

Curriculum Vitae

Paul BUSCH FInstP

1/2018

Department of Mathematics, University of York
Date of appointment: August 2005
Present position: Professor
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A. Academic Career and Development

A1. Previous posts

1. 1979–1982 Graduate Assistant, Institut für Theoretische Physik, Universität Köln.
2. 1982–1987 Research Assistant to Prof. P. Mittelstaedt, Institute for Theoretical Physics, University of Cologne
3. 1/1986–6/1986 Visiting Associate Professor of Mathematics, Florida Atlantic University, Boca Raton.
4. 10/1987–9/1988 Research Associate (DFG) to Prof. E. Ruch, Max Planck Institute for biophysical Chemistry, Göttingen; Project: *Irreversibility and Organisation*
5. 10/1988–9/1995 University Docent for Theoretical Physics, University of Cologne
6. 10/1991– (External) Docent for Theoretical Physics, University of Turku, Finland
7. 4/1994–7/1994 Acting Chair for Philosophy of Science (vacancy upon retirement of Prof. E. Scheibe), University of Heidelberg
8. 9/1995–7/2005 Lecturer/Reader(1996)/Professor(2003) of Mathematical Physics, University of Hull

A2. Qualifications

1. 1973–1979 Studies at the University of Cologne. Physics, Mathematics, Chemistry, Philosophy.
2. March 7, 1979 Physics Diploma (corresponding to MSc), mark: ‘excellent’).
Thesis: *On the empirical relevance of proper time in a gravitational field with singularity.*
3. May 15, 1982 *Rigorosum*, Dr. rer. nat. (PhD), University of Cologne, (Mark: ‘excellent’), with the subjects: Mathematical Physics, Physics, and Philosophy;
Doctoral Thesis: *Indeterminacy relations and simultaneous measurements in quantum theory.*
4. July 7, 1988 Habilitation in Mathematical Physics, University of Cologne;
Thesis: *Physical aspects of a generalised observable concept in quantum theory.*
5. February 9, 1994 Title of ‘apl. Professor’, Theoretical Physics, University of Cologne.

A3. PhD supervisor and post-doctoral supervisors

Emeritus Professor Dr. P. Mittelstaedt, Department of Theoretical Physics, University of Cologne
(PhD supervisor and postdoctoral supervisor)

Emeritus Professor Dr. E. Ruch, Department of Quantum Chemistry, Free University of Berlin,
and Max Planck Institute for biophysical Chemistry, Göttingen (postdoctoral supervisor)

B. Research and Scholarship

B1. Publications

(i) Articles in journals

(1) Refereed contributions

1. On the Behavior of an Oscillator Clock Near the Singularity of a Gravitational Field.
Gen. Rel. Grav. **12**, 483–492 (1980). DOI: [10.1007/BF00756178](https://doi.org/10.1007/BF00756178).
2. On Joint Lower Bounds of Position and Momentum Observables in Quantum Mechanics.
J. Math. Phys. **25**, 1794–1797 (1984). DOI: [10.1063/1.526357](https://doi.org/10.1063/1.526357).
3. with P.J. Lahti: On Various Joint Measurements of Position and Momentum Observables in Quantum Theory. *Phys. Rev. D* **29**, 1634–1646 (1984), DOI: [10.1103/PhysRevD.29.1634](https://doi.org/10.1103/PhysRevD.29.1634)
4. Indeterminacy Relations and Simultaneous Measurements in Quantum Theory.
Int. J. Theor. Phys. **24**, 63–92 (1985). DOI: [10.1007/BF00670074](https://doi.org/10.1007/BF00670074).
5. with P.J. Lahti: A Note on Quantum Theory, Complementarity, and Uncertainty.
Philos. Sci. **52**, 64–77 (1985). www.jstor.org/stable/187598.
6. Momentum Conservation Forbids Sharp Localisation.
J. Phys. A **18**, 3351–3354 (1985). DOI: [10.1088/0305-4470/18/17/016](https://doi.org/10.1088/0305-4470/18/17/016).
7. Unsharp Reality and Joint Measurements for Spin Observables.
Phys. Rev. D **33**, 2253–2261 (1986). DOI: [10.1103/PhysRevD.33.2253](https://doi.org/10.1103/PhysRevD.33.2253).
8. with P.J. Lahti: To What Extent do Position and Momentum Commute?
Phys. Lett. A **115**, 259–264 (1986). DOI: [10.1016/0375-9601\(86\)90549-9](https://doi.org/10.1016/0375-9601(86)90549-9).
9. with P.J. Lahti: Minimal Uncertainty and Maximal Information for Quantum Position and Momentum.
J. Phys. A **20**, 899–906 (1987). DOI: [10.1088/0305-4470/20/4/024](https://doi.org/10.1088/0305-4470/20/4/024).
10. with T.P. Schonbek, F.E. Schroeck: Quantum Observables: Compatibility Versus Commutativity and Maximal Information. *J. Math. Phys.* **28**, 2866–2872 (1987). DOI: [10.1063/1.527686](https://doi.org/10.1063/1.527686).
11. Some Realizable Joint Measurements of Complementary Observables.
Found. Phys. **17**, 905–937 (1987). DOI: [10.1007/BF00734320](https://doi.org/10.1007/BF00734320).
12. with S.T. Ali, J.A. Brooke, R. Gagnon, F.E. Schroeck: Current Conservation as a Geometric Property of Space Time. *Can. J. Phys.* **66**, 238–244 (1988). DOI: [10.1139/p88-036](https://doi.org/10.1139/p88-036).
13. Linearity Versus Symmetry? *Phys. Lett. A* **126**, 300–302 (1988). DOI: [10.1016/0375-9601\(88\)90839-0](https://doi.org/10.1016/0375-9601(88)90839-0).
14. Surprising Features of Unsharp Quantum Measurements.
Phys. Lett. A **130**, 323–329 (1988). DOI: [10.1016/0375-9601\(88\)90220-4](https://doi.org/10.1016/0375-9601(88)90220-4).
15. with P.J. Lahti: The Determination of the Past and the Future of a Physical System in Quantum Mechanics. *Found. Phys.* **19**, 633–678 (1989). DOI: [10.1007/BF00731904](https://doi.org/10.1007/BF00731904).
16. with M. Grabowski, P.J. Lahti: Some Remarks on Effects, Operations, and Unsharp Quantum Measurements. *Found. Phys. Lett.* **2**, 331–345 (1989). DOI: [10.1007/BF00690299](https://doi.org/10.1007/BF00690299).
17. with F.E. Schroeck: On the Reality of Spin and Helicity.
Festschrift for Peter Mittelstaedt, Found. Phys. **19**, 807–872 (1989). DOI: [10.1007/BF01889302](https://doi.org/10.1007/BF01889302).
18. with G. Cassinelli, P.J. Lahti: On the Quantum Theory of Sequential Measurements.
Commemoration of Charles Randall, Found. Phys. **20**, 757–775 (1990), DOI: [10.1007/BF01889690](https://doi.org/10.1007/BF01889690).
19. with P.J. Lahti: Completely Positive Mappings in Quantum Dynamics and Measurement.
Festschrift for John Bell, Found. Phys. **20**, 1429–1439 (1990). DOI: [10.1007/BF01883516](https://doi.org/10.1007/BF01883516).
20. On the Energy-Time Uncertainty Relation. Part I: Dynamical Time and Time Indeterminacy.
Found. Phys. **20**, 1–32 (1990). DOI: [10.1007/BF00732932](https://doi.org/10.1007/BF00732932).
21. On the Energy-Time Uncertainty Relation. Part II: Pragmatic Time Versus Energy Indeterminacy.
Found. Phys. **20**, 33–43 (1990). DOI: [10.1007/BF00732933](https://doi.org/10.1007/BF00732933).

22. with P.J. Lahti: Some Remarks on Unsharp Quantum Measurements, Quantum Non-Demolition, And All That. *Ann. Physik (Leipzig)* **47**, 369–382 (1990). DOI: [10.1002/andp.19905020502](https://doi.org/10.1002/andp.19905020502).
23. with R. Quadts: On Ruch's Principle of Decreasing Mixing Distance in Classical Statistical Physics. *J. Stat. Phys.* **61**, 311–328 (1990). DOI: [10.1007/BF01013967](https://doi.org/10.1007/BF01013967).
24. Informationally Complete Sets of Physical Quantities. *Int. J. Theor. Phys.* **30**, 1217–1227 (1991). DOI: [10.1007/BF00671008](https://doi.org/10.1007/BF00671008).
25. with P. Mittelstaedt: The Problem of Objectification in Quantum Mechanics. *Found. Phys.* **21**, 889–904 (1991). DOI: [10.1007/BF00733214](https://doi.org/10.1007/BF00733214).
26. with P.J. Lahti, P. Mittelstaedt: Some Important Classes of Quantum Measurements and their Information Gain. *J. Math. Phys.* **32**, 2770–2775 (1991). DOI: [10.1063/1.529504](https://doi.org/10.1063/1.529504).
27. with P.J. Lahti, P. Mittelstaedt: Weak Objectification, Joint Probabilities, and Bell Inequalities in Quantum Mechanics: *Found. Phys.* **22**, 949–962 (1992). DOI: [10.1007/BF01889687](https://doi.org/10.1007/BF01889687).
28. with E. Ruch: The Measure Cone - Irreversibility as a Geometrical Phenomenon. In: *Festschrift for Per-Olov Löwdin*, *Int. J. Quant. Chem.* **41**, 163–185 (1992), DOI: [10.1002/qua.560410115](https://doi.org/10.1002/qua.560410115).
29. with H. Scherer: Problem of Signal Transmission via Quantum Correlations and Einstein Incompleteness of Quantum Mechanics. *Phys. Rev. A* **47**, 1647–1651 (1993). DOI: [10.1103/PhysRevA.47.1647](https://doi.org/10.1103/PhysRevA.47.1647).
30. with K.E. Hellwig, W. Stulpe: Classical Representations of Finite-Dimensional Quantum Mechanics. *Int. J. Theor. Phys.* **32**, 399–405 (1993). DOI: [10.1007/BF00673351](https://doi.org/10.1007/BF00673351).
31. with R. Quadts: Concepts of Coarse Graining in Quantum Mechanics. *Int. J. Theor. Phys.* **32**, 2261–2269 (1993). DOI: [10.1007/BF00672998](https://doi.org/10.1007/BF00672998).
32. with P. Kienzler, P. Lahti, P. Mittelstaedt: Testing Quantum Mechanics Against a Full Set of Bell Inequalities. *Phys. Rev. A* **47** 4627–4631 (1993). DOI: [10.1103/PhysRevA.47.4627](https://doi.org/10.1103/PhysRevA.47.4627).
33. with R. Quadts: Coarse Graining and the Quantum-Classical Connection. *Open Systems & Information Dynamics* **2**, 129–155 (1994). DOI: [10.1007/BF02228961](https://doi.org/10.1007/BF02228961).
34. with K. Hass: Causality of Superluminal Barrier Traversal. *Phys. Lett. A* **185**, 9–13 (1994). DOI: [10.1016/0375-9601\(94\)90979-2](https://doi.org/10.1016/0375-9601(94)90979-2).
35. with P.J. Lahti, M. Grabowski: Time Observables in Quantum Theory. *Phys. Lett. A* **191**, 357–361 (1994). DOI: [10.1016/0375-9601\(94\)90785-4](https://doi.org/10.1016/0375-9601(94)90785-4).
36. with P.J. Lahti, M. Grabowski: Phase Statistics and Phase Space Measurements. *Phys. Rev. A* **50**, 2881–2884 (1994). DOI: [10.1103/PhysRevA.50.2881](https://doi.org/10.1103/PhysRevA.50.2881).
37. with P.J. Lahti, M. Grabowski: Who is Afraid of POV Measures? Unified Approach to Quantum Phase Observables. *Ann. Phys. (N.Y.)* **237**, 1–11 (1995). DOI: [10.1002/andp.19905020502](https://doi.org/10.1002/andp.19905020502).
38. with P.J. Lahti: The Complementarity of Quantum Observables: Theory and Experiments. *Riv. Nuovo Cim.* **18**, N. 4, 1–27 (1995), DOI: [10.1007/BF02743814](https://doi.org/10.1007/BF02743814), [arXiv:quant-ph/0406132](https://arxiv.org/abs/quant-ph/0406132).
39. with P.J. Lahti, M. Grabowski: Repeatable Measurements in Quantum Mechanics: Their Role and Feasibility. *Found. Phys.* **25**, 1239–1266 (1995), DOI: [10.1007/BF02055331](https://doi.org/10.1007/BF02055331)
40. with G. Cassinelli, P.J. Lahti: Probability Structures for Quantum State Spaces. *Rev. Math. Phys.* **7**, 1105–1121 (1995). DOI: [10.1142/S0129055X95000402](https://doi.org/10.1142/S0129055X95000402).
41. with P.J. Lahti: The Standard Model of Quantum Measurement Theory: History and Applications. *Special Issue: Festschrift for Max Jammer*, *Found. Phys.* **26**, 875–893 (1996). DOI: [10.1007/BF02148831](https://doi.org/10.1007/BF02148831), [arXiv:quant-ph/9603020](https://arxiv.org/abs/quant-ph/9603020).
42. with A. Shimony: Insolubility of the Quantum Measurement Problem for Unsharp Observables. *Stud. Hist. Phil. Mod. Phys.* **27**, 397–404 (1996). DOI: [10.1016/S1355-2198\(96\)00012-3](https://doi.org/10.1016/S1355-2198(96)00012-3), [arXiv:quant-ph/9604013](https://arxiv.org/abs/quant-ph/9604013).
43. with P.J. Lahti: Correlation Properties of Quantum Measurements. *J. Math. Phys.* **37**, 2585–2601 (1996). DOI: [10.1063/1.531530](https://doi.org/10.1063/1.531530), [arXiv:quant-ph/9603016](https://arxiv.org/abs/quant-ph/9603016).
44. with P.J. Lahti: Individual Aspects of Quantum Measurements. *J. Phys. A* **29**, 5899–5907 (1996). DOI: [10.1088/0305-4470/29/18/019](https://doi.org/10.1088/0305-4470/29/18/019).

45. with P.J. Lahti: Remarks on Separability of Compound Quantum Systems and Time Reversal.
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Lett. Math. Phys. **44**, 215–224 (1998), DOI: [10.1023/A:1007429502809](https://doi.org/10.1023/A:1007429502809) [arXiv:math-ph/9804005](https://arxiv.org/abs/math-ph/9804005).
47. Can ‘Unsharp Objectification’ Solve the Quantum Measurement Problem?
Int. J. Theor. Phys. **37**, 241–247 (1998). DOI: [10.1023/A:1026658532622](https://doi.org/10.1023/A:1026658532622), [arXiv:quant-ph/9802011](https://arxiv.org/abs/quant-ph/9802011).
48. with J. Singh: Lüders Theorem for Unsharp Quantum Measurements.
Phys. Lett. A **249**, 10–12 (1998). DOI: [10.1016/S0375-9601\(98\)00704-X](https://doi.org/10.1016/S0375-9601(98)00704-X), [arXiv:1304.0054](https://arxiv.org/abs/1304.0054) [quant-ph].
49. with S.P. Gudder: Effects as Functions on Projective Hilbert Space.
Lett. Math. Phys. **47**, 329–337 (1999). DOI: [10.1023/A:1007573216122](https://doi.org/10.1023/A:1007573216122), [arXiv:1303.6589](https://arxiv.org/abs/1303.6589) [math-ph].
50. Stochastic Isometries in Quantum Mechanics.
Math. Phys., Analysis and Geometry **2**, 83–106 (1999).
DOI: [10.1023/A:1009822315406](https://doi.org/10.1023/A:1009822315406), [arXiv:1303.6624](https://arxiv.org/abs/1303.6624) [math-ph].
51. Unsharp Localization and Causality in Relativistic Quantum Theory.
J. Phys. A **32**, 6535–6546 (1999). DOI: [10.1088/0305-4470/32/37/305](https://doi.org/10.1088/0305-4470/32/37/305), [arXiv:1303.6649](https://arxiv.org/abs/1303.6649) [quant-ph].
52. Geometric and Operational Aspects of Irreversibility.
Invited contribution, *MATCH-Communications in Mathematical Chemistry* **42**, 71–84 (2000).
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55. with P. Lahti, J.-P. Pellonpää, K. Ylinen: Are Number and Phase Complementary Observables?
J. Phys. A **34** 5923–5935 (2001). DOI: [10.1088/0305-4470/34/30/304](https://doi.org/10.1088/0305-4470/34/30/304), [arXiv:quant-ph/0105036](https://arxiv.org/abs/quant-ph/0105036).
56. with J.A. Brooke, D.B. Pearson: Commutativity up to a Factor for Bounded Positive Operators.
Proc. Roy. Soc. A (Lond.) **458**, 109–118 (2002). DOI: [10.1098/rspa.2002.0549](https://doi.org/10.1098/rspa.2002.0549), [arXiv:math.FA/0007049](https://arxiv.org/abs/math.FA/0007049).
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Int. J. Theor. Phys. **42**, 937–941 (2003). Invited paper, XXVIth School of Theoretical Physics, University of Silesia. DOI: [10.1023/A:1025462220957](https://doi.org/10.1023/A:1025462220957), [arXiv:quant-ph/0209090](https://arxiv.org/abs/quant-ph/0209090).
58. with C.R. Shilladay: Uncertainty Reconciles Complementarity with Joint Measurability.
Phys. Rev. A **68**, 034102/1–4 (2003), DOI: [10.1103/PhysRevA.68.034102](https://doi.org/10.1103/PhysRevA.68.034102), [arXiv:quant-ph/0207081](https://arxiv.org/abs/quant-ph/0207081).
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Phys. Rev. Lett. **91**, 120403/1–4 (2003). DOI: [10.1103/PhysRevLett.91.120403](https://doi.org/10.1103/PhysRevLett.91.120403), [arXiv:quant-ph/9909073](https://arxiv.org/abs/quant-ph/9909073).
60. with S. Weigert: Lüders Theorem for Coherent State POVMs.
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61. with P.J. Lahti, T. Heinonen: Noise and Disturbance in Quantum Mechanics.
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Physics Reports **452**, 155–176 (2007). DOI: [10.1016/j.physrep.2007.05.006](https://doi.org/10.1016/j.physrep.2007.05.006), [arXiv:quant-ph/0609185](https://arxiv.org/abs/quant-ph/0609185).

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Phys. Lett. A **372**, 4379-4380 (2008). DOI: [10.1016/j.physleta.2008.04.019](https://doi.org/10.1016/j.physleta.2008.04.019), [arXiv:0804.4333](https://arxiv.org/abs/0804.4333).
68. with T. Heinosaari: Approximate joint measurements of qubit observables.
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74. with L. Loveridge: ‘Measurement of Quantum Mechanical Operators’ Revisited.
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76. with J.C.G. Biniok: Multi-slit interferometry and commuting functions of position and momentum.
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J. Math. Anal. Appl. **408**, 384–393 (2013), DOI: [10.1016/j.jmaa.2013.06.019](https://doi.org/10.1016/j.jmaa.2013.06.019), [arXiv:1304.7442](https://arxiv.org/abs/1304.7442).
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Phys. Rev. Lett. **111**, 160405 (2013) [5 pp.], DOI: [10.1103/PhysRevLett.111.160405](https://doi.org/10.1103/PhysRevLett.111.160405), [arXiv:1306.1565](https://arxiv.org/abs/1306.1565).
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83. with P. Lahti, R.F. Werner: Quantum root-mean-square error and measurement uncertainty relations.
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84. with T. Bullock: Focusing in Arthurs-Kelly-type Joint Measurements with Correlated Probes.
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DOI: [10.1103/PhysRevLett.113.120401](https://doi.org/10.1103/PhysRevLett.113.120401), [arXiv:1405.5840](https://arxiv.org/abs/1405.5840).
85. with J. Biniok, J. Kiukas: Uncertainty in the context of multislit interferometry.
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86. with N. Stevens: Direct tests of measurement uncertainty relations: what it takes.
Phys. Rev. Lett. **114**, 070402 (2015) [5+3 pp.], DOI: [10.1103/PhysRevLett.114.070402](https://doi.org/10.1103/PhysRevLett.114.070402), [arXiv:1407.7752](https://arxiv.org/abs/1407.7752).
87. with L. Loveridge, T. Miyadera: Approximating relational observables by absolute quantities: A quantum accuracy-size trade-off. *J. Phys. A* **49**, 185301 (2016) [17 pp.],
DOI: [10.1088/1751-8113/49/18/185301](https://doi.org/10.1088/1751-8113/49/18/185301), [arXiv:1510.02063](https://arxiv.org/abs/1510.02063).

88. with L.D. Loveridge, T. Miyadera: Relativity of Quantum States and Observables. *EPL* **117**, 40004 (2017) [5 pp.], DOI: [10.1209/0295-5075/117/40004](https://doi.org/10.1209/0295-5075/117/40004), [arXiv:1604.02836v3](https://arxiv.org/abs/1604.02836v3).
89. with T. Xiong, L. Yan, Z. Ma, F. Zhou, L. Chen, W. Yang, M. Feng: Optimal joint measurements of complementary observables by a single trapped ion. *N. J. Phys.* **19**, 063032 (2017) [9 pp.], DOI: [10.1088/1367-2630/aa70a5](https://doi.org/10.1088/1367-2630/aa70a5), [arXiv:1705.01385](https://arxiv.org/abs/1705.01385).
90. with L.D. Loveridge, T. Miyadera: Symmetry, Reference Frames, and Relational Quantities in Quantum Mechanics. *Found. Phys.* (in press, 2018). [arXiv:1703.10434](https://arxiv.org/abs/1703.10434).

(ii) Books

(1) Authored books

1. P. Busch, P. Lahti, P. Mittelstaedt: *The Quantum Theory of Measurement*, Lecture Notes in Physics, Vol. m2, Springer-Verlag, Berlin, 1991 (165 pages). Second revised edition 1996 (181 pages). DOI: [10.1007/978-3-540-37205-9](https://doi.org/10.1007/978-3-540-37205-9).
2. P. Busch, M. Grabowski, P. Lahti: *Operational Quantum Physics*, Lecture Notes in Physics, Vol. m31, Springer-Verlag, Berlin, 1995 (230 pages). Second, corrected printing 1997. DOI: [10.1007/978-3-540-49239-9](https://doi.org/10.1007/978-3-540-49239-9).
3. P. Busch, P. Lahti, J.-P. Pellonpää, K. Ylinen: *Quantum Measurement*, Theoretical and Mathematical Physics, Springer International Publishing, 2016 (xii+542 pages). DOI: [10.1007/978-3-319-43389-9](https://doi.org/10.1007/978-3-319-43389-9).

(2) Edited books

1. P. Busch, P. Lahti, P. Mittelstaedt (eds.): Proceedings, *Symposium on the Foundations of Modern Physics 1993*, World Scientific, Singapore, 1993 (484 pages).

(iii) Chapters in books

1. with P. Mittelstaedt: *Zur Quantentheorie der Messung*. Book chapter in: *Quanten, Chaos und Dämonen*, eds. K. Mainzer, W. Schirmacher. Bibliographisches Institut, Mannheim, 1993, pp. 107–130.
2. *Is the Quantum State (An) Observable?* In: *Potentiality, Entanglement, and Passion-at-a-Distance: Quantum Mechanical Studies for Abner Shimony*, eds. R.S. Cohen, M.A. Horne, J. Stachel, Kluwer, Dordrecht, 1997, pp. 61–70. DOI: [10.1007/978-94-017-2732-7_5](https://doi.org/10.1007/978-94-017-2732-7_5), [arXiv:quant-ph/9604014](https://arxiv.org/abs/quant-ph/9604014).
3. *The Time Energy Uncertainty Relation*. Book Chapter in: *Time in Quantum Mechanics*, eds. J.G. Muga, R. Sala Mayato, I.L. Egusquiza. Springer-Verlag, 2002, pp. 69–98. 2nd ed. 2008. DOI: [10.1007/978-3-540-73473-4_3](https://doi.org/10.1007/978-3-540-73473-4_3), [arXiv:quant-ph/0105049v3](https://arxiv.org/abs/quant-ph/0105049v3).
4. with G. Jaeger: *Which-Way or Welcher-Weg Experiments*. In: *Compendium of Quantum Physics, Concepts, Experiments, History and Philosophy*, eds. D. Greenberger, K. Hentschel, F. Weinert, Springer-Verlag, 2009, pp. 845–851. DOI: [10.1007/978-3-540-70626-7_237](https://doi.org/10.1007/978-3-540-70626-7_237), [PhilSci Archive Item 4114](https://philsci-archive.berkeley.edu/item/PhilSci-Archive-Item-4114).
5. with B. Falkenburg: *Heisenberg's Uncertainty Relation (Indeterminacy Relations)*. In: *Compendium of Quantum Physics, Concepts, Experiments, History and Philosophy*, eds. D. Greenberger, K. Hentschel, F. Weinert, Springer-Verlag, 2009, pp. 281–283. DOI: [10.1007/978-3-540-70626-7_86](https://doi.org/10.1007/978-3-540-70626-7_86), [PhilSci Archive Item 4112](https://philsci-archive.berkeley.edu/item/PhilSci-Archive-Item-4112).
6. with P. Lahti: *Observable*. In: *Compendium of Quantum Physics, Concepts, Experiments, History and Philosophy*, eds. D. Greenberger, K. Hentschel, F. Weinert, Springer-Verlag, 2009, pp. 425–428. DOI: [10.1007/978-3-540-70626-7_130](https://doi.org/10.1007/978-3-540-70626-7_130), [PhilSci Archive Item 4109](https://philsci-archive.berkeley.edu/item/PhilSci-Archive-Item-4109).
7. with P. Lahti, *Lüders Rule*. In: *Compendium of Quantum Physics, Concepts, Experiments, History and Philosophy*, eds. D. Greenberger, K. Hentschel, F. Weinert, Springer-Verlag, 2009, pp. 356–358. DOI: [10.1007/978-3-540-70626-7_110](https://doi.org/10.1007/978-3-540-70626-7_110), [PhilSci Archive Item 4111](https://philsci-archive.berkeley.edu/item/PhilSci-Archive-Item-4111).
8. with P. Lahti: *Measurement Theory*. In: *Compendium of Quantum Physics, Concepts, Experiments, History and Philosophy*, eds. D. Greenberger, K. Hentschel, F. Weinert, Springer-Verlag, 2009, p. 374–379. DOI: [10.1007/978-3-540-70626-7_117](https://doi.org/10.1007/978-3-540-70626-7_117), [PhilSci Archive Item 4108](https://philsci-archive.berkeley.edu/item/PhilSci-Archive-Item-4108).

9. *Effect*. In: *Compendium of Quantum Physics, Concepts, Experiments, History and Philosophy*, eds. D. Greenberger, K. Hentschel, F. Weinert, Springer-Verlag, 2009, p. 179–180.
DOI: [10.1007/978-3-540-70626-7_57](https://doi.org/10.1007/978-3-540-70626-7_57), [PhilSci Archive Item 4110](#).

(iv) **Papers published in refereed conference proceedings**

1. Can Quantum Theoretical Reality be Considered Sharp? In: *Recent Developments in Quantum Logic*, eds. P. Mittelstaedt, E.W. Stachow, Bibliographisches Institut, Mannheim, 1985, pp. 81–101.
2. Elements of Unsharp Reality in the EPR Experiment. In: *Symposium on the Foundations of Modern Physics 1985: 50 Years of the Einstein-Podolsky-Rosen Gedanken Experiment*, eds. P. Lahti, P. Mittelstaedt, World Scientific, Singapore, 1985, pp. 343–357.
3. Unsharp Reality and the Question of Quantum Systems. In: *Symposium on the Foundations of Modern Physics 1987: The Copenhagen Interpretation 60 Years after the Como Lecture*, eds. P. Lahti, P. Mittelstaedt, World Scientific, Singapore, 1987, pp. 105–125.
4. A ‘Natural’ Explanation of the Aharonov et al ‘Surprising Quantum Effect’. In: (Proceedings, The 3rd International Symposium on) *Foundations of Quantum Mechanics in the Light of New Technology*, The Physical Society of Japan, Tokyo, 1990, pp. 25–31.
5. Macroscopic Quantum Systems and the Objectification Problem. In: *Symposium on the Foundations of Modern Physics 1990: Quantum Measurement Theory and its Philosophical Implications*, eds. P. Lahti, P. Mittelstaedt, World Scientific, Singapore, 1991, pp. 62–76.
6. The Quantum Theory of Unsharp Measurements. **Invited Plenary Lecture**. In: *Classical and Quantum Systems - Foundations and Symmetries*. Proceedings of the 2nd International Wigner Symposium, Goslar, Germany, 16–20 July 1991, eds. H.D. Doebner, W. Scherer, F.E. Schroeck. World Scientific, Singapore, 1993, pp. 19–28.
7. Quantum-to-Classical Transition for Galilei-Covariant Observables. In: *Symposium on the Foundations of Modern Physics 1993: Quantum Measurement, Irreversibility and the Physics of Information*, eds. P. Busch, P. Lahti, P. Mittelstaedt. World Scientific, Singapore, 1993, pp. 145–152.
8. The Status of Quantum Mechanics in the Light of the Objectification Problem. **Invited Plenary Lecture**. In: *The Interpretation of Quantum Mechanics - Where do we stand?* ed. L. Accardi. Istituto della Enciclopedia Italiana, Rome, 1994, pp. 205–217.
9. with H. Scherer: Weakly Disturbing Phase Space Measurements in Quantum Mechanics. In: *Quantum Communications and Measurement*, eds. V.P. Belavkin, O. Hirota, R.L. Hudson. Plenum, New York, 1995, pp. 155–163. DOI: [10.1007/978-1-4899-1391-3_14](https://doi.org/10.1007/978-1-4899-1391-3_14).
10. Remarks on Unsharp Quantum Observables, Objectification and Modal Interpretations. **Invited talk**. Proceedings, *The Modal Interpretation of Quantum Mechanics*, eds. D. Dieks, P.E. Vermaas, Western Ontario Series in Philosophy of Science, Vol. 60, Kluwer, Dordrecht, 1998, pp. 279–288.
DOI: [10.1007/978-94-011-5084-2_12](https://doi.org/10.1007/978-94-011-5084-2_12), [arXiv:quant-ph/9802006](https://arxiv.org/abs/quant-ph/9802006).
11. EPR-Bell Tests with Unsharp Observables and Relativistic Quantum Measurement. In: *Non-locality and Modality*, eds. T. Placek, J. Butterfield, Kluwer Academic Publishers, Dordrecht, NATO Science Series II. Mathematics, Physics and Chemistry, Vol. 64, 2002, pp. 175–193.
DOI: [10.1007/978-94-010-0385-8_12](https://doi.org/10.1007/978-94-010-0385-8_12), [arXiv:quant-ph/0110023](https://arxiv.org/abs/quant-ph/0110023).
12. Less (Precision) is More (Information): Quantum Information in Fuzzy Probability Theory. **Invited talk**. In: *Proceedings, International Conference in Quantum Theory: Reconsideration of Foundations - 2, Växjö, Sweden, June 1-6, 2003*, eds. H. Barnum, C.A. Fuchs, A. Khrennikov, Växjö University Press (2004) (ISSN: 91-7636-409-7), pp. 113–128. [arXiv:quant-ph/0401027](https://arxiv.org/abs/quant-ph/0401027)
13. No Information Without Disturbance: Quantum Limitations of Measurement. **Invited Plenary Lecture**. In: *Quantum Reality, Relativistic Causality, and Closing the Epistemic Circle: Essays for Abner Shimony*, eds. W.C. Myrvold, J. Christian, Springer-Verlag, 2009, pp. 229–256.
DOI: [10.1007/978-1-4020-9107-013](https://doi.org/10.1007/978-1-4020-9107-013), [arXiv:0706.3526](https://arxiv.org/abs/0706.3526) [quant-ph].
14. Quantum mechanics as a framework for dealing with uncertainty. **Invited Plenary Lecture**, *16th Central European Workshop on Quantum Optics, Turku, Finland, 23-27 May 2009*. *Phys. Scr.* **T140** (2010) 014003 (7pp). DOI: [10.1088/0031-8949/2010/T140/014003](https://doi.org/10.1088/0031-8949/2010/T140/014003), [arXiv:1004.2985v1](https://arxiv.org/abs/1004.2985v1) [quant-ph].

15. with L.D. Loveridge: Quantum Measurements Constrained by Symmetries. *Invited Lecture*. In: *Symmetries and Groups in Contemporary Physics, Proceedings of the XXIX International Colloquium on Group- Theoretical Methods in Physics, Tianjin, China, 20-26 August 2012* (eds. C. Bai, J.-P. Gazeau, M.-L. Ge), Nankai Series in Pure, Applied Mathematics and Theoretical Physics: Vol. 11, World Scientific, 2013, pp. 587-592. DOI: [10.1142/9789814518550_0083](https://doi.org/10.1142/9789814518550_0083), arXiv:1303.6536v1.
16. Quantum rms error and Heisenberg's error-disturbance relation. *Invited Plenary Lecture*. In: *Web Proceedings of the International Symposium Wigner 111 – Colorful and Deep, Budapest, 11-13 November, 2013*. EPJ Web of Conferences **78**, 01002 (2014) [8 pp.]. DOI: [10.1051/epjconf/20147801002](https://doi.org/10.1051/epjconf/20147801002).

(vi) **Further publications on arXiv, etc.**

1. with P. Lahti, R.F. Werner: Measurement Uncertainty: Reply to Critics. [arXiv:1402.3102v1](https://arxiv.org/abs/1402.3102v1) [quant-ph] (2014).
2. with P. Lahti, R.F. Werner: Comment on ‘Experimental Test of Error-Disturbance Uncertainty Relations by Weak Measurement’. [arXiv:1403.0367v2](https://arxiv.org/abs/1403.0367v2) [quant-ph] (2014).
3. with P. Lahti, R.F. Werner: Comment on ‘Noise and Disturbance in Quantum Measurements: An Information-Theoretic Approach’. [arXiv:1403.0368v1](https://arxiv.org/abs/1403.0368v1) [quant-ph] (2014).
4. with D.B. Pearson: Error and unsharpness in approximate joint measurements of position and momentum. [arXiv:1405.6956](https://arxiv.org/abs/1405.6956) [quant-ph] (2014).
5. with J. Biniok: Heisenberg-Type Uncertainty Relation for Qubits. Wolfram Demonstrations Project, <http://demonstrations.wolfram.com/HeisenbergTypeUncertaintyRelationForQubits/>.
6. Quantum Uncertainty Tutorial. Slides of a 3-hour tutorial presented at the Workshop *Quantum Physics and Logic – QPL 2015*, Oxford, 13-17 July 2015. <https://www.cs.ox.ac.uk/qpl2015/tutorials/busch.pdf>.
7. Quantum Measurement Uncertainty – Reading Heisenberg's mind or invoking his spirit? Slides of Plenary Lecture at the eWorkshop *Quantum Physics and Logic – QPL 2015*, Oxford, 13-17 July 2015. <https://www.cs.ox.ac.uk/qpl2015/slides/Busch-Invited.pdf>.
8. with T. Bullock: Optimal Joint Measurements of Qubit Observables. Wolfram Demonstrations Project, <http://demonstrations.wolfram.com/OptimalJointMeasurementsOfQubitObservables/>.
9. with T.J. Bullock: Measurement uncertainty relations: characterising optimal error bounds for qubits. *Submitted to J. Phys. A as proposed topical review* (2018). [arXiv:1512.00104v3](https://arxiv.org/abs/1512.00104v3).
10. with J. Kiukas, R.F. Werner: Sharp uncertainty relations for number and angle. *Resubmitted to J. Math. Phys.* (2018). [arXiv:1604.00566](https://arxiv.org/abs/1604.00566)

(vi) **Book Reviews, Editorials, etc.**

1. with A. van der Merwe: Editorial: Peter Mittelstaedt: Philosopher-Physicist. *Found. Phys.* **19**, 789–791 (1989). DOI: [10.1007/BF01889300](https://doi.org/10.1007/BF01889300).
2. Invited Featured Book Review: Thomas S. Kuhn, *Black-body theory and the quantum discontinuity*, *Mathematical Reviews* [MR0957503](https://arxiv.org/abs/MR0957503) (90c:01040) (1990).
3. Featured Book Review: Jeffrey Bub, *Interpreting the Quantum World*, *Mathematical Reviews* [MR1464691](https://arxiv.org/abs/MR1464691) (99f:81006) (1999).
4. Classical versus Quantum Ontology – Invited Book Review Essay: D. Home, *Conceptual Foundations of Quantum Mechanics. Stud. Hist. Philos. Mod. Phys.* **33B**, 517-539 (2002). DOI: [10.1016/S1355-2198\(02\)00023-0](https://doi.org/10.1016/S1355-2198(02)00023-0), [arXiv:quant-ph/0010115](https://arxiv.org/abs/quant-ph/0010115).
5. with E. Beltrametti, P. Lahti: Obituary, Sławomir Bugajski 1941-2003. *Int. J. Theor. Phys.* **42** 1133-1137 (2003). DOI: [10.1023/A:1025430819299](https://doi.org/10.1023/A:1025430819299).
6. Book review: W.M. deMuynck, *Foundations of quantum mechanics, an empiricist approach*, Kluwer 2002. *Mathematical Reviews* [MR2040793](https://arxiv.org/abs/MR2040793) (2005i:81004) (2005).
7. Book Review: *Physical Theory and its Interpretation – Essays in Honor of Jeffrey Bub*, Springer, 2006. *Stud. Hist. Philos. Mod. Phys.* **40** 92-93 (2009). DOI: [10.1016/j.shpsb.2008.07.002](https://doi.org/10.1016/j.shpsb.2008.07.002).

8. with D. Dieks, G. 't Hooft: Editorial, *Pekka Johannes Lahti – 60th Birthday*, *Found. Phys.* **39**, 519–520 (2009). DOI: [10.1007/s10701-009-9309-6](https://doi.org/10.1007/s10701-009-9309-6).
9. Editorial: *Between Physics and Philosophy—Festschrift for Peter Mittelstaedt on His 80th Birthday*. *Found. Phys.* **40**, 1161–1162 (2010). DOI: [10.1007/s10701-010-9468-5](https://doi.org/10.1007/s10701-010-9468-5).
10. *Peter Mittelstaedt: List of Publications until 2010 – Including a List of Doctoral Students and Their Dissertation Titles*. *Found. Phys.* **40** 1189–1199 (2010). DOI: [10.1007/s10701-010-9466-7](https://doi.org/10.1007/s10701-010-9466-7).
11. with J. Pfarr, M.L. Ristig, E.W. Stachow: *Quantum, Matter, Spacetime: Peter Mittelstaedt's Contributions to Physics and Its Foundations*. *Found. Phys.* **40**, 1163–1170 (2010). DOI: [10.1007/s10701-010-9478-3](https://doi.org/10.1007/s10701-010-9478-3).
12. with M. Dodson, A. Higuchi, S. Weigert: *Preface: Quantum Groups, Quantum Foundations and Quantum Information: a Festschrift for Tony Sudbery*. *J. Phys.: Conf. Ser.* **254** 011001. [Journal page: Editorial]
13. Translation of “Die Messung quantenmechanischer Operatoren” by E. Wigner. *Z. Phys.* (1952). [arXiv:1012.4372v1](https://arxiv.org/abs/1012.4372v1) [quant-ph].
14. Book Review: T. Heinosaari, M. Ziman, *Mathematical Language of Quantum Theory*, CUP 2012. *Mathematical Reviews*, [MR2896337](https://doi.org/10.1090/MR2896337) (2013).
15. Nachruf auf Peter Mittelstaedt. *Physik Journal* **2/2015**, 45–47 (2015). Web: [Physik Journal](https://www.physik-journal.de/2015/02/), 2/2015.
16. Obituary: *Philosophical Problems of Modern Physics – Peter Mittelstaedt 1929–2014*. *Found. Phys.* **45**, 483–495 (2015). DOI: [10.1007/s10701-015-9872-y](https://doi.org/10.1007/s10701-015-9872-y).

(vii) Editorial work

with A. van der Merwe (eds.): *Special Issues in Honor of Peter Mittelstaedt's 60th birthday*. *Found. Phys.* **19** (1989), [Issues 7, 8, 9](#) (330 pages).

1/2007 – 9/2016: Associate Editor and Member of Editorial Board, *Foundations of Physics* journal (Springer Verlag).

10/2016 – current: Editor (for Quantum Mechanics), *Foundations of Physics* journal [Web: [FoP @ Springer](https://www.fop-journal.org/)]

12/2009 – current: Co-Editor, Springer Monograph Series: *Fundamental Theories of Physics*. [Web: [FTHP @ Springer](https://www.fthp-journal.org/)]

with D. Dieks, G. 't Hooft (eds.): Special Issues: *Festschrift for Pekka Johannes Lahti – 60th Birthday*, *Foundations of Physics* **39** (2009), [Issues 6, 7](#) (360 pages).

Special Issue: *Between Physics and Philosophy—Festschrift for Peter Mittelstaedt on His 80th Birthday*. *Found. Phys.* **40** (2010), [Issue 10](#) (500 pages).

Special Issue: *Mathematics of Quantum Uncertainty*, MDPI Journal *Mathematics*, Guest Editors P. Busch, T. Heinosaari, T. Miyadera; 12 papers published (as of 9/2016).

B2. Research funding

1. 1986 Travel Grant, Deutsche Forschungsgemeinschaft. Department of Mathematics, Florida Atlantic University, Boca-Raton 1-6/1986. Research with Prof. F.E. Schroeck.
2. 1986–1990 Research Exchange Programme of the BMFT, Bonn, and the Finnish Academy of Sciences, Helsinki, for collaboration between P. Busch and P. Mittelstaedt (Cologne) and P. Lahti and K. Ylinen (Turku).
3. 1994–1995 **Feodor Lynen Fellowship** of the Alexander von Humboldt Foundation, to visit Lyman Laboratory of Physics, Harvard, 1 year. 25% contribution by Harvard University.
4. 1998–1999 **Visiting Fellowship Programme**, funded by EPSRC. Value: £8,000. Project: “Operational Approach to the Quantum-Classical Connection.” Visitors: Profs. J.A. Brooke (Saskatoon), S. Bugajski (Katowice), P.J. Lahti (Turku), F.E. Schroeck (Boca Raton).
5. 1996–2005 Several small grants from the London Mathematical Society, British Council, Royal Society, for mutual research visits between myself at Hull and collaborators in Katowice, Turku, Saskatoon.

- 2005–2007 (2 years): **Visiting Professorship** appointment at the Perimeter Institute of Theoretical Physics, Waterloo, Canada. Unpaid research leave from UoY.
6. Member of **EPSRC Network** *Transport, Dissipation and Control in Quantum Devices*, 2005–2007 (3 years). [Home: Bradford U.](#)
 7. **EUROPE - QIPC in Europe** (2006–2009): the Quantum Information group at the Mathematics Department was an affiliate member.
 8. **London Mathematical Society** award of £600, for visit of H-J Schmidt (Osnabrück), 3–16 May 2009.
 9. **Royal Society**, £580 awarded for conference and collaboration visit to Turku, Finland 23–27 May 2009.
 10. Named collaboration partner in the **Academy of Finland Research Project** *Quantum Information Processing with Continuous Variables*, at the Turku Centre for Quantum Physics, Academy of Finland Grant No. 138135. PI: P.J. Lahti. Duration: 1/2011–12/2014. Value: €310k.
 11. Member of **White Rose Studentship Network** (funds 3 PhD students, 10/2011–09/2014, PI: Dr. A. Beige (Leeds)), *Optimising Quantum Processes and Quantum Devices for future Digital Economy Applications*, [\[Web:Optimising Quantum Processes\]](#).
 12. Member of **COST Action MP1006: Fundamental Problems in Quantum Physics**, 2011–2015. [\[Web: EU COST Action\]](#).
 13. Host of **Visiting Research Associates**
 Dr. Roberto Beneduci, University of Calabria (10/2011–7/2012);
 Dr. Yuan Li, Shaanxi Normal University, Xi'an (9/2012–8/2013);
 Dr. Tommaso Gentile, University of Calabria (4/2014–9/2014 and 2/2015–6/2015);
 Mr. Juba Messamah, PhD Internship, University of Algiers USTHB (May 2015).
 14. **LMS Spitalfields Day: Mathematics of Quantum Uncertainty** (29/05/2015, £1,000)
 15. **LMS Scheme 4 Researchers in Pairs**, Visit to Turku, July–August 2017 £900
 16. **FQXi Workshop: Quantum Incompatibility**, Maria Laach, Germany, 28/08–01/09/2017, US\$ 8,000
 17. **Royal Society Leverhulme Trust Senior Research Fellowship: Quantum Measurement Uncertainty in Quantum Metrology and Estimation**, 2017–18, £51,000.

B3. Research students

(i) Supervision (PhD)

1. Ralf QUADT, *Generalised Entropy and Applications in the Theory of Dynamical Systems and in Information Theory* (in German). Completion 7/1992, Cologne.
2. Harald SCHERER, *Quantum Mechanical Models of Preparatory and Weakly Disturbing Measurements* (in German). Supervision jointly with P. Mittelstaedt, completion 7/1994, Cologne.
3. Elmar VOGEL, *Operational Analysis of Some Quantum Optical Experiments* (in German). Completion 6/1996, Cologne.
4. Javed SINGH, *Topics in the Geometry and Physics of Galilei Invariant Quantum and Classical Dynamics*. Completion 12/2000, Hull. ([Thesis - Web Record](#)).
5. Christopher R SHILLADAY, *Complementarity and Uncertainty in Quantum Interference*. Completion: 02/2008, Hull. ([Thesis 2007](#)).
Chris was a retired physics teacher, who pursued his PhD in his free time alongside his work as OU tutor.
6. Leon D LOVERIDGE, *Quantum Measurements in the Presence of Symmetries*. Completion: 7/2012, York. Funded by EPSRC Doctoral Training Grant. ([Thesis 2012](#)).
Leon was subsequently postdoctoral researcher at UBC, Vancouver, (2012–2014); Oxford (2015–2016).
7. Johannes GC BINIOK, *Compatible and incompatible observables in the paradigmatic multislit experiments of quantum mechanics*. Completion: 02/2015. ([Thesis 2015](#)).

8. Neil STEVENS, *Concepts surrounding incompatibility in quantum physics*. Completion: 2/2015. Funding: Annie Currie Williamson Bursary, Holbeck Bursary, WW Smith Fund. ([Thesis 2015](#)).
9. Thomas BULLOCK, *From incompatibility to optimal joint measurability in quantum mechanics*. Completion 2/2016. Funding: White Rose Studentship Network, WW Smith Fund. ([Thesis 2015](#)).
10. Oliver REARDON-SMITH, *Preparation and Measurement Uncertainty Regions*. Start: 10/2015. Funding: EPSRC Doctoral Training Grant.

(2) Supervision of Physics Diploma theses (1 year of research including writing-up)

Harald SCHERER, Thesis: ‘Statistical completeness of measurement outcomes in photon polarisation experiments’ (in German), supervision jointly with P. Mittelstaedt, completion 11/1990 Cologne.

Peter KIENZLER, Thesis: ‘Investigation of a complete set of Bell inequalities and a realistic description of experiments with correlated photon pairs’ (in German), supervision jointly with P. Mittelstaedt, completion 6/1993, Cologne.

Klaus HASS, Thesis: ‘Wave propagation in microwave guides with cut-off region’ (in German), completion 9/1993, Cologne.

Bernhard BECK, Thesis: ‘On the Possibility of Semi-classical Explanations of Quantum Experiments’ (in German), supervision jointly with P. Mittelstaedt, completion 11/1994, Cologne.

(ii) **Examining**

1. External PhD Examiner, St. Andrews, Theoretical Physics (Colin Trueman 12/1999).
2. Internal PhD Examiner, Hull, Applied Mathematics (Sandra Breimesser 12/2001 and Yiannis Christodoulides 4/2002).
3. Internal PhD Examiner, York, Mathematical Physics (Paul Butterley 12/2008).
4. 8/9/2012 Opponent in Public Thesis Defense, University of Turku, Finland, for PhD candidate Jussi Schultz. [[Web: Jussi Schultz Thesis 2012](#)].
5. Internal PhD Examiner, York, Quantum Information (Daniel McNulty 4/2013).
6. External PhD Examiner, Bradford, Quantum Information (Pavlos Evangelides 6/2015).
7. Internal PhD Examiner, York, Quantum Foundations (Spiros Kechrimparis 2/2016).
8. External PhD Examiner, Bradford, Quantum Information (S Agyo 7/2016).
9. External PhD Examiner, Nijmegen, Quantum Information (Robert Furber 11/2016).
10. External PhD Examiner, Kolkata. Quantum Information and Foundations (Shiladitya Mal 5/2017).

B4. Other research activities and distinctions

(i) **Visiting research posts**

1. 8/1994–7/1995: **Visiting Research Scholar**, Harvard University, Lyman Laboratory of Physics, funded by Harvard University and the Alexander von Humboldt Foundation, Germany (Feodor Lynen Fellowship). Host: Professor Roy Glauber.
2. 9/2005–8/2007: **Visiting Research Professor**, Perimeter Institute for Theoretical Physics, Waterloo, Ontario.

(ii) **Prizes, awards, honours**

1. 1991– current: Appointment as External Docent/Adjunct Professor, Department of Physics and Astronomy, University of Turku, Finland.
2. 1995–2007 Member of Editorial Board, Foundations of Physics Letters, invited as successor to Sir Karl Popper (in 2007 the journal was subsumed into Foundations of Physics).
3. 1997 Prize of the Ministry of Education, Warsaw, Poland, for coauthorship on the monograph Operational Quantum Physics (Springer-Verlag, 1995).

4. 2006-2010: Member of Nominating Committee, *International Quantum Structures Association* (IQSA).
5. 10/2008: Elected corresponding member of L'Académie Internationale de Philosophie des Sciences (A.I.P.S.).
6. 2012-2016: Council Member, (IQSA).
7. 10/2014: Elected Fellow of the Institute of Physics (FInstP).
8. 2/2015: Invited to Membership of *Foundational Questions Institute* (FQXi).
9. 7/2016: Elected President of International Quantum Structures Association IQSA.
10. 10/2016: Elected full member of L'Académie Internationale de Philosophie des Sciences (A.I.P.S.).

(iii) **Invited lectures and conference papers**

1. 1983-1999: 49 invited (plenary) lectures at major conferences, contributed papers, seminars
2. **Plenary Lecture:** *Into the Second Century of Quantum Physics: a Final Theory, Or Are There Clouds on the Horizon?* [Quantum Centennial Symposium](#), University of Saskatchewan, Saskatoon, 18 March 2000.
3. **Lecture:** *EPR-Bell Tests with Unsharp Observables and Relativistic Quantum Measurement.* NATO Advanced Research Workshop “Modality, Probability, and Bell’s Theorem”, Cracow, Poland, 19-23 August 2001.
4. **Lecture:** *The role of entanglement in quantum measurement and information processing.* XXVIth School of Theoretical Physics “Quantum Composite Systems”, Ustroń, Poland, 3-7 September 2002.
5. **Philosophical Colloquium:** *Complementarity, Entanglement, and No End to Uncertainty* U of Dortmund, 8 July 2004.
6. **Invited conference discussant:** *Being Bayesian in a Quantum World*, University of Konstanz, Germany, August 1 - 5, 2005.
7. **Colloquium:** *Complementarity, Entanglement, and No End to Uncertainty* Perimeter Institute, Waterloo, Canada, 12 October 2005.
8. **Main Lecture:** *Nonlocalizability Theorems and Localized Events in Relativistic Quantum Physics.* Spring Meeting of German Physical Society (DPG), [Symposium Grundlagen des Teilchenbegriffs](#), 28 March 2006.
9. **Plenary Lecture:** *Complementarity, Disturbance, Entanglement – And No End to Uncertainty* AIP Conference [New Directions in the Foundations of Physics](#), AIP, College Park, MD, 28-30 April 2006.
10. **Plenary Lecture:** *No Information Without Disturbance - Myths and Facts in Quantum Measurement*, [International Conference in Honor of Abner Shimony](#), Perimeter Institute, Waterloo, Canada, 18-21 July 2006.
11. **Guest lecture series (2 hours):** *Heisenberg’s Uncertainty Principle: A long story concluded after (nearly) 80 years?* Turku Centre for Quantum Physics, Turku, 24 November 2006.
12. **Plenary Lecture:** *Heisenberg’s Uncertainty Principle: A long story concluded after 80 years?* 10th International Conference on Squeezed States and Uncertainty Relations, Bradford, UK, 31 March - 4 April 2007 ([ICSSUR 2007](#)).
13. **Invited lecture:** *Unsharp reality and the quantum-classical contrast.* [Workshop:](#) Operational Quantum Physics and the Quantum-Classical Contrast, Perimeter Institute, 4-7 June 2007.
14. **Plenary lecture:** *Heisenberg’s Uncertainty Principle.* [Workshop](#) on Quantum Mechanics: Foundations and Open Systems, Turku, Finland, 24-26 October 2007.
15. **Physics Seminar:** *80 Years of Quantum Indeterminacy - new aspects.* U of Osnabrück, 15 January 2008.
16. **Invited Talk:** *Structures in the Set of Quantum Observables: Coexistence, Unsharpness, Approximation.* North British Mathematical Physics Seminar, York, 26 June 2008.

17. **The Oxford Advanced Seminar on Informatic Structures:** *Operational Reconstructions of Hilbert Space Quantum Mechanics - A Guided Tour*. Oxford University Computing Lab, 31 October 2008. [[Departmental Seminar Page](#)].
18. **Introductory Lecture Series (5 hours):** *Topics in Operational Quantum Physics*. EQUALS 2 – Expository Quantum Lecture Series 2, Foundations of Quantum Science and Technology 2008, Universiti Putra Malaysia, Kuala Lumpur, 24-28 November 2008. [[Web: EQUALS2](#)].
19. **Plenary lecture:** *Quantum Mechanics as a Framework for Dealing with Uncertainty*. [16th Central European Workshop on Quantum Optics](#), Turku, Finland, 23-27 May 2009.
20. **Philosophy Seminar – Sigma Club, LSE:** *Unsharp Quantum Reality*. 15 March 2010.
21. **Invited discussant:** *Quantum Physics And The Nature Of Reality – A conference in honour of John Polkinghorne's 80th birthday*. Oxford University, 26-29 September 2010.
22. **Physics Seminar:** *Quantum Fuzziness and the Quantum-Classical Contrast*, Leeds, 2 February 2011.
23. **Invited Talk:** *Quantum and Classical Structures for Individual Objects*. CHPSTM Workshop on Quantum States: Ontic or Epistemic? Aberdeen, 25-26 June 2011.
24. **Philosophy and Physics Seminar:** *Unsharp Quantum Reality*. U of Bristol, 7 December 2011.
25. **Invited Speaker:** *Quantum Measurements Constrained by Symmetries*. International Symposium [Groups 29](#), Chern Institute, Tianjin, 20-26 August 2012.
26. **Colloquium:** *Quantum Uncertainty – in all its guises*.
Expository lecture (2 hours): *On the “Zoo” of Heisenberg Uncertainties, and How to Measure Incompatible Quantum Observables*. Distinguished Lecture Series [Topology in Dynamics and Physics \(TIDY\)](#), Department of Mathematics, U of Tel Aviv, 9-10 April 2013.
27. **Plenary Speaker:** *Heisenberg's Uncertainty Principle for Joint Measurements*. Workshop: [Incompatible Quantum Measurements](#), TU Munich, 9-12 September 2013.
28. **Plenary Speaker:** *Quantum RMS Deviation and Heisenberg's Error-Disturbance Relation*. [International Symposium: Wigner 111 – Colorful and Deep](#), Budapest 11-13 November 2013.
29. **Seminar:** *Heisenberg-type error-disturbance trade-off for qubits*. Atominsitute, TU Vienna, 11 January 2014.
30. **Plenary Speaker:** *Heisenberg-type error-disturbance trade-off for qubits*. [554th W&E Heraeus Seminar: Quantum Contextuality, Non-Locality, and the Foundations of Quantum Mechanics](#), Bad Honnef, 17-19 February 2014.
31. **Invited Talk:** *Rescuing Heisenberg's Measurement Uncertainty Relation*. White Rose QI Workshop, Leeds, 7 January 2015.
32. **LMS Spitalfields Day lecture:** *Quantum Measurement Uncertainty: A Simple Demonstration*. York, 29 May 2015.
33. **Invited Talk:** *Quantifying Quantum Measurement Uncertainty – Why did it take so long?* Conference: Quantum Theory – From Foundations to Technologies, Växjö, Sweden, 8-11 June 2015 .
34. **Physics Colloquium:** *Heisenberg Measurement Uncertainty: New Relations for Qubits*. University of Siegen, 9 July 2015.
35. **Plenary Lecture:** *Quantum Measurement Uncertainty: reading Heisenbergs mind or invoking his spirit?* Workshop: QPL 2015: Quantum Physics and Logic, Oxford, 13-17 July 2015.
36. **Tutorial (3 hours):** *Qubit Uncertainty*. Workshop: QPL 2015: Quantum Physics and Logic, Oxford, 13-17 July 2015.
37. **Key Note Lecture:** *Quantum Measurement Uncertainty - Recent Developments*. International Conference on Quantum Foundations 2015 (ICQF15), Patna, 30 November-4 December 2015.
38. **Invited Talk:** *Quantum Measurement Uncertainty: Recent Developments*, Discussion Meeting on Quantum Mechanics, S. N. Bose National Centre for Basic Sciences, Kolkata, India, 7 December 2015.
39. **Seminar:** *Qubit uncertainty relations – new wine in old skins?* Bose Institute, Kolkata, 8 December 2015.

40. **Seminar:** *Heisenberg Uncertainty for Joint Measurements: Recent Developments*, IISER, Kolkata, 9 December 2015.
41. **Invited lecture:** *Optimal joint measurements of incompatible quantities: the problem of quantifying measurement uncertainty*, Two Days in Quantum Mechanics – In honour of Gianni Cassinelli's 70th birthday, Genova, 29-30 June 2016.
42. **Invited lecture:** *The Two Faces of Heisenberg's Uncertainty Principle*, Quantum Structures 2016, Biennial Meeting of the International Quantum Structures Association, Leicester, 11-15 July.
43. **Invited lecture:** *"Unsharp objectification" revisited – and what does it mean anyway to test quantum uncertainty?*, Warwick Physics Day: Quantum measurement: a dialog of big and small, 28 September 2016.
44. **Keynote lecture:** *Quantum Uncertainty Regions – Theory and Experiment*, 3rd International Conference on Quantum Foundations 2017, Patna, India, 4-9 December 2017.

(iv) Public Lectures, Talks to Broad Audiences

1. 1997-2002: Various talks to school audiences (Hull, Manchester) on quantum mechanics, quantum nonlocality, quantum uncertainty
2. **Public Lecture:** *100 Years of Quantum Physics: Coming to Terms with, and Taming the Weirdness of the Microworld*. [Quantum Centennial Symposium](#), University of Saskatchewan, Saskatoon, 17 March 2000.
3. 17 February 2003: Inaugural Lecture, University of Hull: The Second Quantum Revolution: The Power of Uncertainty
4. 2 March 2009: Inaugural Lecture, University of York: *Less is More – The Power of Quantum Uncertainty*.
5. **Invited Talk:** *Uncertainty over Quantum Uncertainty: Rescuing Heisenberg's Principle*. Annual Meeting of the Alexander von Humboldt Association, Nottingham University, 20 September 2014.

(v) Membership in professional associations

1. Foundational Questions Institute ([FQXi](#))
2. Institute of Physics (Fellow) ([IoP](#))
3. London Mathematical Society (Member) ([LMS](#))
4. International Association of Mathematical Physics (Member) ([IAMP](#))
5. International Quantum Structures Association (Member) ([IQSA](#))
6. L'Académie Internationale de Philosophie des Sciences (elected Member) ([A.I.P.S.](#))

(vi) Referee and reviewer

1. Referee for numerous major scientific journals in mathematics, physics, philosophy including: Am J Phys, Ann Phys (NY), Ann d Physik, Commun Math Phys, Eur Phys J, Eur Phys Lett, Found Phys, Int J Theor Phys, J Math Phys, J Mod Optics, J Phys A, Nature, Nature Scient Rep, Phys. Lett. A, Physica Scripta, Phys Rep, Phys Rev A, Phys Rev Lett, Physics and Philosophy, Rep Math Phys, Stud Hist Phil Mod Phys, Symmetry, Studia Logica.
2. Referee for book proposals for Cambridge University Press, Springer-Verlag, World Scientific Publishers
3. Reviewer for Mathematical Reviews, Zentralblatt für Mathematik.
4. Reviewer/Assessor for Promotions/Tenure procedures, Chair appointments (Canada, Germany, India, Italy, USA).
5. Reviewer for research grant and fellowship applications: Estonian Research Council; EPSRC (UK); NSF (USA), National Research Foundation of South Africa, Austrian Science Fund (2017).

(vii) Conferences: organiser, scientific board member

1. 1986–2005 Co-Organizer of 9 international conferences and workshops.
2. 1995–2005 Member of Scientific Committees International for 9 major international symposia.
3. 18–21 July 2006, *Quantum Reality, Relativistic Causality, and Closing the Epistemic Circle: An International Conference in Honour of Abner Shimony*, Perimeter Institute. (Member of Scientific Board).
4. 4–7 June 2007 Perimeter Institute Workshop *Operational Quantum Physics and the Quantum-Classical Contrast* (Main Organiser, jointly with L Hardy).
5. 9 September 2007: EPSRC Network Meeting: "Transport, Dissipation and Control in Quantum Devices" (Organised jointly with S Weigert).
6. 29–30 Sept 2008, *Sudbery Fest: Quantum (Groups+Foundations+Information), A Symposium to Celebrate the Achievements of Professor Tony Sudbery on the Occasion of his 65th Birthday*, York, 29–30 September 2008, funded by LMS and IOP. [Web: Tony-Fest](#). (Organised jointly with S. Weigert).
7. 4–5 December 2009, *Between Physics and Philosophy: Symposion in Honor of Professor Peter Mittelstaedt on the Occasion of his 80th Birthday*, Talk: *Unsharp Quantum Reality*, and Laudatio. (Co-organiser and Scientific Chair).
8. 2012–2014 White Rose Quantum Information Theory Meetings, York: [19/3/2012](#); [7/4/2014](#) (Organised jointly with I. d'Amico, S. Weigert).
9. 2013–2014 *White Rose Quantum Information Workshops: MUBs, SICs, and All That*, York. I: [4 February 2013](#); II: [6–7 May 2013](#); III: [16–17 June 2014](#). (Organiser, jointly with S. Weigert).
10. 29–30 May 2015 *Workshop: Quantum Uncertainty Days@York*.
11. 29 May 2015 *LMS Spitalfields Day (York): Mathematics of Quantum Uncertainty*.
12. 15–19 May 2016, co-organiser (with L. Polterovich, Y. Ostrover, S. Nonnenmacher) of ERC funded Conference *Quantum Mechanics Meets Symplectic Topology* (Tel Aviv, Israel).
13. 11–15 July 2016: *Quantum Structures 2016*, Leicester. Member of Programme Committee.
14. *2nd International Conference on Quantum Foundations 2016*, 17–21 October 2016: Member of International Advisory Committee.
15. *QPL/IQSA 2017*, Nijmegen 2–7 July 2017: Member of International Advisory Committee.
16. *FQXi Workshop: Quantum Incompatibility 2017*, Maria Laach (Germany), 28 August–1 September: Co-organiser with T Heinosaari (Turku), O. Gühne (Siegen).
17. *3rd International Conference on Quantum Foundations 2017*, Patna, 4–9 December 2017: Member of International Advisory Committee.

(viii) Conference attendance and research visits**(1) Conference attendance**

1983–2004 Attendance and contributor at **70+** conferences

Selected recent conferences (other than invited):

29–31 March 2007, *15th UK and European Meetings on the Foundations of Physics*, Leeds. Contributed talk: *Complementarity and Uncertainty in Mach-Zehnder Interferometry and Beyond*

6–12 July 2008 Quantum Structures '08, IQSA Biennial Meeting, Sopot, Gdansk, Poland. Talk: *Structures in the Set of Quantum Observables: Coexistence, Unsharpness, Approximation*; Member of Nomination Committee for election of IQSA officers and awards of prizes.

5–7 July 2010, 16th U.K. and European Meeting on the Foundations of Physics, Aberdeen.

(2) Research visits

1983–1994 Department of Physical Sciences, University of Turku, Finland, annually 1–6 weeks.

October 1989 Department of Theoretical Physics, University of Genova, 2 weeks.

1989–1993 4 visits: Institute of Physics, Nicolaus-Copernicus-University, Toruń, Poland.

One week each: 12/1989, 7/1991, 1/1993, 9/1993.

1998–2001 3 visits: Department of Physics, University of Silesia, Katowice, Poland.

9/1998: 4 days; 8/1999: 10 days, 11.-18.8.2001 (Royal Society, U. of Hull and U. of Silesia)

2000–2001 2 visits: Department of Mathematics and Statistics, University of Saskatchewan, Saskatoon, Canada. 14.-19.3.2000; 13.-26.5.2001.

2001 All Souls College, Oxford, 12.-14.3.2001.

Nuclear Accelerator Institute, U. of Groningen, 22.-24.4.

Department of Physics, U. of Utrecht, 25.-26.4.

Department of Mathematics and Statistics, U. of Denver, 27.5.-31.5.

1997–2006 10 visits: Department of Physics, U of Turku, Collaborations with P. Lahti, K. Ylinen.

2007–2013: 8 visits, Turku Centre for Quantum Physics, U of Turku

24–26 October 2007; 21–27 May 2009; 16 May–12 June 2010; 29 July–14 August 2010; 3–10 April 2011; 26 Sep - 5 Oct 2011; (both funded by a UoY Research Seedcorn Grant and U of Turku).

5–17 May 2011 Research visit to U of Sydney, Dept of Physics, Prof S Bartlett; Macquarie Univ, Prof John Corbett and Prof D Terno.

2012–2014: Research visits to Turku Centre for Quantum Physics, U of Turku

7–16 September 2012, 24–31 August 2013, 24 August–4 September 2014.

27–31 March 2014: Research visit to U of Hannover, Dept of Physics, Collaboration meeting with Prof. R.F. Werner (host) and Prof. Lahti (visiting from Turku).

18–29 March 2015: Research visit to Turku Centre for Quantum Physics, U of Turku. Collaboration with T. Heinosaari, P. Lahti, J.-P. Pellonpää, K. Ylinen.

5–17 September 2016: Research visit to Department of Physics, University of Calabria. Collaboration with Dr. Roberto Beneduci.

C. Teaching and the Promotion of Learning

My interest both in research and teaching lie in an interdisciplinary orientation which combines the areas of theoretical and mathematical physics, mathematics, and philosophy. This is reflected in my teaching record; I have taught courses at undergraduate and graduate level in all three disciplines.

C1. Undergraduate and Graduate Teaching

1. 1976–1986 Problem classes in all main areas of undergraduate theoretical physics (U of Cologne)
2. 1986 Lecture Courses at Florida Atlantic University: Calculus (1st year); Advanced Calculus (3rd year).
3. 1988–2000 Graduate Level Lecture Courses in Theoretical and Mathematical Physics at the University of Cologne. I designed and delivered the following courses (and variations thereof) comprising 12 double hours each:
Foundations of Quantum Mechanics; Relativistic Quantum Theory; Mathematical Methods of Quantum Theory I+II; Probabilistic and Statistical Aspects of Quantum Theory; New Operational Concepts in Quantum Physics (based on own monograph); Physics of Information; Dynamical Systems and Irreversibility.
4. 1994 Visiting Professor, Philosophical Seminar, University of Heidelberg: Lecture course: Philosophy of Science; Seminar: Theory of Relativity; Seminar: Foundations of Quantum Mechanics.
5. 1995–2005 Undergraduate Modules in Applied and Pure Mathematics at the University of Hull:
Applied: Classical Dynamics (continuously redesigned; level 2); Optimisation (newly designed; level 2); Inequalities (level 3); Foundations of Quantum Mechanics (newly designed; level 4).
Pure: Series and Integrals (level 2); Measure, Probability and Random Processes (level 3); Number Theory and Cryptography (level 3); Spectral Theory (level 4).

Service Courses: Mathematics for Physics (level 1); Mathematics for Economics (level 1); Mathematics for Electronic Engineering (level 1).

6. 2011-2013 Masters level Lecture series via online videolink for Mathematics PhD students in MAGIC Network (EPSRC): Quantum Mechanics – A Conceptual Introduction (two times); Introduction to Quantum Information (once).
7. 2007–2016 Undergraduate Modules at York: Applied Mathematics (1st year); Quantum Mechanics (3rd year); Further Quantum Mechanics (3rd year); Advanced Quantum Mechanics (4th year); Quantum Field Theory (4th year); Vector Calculus (2nd year); Special Relativity (3rd year); Applications of Nonlinear Dynamics (3rd year).

C2. External Teaching Engagements

1. 2002–2005 External Examiner for Degree Programme MSc in Applied Mathematics and Theoretical Physics, Department of Mathematics, Dublin Institute of Technology.
2. Set of Lectures: *The quantum measurement problem from the perspective of a realist interpretation*. ‘Edgar Lüscher Course’, Bavarian Teacher Academy (for High School Physics Teachers, Dillingen, Germany, September 1991).

C3. Wider involvement in the UoY learning and teaching community

1. In 2008 I have coordinated a first White Rose proposal for a **Doctoral Training Centre in Quantum Information Science**, jointly with Leeds (Physics) and Sheffield (Physics). While the proposal was not successful, it provided further opportunities for the partners to identify joint research interests, which helped with a later successful bid for a White Rose PhD Studentship Network.
2. In 2010 I have liaised with the Academic Support Office in my capacity as Maths Graduate Chair to explore the feasibility of a **joint PhD programme** proposal from the University of Technology of Jamaica. In the end this did not result in a formal proposal.
3. As Chair of the Department’s Graduate School Committee I have introduced a **new 4-year PhD programme** to supplement the existing 3-year PhD. To this end I led a small departmental working group that helped me to consider and develop the design of the course. I produced all the documentation and conducted all correspondence with the University academic and administrative units concerned. The programme was approved and has been open for admissions since Autumn 2011.

D. Administration and Management

D1. Departmental administrative posts

1. 1997-2002: International Officer; Course Coordinator: BSc Mathematics with a Modern Language (Hull).
2. 08/2001-01/2002: Deputy Head of Department (Hull).
3. 10/2008-9/2014: Head of the Applied Mathematics Section in the Department and member of the Departmental Management Team.
4. 10/2008-09/2012: Chair of the Mathematics Graduate School Committee.
5. 2008-2012, 2015-2017: Member, Departmental Research Committee.
6. 10/2015-09/2017: Chair of the Mathematics Graduate School Committee.

D2. University administrative posts

1. 02/2002-01/2005: Head of the Department of Mathematics, University of Hull.
2. 2007+2008: Member, Science Advisory Group for Academic Staff Promotions.
3. 10/2008-2014: Proxy Member of Senate for Head of Department.