

MORDECAI J. WAEGELL

WORK ADDRESS

Institute for Quantum Studies
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CURRENT RESEARCH INTERESTS

- Nonclassical structures in Hilbert spaces, proofs of the Bell-Kochen-Specker theorem and the Greenberger-Horne-Zeilinger theorem, characterization of entanglement, contextuality, and nonlocality, quantum key distribution, quantum teleportation protocols, and the development of algorithms and protocols for robust and efficient quantum information processing using these resources.
- Foundations and interpretations of quantum mechanics and quantum cosmology, particularly many-worlds-type formulations, and also the time-symmetric reformulation of quantum mechanics of Aharonov-Bergmann Lebowitz, weak values, and superoscillations.

ADDITIONAL RESEARCH INTERESTS

- Experimental realizations of quantum computation algorithms in real physical systems, including linear optics, superconducting-qubits, trapped ions, diamond NV-centers, and others.
- Nonclassical phenomena in quantum mechanics including delayed choice experiments, quantum erasers, interaction-free measurements, and quantum beats.

EDUCATION

Worcester Polytechnic Institute, Worcester MA

Doctor of Philosophy, Physics G.P.A. 3.92/4.00 May 2013

Doctoral Thesis Title: "[Nonclassical Structures within the N-qubit Pauli Group](#)"

Advisor: Prof. P.K. Aravind, Department of Physics

Master of Science, Physics G.P.A. 3.70/4.00 February 2008

Bachelor of Science, Physics G.P.A. 3.54/4.00 February 2006

Quinsigamond Community College, Worcester MA

Associate of Arts, Liberal Arts G.P.A 3.97/4.00 May 2003

RESEARCH EXPERIENCE

Postdoctoral Research Associate, Chapman University, Orange, CA Summer 2014-present

Ongoing research at the Institute for Quantum Studies on the theoretical foundations of quantum mechanics and quantum information.

Research Assistant, WPI, Worcester MA

Summer 2007-Spring 2013

Conducted research in theoretical quantum mechanics. Studied entanglement, Bell's theorem, the Kochen-Specker theorem, the GHZ theorem, mutually unbiased bases, the Majorana representation of spin states, and other topics related to quantum information. Developed general theoretical framework for characterizing primitive nonclassical structures within the N-qubit Pauli group. Developed and applied optimized combinatorial search algorithms and numerous software tools for handling geometric structures in Hilbert spaces.

Research Assistant, Major Qualifying Project

Summer 2005

Worked on experimental phase transition study. Designed and constructed a cell for high pressure and temperature containing a quartz crystal microbalance (QCM) and a sapphire window for direct observation of surface wetting transitions. Developed LabVIEW software to automate repeated QCM measurements.

LEADERSHIP EXPERIENCE

- Organized preliminary seminar series associated with the *Concepts and Paradoxes in a Quantum Universe* in June of 2016 at The Perimeter Institute for Theoretical Physics, Waterloo, Ontario, Canada
- Organized the *Interpretations of Quantum Mechanics* conference in February of 2015 at the Institute for Quantum Studies, Chapman University, Orange CA

INVITED TALKS

1. M. Waegell, "A Model of Quantum Mechanics with True Local Causality in Space-Time." *Presented at the 7th International Conference on New Frontiers in Physics, Kolymbari, Crete, Greece, July 2018*
2. M. Waegell, "Contextuality, Pre- and Post-Selection Paradoxes, and Weak Values." *Presented at the Aharonov-Albert-Vaidman 30th Anniversary conference at Chapman University, Orange, CA, USA, February 2018*
3. M. Waegell, "Primitives of Nonclassicality in the N-qubit Pauli Group." *Updated, and presented as a colloquium at the Department of Computer Science, University of Oxford, Oxford, United Kingdom, October 2017*
4. M. Waegell, "Quantum Reality: Counterintuitive Lessons About Nature," *Colloquium presentation in September 2017 at the Physics Department of Worcester Polytechnic Institute, Worcester MA*
5. M. Waegell, "Confined Contextuality and Weak Measurement." *Contextuality: Presented at "Conceptual Issues, Operational Signatures, and Applications," conference at The Perimeter Institute, Waterloo, Ontario, Canada, July 2017*
6. M. Waegell, "Confined Contextuality: How specific paradoxes in pre- and post-selected Kochen-Specker sets give rise to experimentally observable consequences." *Presented in June 2016 at the 'Concepts and Paradoxes in a Quantum Universe' conference at The Perimeter Institute for Theoretical Physics, Waterloo, Ontario, Canada.*
7. M. Waegell, "Primitives of Nonclassicality in the N-qubit Pauli Group." *Updated and presented in June 2016 at 'Concepts and Paradoxes in a Quantum Universe' seminar series at The Perimeter Institute for Theoretical Physics, Waterloo, Ontario, Canada.*
8. M. Waegell, "Primitives of Nonclassicality in the N-qubit Pauli Group," *Presented in October 2015 at the Institut Laue-Langevin, Grenoble, France.*
9. M. Waegell, P.K. Aravind, "New Proofs of Quantum Contextuality." *Presentation at the workshop on "Quantum Information and Foundations of Quantum Mechanics," University of British Columbia, Vancouver, Canada, July 2013*
10. M. Waegell, P.K. Aravind, "The Quantum Physics of the Classically Impossible." *Colloquium presentation in March 2013 at the Physics Department of Dartmouth College, Hanover NH*

PUBLICATIONS IN REFEREED JOURNALS

1. M. Waegell, K.J. McQueen, Waegell, Mordecai, and Kelvin J. McQueen. "[Reformulating Bell's theorem: The search for a truly local quantum theory](#)," *Studies in History and Philosophy of Science Part B: Studies in History and Philosophy of Modern Physics* (2020).
2. M. Waegell, C. Elouard, A.N. Jordan, "[Energy-based weak measurement](#)," *Quantum Studies: Mathematics and Foundations* 1-6 (2020)
3. C. Elouard, M. Waegell, B. Huard, A.N. Jordan, "[Spooky Work at a Distance: an Interaction-Free Quantum Measurement-Driven Engine](#)," submitted to *Foundations of Physics*, arXiv:1904.09289 (2019)
4. M. Waegell, J. Dressel, "[Benchmarks of nonclassicality for qubit arrays](#)," *npj Quantum Information* 5(1) 1-8 (2019)
5. M. Pavičić, M. Waegell, N.D. Megill, P.K. Aravind, "[Automated generation of Kochen-Specker sets](#)," *Scientific reports* 9(1) 1-11 (2019)

6. I.L. Paiva, Y. Aharonov, J. Tollaksen, M. Waegell, "[Topological bound states for quantum charges](#)," *Physical Review A: Rapid Communications* **100**, 04010(R) (2019)
7. Y. Aharonov, E. Cohen, M. Waegell, E. Elitzur, "[The weak reality that makes quantum phenomena more natural: Novel insights and experiments](#)," *Entropy* **20**(11) p854 (2018).
8. A Matzkin, S.V. Mousavi, M. Waegell, "[Nonlocality and local causality in the Schrödinger equation with time-dependent boundary conditions](#)," *Physics Letters A* **382**(46), p3347-3354 (2018)
9. Waegell, M., 2018. "[An Ontology of Nature with Local Causality, Parallel Lives, and Many Relative Worlds](#)," *Foundations of Physics*, **48**(12), pp.1698-1730 (2018).
10. J. Dressel, , J.R. González Alonso, M. Waegell, and N. Yunger Halpern. "[Strengthening weak measurement of qubit out-of-time-order correlators](#)," *Physical Review A* **97**, 042105 (2018).
11. M. Waegell, T. Denkmayr, H. Geppert, D. Ebner, T. Jenke, Y. Hasegawa, S. Sponar, J. Dressel, and J. Tollaksen "[Confined Contextuality in Neutron Interferometry: Observing the Quantum Pigeonhole Effect](#)," *Physical Review A* **96**, 052131 (2017).
12. M. Waegell and J. Tollaksen, "[Contextuality, Pigeonholes, Cheshire Cats, Mean Kings, and Weak Values](#)," *Quantum Studies: Mathematics and Foundations* <https://doi.org/10.1007/s40509-017-0127-9> (2017).
13. M. Waegell "[Locally causal and deterministic interpretations of quantum mechanics: parallel lives and cosmic inflation](#)," *Quantum Studies: Mathematics and Foundations* **4.4**: 323-337 (2017).
14. M. Waegell and P.K. Aravind, "[Minimal complexity of Kochen-Specker sets does not scale with dimension](#)," *Physical Review A: Rapid Communications*, **95**(5), p.050101 (2017).
15. M. Waegell and P.K. Aravind, "[The Penrose dodecahedron and the Witting polytope are identical in CP\(3\)](#)," *Physics Letters A* **381.22**: 1853-1857 (2017).
16. T. Denkmayr, H. Geppert, H. Lemmel, M. Waegell, J. Dressel, Y. Hasegawa, and S. Sponar, "[Experimental demonstration of direct path state characterization by strongly measuring weak values in a matter-wave interferometer](#)," *Physical Review Letters*, **118**(1), p.010402 (2017).
17. M. Waegell, Y. Aharonov, and T. L. Patti, "[Interference Energy Spectrum of the Infinite Square Well](#)," *Entropy* **18**(4) p149 (2016).
18. M. Waegell and P.K. Aravind, "[Parity proofs of the Kochen-Specker theorem based on the Lie algebra E8](#)," *J. Phys. A: Math. Theor.* **48**(22), 225301 (2015)
19. C. Greganti, M.-C. Roehsner, S. Barz, M. Waegell, P. Walther "[Practical and efficient experimental characterization of multi-qubit stabilizer states](#)," *Phys. Rev. A* **91**(2), 022325 (2015)
20. M. Waegell, "[A bonding model of entanglement for N-qubit graph states](#)," *International Journal of Quantum Information*, **12**(06), 1430005 (2014).
21. M. Waegell, "[Primitive Nonclassical Structures of the N-qubit Pauli Group](#)," *Phys. Rev. A* **89**, 012312 (2014)
22. M. Waegell and P.K. Aravind, "[Parity proofs of the Kochen-Specker theorem based on the 120-cell](#)," *Found Phys.* **44**,1085-1095 (2014)
23. M. Waegell and P.K. Aravind, "[Proofs of the Kochen-Specker theorem based on the N-qubit Pauli group](#)," *Phys. Rev. A* **88**, 012102 (2013)
24. M. Waegell, P.K. Aravind, "[GHZ paradoxes based on an even number of qubits](#)," *Physics Letters A* **377**, 546-549 (2013)
25. M. Waegell, P.K. Aravind, "[Proofs of the Kochen-Specker theorem based on a system of three qubits](#)," *J. Phys. A: Math. Theor.* **45** 405301 (2012)
26. M. Waegell, P.K. Aravind, "[Parity proofs of the Bell-Kochen-Specker theorem based on 60 complex rays in four dimensions](#)," *J. Phys. A: Math. Theor.* **44** 505303 (2011)
27. N.D. Megill, K. Fresl, M. Waegell, P.K. Aravind, M. Pavičić, "[Probabilistic Generation of Quantum Contextual Sets](#)," *Physics Letters A* **375**, 3419-3424 (2011)
28. M. Waegell, P.K. Aravind, "[Parity proofs of the Kochen-Specker theorem based on the 24 rays of Peres](#)," *Foundations of Physics* **41**:1786-1799 (2011)
29. M. Waegell, P.K. Aravind, N.D. Megill, M. Pavičić, "[Parity proofs of the Bell-Kochen-Specker theorem based on the 600-cell](#)," *Foundations of Physics* **41**, 883-904 (2011)
30. M. Pavičić, N.D. Megill, P.K. Aravind, M. Waegell, "[New Class of 4-Dim Kochen-Specker Sets](#)," *Journal of Mathematical Physics*, Vol.**52** No. 2, pp 022104-1-9 (2011)
31. M. Waegell, P.K. Aravind, "[Critical noncolorings of the 600-cell proving the Bell-Kochen-Specker theorem](#)," *J. Phys. A: Math. Theor.* **43** 105304 (2010)

CONFERENCE PRESENTATIONS

1. C. Elouard, M. Waegell, B. Huard, A.N. Jordan, "Interaction-Free Energy Transfer," *Presentation at the 2019 PIMan Conference at Chapman University, Orange, CA*
2. C. Elouard, M. Waegell, B. Huard, A.N. Jordan, "Interaction-Free Energy Transfer," *Presentation at Superscillations: Theoretical Aspects and Applications, Cetraro, Italy, 2019*
3. C. Elouard, M. Waegell, B. Huard, A.N. Jordan, "Spooky Work at a Distance: an Interaction-Free Quantum Measurement-Driven Engine," *Presentation at the 2019 Conference on Coherence and Quantum Optics in Rochester, NY Optical Society of America*
4. M. Waegell, "Locally Causal Quantum Mechanics in Space-Time," *Presentation at the 2019 APS March Meeting, Boston, MA.*
5. I. Paiva, Y. Aharonov, M. Waegell, and J. Tollaksen, "Topological Barriers for Charged Quantum Systems," *Presentation at the 2019 APS March Meeting, Boston, MA.*
6. R. Mohseninia, J.R. González Alonso, M. Waegell, N. Yunger Halpern, J. Dressel, "Measuring qubit quasi-probability distributions behind out-of-time-ordered correlators," *Presentation at the 2019 APS March Meeting, Boston, MA.*
7. M. Waegell, "A Model of Quantum Mechanics with True Local Causality in Space-Time," *Presentation at DICE2018 in Castiglioncello, Tuscany, Italy.*
8. M. Waegell, Eric Freda, and Justin Dressel, "Optimal Nonclassicality-based Benchmarks for Linear Qubit Arrays," *Presentation at the 2018 APS March Meeting, Los Angeles CA.*
9. M. Waegell and P.K. Aravind, "The Minimal Complexity of Kochen-Specker Sets Does Not Scale With Dimension," *Presentation at the 2017 APS March Meeting, New Orleans LA.*
10. M. Waegell, T. Denkmayr, H. Geppert, D. Ebner, T. Jenke, Y. Hasegawa, S. Sponar, J. Dressel, and J. Tollaksen, "Localizing and Measuring Contextuality through Weak Measurements & The Quantum Pigeonhole Principle," *Presentation at the 2016 APS March Meeting, Baltimore MD.*
11. M. Waegell, "The Clockwork Interpretation of Quantum Mechanics and Cosmology," *Presentation at the 2015 Interpretations of Quantum Mechanics conference at Chapman University, Orange CA*
12. M. Waegell, P.K. Aravind, "Entanglement and Nonclassicality in the N-qubit Pauli Group," *Presentation to the Group on Quantum Information at the 2013 APS March Meeting, Baltimore MD.*
13. M. Waegell, P.K. Aravind, "Minimal Proofs of the Kochen-Specker theorem within the N-qubit Pauli group," *Presentation at the 2012 APS New England Fall Meeting, Williamstown MA.*
14. M. Waegell, P.K. Aravind, "New Proofs of the Kochen-Specker theorem for a system of three qubits," *Presentation to the Group on Quantum Information at the 2012 APS March Meeting, Boston MA.*
15. M. Waegell, P.K. Aravind, "Proofs of the Kochen-Specker theorem based on the 600-cell," *Presentation to the Group on Quantum Information at the 2011 APS March Meeting, Dallas TX.*
16. P.K. Aravind, M. Waegell, "Proofs of the Kochen-Specker theorem based on two qubits," *Presentation to the Group on Quantum Information at the 2011 APS March Meeting, Dallas TX.*
17. R. Weiler, M. Waegell, R. Garcia, "Wetting Behavior of Nitrous Oxide Near its Critical Point," *Presentation to the Division of Chemical Physics at the 2006 APS March Meeting, Baltimore MD.*

POSTER PRESENTATIONS

1. M. Waegell, "Local Lorentz-Invariant Quantum Mechanics," *Presented at the 2017 Emergent Quantum Mechanics conference (EmQM17) in London, United Kingdom.*
2. M. Waegell, "The Minimal Complexity of Kochen-Specker Sets Does Not Scale With Dimension," *Presented at the Solstice of Foundation, ETH Zurich, June 2017, Zurich, Switzerland.*
3. M. Waegell, "Locally Deterministic Interpretations of Quantum Mechanics: Cosmic Inflation, Parallel Lives, and Weak Values," *Presented at the 2015 Emergent Quantum Mechanics conference (EmQM15) in Vienna, Austria.*
4. M. Waegell, "Down the Quantum Rabbit Hole: Contextuality, Pigeonholes, Cheshire Cats, Mean Kings, and Weak Values," *Presented at the 2015 Quantum Physics of Nature conference in Vienna, Austria.*
5. M. Waegell, P.K. Aravind, "Nonclassical Structures within the N-qubit Pauli Group" *Presentation at the 2014 Gordon Research Conference on Quantum Science at Stonehill College, Easton MA.*
6. M. Waegell, "A bonding model of entanglement for N-qubit graph states," *Presentation at the 2014 Gordon Research Seminar on Quantum Science at Stonehill College, Easton MA.*

BOOK REVIEWS

1. “Foundations of Quantum Mechanics: An Exploration of the Physical Meaning of Quantum Theory,” by Travis Norsen (Springer 2017), *reviewed in The Quantum Times - Newsletter of the APS Division of Quantum Information, May 2018*

CONSULTING EXPERIENCE

Chapman University, Orange, CA

May-October 2018

Consulted on exploring feasibility of research partnership between Chapman University and Astronics Corporation to work on computational biology.

TEACHING EXPERIENCE

Adjunct Professor, Chapman University, Orange CA

Fall 2018

Taught Physics for Life Science II, PHYS-108-01: Introductory electricity and magnetism.

Assistant Teaching Professor, WPI, Worcester MA

Summer 2012 and 2013, Fall 2013-Spring 2014

Taught full courses in introductory electrodynamics and introductory wave mechanics during summer sessions, and conferences in various introductory subjects during the academic year.

Teaching Assistant, WPI, Worcester MA

Fall 2006-Spring 2013

Gave conference and laboratory instruction, and private tutoring. Lectured on introductory kinematics and electrodynamics. Conducted laboratory exercises in introductory kinematics, electrodynamics, and quantum mechanics.

INTERNSHIP EXPERIENCE

Student Intern, NASA Jet Propulsion Laboratory, Pasadena CA

Summer 2008 & 2009

Developed fast automatic image registration algorithms and packaged software for digital image and video processing applications.

TECHNICAL RESEARCH

1. M. Waegell, D.M. Palacios, “Jitter Correction,” *NASA New Technology Report*. Jet Propulsion Laboratory (2011)

SKILLS

Proficient with MATLAB, Excel, LabView, LaTeX, Maple, Mathematica, C++.

PROFESSIONAL ASSOCIATIONS

American Physical Society

Sigma Xi, The Scientific Research Society

Sigma Pi Sigma: National Physics Honor Society

Phi Theta Kappa: International Honor Society of the Two Year College

Erdős Number = 3