

# LORENZO MACCONE'S CURRICULUM VITÆ

with a statement of research interest and a list of publications

January 2011

Lorenzo Maccone, born in Ivrea (TO) –Italy– on April 21, 1972 (Italian citizen).

## CONTACT INFORMATION

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## ACADEMIA (reverse chronological order)

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October 2010: **Associate professor** at the Dipartimento di Fisica “A. Volta” of the University of Pavia (Italy). His main current research lines refer to **theoretical quantum mechanics and its applications**, primarily: Quantum Information, Quantum Optics, and Foundations of Quantum Mechanics.

June 2010-September 2010: **Official Faculty Guest at the Los Alamos National Laboratories** in the group of W.H. Zurek, working on Foundations of Quantum Mechanics and Quantum Metrology.

June 2009-May 2010: **Visiting Scientist at MIT** in the xQIT, “Center for Extreme Quantum Information theory” (funded by the W. M. Keck foundation).

February 2009-May 2009: **Research associate at ISI** (Institute for Scientific Interchange Foundation) in Torino, Italy.

December 2004- December 2008: **Contract Professor** at the University of Pavia (contract of 4 years). He has taught

the full course of “Quantum Optics” (5 credits) for five years (04/05–08/09). It is primarily directed to Physics students, and is basically an advanced quantum mechanics course (with special emphasis on the techniques employed in quantum optics).

the section on “Foundations of Quantum Mechanics” (2 credits out of 5) in the course of “Epistemology of Physics” (converted to “Foundations of Physics” in 06/07) for four years (04/05–07/08). It is directed to Physics and Math students, and is an introductory course on quantum mechanics.

March 2004-December 2004: **Postdoctoral Associate** in the Quantum Information theory group of the University of Pavia.

November 2000-February 2004: **Postdoctoral Associate** in the Research Laboratory of Electronics of the Massachusetts Institute of Technology (MIT) in the groups of Prof. J. H. Shapiro and Prof. S. Lloyd. This position was renewed three times: in November 2001, November 2002, and November 2003.

January 2000-November 2000: **Postdoctoral fellowship** for the PAIS project in the Quantum Optics and Information Group of Prof. G. M. D’Ariano in University of Pavia.

## CURRICULUM STUDIORUM

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September 1996-December 13, 1999: **Ph.D. in theoretical Physics** in Pavia under the supervision of Prof. G. M. D’Ariano. Thesis “Quantum tomography: methods and applications”, in which the theory and various applications of quantum state reconstruction techniques are analyzed.

September 1992-June 7, 1996: **Master in Physics** obtained with full marks (110 on 110) *cum laude* and an average mark of 29.77 on 30 for the eighteen required exams.

High School: Liceo Classico (Liceo “C. Botta”, Ivrea), where literary and humanistic subjects are emphasized. Final score: 60 on 60 (full marks).

## SKILLS

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### **Scientific research:**

Numerous publications on peer-reviewed international scientific journals— Nature, Science, Nature Photonics, Nature Physics, Physical Review Letters, and IEEE Transactions on Information Theory among others (see full list of publications below).

Presentation of his research in numerous conferences and workshops, and in invited seminars (see full list below).

Referee for the journals Science, Nature Physics, Nature Communications, IEEE Photonics Technology Letters, Foundations of Physics, Phys. Rev. Lett., Phys. Rev. A, Quantum Information and Computation, Physics Letters, New Journal of Physics, Journal of Physics A: Mathematical and General, Journal of Physics B: Atomic, Molecular & Optical Physics, European Physical Journal D, Journal of the Optical Society of America B, Journal of Mathematical Physics, Complexity, Theoretical Computer Science.

**Foreign languages:** Fluent English, basic French.

**Computer abilities:** excellent skills in information technologies; started programming in 1981; programming languages: C, Fortran, Assembler 8086, and Basic; Latex typesetting language; Operating systems: Linux (since 1995), MS-DOS, and Windows (from 2.0 to XP); system administrator for Linux and mixed Linux-Windows computer clusters, web servers, mail servers, FTP servers, samba servers, and a domain name server; architectures: IBM compatibles, Sun Sparc, and DEC Alpha; applications: Mathematica, emacs, Open Office, Microsoft Office, etc.

**Scholarships:** three scholarships from the private institution INPDAI for study achievements.

## MISCELLANEA:

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Sports: mountain sports (alpine ski, trekking, free climbing, *piolet traction*, mountain biking), sailing (provisional rating and experience on a 38-foot vessel), long distance bicycle trips, swimming.

Hobbies: computers and electronics (radio amateur license I-W1ETZ), reading.

Civil service: EMT-trained ambulance technician with “Croce Verde Fornovese” in Fornovo, PR (he has also volunteered on the Italian Red Cross ambulances). He has thus fulfilled the mandatory military requirements for his country.

#### STATEMENT OF RESEARCH INTEREST AND RESEARCH ACTIVITIES

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I am a theoretical physicist, mainly interested in the study of fundamental aspects and of practical applications of Quantum Mechanics. My research activity has been chiefly devoted to quantum optics, quantum theory of measurement, quantum information theory, and foundations of quantum mechanics. A schematic list of the research topics I pursued, or I am currently pursuing, follows. The references refer to the publications in the subsequent list. The research has been performed in collaboration with numerous coauthors.

- **Quantum parameter estimation:** quantum positioning [17], quantum metrology [51,41], interferometric tunability of the absorption [53], quantum imaging [66,84], quantum illumination [64,60].
- **Quantum foundations:** information-disturbance tradeoffs [52,56], quantum thermodynamics [68], quantum descriptions of closed timelike curves [72].
- **Quantum computation:** quantum solution to the Ulam problem [50], quantum Random Access Memory [59,63], quantum optical computation [9].
- **Quantum cryptography:** quantum cryptographic ranging [22], quantum cryptographic protocol for the communication of reference frames [57], secure database interrogation, the QPQ cryptographic primitive [61].
- **Quantum state reconstruction:** theoretical analysis and proposal of tomographic procedures for optical systems [3,5] and systems with  $SU(1,1)$  and  $SU(2)$  symmetries [16,25], contribution to generalized tomography [14,15], application of quantum tomography to classical imaging [46].
- **Experimental proposals:** Liouvillian superoperator measurement [3,4], optical Schrödinger cat [5], optical Fock state synthesis-measurement [12,13].
- **Entanglement, uses:** quantum clock synchronization with dispersion cancellation [18], dynamical evolution of composite systems [27,28], conversion between speakable and unspeakable information [82].
- **Entanglement, new sources:** difference-beam state [20,24].
- **Quantum-channel capacities:** entanglement assisted capacity of bosonic channels [29,31], classical capacity of bosonic and Gaussian channels [32,81], waveguide capacity [35], ultimate limits to channel capacity [39], decoding schemes for achieving the classical capacity [77,78].
- **Numerical simulations:** Monte-Carlo simulations of laser master and Fokker Plank equations [1], Monte-Carlo simulations of numerous tomographic schemes.

- Clock synchronization: conveyor belt clock synchronization protocol [40], limits to synchronization in the presence of decoherence [21].

In addition to the above research, I have also devoted some effort to the divulgation of Quantum Physics [54,62,73].

## PATENTS

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- “Method for ensuring privacy while querying a database by using quantum superposition and multiple responses”. US Patent 8126830 B2. Filed on June 24, 2008, serial number 12/145,050. Internationally (PCT) filed on July 2, 2008, serial number PCT/US08/68995. [Provisional patent filed on July 3, 2007, serial number 60/947,720.]
- “Bucket Brigade Address Decoding Architecture for Classical and Quantum Random Access Memories”. US Patent 7764568. Internationally (PCT) filed on July 2, 2008, serial number PCT/US08/68993. [Provisional patent filed on July 3, 2007, serial number 60/947,719.]

## PUBLICATIONS

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1. G. M. D’Ariano, C. Macchiavello, L. Maccone, “*Noise, errors and information in quantum amplification*”, Int. J. Mod. Phys. B **11**, 3385 (1997).
2. G. M. D’Ariano and L. Maccone, “*Quantum Tomography of Optical Devices*”, in *5th International Conference on Squeezed States and Uncertainty Relations*, ed. by J. Janszky, Y. S. Kim, and V. I. Man’ko, p. 529 (1997).
3. G. M. D’Ariano, L. Maccone, “*Measuring Quantum Optical Hamiltonians*”, Phys. Rev. Lett. **80**, 5465 (1998).
4. G. M. D’Ariano and L. Maccone, “*Quantum characterization of optical devices*”, Fortschr. Phys. **46**, 6 (1998).
5. G. M. D’Ariano, C. Macchiavello, and L. Maccone, “*Quantum tomography of mesoscopic superpositions of radiation states*”, Phys. Rev. A **59**, 1816 (1999).
6. G. M. D’Ariano, P. Kumar, C. Macchiavello, L. Maccone, and N. Sterpi, “*A Test of the State Reduction Rule*”, Phys. Rev. Lett. **83**, 2490 (1999).
7. G. M. D’Ariano, A. Garuccio, L. Maccone, and M. F. Sacchi, “*Tomographic test of Bell’s inequality*”, J. Opt. B, **1**, 576 (1999).
8. G. M. D’Ariano, L. Maccone, M. G. A. Paris and M. F. Sacchi, “*Generation and measurement of nonclassical states by quantum Fock filter*”, Acta Phys. Slov. **49**, 659 (1999).
9. G. M. D’Ariano, C. Macchiavello, and L. Maccone, “*Quantum Computation with Polarized Photons*”, Fortschr. Phys. **48**, 573 (2000).

10. G. M. D'Ariano, L. Maccone, M. F. Sacchi and A. Garuccio, "*Homodyning Bell's inequality*", in '4<sup>th</sup> Int. Conf. on Quantum Communication, Measurement, and Computing', Kluwer/Plenum, pg. 163 (2000).
11. G. M. D'Ariano, L. Maccone, M. G. A. Paris and M. F. Sacchi, "*State preparation by photon filtering*", Fortschr. Phys. **48**, 671 (2000).
12. G. M. D'Ariano, L. Maccone, M. G. A. Paris, and M. F. Sacchi, "*Optical Fock-state synthesizer*", Phys. Rev. A, **61**, 053817 (2000).
13. G. M. D'Ariano, L. Maccone, M. G. A. Paris and M. F. Sacchi, "*State measurement by photon filtering in a ring cavity*", Mod. Phys. Lett. B **14**, 15 (2000).
14. G. M. D'Ariano, L. Maccone and M. G. A. Paris, "*Orthogonality relations in Quantum Tomography*", Phys. Lett. A **276**, 25 (2000).
15. G. M. D'Ariano, L. Maccone, M. G. A. Paris "*Quorum of observables for universal quantum estimation*", Journ. of Phys. A **34**, 93 (2001).
16. G. M. D'Ariano, E. De Vito, and L. Maccone, "*SU(1,1) tomography*", Phys. Rev. A **64**, 033805 (2001).
17. V. Giovannetti, S. Lloyd, and L. Maccone, "*Quantum-enhanced positioning and clock synchronization*", Nature **412**, 417 (2001).
18. V. Giovannetti, S. Lloyd, L. Maccone, and F. N. C. Wong, "*Clock synchronization with dispersion cancellation*", Phys. Rev. Lett. **87**, 117902 (2001).
19. V. Giovannetti, S. Lloyd, and L. Maccone, "*Positioning and clock synchronization through entanglement*", Phys. Rev. A **65**, 022309 (2002).
20. V. Giovannetti, L. Maccone, J. H. Shapiro, and F. N. C. Wong, "*Generating entangled two-photon states with coincident frequencies*", Phys. Rev. Lett. **88**, 183602 (2002).
21. V. Giovannetti, S. Lloyd, L. Maccone, and S. M. Shahriar, "*Limits to clock synchronization induced by completely dephasing communication channels*", Phys. Rev. A **65**, 062319 (2002).
22. V. Giovannetti, S. Lloyd, and L. Maccone, "*Quantum cryptographic ranging*", J. Opt. B: Quantum Semiclass. Opt. **4**, S413 (2002).
23. V. Giovannetti, S. Lloyd, L. Maccone, and F. N. C. Wong, "*Clock synchronization and dispersion*", J. Opt. B: Quantum Semiclass. Opt. **4**, S415, (2002).
24. V. Giovannetti, L. Maccone, J. H. Shapiro, and F. N. C. Wong, "*Extended phase-matching conditions for improved entanglement generation*", Phys. Rev. A **66**, 043813 (2002).
25. G. M. D'Ariano, L. Maccone, M. Painsi, "*Spin tomography*", J. Opt. B: Quantum Semiclass. Opt. **5**, 77 (2003).

26. V. Giovannetti, S. Lloyd, and L. Maccone, “*The quantum speed limit*” in ‘Fluctuations and Noise in Photonics and Quantum Optics’, edited by D. Abbott, J. H. Shapiro, and Y. Yamamoto, proc. of the SPIE, **5111**, 1 (2003).
27. V. Giovannetti, S. Lloyd, and L. Maccone, “*Quantum limits to dynamical evolution*”, Phys. Rev. A **67**, 052109 (2003).
28. V. Giovannetti, S. Lloyd, and L. Maccone, “*The role of entanglement in dynamical evolution*”, Europhys. Lett. **62**, 615 (2003).
29. V. Giovannetti, S. Lloyd, L. Maccone, and P. Shor, “*Entanglement assisted capacity of the broadband lossy channel*”, Phys. Rev. Lett. **91**, 047901 (2003).
30. V. Giovannetti, L. Maccone, J. H. Shapiro, and F. N. C. Wong, “*Maximal entanglement generation via pulsed parametric downconversion*”, in *6<sup>th</sup> International Conference on Quantum Communication Measurement and Computing*, (Rinton Press, Princeton NJ, 2003), pg. 163.
31. V. Giovannetti, S. Lloyd, L. Maccone, and P. Shor, “*Broadband channel capacities*”, Phys. Rev. A **68**, 062323 (2003).
32. V. Giovannetti, S. Guha, S. Lloyd, L. Maccone, J. H. Shapiro, and H. P. Yuen, “*Classical Capacity of the lossy bosonic channel: the exact solution*”, Phys. Rev. Lett. **92**, 027902 (2004).
33. V. Giovannetti, S. Lloyd, and L. Maccone, “*Quantum positioning system*”, in *Coherence and Quantum Optics VIII* pg. 303, Proceedings of the 8<sup>th</sup> Rochester Conference, ed. N. P. Bigelow, J. H. Eberly, C. R. Stroud, and I. A. Walmsley (Kluwer Academic, New York, 2003).
34. V. Giovannetti, S. Lloyd, and L. Maccone, “*The speed limit of quantum unitary evolution*”, “Special Issue on Fluctuations & Noise in Photonics & Quantum Optics” of J. Opt. B: Quantum Semiclass. Opt. **6**, S807 (2004) (Hermann Haus memorial special issue).
35. V. Giovannetti, S. Lloyd, L. Maccone, and J. H. Shapiro, “*Information rate of a waveguide*”, Phys. Rev. A **69**, 052310 (2004).
36. V. Giovannetti, S. Guha, S. Lloyd, L. Maccone, and J. H. Shapiro, “*Minimum output entropy of bosonic channels: a conjecture*”, Phys. Rev. A **70**, 032315 (2004).
37. V. Giovannetti, S. Lloyd, L. Maccone, J. H. Shapiro, and B. J. Yen, “*Minimal Rényi and Wehrl entropies at the output of bosonic channels*”, Phys. Rev. A **70**, 022328 (2004).
38. V. Giovannetti, S. Lloyd, and L. Maccone, “*Capacity of nonlinear bosonic systems*”, Phys. Rev. A **70**, 012307 (2004).
39. S. Lloyd, V. Giovannetti, and L. Maccone, “*Physical limits to communication*”, Phys. Rev. Lett. **93**, 100501 (2004).

40. V. Giovannetti, S. Lloyd, L. Maccone, J. H. Shapiro, and F. Wong, “*Conveyor belt clock synchronization*”, Phys. Rev. A **70**, 043808 (2004).
41. V. Giovannetti, S. Lloyd, and L. Maccone, “*Quantum-enhanced measurements: beating the standard quantum limit*”, Science **306**, 1330 (2004).
42. V. Giovannetti, S. Guha, S. Lloyd, L. Maccone, J. H. Shapiro, and B. J. Yen, “*Minimum output entropy of a gaussian bosonic channel*” proceedings of FQI04, International Journal of Quantum Information **3**, No. 1, 153-158 (2005).
43. G. M. D’Ariano, P. Lo Presti, and L. Maccone, “*Quantum Calibration of measurement instrumentation*”, Phys. Rev. Lett. **93**, 250407 (2004).
44. V. Giovannetti, S. Guha, S. Lloyd, L. Maccone, J. H. Shapiro, B. J. Yen, and H. P. Yuen, “*Classical Capacity of Free-Space Optical Communication*”, in *Quantum Information, Statistics, Probability, dedicated to A. S. Holevo on the occasion of his 60<sup>th</sup> birthday*, edited by O. Hirota (Rinton Press, 2004), pg. 90. Published also as Quantum Information and Computation, **4**, 489 (2005).
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46. G. M. D’Ariano, L. Maccone, “*Quantum Tomography for Imaging*”, Electronic Notes in Discrete Mathematics, **20**, 133 (2005), Proceedings of the Workshop on Discrete Tomography and its Applications 13-15 June 2005 Ed. G. T. Herman; A. Kuba.
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49. V. Giovannetti, S. Guha, S. Lloyd, L. Maccone, J. H. Shapiro, and B. J. Yen, “*Minimum bosonic channel output entropies*”, S. M. Barnett, E. Anderson, J. Jeffers, P. Öhberg, and O. Hirota, eds., *Proceedings of the Seventh International Conference on Quantum Communication, Measurement and Computing* (American Institute of Physics, New York, 2004), pg. 21.
50. S. Mancini, L. Maccone, “*Using Quantum Mechanics to Cope with Liars*”, Int. J. Quantum Inf. **3**, 729 (2005).

51. V. Giovannetti, S. Lloyd, L. Maccone, “*Quantum metrology*”, Phys. Rev. Lett. **96**, 010401 (2006). [This paper was highlighted in Nature’s “News and Views”: S. L. Braunstein, Nature **440**, 617 (2006), which is dedicated to our paper.]
52. L. Maccone, “*Information-disturbance tradeoff in quantum measurements*”, Phys. Rev. A **73**, 042307 (2006).
53. V. Giovannetti, S. Lloyd, and L. Maccone, “*Interferometric tunability of the absorption*”, Opt. Express **14**, 8622 (2006).
54. S. Mancini, L. Maccone, “*Una strategia per Geppetto*”, italian didactic version of [50], Sapere October 2006, pg. 78 (2006).
55. M. Razavi, V. Giovannetti, L. Maccone, and J. H. Shapiro, “*Hot-cavity loading: A Heisenberg-Langevin analysis*”, in *Quantum Electronics and Laser Science Conference, Technical Digest:QFA7*, Long Beach, CA, (2006).
56. L. Maccone, “*Entropic information-disturbance tradeoff*”, Europhys. Lett. **77**, 40002 (2007).
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58. L. Maccone, “*A quantification of disturbance*”, in *Foundations of Probability and Physics-4*, Eds. G. Adenier, C. A. Fuchs, A. Yu. Khrenikov (AIP Conference Proceedings, Melville NY, 2007).
59. V. Giovannetti, S. Lloyd, L. Maccone, “*Quantum random access memory*”, Phys. Rev. Lett. **100**, 160501 (2008). New Scientist news service reviewed this article (even before it was published) in Stephen Battersby, NewScientist.com news service, <http://technology.newscientist.com/article/dn12516-blueprints-drawn-up-for-quantum-computer-ram.html> This preprint also made slashdot.org on August 23 (2007).
60. S. Tan, B. I. Erkmen, V. Giovannetti, S. Guha, S. Lloyd, L. Maccone, and J. H. Shapiro, “*Quantum Illumination: Enhanced Background-Limited Target Detection by Means of Entanglement*,” in *International Conference on Quantum Information*, paper QTuB6, (Optical Society of America, 2008).
61. V. Giovannetti, S. Lloyd, L. Maccone, “*Quantum private queries*”, Phys. Rev. Lett. **100**, 230502 (2008). An article on Scientific American (October 2009) was devoted to the results presented here. This paper was reviewed by physorg.com scientific news service on June 27, 2008: <http://www.physorg.com/news133765318.html>
62. L. Maccone and L. Salasnich, “*Fisica moderna: Meccanica Quantistica, Caos e Sistemi Complessi*”, (i.e. “*Modern Physics: Quantum Mechanics, Chaos and Complex Systems*”) Italian textbook, Carocci Ed., ISBN 978-88-430-4725-3 (2008).
63. V. Giovannetti, S. Lloyd, L. Maccone, “*Architectures for a quantum random access memory*”, Phys. Rev. A **78**, 052310 (2008).

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65. L. Maccone, G. De Cillis, “*Robust strategies for lossy quantum interferometry*”, Phys. Rev. A **79**, 023812 (2009).
66. V. Giovannetti, S. Lloyd, L. Maccone, J. H. Shapiro, “*Sub-Rayleigh-diffraction-bound quantum imaging*”, Phys. Rev. A **79**, 013827 (2009).
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68. L. Maccone, “*A quantum solution to the arrow-of-time dilemma*”, Phys. Rev. Lett. **103**, 080401 (2009).
69. V. Giovannetti, S. Lloyd, L. Maccone, “*Quantum Private Queries: security analysis*”, IEEE Trans. Inf. Theory **56**, 3465 (2010).
70. V. Giovannetti, A. S. Holevo, S. Lloyd, L. Maccone, “*Generalized minimal output entropy conjecture for Gaussian channels: definitions and some exact results*”, J. Phys. A: Math. Theor. **43**, 415305 (2010).
71. F. Guerrieri, L. Maccone, F. N. C. Wong, J. H. Shapiro, S. Tisa, and F. Zappa, “*Sub-Rayleigh Imaging via N-Photon Detection*”, Phys. Rev. Lett. **105**, 163602 (2010).
72. S.Lloyd, L.Maccone, R.Garcia-Patron, V.Giovannetti, Y.Shikano, S.Pirandola, L.A. Rozema, A.Darabi, Y.Soudagar, L.K.Shalm, A.M.Steinberg, “*Closed timelike curves via postselection: theory and experimental test of consistency*”, Phys. Rev. Lett. **106**, 040403 (2011).
73. L. Maccone, “*Il Gatto di Schrödinger*” (a didactic explanation of the Schrödinger’s cat paradox, analyzed from a modern perspective), Atti dell’Accademia degli Agiati, anno 260, ser. VIII, Vol. 10B, pg.19 (2011).
74. L.Maccone, “*The Thermodynamic Arrow-of-time and Quantum Mechanics*”, Electronic Notes in Theoretical Computer Science **270**, 75-79 (2011) [Proceedings of the Joint 5th International Workshop on Quantum Physics and Logic and 4th Workshop on Developments in Computational Models (QPL/DCM 2008)].
75. V.Giovannetti, S.Lloyd, L.Maccone, “*Advances in Quantum Metrology*”, Nature Phot. **5**, 222 (2011).
76. L.Maccone, V.Giovannetti, “*Beauty and the noisy beast*”, Nature Phys. **7**, 376 (2011).
77. V.Giovannetti, S.Lloyd, L.Maccone, “*Sequential projective measurements for channel decoding*”, Phys. Rev. Lett. **106**, 250501 (2011).

78. V.Giovannetti, S.Lloyd, L.Maccone, “*Achieving the Holevo bound via sequential measurements*”, Phys. Rev. A **85**, 012302 (2012).
79. S. Lloyd, L. Maccone, R. Garcia-Patron, V. Giovannetti, Y. Shikano, “*The quantum mechanics of time travel through post-selected teleportation*”, Phys. Rev. D **84**, 025007 (2011).

— Papers in progress (NOT YET PUBLISHED): —

80. S.Lloyd, L.Maccone, R.Garcia-Patron, V.Giovannetti, Y.Shikano, S.Pirandola, L.A. Rozema, A.Darabi, Y.Soudagar, L.K.Shalm, A.M.Steinberg, “*A reply to ”Problems with modelling closed timelike curves as post-selected teleportation”*”, arXiv:1108.0153 (2011).
81. S. Lloyd, V. Giovannetti, L. Maccone, N.J. Cerf, S. Guha, R. Garcia-Patron, S. Mitter, S. Pirandola, M.B. Ruskai, J.H. Shapiro, H. Yuan, “*The bosonic minimum output entropy conjecture and Lagrangian minimization*”, arXiv:0906.2758 [quant-ph] (2009).
82. G. Chiribella, V. Giovannetti, L. Maccone, P. Perinotti, “*Teleportation can only transfer speakable quantum information*”, arXiv:1008.0967 (2010).
83. V. Giovannetti, S. Lloyd, L. Maccone, “*Quantum internet routers*”, in progress (2009).
84. V. Giovannetti, S. Lloyd, L. Maccone, “*Sub-Rayleigh Ghost Imaging*”, in progress (2009).
85. V. Giovannetti, S. Lloyd, L. Maccone, and J. H. Shapiro, “*Improved resolution in imaging through quantum post-selection*” (*Paper P1-1*), proceedings for the QCM&C 2008 conference.
86. F. Guerrieri, L. Maccone, F. N. C. Wong, J. H. Shapiro, S. Tisa, F. Zappa, “*Imaging Beyond the Rayleigh Bound*” (*Paper MON-6*), proceedings for the QCM&C 2010 conference (Brisbane, Australia).

SEMINARS, CONFERENCES AND WORKSHOPS

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International scientific conferences with presentation of research in oral or poster form:

- 2012: First NASA Quantum Future Technologies Conference (Mountain View, CA, USA, Jan 17-21) (**invited oral presentation**).
- 2011: Seminar at INRIM (Torino, May 12) (**invited oral presentation**); *Difficult Problems in Quantum Information Theory (2011 xQIT conference)* (Cambridge MA, May 3-4) **invited oral presentation**; PhD cycle of lectures on quantum information and computation (Padova, Italy, April-May) (**invited oral presentation**); International Conference on Quantum Optics and Quantum Computing ICQOQC11 (Noida, India, March 22-26) (**invited oral presentation**); Los Alamos National Laboratory, quantum lunch seminar series (Los Alamos, NM, January 27) (**invited oral presentation**).

- 2010: Quantum Coherence and Decoherence workshop (Benasque, Spain, September 6-17) (**oral presentation**); CQuIC Seminar at UNM (Albuquerque, September 2) (**invited oral presentation**); PIQuDos seminar at the Perimeter Institute for Theoretical Physics (Waterloo, Canada, April 28) (**invited oral presentation**); BBN Technologies Corporation (Cambridge, MA, April 20) (**invited oral presentation**); Chalmers University of Technology, Linnaeus Colloquium (Göteborg, Sweden, March 4) (**invited oral presentation**); Nagoya Winter Workshop on Quantum Information, Measurement, and Foundations (Nagoya, Japan, February 18-24) (**invited oral presentation**); Los Alamos National Laboratory, quantum lunch seminar series (Los Alamos, NM, February 3) (**invited oral presentation**).
- 2009: Amherst College Physics Colloquium (Amherst, MA, December 3) (**invited oral presentation**); Aspuru-Guzik Group meeting seminar, Harvard university (Cambridge, MA, October 14) (**invited oral presentation**); Seminar at IFISC (Palma de Mallorca, Spain, October 1) (**invited oral presentation**); *Intern. Conf. on Quantum Information Processing and Communication (QIPC09)* (Roma, September 21-25); *Quantum Information Benasque workshop* (Benasque, Spain, June 7-17); *Central European Workshop on Quantum Optics 2009 (CEWQO09)* (Turku, Finland, May 23-26) (**oral presentation**); Seminar at ETH in the group of Stefan Wolf, Zürich (Zürich, Switzerland, May 19) (**invited oral presentation**); *Quantum Information and Many body Quantum Systems, QUROPE09 International school* (Cortona, Italy, May 3-8) (**oral presentation**); Seminar at INRIM (Torino, April 2) (**invited oral presentation**); Seminar at Scuola Normale Superiore (Pisa, April 16) (**invited oral presentation**).
- 2008: three weeks invitation at the Massachusetts Institute of Technology for a research project (Cambridge MA, January 6-February 1); *IV workshop ad memoriam of Carlo Novero Advances in Foundations of QM and QI with atoms and photons* (Torino, May 19-23) (**oral presentation**); *Quantum Information and Control In Queensland QICIQ and Asia Pacific Conference on Quantum Information Science, APCQIS* (Cairns, Australia, June 30 - July 5) (**oral presentation**); *Joint 5th QPL and 4th DCM Workshops: Quantum Physics and Logic*, satellite workshop of ICALP2008 (Reykjavik, Iceland, July 12-13) (**oral presentation**); *Quantum Communication Measurement and Computing (QCMC) 2008* (Calgary, August, 19-24); *Italian Quantum Information Science Conference 2008 (IQIS08)* (Camerino, October, 24-29) (**oral presentation**); *Difficult Problems in Quantum Information Theory (2008 xQIT conference)* (Cambridge MA, November 19-20) (**invited oral presentation**); *Theorie Kolloquium at the ITP* (Innsbruck, December 3) (**invited oral presentation**).
- 2007: three weeks invitation at the Massachusetts Institute of Technology for a research project (Cambridge MA, January 7-February 2); *Quantum Information and Many-Body Quantum Systems* (Pisa, March 26-31) (**oral presentation**); *first Quantumbionet Workshop* (Pavia University, May 25) (**invited oral presentation**); *Vienna Symposium on the Foundations of Modern Physics* (Vienna, Austria, June 7-10); *Quantum Information Benasque workshop* (Benasque, Spain, June 11-20); *Photons, Atoms and Qubits 2007 - PAQ07* (Royal Society, London, United Kingdom, September 2-5); *International Iran Conference on Quantum Information - IICQI* (Kish, Iran, September 7-10) (**invited oral presentation**).

- tation**); *Noise Information & Complexity @ Quantum Scale* (Centro Ettore Majorana, Erice, Italy, November 4-10) (**oral presentation**).
- 2006: *Advances in Foundations of Quantum Mechanics and Quantum Information with atoms and photons*, (Torino, May 2-5) (**oral presentation**); *XI International Conference on Quantum Optics ICQO'2006*, (Minsk, Belarus, May 26-31) (**invited oral presentation**); *Foundations of Probability and Physics-4* (Växjö, Sweden, June 4-9) (**oral presentation**); *QUPREST 2006, Focus meeting: quantum process estimation*, (Budmerice, Slovakia, September 27–October 1) (**invited oral presentation**); *QCM&C 2006* (Tsukuba, Japan, November 28– December 3); Quantum information seminar in Hiroshima (Hiroshima University, December 8) (**invited oral presentation**).
- 2005: *Frisno8, 8th French-Israeli symposium on nonlinear optics* (Ein Bokek, Israel, February 20-25) (**oral presentation**); *Quantum Information Benasque workshop* (Benasque, Spain, June 12-25); *Seminari di Quantum Information* (Milano, October 28) (**invited oral presentation**).
- 2004: *International DFG Workshop on Quantum Entanglement - from Error Correction to Secure Key Distribution* (Hirschegg, Austria, March 30 - April 2) (**invited oral presentation**); *Foundations of Quantum Information* (Camerino, April 16-19); 2nd Workshop ad memoriam of Carlo Novero “Advances in Foundations of Quantum Mechanics and Quantum Information with atoms and photons” (Torino, April 26); *X International Conference on Quantum Optics* (Minsk, Belarus, May 30-June 3) (**invited oral presentation**); *5th European QIPC Workshop* (Roma, September 20-22); *Mini workshop on Quantum Open Systems* (Pavia, Italy, October 25-26). Cambridge, Pisa.
- 2003: *Advances in Quantum Information Processing: from theory to experiment* (Erice, Italy, March 15-22); *8<sup>th</sup> International Conference on Squeezed States and Uncertainty Relations* (Puebla, Mexico, June 9-13); *Third annual MIT/NU MURI workshop* (Cambridge MA, USA, July 10-11); *QIT-EQIS ERATO conference on quantum information science* (Kyoto, Japan, September 2-6) (**oral presentation**); *3<sup>rd</sup> Annual MIT-Cambridge Quantum Information Workshop* (Cambridge MA, USA, October 2-3).
- 2002: *Quantum Information Quantum Entanglement – Euroconference* (San Feliu de Guixols, Spain, March 23-28); *Second annual MIT/NU MURI workshop* (Northwestern University, Evanston IL, USA, 11 April); *IX international conference on quantum optics 2002* (Raubichi, Belarus, May 14-17) (**invited oral presentation**); *II Cambridge-MIT Quantum Information Workshop* (Cambridge, UK, June 13-14) (**oral presentation**); *Progress in Electromagnetics Research Symposium: Quantum computation session* (Cambridge MA, USA, July 5); *QCM&C 2002* (Cambridge MA, USA, July 22-26); *MIT/NU MURI review workshop* (Cambridge MA, USA, October 23); *NASA-DoD workshop on quantum Imaging and Metrology* (Pasadena CA, USA November 14-15) (**invited oral presentation**).
- 2001: *7th International Conference on Squeezed States and Uncertainty Relations ICSSUR2001* (Boston MA USA, June 4-8); *CQO8: 8<sup>th</sup> Rochester Conference on Coherence & Quantum Optics* and *ICQI2001: International Conference on Quantum Information* (Rochester NY

USA, June 10-16) (**oral presentation**); *Mysteries, Puzzles and Paradoxes in Quantum Mechanics* (Gargnano Italy, August 27-September 1); *Quantum Optics – EuroConference* (San Feliu de Guixols, Spain, October 06-11).

2000: *Seventh central-european workshop on quantum optics* (Balatonfured Hungary, April 28 - May 1); *QCM&C Y2K* (Capri Italy, 3-8 July); *Mysteries, puzzles and paradoxes in Quantum Mechanics* (Gargnano Italy, September 17-23); *Quantum Optics XI – EuroConference* (Palma Spain, October 14-19).

1999: *III Adriatico research conference on quantum interferometry* (Trieste Italy, March 1-5); *Fundamental Problems in Quantum Theory Workshop* (Baltimore MD USA, August 9-13).

1997: *II Working Party on Quantum Optics and Quantum Computation* (at the Scuola Normale di Pisa, Pisa, June 26-28); *LXXXIII congresso nazionale Società Italiana di Fisica, Congresso del Centenario* (Villa Olmo Como Italy, October 27-31).