

# CURRICULUM VITAE of ALESSANDRO TOIGO

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## EDUCATION AND CAREER

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**10/10/2001:** I graduated in Physics at the University of Genoa with a thesis entitled *Modelli cosmologici in relatività generale* (supervisor Prof. E. Massa) with the mark of 110/110 *cum laude*.

**01/02/2002 - 31/01/2005:** I got a 3 years grant from the University of Genoa to attend the doctoral course in Physics (XVII cycle).

**15/04/2005:** I achieved the title of Ph.D. in Physics presenting a thesis entitled *Positive operator measures, generalised imprimitivity theorem and their applications* (supervisors Profs. G. Cassinelli and P. Lahti).

**01/02/2005 - 31/10/2005:** I got a 9 months postdoctoral research grant issued by Fondazione Cassa di Risparmio di Genova e Imperia, aimed at continuing my research activity at the Department of Physics of the University of Genoa.

**19/09/2007 - 08/10/2007:** I worked with a part-time contract at the Department of Physics of the University of Genoa.

**02/01/2008 - 01/01/2009:** I had a 1 year research grant financed by the Department of Information Science of the University of Genoa.

**02/01/2009 - 31/10/2009:** My previous grant at the Department of Information Science of the University of Genoa was renewed for another 1 year.

**01/11/2009 - 07/03/2012:** I got a 4 years (renewable for another 4 years) temporary researcher position at the Department of Mathematics of Politecnico di Milano in the scientific sector MAT/06 - Probability and Mathematical Statistics.

**08/03/2012 - 07/03/2015:** I replaced the previous position with a new 3 years temporary researcher position of “Junior” type at the Department of Mathematics of Politecnico di Milano (scientific sector: MAT/06 - Probability and Mathematical Statistics), since I became coordinator of the local unit of the national FIRB Project *Quantum Markov semigroups and their empirical estimation*, financed by the Italian Ministry of Education, University and Research (MIUR).

**03/12/2013:** I got the National Scientific Qualification (ASN) pursuant to article 16 of Law 240/2010, for the level of Associate Professor in the scientific sector 01/A4 - Mathematical Physics.

**30/12/2013:** I got the National Scientific Qualification (ASN) pursuant to article 16 of Law 240/2010, for the level of Associate Professor in the scientific sector 01/A3 - Mathematical Analysis, Probability and Mathematical Statistics.

**08/03/2015 - 15/06/2015:** I got a 1 year research grant at the Department of Mathematics of Politecnico di Milano financed by my FIRB Project *Quantum Markov semigroups and their empirical estimation*.

**16/06/2015 - 15/06/2018:** I replaced the previous position with a new 3 years temporary researcher position of “Senior” type at the Department of Mathematics of Politecnico di Milano (scientific sector: MAT/06 - Probability and Mathematical Statistics).

**16/06/2018 - today:** Presently, I am full time associate professor at the Department of Mathematics of Politecnico di Milano (scientific sector: MAT/06 - Probability and Mathematical Statistics).

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RESEARCH TOPICS

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Quantum Probability and Quantum Information:

- techniques and methods from commutative and non-commutative harmonic analysis (Fourier analysis, Heisenberg groups) and their applications to the study of sequential or approximate joint measurements of complementary observables in Quantum Mechanics;
- measures with values in the sets of positive operators and completely positive maps covariant with respect to representations of symmetry groups;
- symmetries and state reconstruction methods in Quantum Tomography;
- quantum incompatibility and uncertainty relations;
- transformations of completely positive maps and their applications to Quantum Information.

Lie Supergroups:

- representation theory for Lie supergroups and study of their induction process.

Non-parametric Statistics:

- reproducing kernel Hilbert spaces and their applications to statistical learning;
- manifold learning;
- empirical state estimation in quantum tomography.

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PUBLICATIONS

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*Articles published in international journals with referees*

- (1) G. Cassinelli, E. De Vito, A. Toigo, Positive operator valued measures covariant with respect to an irreducible representation, *J. Math. Phys.* **44** No. 10 (2003) 4768-4775
- (2) G. Cassinelli, E. De Vito, A. Toigo, Positive operator valued measures covariant with respect to an Abelian group, *J. Math. Phys.* **45** No. 1 (2004) 418-433
- (3) C. Carmeli, G. Cassinelli, E. De Vito, A. Toigo, B. Vacchini, A complete characterization of phase space measurements, *J. Phys. A* **37** No. 18 (2004) 5057-5066
- (4) C. Carmeli, T. Heinonen, A. Toigo, Position and momentum observables on  $\mathbb{R}$  and on  $\mathbb{R}^3$ , *J. Math. Phys.* **45** No. 6 (2004) 2526-2539
- (5) C. Carmeli, T. Heinonen, A. Toigo, On the coexistence of position and momentum observables, *J. Phys. A* **38** No. 23 (2005) 5253-5266
- (6) C. Carmeli, G. Cassinelli, A. Toigo, Unitary representations of super groups and Mackey theory, *Bulg. J. Phys.* **33** No. s2 (2006) 269-279
- (7) C. Carmeli, G. Cassinelli, A. Toigo, V. S. Varadarajan, Unitary representations of super Lie groups and applications to the classification and multiplet structure of super particles, *Comm. Math. Phys.* **263** No. 1 (2006) 217-258
- (8) C. Carmeli, E. De Vito, A. Toigo, Vector valued reproducing kernel Hilbert spaces of integrable functions and Mercer theorem, *Anal. Appl.* **4** No. 4 (2006) 377-408
- (9) C. Carmeli, T. Heinonen, A. Toigo, Intrinsic unsharpness and approximate repeatability of quantum measurements, *J. Phys. A* **40** No. 6 (2007) 1303-1323
- (10) C. Carmeli, T. Heinonen, A. Toigo, Why unsharp observables?, *Int. J. Theor. Phys.* **47** No. 1 (2008) 81-89
- (11) P. Albin, A. Toigo, V. Umanità, Relations between convergence rates in Schatten  $p$ -norms, *J. Math. Phys.* **49** No. 1 (2008) 013504

- (12) C. Carmeli, T. Heinosaari, J. P. Pellonpää, A. Toigo, Extremal covariant positive operator valued measures: the case of a compact symmetry group, *J. Math. Phys.* **49** No. 6 (2008) 063504
- (13) C. Carmeli, T. Heinosaari, J. P. Pellonpää, A. Toigo, Optimal covariant observables: the case of a compact symmetry group and phase observables, *J. Phys. A* **42** No. 14 (2009) 145304
- (14) S. T. Ali, C. Carmeli, T. Heinosaari, A. Toigo, Commutative POVMs and Fuzzy Observables, *Found. Phys.* **39** No. 6 (2009) 593-612
- (15) P. Albin, E. De Vito, A. Toigo, Quantum homodyne tomography as an informationally complete positive operator valued measure, *J. Phys. A* **42** No. 29 (2009) 295302
- (16) C. Carmeli, T. Heinosaari, A. Toigo, Covariant quantum instruments, *J. Funct. Anal.* **257** No. 11 (2009) 3353-3374
- (17) C. Carmeli, E. De Vito, A. Toigo, V. Umanità, Vector valued reproducing kernel Hilbert spaces and universality, *Anal. Appl.* **8** No. 1 (2010) 19-61
- (18) C. Carmeli, T. Heinosaari, A. Toigo, Sequential measurements of conjugate observables, *J. Phys. A* **44** No. 28 (2011) 285304
- (19) C. Carmeli, G. Cassinelli, A. Toigo, V. S. Varadarajan, Erratum to: Unitary Representations of Super Lie Groups and Applications to the Classification and Multiplet Structure of Super Particles, *Comm. Math. Phys.* **307** No. 2 (2011) 565-566
- (20) C. Carmeli, T. Heinosaari, A. Toigo, Informationally complete joint measurements on finite quantum systems, *Phys. Rev. A* **85** No. 1 (2012) 012109
- (21) G. Chiribella, A. Toigo, V. Umanità, Normal completely positive maps on the space of quantum operations, *Open Syst. Inf. Dyn.* **20** No. 1 (2013) 1350003
- (22) C. Carmeli, T. Heinosaari, A. Toigo, Minimal covariant observables identifying all pure states, *Phys. Lett. A* **377** No. 21-22 (2013) 1407-1415
- (23) R. Beneduci, T. J. Bullock, P. Busch, C. Carmeli, T. Heinosaari, A. Toigo, Operational link between mutually unbiased bases and symmetric informationally complete positive operator-valued measures, *Phys. Rev. A* **88** No. 3 (2013) 032312
- (24) C. Carmeli, T. Heinosaari, J. Schultz, A. Toigo, Tasks and premises in quantum state determination, *J. Phys. A* **47** No. 7 (2014) 075302
- (25) E. De Vito, L. Rosasco, A. Toigo, Learning sets with separating kernels, *Appl. Comput. Harmon. Anal.* **37** No. 2 (2014) 185217
- (26) T. Heinosaari, J. Schultz, A. Toigo, M. Ziman, Maximally incompatible quantum observables, *Phys. Lett. A* **378** No. 24-25 (2014) 1695-1699
- (27) C. Carmeli, T. Heinosaari, J. Schultz, A. Toigo, Nonuniqueness of phase retrieval for three fractional Fourier transforms, *Appl. Comput. Harmon. Anal.* **39** No. 2 (2015) 339-346
- (28) C. Carmeli, T. Heinosaari, J. Schultz, A. Toigo, Expanding the principle of local distinguishability, *Phys. Rev. A* **91** No. 4 (2015) 042121
- (29) C. Carmeli, T. Heinosaari, J. Schultz, A. Toigo, How many orthonormal bases are needed to distinguish all pure quantum states?, *Eur. J. Phys. D* **69** No. 7 (2015) 179
- (30) C. Carmeli, J. Schultz, A. Toigo, Covariant mutually unbiased bases, *Rev. Math. Phys.* **28** No. 4 (2016) 1650009
- (31) C. Carmeli, T. Heinosaari, D. Reitzner, J. Schultz, A. Toigo, Quantum incompatibility in collective measurements, *Mathematics* **4** No. 3 (2016) 54

- (32) C. Carmeli, T. Heinosaari, M. Kech, J. Schultz, A. Toigo, Stable pure state quantum tomography from five orthonormal bases, *Europhys. Lett.* **115** No. 3 (2016) 30001
- (33) C. Carmeli, T. Heinosaari, A. Karlsson, J. Schultz, A. Toigo, Verifying the Quantumness of Bipartite Correlations, *Phys. Rev. Lett.* **116** No. 23 (2016) 230403
- (34) C. Carmeli, J. Schultz, A. Toigo, Maximally symmetric stabilizer MUBs in even prime-power dimensions, *J. Math. Phys.* **58** No. 3 (2017) 032201
- (35) C. Carmeli, T. Heinosaari, J. Schultz, A. Toigo, Probing quantum state space: does one have to learn everything to learn something?, *P. R. Soc. A* **473** No. 2201 (2017) 20160866
- (36) A. Barchielli, M. Gregoratti, A. Toigo, Measurement Uncertainty Relations for Position and Momentum: Relative Entropy Formulation, *Entropy* **19** No. 7 (2017) 301
- (37) A. Barchielli, M. Gregoratti, A. Toigo, Measurement uncertainty relations for discrete observables: Relative entropy formulation, *Comm. Math. Phys.* **357** No. 3 (2018) 1253-1304
- (38) C. Carmeli, T. Heinosaari, S. Maniscalco, J. Schultz, A. Toigo, Determining quantum coherence with minimal resources, *New J. Phys.* **20** No. 6 (2018) 063038
- (39) C. Carmeli, T. Heinosaari, A. Toigo, State discrimination with postmeasurement information and incompatibility of quantum measurements, *Phys. Rev. A* **98** No. 1 (2018) 012126
- (40) C. Carmeli, T. Heinosaari, A. Toigo, Quantum Incompatibility Witnesses, *Phys. Rev. Lett.* **122** No. 13 (2019) 130402
- (41) C. Carmeli, T. Heinosaari, T. Miyadera, A. Toigo, Noise-Disturbance Relation and the Galois Connection of Quantum Measurements, *Found. Phys.* **49** No. 6 (2019) 492-505
- (42) C. Carmeli, G. Cassinelli, A. Toigo, Constructing Extremal Compatible Quantum Observables by Means of Two Mutually Unbiased Bases, *Found. Phys.* **49** No. 6 (2019) 532-548

### *Proceedings*

- (43) E. De Vito, L. Rosasco, A. Toigo, Spectral Regularization for Support Estimation, *Advances in Neural Information Processing Systems 23: 24th Annual Conference on Neural Information Processing Systems 2010, NIPS 2010*
- (44) G. Chiribella, A. Toigo, V. Umanità, Completely positive transformations of quantum operations, *QP-PQ Quantum Probability and White Noise Analysis 29: 32nd Conference on Quantum Probability and Related Topics 2011*

### *Preprints*

- (45) C. Carmeli, T. Heinosaari, T. Miyadera, A. Toigo, Witnessing incompatibility of quantum channels, *arXiv:1906.10904* (2019)
- (46) C. Carmeli, T. Heinosaari, A. Toigo, Quantum random access codes and incompatibility of measurements, *arXiv:1911.04360* (2019)

### *Theses*

- (47) A. Toigo, *Modelli cosmologici in relatività generale*, graduation thesis (2001)
- (48) A. Toigo, *Positive operator measures, generalised imprimitivity theorem and their applications*, Ph.D. thesis (2005)

### *Conferences and schools*

- (1) First national meeting “Problemi Matematici in Meccanica Quantistica”, Modena, 18-20th December 2003
- (2) 10th conference “Problemi Attuali di Fisica Teorica”, Vietri, 2-7th April 2004
- (3) 11th international conference “Symmetry Methods in Physics”, Prague, 21-24th June 2004
- (4) Workshop “Mathematical Methods in Quantum Mechanics”, Bressanone, 21-26th February 2005
- (5) 32nd international conference “Quantum Probability and Related Topics”, Levico, 29th May - 4th June 2011
- (6) 32nd National Conference on Harmonic Analysis, Genova, 4-8th June 2012
- (7) Workshop “Quantum Markov Semigroups: Decoherence and Empirical Estimates”, Genova, 26-28th June 2013
- (8) Workshop “Workshop on Incompatible Quantum Measurements”, Munich, 9-12th September 2013
- (9) 46th international conference “Symposium on Mathematical Physics”, Toruń, 15-17th June 2014
- (10) 2nd workshop “Quantum Markov Semigroups: Decoherence and Empirical Estimates”, Genova, 29th June - 1st July 2015
- (11) Workshop “Two Days in Quantum Mechanics”, Genova, 29-30th June 2016
- (12) Workshop “Quantum Incompatibility 2017”, Maria Laach Abbey, 28th August - 1st September 2017

### *Conference organization*

- (1) Workshop “Quantum Markov Semigroups: Decoherence and Empirical Estimates”, Genova, 26-28th June 2013
- (2) 2nd workshop “Quantum Markov Semigroups: Decoherence and Empirical Estimates”, Genova, 29th June - 1st July 2015
- (3) Workshop “Two Days in Quantum Mechanics”, Genova, 29-30th June 2016
- (4) Workshop “Three Days in Quantum Mechanics”, Genova, 6-8th June 2018
- (5) Workshop “QQQ - Workshop on Quantum open systems, Quantum thermodynamics and Quantum probability”, Milano, 18th-21st February 2020

### *Talks*

- (1) “Unitary representations of super Lie groups and super semidirect products”, presented at the workshop “Mathematical Methods in Quantum Mechanics”, Bressanone, 21-26th February 2005
- (2) “Normal completely positive maps on the space of quantum operations”, presented at the 32nd international conference “Quantum Probability and Related Topics”, Levico, 29th May - 4th June 2011
- (3) “Dirac equation in 1+1 Anti-de Sitter space-time: complex structure, unitarizability and representations of  $SU(1,1)$ ”, presented at the 32nd National Conference on Harmonic Analysis, Genova, 4-8th June 2012
- (4) “Normal completely positive maps on the space of quantum operations”, presented at the workshop “Quantum Markov Semigroups: Decoherence and Empirical Estimates”, Genova, 26-28th June 2013

- (5) “On the coexistence of conjugated observables on locally compact abelian groups”, presented at the workshop “Workshop on Incompatible Quantum Measurements”, Munich, 9-12th September 2013
- (6) “Quantum tomography for finite fields”, presented at the 46th international conference “Symposium on Mathematical Physics”, Toruń, 15-17th June 2014
- (7) “Covariant mutually unbiased bases”, presented at the 2nd workshop “Quantum Markov Semigroups: Decoherence and Empirical Estimates”, Genova, 29th June - 1st July 2015
- (8) “Entropic uncertainty relations – The measurement case”, presented at the workshop “Two Days in Quantum Mechanics ”, Genova, 29 - 30th June 2016
- (9) “Entropic uncertainty relations - The measurement case”, presented at the workshop “Quantum Incompatibility 2017”, Maria Laach Abbey, 28th August - 1st September 2017

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#### SUPERVISION OF THESES AND POSTDOCS

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- Co-supervisor of the doctoral thesis “Mathematical methods in Quantum Tomography” by Dr. Paolo Albini, 20th Doctoral Course in Physics of the University of Genoa (2008)
- Scientific supervisor of Dr. Jussi Schultz for the one-year grant “State and process empirical estimation in Quantum Tomography”, issued by Politecnico di Milano and financed with my FIRB project fundings (2013/14)
- Scientific supervisor of Dr. Jussi Schultz for the one-year grant “State and process reconstruction methods in Quantum Tomography”, issued by Politecnico di Milano and financed with my FIRB project fundings (2014/15)

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#### TEACHING EXPERIENCE

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- Holder of the integrated course in Analytical and Statistical Methods for the 2nd year students in Physical Engineering at Politecnico di Milano, Academic Years 2013/14, 2014/15 and 2015/16
- Holder of the course in Statistics for the 1st year students in Physical Engineering at Politecnico di Milano, Academic Years 2015/16, 2017/18 and 2018/19
- Holder and exercise sessions of the course in Statistics for the 2nd year students in Energetic Engineering at Politecnico di Milano, Academic Year 2016/17
- Holder of the course in Statistics for the 2nd year students in Energetic Engineering at Politecnico di Milano, Academic Years 2017/18, 2018/19 and 2019/20
- Exercise sessions of the courses in Stochastic Dynamical Models and Complements of Stochastic Processes (holder: prof. F. Fagnola) for the 4th year students of the degree course in Mathematical Engineering at Politecnico di Milano, Academic Years 2009/10, 2010/11, 2011/12, 2012/13 and 2013/14
- Exercise sessions of the course in Probability and Statistics (holder: prof. A. Barchielli) for the 2nd year students of the degree course in Computer Engineering at Politecnico di Milano, Academic Years 2010/11, 2011/12, 2012/13 and 2016/17
- Exercise sessions of the course in Probability and Statistics (holder: prof. F. Fagnola) for the 1st year students of the degree course in Management Engineering at Politecnico di Milano, Academic Year 2010/11