapore, 9-17 September 2013. Title: *Gapped ground state phases of quantum lattice systems.*
- 32th Annual Western States Mathematical Physics Meeting, Caltech, February 17-18, 2014. Title: *Gapped ground state phases of quantum lattice systems.*
- Symposium on Many-Body Quantum Systems, March 17-21, 2014, University of Warwick, UK. Title: *Gapped ground state phases of quantum lattice systems.* (with Sven Bachmann)
- Workshop in Honor of Reinhard Werner (60th birthday) March 28, 2014, Leibniz Universität Hanover. Title: *Lessons Learned from FCS and RFW.*

- Workshop Tensor Networks and Simulations, April 21 – 25, 2014, Program on Hamiltonian Complexity, Simons Institute for the Theory of Computing, Berkeley. Title: *Invariants for Symmetry Protected Topological Order in One Dimension*.
- NSF/CBMS Regional Conference in the Mathematical Sciences, June 16-12, 2014, University of Alabama, Birmingham (Distinguished Lecturer). Title: *Quantum Spin Systems*.
- Topological Phases of Quantum Matter, Schrödinger International Institute for Mathematical Physics, Vienna, August 4 - September 12, 2014. Title: *Invariants for gapped ground state phases in dimensions one and higher*.
- Workshop of the Leverhulme International Network *Laplacians, Random Walks and Quantum Spin Systems*, September 15-19, 2014, Bristol. Keynote survey lecture. Title: *Invariants for gapped ground state phases in one dimension*.
- Special Session on *Spectral Theory, Disorder and Quantum Many Body Physics*, AMS Sectional Meeting, March 14-15, 2015, Michigan State University in East Lansing, Michigan. Title: *Strongly Continuous Approximations of Continuum Fermion Dynamics*.
- Master Class on Quantum Mechanics, May 26-29, 2015, University of Copenhagen. Four lectures. Title: *Gapped ground states and topological order in quantum spin systems: stability, classification, and invariants*.
- ESI Program on *Quantum many-body systems, random matrices, and disorder*, July 1-17, 2015, Erwin Schrödinger Institute, Vienna, Austria. Title: *Frustration-Free Quantum Spin Systems*.
- ICMP2015 Satellite Conference on *Operator Algebras and Quantum Physics*, July 17-23, 2015, Sao Paulo, Brazil. Title: *Frustration-Free Quantum Spin Systems*.
- Conference on *Mathematical Approach to Topological Phase in Spintronics*, October 3-10, 2015, Sendai, Japan. Title: *Topological Phases in Quantum Spin Systems. Part I: Gapped Ground State Phases and Frustration-Free Quantum Spin Systems. Part II: An Invariant for Symmetry-Protected Topological Order in One Dimension*.
- Special Session on *Spectral Theory of Ergodic Schrödinger Operators and related models*, October 24-25, 2015, AMS Western Sectional Meeting, California State University, Fullerton Title: *Entanglement Dynamics of Disordered Quantum XY Chains*.
- Warwick-Davis Joint Workshop, December 14-16, 2015, Davis, CA. Title: *Entanglement Dynamics of Disordered Quantum XY Chains*.
- Workshop on *Spectral Theory of Novel Materials*, April 18-22, 2016, CIRM, Luminy, France. Title: *Stability of Frustration-Free Ground States of Quantum Spin Systems*.
- John von Neumann Guest Lectures, April-June, 2016, Technical University Munich, Germany. Title: *Quantum Spin Systems - An introduction to the general theory, Frustration-Free models, and Gapped Quantum Phases*.

- Workshop on *Mathematical Many-Body Theory and Its Applications*, June 13-17, 2016, Basque Center for Applied Mathematics, Bilbao, Spain. Title: *Stability of Frustration-Free Ground States of Quantum Spin Systems*.
- August 2016, Sendai, Japan. Title: *TBD*.
- August 2016, Natal, Brazil. Title: *TBD*.
- September, 2016 Frascati, Italy. Title: *TBD*.
- QMTAH13, October, 2016, Atlanta Title: *TBD*.