

Rafael Chaves Souto Araujo

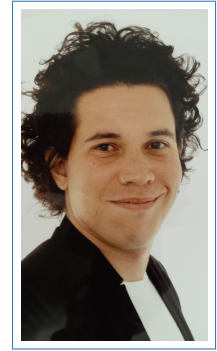
Curriculum Vitae

Campus Universitario UFRN - Lagoa Nova
59078-970 - CP: 1613 - Natal/RN - Brazil

☎ +55 84 99653 3582

✉ rchaves@iip.ufrn.br

🌐 <http://iip.ufrn.br/researchers>



Personal Details

Nationality: Brazilian.

Date of Birth: April 2, 1982.

Languages: Portuguese (native speaker), English (fluent), Spanish (Intermediate, B1-Level), German (Intermediate, B1-Level).

Family: Married to Anne-Catherine Leniger, two children.

Research Interests

Quantum information and computation, open systems and decoherence, entanglement theory, nonlocality and foundational aspects of quantum mechanics, quantum metrology, quantum optics, machine learning, Bayesian networks and causal models.

Education

- Doctor in Sciences (Physics), Federal University of Rio de Janeiro (UFRJ), Brazil, 2006 - 2010.
Thesis: *Entanglement under decoherence and its applications.*
Supervisor: Luiz Davidovich.
Examiners: Luiz Davidovich, Amir Ordacgi Caldeira, Reinaldo Oliveira Vianna, Paulo Americo Maia Neto, Fabricio Toscano, Belita Koiller.
Date of Defense: 10.08.2010.
- Research stay at Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Germany, 2008.
Supervisor: Andreas Buchleitner.
- Master in Physical Sciences, Brazilian Center for Physics Research (CBPF), Brazil, 2004 - 2006.
Dissertation: *Anomaly cancellation in non-Abelian Gauge theories.*
Supervisor: Sebastião Alves Dias.
Examiners: Sebastião Alves Dias, Silvio Paolo Sorella, Francesco Toppan.
Date of Defense: 17.08.2006.
- Bachelor in Physics, Federal University of Minas Gerais (UFMG), Brazil, 2000 - 2004.
Scientific initiation program: *Classical and quantum error correcting codes.*
Advisor: Reinaldo Oliveira Vianna.
Physics Demonstration Lab: *assistant.*
Advisor: Elmo Salomão Alves.
- Education on the technical level: Industrial Informatics, CEFET-MG, Belo Horizonte, Brazil, 1997 - 1999.

Employment and Research Positions

- **Tenure-track position for full professorship** (Current)
International Institute of Physics, Natal, Brazil.
- **Senior Postdoctoral Researcher** (May 2015 to June 2016)
Quantum information group (head: Prof. David Gross).
Institute for Theoretical Physics, University of Cologne, Germany.
- **Senior Postdoctoral Researcher** (September 2012 to February 2016)
Quantum Correlations in Physics, Mathematics, and Computer Science (head: Prof. David Gross).
Institute of Physics, Freiburg University, Germany.
- **Postdoctoral Fellow** (September 2010 to August 2012)
Quantum information theory group (head: Prof. Antonio Acin).
The Institute of Photonic Sciences (ICFO), Barcelona, Spain.

Fellowships and Awards

Ph. D.

- Academic Excellence Fellowship *Aluno Nota 10* FAPERJ, March 2009 - August 2010.
This fellowship is a special award to the most outstanding science students of the state of Rio de Janeiro (Brazil) after the completion of the first half of the PhD.
- Fellowship CAPES/DAAD, July - December 2008.
- Fellowship CNPq, August 2006 - February 2009.
- First position in the selection process of PhD students, UFRJ July 2006.

M. Sc.

- Academic Excellence Fellowship *Aluno Nota 10* FAPERJ, March 2006 - July 2006.
This fellowship is a special award to the most outstanding science students of the state of Rio de Janeiro (Brazil) after the completion of the first half of the master.
- Fellowship CAPES, March 2005 - February 2006.

Graduation

- Scholarship CNPq, June 2002 - May 2004.
- Scholarship CAPES/PROIN March 2001 - February 2002.

Others

- Best Poster Award: Quantum Contextuality, Non-Locality, and the Foundations of Quantum Mechanics, Bad Honnef, Germany, February 2014.

Research Grants

- Research Innovation Fund from the University of Freiburg, March 2014 - August 2014.
Project: *Causal inference for machine learning and quantum non-locality.*
Role: Principal investigator.
- FQXi (Foundational Questions Institute) large grant, September 2015 - August 2017.
Project: *Quantum Bayesian networks: the physics of nonlocal events.*
Role: Co-investigator.

Supervision

- Supervision of master project (concluded)
Student: Lukas Luft (University of Freiburg).
Project: "Marginal problems, causality, and local realism: an information-theoretic approach".

- Co-supervision of master project (concluded)
Student: Kai von Prillwitz (University of Freiburg).
Project: "Statistical aspects of inferring Bayesian networks from marginal observations".
- Supervision of master project (concluded)
Student: Thomas Glaessle (University of Freiburg).
Project: "Numerical treatment of the marginalization problem in causal inference and quantum nonlocality".
- Co-supervision of master project (ongoing)
Student: Aditya Kela (University of Cologne).
Project: "Causal discovery with covariance information".

Teaching and Coordination Experience

- Lecturer: Quantum Information. Federal University of Rio Grande do Norte, 2nd semester 2016.
- Tutor: Disentangling quantum matter with quantum information theory (Seminar). Universität zu Köln, summer semester 2016.
- Tutor: Graphical Modelling and Network Inference (Seminar). Universität zu Köln, winter semester 2015.
- Teaching assistant: Experimental Physics III (Electrodynamics). Albert-Ludwigs-Universität Freiburg, summer semester 2015.
- Tutor: Theoretical Physics V (Statistical mechanics). Albert-Ludwigs-Universität Freiburg, winter semester 2014.
- Teaching assistant: The Mathematical Structure of Quantum Mechanics. Albert-Ludwigs-Universität Freiburg, summer semester 2014.
- Co-Organizer: Interpretations of Quantum Mechanics (Term Paper). Albert-Ludwigs-Universität Freiburg, summer semester 2014.
- Tutor: Theoretical Physics III (Electrodynamics). Albert-Ludwigs-Universität Freiburg, winter semester 2013.
- Co-Organizer: Entropy (Term Paper). Albert-Ludwigs-Universität Freiburg, summer semester 2013.
- Teaching assistant: Experimental Physics III (Electrodynamics). Albert-Ludwigs-Universität Freiburg, summer semester 2013.
- Teaching assistant: Path Integrals in Quantum and Statistical Physics. Albert-Ludwigs-Universität Freiburg, winter semester 2012.
- Lecturer: Experimental physics I (Classical mechanics). Federal University of Rio de Janeiro (UFRJ).

Organization of Conferences and Workshops

- Co-organizer of "Workshop on Quantum Correlations, Contextuality and All That... Again", IIP Natal, November 2015.
- Organizer of "The Impromptu Meeting on Quantum Foundations", Cologne, October 2015.
- Organizer of Workshop "Quantum Bayesian Networks", Barcelona, March 2016.
- Organizer of Workshop "Quantum Bayesian Networks", Natal, November 2016.

Work as referee for scientific journals

- Physical Review Letters • Physical Review A • New Journal of Physics • Annals of Physics • Scientific Reports • Journal of Physics A • Quantum Information and Computation • Journal of Causal Inference • IEEE Transactions on Information Theory

Outreach

- Scientific Advisor: Top Science at CosmoCaixa. This was a general public exhibition held in Barcelona that included explanations outlining the history of secrecy and the basics of ultra-secure communication based on quantum physics.

Media Coverage

Some of my publications have attracted attention in various media coverage channels, including the highlighted news in the Brazilian Academy of Science (ABC), the Brazilian Physical Society (SBF), university, research institute and science coverage websites. For a partial list of the media coverage click on the hyperlinks below.

[A Big leap for quantum computation](#) (In Portuguese)

[Researchers invent scheme to extract quantum computing power from noise](#) (also here).

[A boot suggestion for a quantum computer](#) (In Portuguese).

[First intrinsically multipartite principle for quantum correlations introduced in Nature Communications.](#)

[Quantum mechanics trumps nonlocal causality](#)

[Quantum correlation do not imply instant causation](#)

Publication Highlights

Foundations of quantum mechanics

- *An entropic approach to local realism and noncontextuality*
[Physical Review A](#) **85**, 032113 (2012).
- *Local orthogonality: a multipartite principle for correlations*
[Nature Communications](#) **4**, 3263 (2013).
- *Information-theoretic implications of quantum causal structures*
[Nature Communications](#) **6**, 5766 (2015).
- *A unifying framework for relaxations of the causal assumptions in Bell's theorem*
[Physical Review Letters](#) **114**, 140403 (2015).
- *Polynomial Bell inequalities.*
[Physical Review Letters](#) **116**, 010402 (2016).
- *Entropic Nonsignaling Correlations.*
[Physical Review Letters](#) **116**, 240501 (2016).

Quantum metrology

- *Noisy metrology beyond the standard quantum limit*
[Physical Review Letters](#) **111**, 120401 (2013).
- *Improved quantum magnetometry beyond the standard quantum limit*
[Physical Review X](#) **5**, 031010 (2015).

Quantum open systems

- *Scaling laws for the decay of multiqubit entanglement*
[Physical Review Letters](#) **100**, 080501 (2008).
- *Open-system dynamics of graph-state entanglement*
[Physical Review Letters](#) **103**, 030502 (2009).

Quantum computation

- *Quantum computing with incoherent resources and quantum jumps*
[Physical Review Letters](#) **108**, 170501 (2012).

Experimental collaborations

- *Linear-optical simulation of the adiabatic cooling of a cluster-state Hamiltonian system*
[Physical Review Letters](#) **112**, 160501 (2014).
- *Experimental test of nonlocal causality*
[Science Advances](#), **2**, e1600162 (2016).

Quantum information processing

- *Device-independent tests of entropy*
[Phys. Rev. Lett.](#) **115**, 110501 (2015).

Quantum field theory

- *Gauge anomaly cancellation in chiral gauge theories*
[Annals of Physics](#) **327**, 1435 (2012).

Information theory

- *Entropic inequalities and marginal problems*
[IEEE Transactions on Information Theory](#) **59**, 803 (2013).

Causal discovery in machine learning

- *Inferring latent structures via information inequalities*
[Proceedings of the 30th Conference on Uncertainty in Artificial Intelligence](#) (2014).

Complete List of Publications

ResearcherID profile: <http://www.researcherid.com/rid/H-4725-2016>.

Bibliometrics provided by Google Scholar:

- Citations: **793**, h-index: **15**, i10-index: **19**

More than half of these citations come from the past two years. Detailed bibliometric information is available at <https://scholar.google.de/citations?user=HhCom8wAAAAJ>.

Under review

36. Experimental non-locality in a quantum network.
G. Carvacho, F. Andreoli, L. Santodonato, M. Bentivegna, **R. Chaves**, and F. Sciarrino.
Under review.
35. Indistinguishability of causal relations from limited marginals.
Costantino Budroni, Nikolai Miklin, **Rafael Chaves**.
arxiv.org/abs/1607.08540 (2016).
Under review in *Physical Review A*.
34. Bell scenarios with communication.
Jonatan Bohr Brask, **Rafael Chaves**.
arxiv.org/abs/1607.08182 (2016).
Under review in *Journal of Physics A* (Special issue *Emerging talents*).
33. Causal hierarchy of multipartite Bell nonlocality.
Rafael Chaves, Daniel Cavalcanti, Leandro Aolita.
arxiv.org/abs/1607.07666 (2016).
To be submitted.

Peer-Reviewed Journals

32. Algorithmic independence of initial condition and dynamical law in thermodynamics and causal inference.
D. Janzing, **R. Chaves**, B. Schoelkopf.
arxiv.org/abs/1512.02057 (2015).
Accepted for publication in *New Journal of Physics*.

31. Experimental test of nonlocal causality.
M. Ringbauer, C. Giarmatzi, **R. Chaves**, F. Costa, A. White, A. Fedrizzi.
[Science Advances](#), **2**, e1600162 (2016).
30. Entropic Nonsignaling Correlations.
R. Chaves and C. Budroni.
[Phys. Rev. Lett.](#) **116**, 240501 (2016).
29. Polynomial Bell inequalities.
R. Chaves.
[Phys. Rev. Lett.](#) **116**, 010402 (2016).
28. Device-independent tests of entropy.
R. Chaves, J. B. Brask, N. Brunner.
[Phys. Rev. Lett.](#) **115**, 110501 (2015).
27. Improved quantum magnetometry beyond the standard quantum limit.
J. B. Brask, **R. Chaves**, J. Kolodynski.
[Phys. Rev. X](#) **5**, 031010 (2015).
26. A unifying framework for relaxations of the causal assumptions in Bell's theorem.
R. Chaves, R. Kueng, J. B. Brask, D. Gross.
[Phys. Rev. Lett.](#) **114**, 140403 (2015).
25. Information-theoretic implications of quantum causal structures.
R. Chaves, C. Majens, D. Gross.
[Nature Communications](#) **6**, 5766 (2015).
Selected as a talk in QIP 2015.
24. Inferring latent structures via information inequalities.
R. Chaves, L. Luft, T. O. Maciel, D. Gross, D. Janzing, B. Schoelkopf.
[Proceedings of the 30th Conference on Uncertainty in Artificial Intelligence \(2014\)](#), pp. 112 - 121.
Selected as a plenary talk.
23. Linear-optical simulation of the adiabatic cooling of a cluster-state Hamiltonian system.
G. H. Aguilar, T. Kolb, D. Cavalcanti, L. Aolita, **R. Chaves**, S. P. Walborn, P. H. Souto Ribeiro.
[Phys. Rev. Lett.](#) **112**, 160501 (2014).
Editor's suggestion.
22. Detecting nonlocality of noisy multipartite states with the CHSH inequality.
R. Chaves, A. Acin, L. Aolita, D. Cavalcanti.
[Phys. Rev. A](#) **89**, 042106 (2014).
21. Causal structures from entropic information: Geometry and novel scenarios.
R. Chaves, L. Luft, D. Gross.
[New J. Phys.](#) **16**, 043001 (2014).
20. Nonlocality in sequential correlation scenarios.
R. Gallego, L. E. Wurfliinger, **R. Chaves**, A. Acin, M. Navascues.
[New J. Phys.](#) **16**, 033037 (2014).
19. Exploring the local orthogonality principle.
B. Sainz, T. Fritz, R. Augusiak, J. B. Brask, **R. Chaves**, A. Leverrier, A. Acin.
[Phys. Rev. A](#) **89**, 032117 (2014).
18. Noisy metrology beyond the standard quantum limit.
R. Chaves, J. B. Brask, M. Markiewicz, J. Kolodynski, A. Acin.
[Phys. Rev. Lett.](#) **111**, 120401 (2013).
17. Local orthogonality: a multipartite principle for correlations.
T. Fritz, B. Sainz, R. Augusiak, J. B. Brask, **R. Chaves**, A. Leverrier, A. Acin.
[Nature Communications](#) **4**, 3263 (2013).

16. Testing nonlocality of single-photon entanglement without a shared reference frame.
J. B. Brask, **R. Chaves**, N. Brunner.
[Phys. Rev. A **88**, 012111 \(2013\)](#).
15. Entropic inequalities as a necessary and sufficient condition to noncontextuality and locality.
R. Chaves.
[Phys. Rev. A **87**, 022102 \(2013\)](#).
14. Entropic inequalities and marginal problems.
T. Fritz, **R. Chaves**.
[IEEE Trans. Inf. Th. **59**, 803 \(2013\)](#).
13. Robust nonlocality tests with displacements-based measurements.
J. B. Brask, **R. Chaves**.
[Phys. Rev. A **86**, 010106\(R\) \(2012\)](#).
12. Robust macroscopic quantum correlations without complex encodings.
R. Chaves, L. Aolita, A. Acin.
[Phys. Rev. A **86**, 020301\(R\) \(2012\)](#).
11. Multipartite nonlocality under local decoherence.
R. Chaves, L. Aolita, D. Cavalcanti, A. Acin.
[Phys. Rev. A **86**, 012108 \(2012\)](#).
10. Gauge anomaly cancellation in chiral gauge theories.
G. D. L. S. Lima, **R. Chaves**, S. A. Dias.
[Annals of Physics **327**, 1435 \(2012\)](#).
9. Quantum computing with incoherent resources and quantum jumps.
M. F. Santos, M. T. Cunha, **R. Chaves**, A. R. R. Carvalho.
[Phys. Rev. Lett. **108**, 170501 \(2012\)](#).
8. An entropic approach to local realism and noncontextuality.
R. Chaves, T. Fritz.
[Phys. Rev. A **85**, 032113 \(2012\)](#).
7. Feasibility of loophole-free nonlocality tests with a single photon.
R. Chaves, J. B. Brask.
[Phys. Rev. A **84**, 062110 \(2011\)](#).
6. Noisy one-way quantum computations: The role of correlations.
R. Chaves, F. de Melo.
[Phys. Rev. A **84**, 022324 \(2011\)](#).
5. Robustness of entanglement as a resource.
R. Chaves, L. Davidovich.
[Phys. Rev. A **82**, 052308 \(2010\)](#).
4. Noisy entanglement evolution of graph states.
L. Aolita, D. Cavalcanti, **R. Chaves**, C. Dhara, L. Davidovich, A. Acin.
[Phys. Rev. A **82**, 032317 \(2010\)](#).
3. Open-system dynamics of graph-state entanglement.
D. Cavalcanti, **R. Chaves**, L. Aolita, L. Davidovich, A. Acin.
[Phys. Rev. Lett. **103**, 030502 \(2009\)](#).
2. Scaling laws for the decay of multiqubit entanglement.
L. Aolita, **R. Chaves**, D. Cavalcanti, A. Acin, L. Davidovich.
[Phys. Rev. Lett. **100**, 080501 \(2008\)](#).

Conference Proceedings

1. Anomalies cancellation in Abelian gauge theories: Functional Approach .

R. C. S. Araujo, S. A. Dias.

[Proceedings of the XXVII ENFPC, T0169-1 \(2005\).](#)

Seminars, Colloquiums and Oral Presentations

- *Introduction to Quantum Information*, invited lecture at the II Advanced School of Quantum Computation and Quantum Foundation, August 2016, Joao Pessoa, Brazil.
- *Experimental test of nonlocal causality*, invited talk at the Quantum and Beyond conference, June 2016, Vaxjo, Sweden.
- *Generalizing Bell's theorem*, invited talk at the Workshop on Quantum Correlations, Contextuality and All That... Again, November 2015, Natal, Brazil.
- *Quantum nonlocality from a causal inference perspective*, contributed talk at the V Quantum Information Workshop, August 2015, Paraty/RJ, Brazil.
- *Quantum nonlocality from a causal inference perspective*, invited colloquium presentation at the University of Cologne, July 2015, Cologne, Germany.
- *Quantum nonlocality from a causal inference perspective*, invited seminar at the ICFO (Institute of Photonic Sciences), March 2015, Barcelona, Spain.
- *Information-theoretical implications of classical and quantum causal structures*, contributed talk at the Quantum Information Processing conference, January 2015, Sydney, Australia.
- *An Entropic approach to causal inference and applications to nonlocality and machine learning*, contributed talk at CEQIP conference, June 2014, Znojmo, Czech Republic.
- *An Entropic approach to causal inference and applications to nonlocality and machine learning*, invited seminar at the ICFO (Institute of Photonic Sciences), March 2014, Barcelona, Spain.
- *An information-theoretic approach to causal inference*, invited seminar at the Max Planck Institute for Intelligent Systems, February 2014, Tuebingen, Germany.
- *Entropies, causal structures and quantum nonlocality*, invited talk at the Workshop on Quantum Correlations, Contextuality and All That, December 2013, Natal, Brazil.
- *Inferring Causal Structures from entropic information*, invited seminar at UFMG, December 2013, Belo Horizonte, Brazil.
- *Noisy metrology beyond the standard quantum limit*, invited seminar at the Free University of Berlin, November 2013, Berlin, Germany.
- *Quantum simulation of the adiabatic cooling of a cluster-state Hamiltonian system*, invited talk at Workshop for Quantum Simulation of Open Quantum Systems, November 2013, Freiburg, Germany.
- *Noisy metrology beyond the standard quantum limit*, contributed talk at the DPG spring meeting, march 2013, Hannover, Germany.
- *Quantum metrology and its realistic implementations*, invited seminar at the University of Freiburg, December 2012, Freiburg, Germany.
- *Resilient macroscopic quantum superpositions without complex encodings*, contributed talk at the III Quantum Information Workshop, August 2011, Paraty/RJ, Brazil.
- *Entanglement under decoherence and its applications*, invited seminar at UFMG, July 2010, Belo Horizonte, Brazil.

Participation in Events/Conferences

- Quantum and Beyond conference, Vaxjo, Sweden, June 2016.
- Contextuality and All That... Again, Natal, Brazil, November 2015.

- V Quantum Information School and Workshop, Paraty/RJ, Brazil, August 2015.
- Quantum Information, Benasque, Spain, June 2015.
- Quantum Information Processing, Sydney, Australia, January 2015.
- CEQIP conference, Znojmo, Czech Republic, June 2014.
- Quantum Contextuality, Non-Locality, and the Foundations of Quantum Mechanics, Bad Honnef, Germany, February 2014.
- Workshop on Quantum Correlations, Contextuality and All That, Natal, Brazil, December 2013.
- Workshop for Quantum Simulation of Open Quantum Systems, Freiburg, Germany, December 2013.
- Causal Structure in Quantum Theory, Benasque, Spain, July 2013.
- Quantum Information, Benasque, Spain, June 2013.
- DPG Spring Meeting, Hannover, Germany, March 2013.
- Quantum Information Processing, Beijing, China, January 2013.
- Quantum Information Workshop, Seefeld, Austria, July 2012.
- III Quantum Information School and Workshop, Paraty/RJ, Brazil, September 2011.
- Quantum Information, Benasque, Spain, June 2011.
- New Trends in Quantum Information and Quantum Optics, Sant Benet, Spain, December 2010.
- International Conference on Quantum Information and Computation, Stockholm, Sweden, October 2010.
- Escola de Altos Estudos, Quantum Information Theory by Vlatko Vedral, Belo Horizonte, Brazil, June 2010.
- II Quantum Information School and Workshop, Paraty/RJ, Brazil, September 2009.
- Quantum Information, Benasque, Spain, June 2009.
- Quantum Coherence and Decoherence, Benasque, Spain, September 2008.
- XI School Jorge André Swieca de Óptica Quântica e Óptica Não Linear, São Paulo/SP, Brazil, February 2008.
- Quantum Information, Benasque, Spain, June 2007.
- Quantum Information - School and Workshop, Paraty/RJ, Brazil, August 2007.
- ENFPC, São Lourenço/MG, Brazil, September 2006.

Computational Skills

I have studied industrial informatics (CEFET-MG) at the technical level in parallel to the usual high school, followed by a trainee internship. I have basic notions of hardware and extensive programming experience (C++, Mathematica, Matlab).