

Alioscia Hamma

- CONTACT INFORMATION** **Perimeter Institute for Theoretical Physics**
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Waterloo, ON N2L 2Y5 Canada
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ahamma@perimeterinstitute.ca
- WHO AM I** I am a quantum physicist whose main interest is the understanding of the quantum behavior of many-body systems. I am interested in showing how peculiar characteristics of quantum theory explain the observable behavior of many-body quantum systems. In particular, I am interested in the theory of topological and quantum orders, non equilibrium dynamics, and the emergence of gauge fields, symmetries and particles. My activity lies in between the fields of Theoretical Condensed Matter, Quantum Information Theory, and Mathematical Physics.
- RESEARCH INTERESTS** Topics of research I have been particularly interested in are quantum phase transitions, theory of entanglement, topological quantum computing, quantum information in open systems, theory of quantum and topological orders and novel quantum materials, emergent quantum gravity from many-body theory, quantum statistical mechanics, integrability and exact solvability, away from equilibrium dynamics, thermalization and equilibration.
- EDUCATION** **University of Napoli Federico II**, Naples, Italy
Ph.D., **Theoretical Physics**, January 2005
• Thesis Title: *Topological Order and Quantum Information Processing*
• Advisers: **Professor Giuseppe Marmo**, **Professor Paolo Zanardi**
• Qualification: *Excellent*
M.S., **Theoretical Physics**, November 2001
• Thesis Title: *Equivalent metrics and perturbations in General Relativity*
• Adviser: **Professor Giuseppe Marmo**
• Final Mark: 110/110 cum laude
- ACADEMIC APPOINTMENTS**
- **Distinguished Research Fellow** September 2008 to present
Perimeter Institute for Theoretical Physics
 - **Visiting Scientist** March 2008 to September 2008
Research Laboratory of Electronics at **Massachusetts Institute of Technology** ,
Cambridge MA
 - **Postdoctoral Fellow** December 2005 to December 2007
University of Southern California in **Daniel Lidar's group** , Los Angeles CA
 - **Research Associate** January 2005 to December 2005
Institute for Scientific Interchange in Quantum Information group , Turin, Italy
 - **Visiting Student** October 2003 to February 2004 and October 2004
Department of Mechanical Engineering at **Massachusetts Institute of Technology**
- EVIDENCE OF SCIENTIFIC IMPACT**
- *Citations:* according to a counting based on the **SAO/NASA ADS** database, my *h*-index is 13 with a number of total number of 439 citations. **Google Scholar** reports *h*-index 12.
 - *Physical Review's Editor's Suggestion:* the article Phys. Rev. B **79**, 245122 (2009); arXiv:0812.4622 was selected as Editors Suggestion in Phys. Rev. B

ACADEMIC SERVICE	<ul style="list-style-type: none"> • I have served in the postdoc hiring committee of the Perimeter Institute for Theoretical Physics. • Organizer of the Seminars in condensed matter theory at the Perimeter Institute for Theoretical Physics. • Member of the Library Committee at the Perimeter Institute • Member of the Arts and Culture Committee at the Perimeter Institute
AWARDS	Perimeter Institute, distinguished research fellowship 2009.
PROGRAMMING SKILLS	Mathematica, Matlab, LaTeX
TEACHING EXPERIENCE	<p>Sherbrooke University, Quebec, Canada</p> <ul style="list-style-type: none"> • <i>Four lectures on topological order</i> April 2009 <p>University of Southern California, Los Angeles, CA</p> <ul style="list-style-type: none"> • <i>Advanced Electromagnetism</i> October 2007 <p>Università di Napoli Federico II, Italy</p> <ul style="list-style-type: none"> • <i>Short course on Quantum entanglement</i> April 2005 • <i>Teaching Assistanship</i> May 2002 - May 2003
REFeree SERVICE	<ul style="list-style-type: none"> • <i>Physical Review Letters</i> • <i>Physical Review A</i> • <i>Physical Review B</i> • <i>Journal of Modern Optics</i> • <i>New Journal of Physics</i> • <i>Europhysics Letters</i> • <i>JSTAT</i>
STUDENTS MENTORED	<ul style="list-style-type: none"> • <i>Francesco Caravelli</i> 2009- current, Perimeter Institute • <i>Gabor Halasz</i> June 2010-September 2011, now at Oxford University • <i>Sebastian Montes Valencia</i> May 2011- current, Perimeter Institute • <i>Dalimil Mazac</i> June 2011- current, Perimeter Institute • <i>Juho Happola</i> June-August 2011 • <i>Damian Abasto</i> 2007, University of Southern California • <i>Wan Jung Kuo</i> 2007, University of Southern California

REFERENCES
AVAILABLE TO
CONTACT

Dr. Paolo Zanardi (e-mail: zanardi@usc.edu; Phone: +1 (213) 740- 4649)

- Professor, **Physics and Astronomy**
University of Southern California
- ◇ Seaver Science Center, USC 920 Bloom Walk, Los Angeles, CA 90089
- ★ *Dr. Zanardi was my PhD adviser.*

Dr. Daniel Lidar (e-mail: lidar@usc.edu; Phone: +1 (213) 740-0198)

- Professor, **Electrical Engineering**
University of Southern California
- ◇ Seaver Science Center, USC 920 Bloom Walk, Los Angeles, CA 90089
- ★ *Dr. Lidar hired me for my first Postdoc*

Dr. Seth Lloyd (e-mail: sloyd@mit.edu; Phone: +1 (617) 252 1803)

- Professor, **Mechanical Engineering**
Massachusetts Institute of Technology
- ◇ Room 3-160 77 Massachusetts Avenue Cambridge, MA 02139
- ★ *Dr. Lloyd hosted me at the Research Laboratory of Electronics at MIT in 2008*

Dr. Claudio Chamon (e-mail: chamon@bu.edu; Phone: +1 (617) 353 5787)

- Professor, **Physics**
Boston University
- ◇ 590 Commonwealth Avenue, Boston, MA 02215 USA

Dr. Stephan Haas (e-mail: shaas@usc.edu; Phone: +1 (213) 740-4528)

- Professor, **Physics**
University of Southern California
- ◇ Seaver Science Center, USC 920 Bloom Walk, Los Angeles, CA 90089
- ★ *Dr. Haas is a collaborator since my postdoc at USC*

Dr. Xiao-Gang Wen (e-mail: wen@dao.mit.edu; Phone: +1 (617) 253 5016)

- Professor, **Physics**
Massachusetts Institute of Technology
- ◇ 77 Massachusetts Ave. Cambridge, MA 02139
- ★ *Dr. Wen mentored my work when I was visiting student at MIT and is a current collaborator*

Dr. Fotini Markopoulou-Kalamara (e-mail: fmarkopoulou@perimeterinstitute.ca;
Phone: +1 (519) 569 7600 ext 8631)

- Faculty, **Perimeter Institute for Theoretical Physics**
- ◇ 31 Caroline St. N. Waterloo Ontario, Canada N2L 2Y5

CONFERENCE
ORGANIZATION

I was the chair of the organizing committee for the workshop held in dates May 25-29 2010 at the Perimeter Institute, with title **Emergence and Entanglement**. The abstract for the workshop is the following:

In recent years, there has been considerable interest in quantum systems which show novel behaviour of the whole system emerging from the collective behaviour and interaction of the constituent local degrees of freedom. The novel phenomena include fractional quantum number, fractional statistics, topologically protected gapless bulk/edge excitations, etc. It appears that the long-range quantum entanglement in those systems plays a critical role in generating those novel phenomena. The goal of this workshop is the study of the emergent and entanglement properties of quantum many-body systems. Possible topics of the workshop will be the emergence of gauge fields, fractionalized particles and symmetries as low energy properties of condensed matter systems, the study of entanglement in many body systems and its relationships with novel quantum phase transitions, the study of the AdS/CFT correspondence to understand properties

of systems of strongly interacting fermions, the study of topological order, topological insulators, and quantum spin liquids.

Organizers:

- Alioscia Hamma (Chair)
- Hector Bombin
- Daniel Gottesman
- Subir Sachdev
- Neil Turok

Invited Speakers:

- Ian Affleck, University of British Columbia
- Sougato Bose, University College of London
- Claudio Chamon, Boston University
- Xie Chen, Massachusetts Institute of Technology
- Ignacio Cirac, Max Planck Institute
- Jens Eisert, University of Potsdam
- Paul Fendley, University of Virginia
- Matthew Fisher, California Institute of Technology
- Eduardo Fradkin, University of Illinois at Urbana-Champaign
- Michel Gingras, University of Waterloo
- Taylor Hughes, University of Illinois at Urbana-Champaign
- Shamit Kachru, KITP/Stanford
- Andreas Karch, University of Washington
- Yong Baek Kim, University of Toronto
- Israel Klich, University of Virginia
- Karyn Le Hur, Yale University
- Sung-Sik Lee, McMaster University
- Anthony Leggett, University of Illinois at Urbana-Champaign
- John McGreevy, Massachusetts Institute of Technology
- Roger Melko, University of Waterloo
- Max Metlitski, Harvard University
- Chetan Nayak, Microsoft Station Q and University of California, Santa Barbara
- Gil Refael, California Institute of Technology
- Subir Sachdev, Harvard University
- Omid Saremi, McGill University

- Barbara Terhal, IBM
- Frank Verstraete, Universitat Wien
- Guifre Vidal, University of Queensland
- Xiao-Gang Wen, Massachusetts Institute of Technology
- Cenke Xu, Harvard University
- Paolo Zanardi, University of Southern California

All the talks can be viewed online at PIRSA: <http://pirsa.org/C10012/3>

PUBLICATIONS

1. A.H., S. Santra, and P. Zanardi
Quantum entanglement in random physical states
<http://arxiv.org/abs/1109.4391>
2. Francesco Caravelli, A.H., Fotini Markopoulou, Arnau Riera
Trapped surfaces and emergent curved space in the Bose-Hubbard model
<http://arxiv.org/abs/1108.2013>
Citations: 3
3. Wonmin Son, Luigi Amico, Rosario Fazio, A.H., Saverio Pascazio, Vlatko Vedral
Quantum phase transition between cluster and antiferromagnetic states
Europhys. Lett. vol. **95**, 50001 (2011); <http://arxiv.org/abs/1103.0251>
Citations: 5
4. B. Tomasello, L. Amico, A.H., D. Rossini
Ground state factorization and correlations with broken symmetry
Europhys. Lett. vol. **96**, 27002 (2011); <http://arxiv.org/abs/1012.4270>
Citations: 7
5. A.H., Fotini Markopoulou
Background independent condensed matter models for quantum gravity
New Journal of Physics vol. **13**, 095006 (2011); <http://arxiv.org/abs/1011.5754>
Citations: 5
6. Juho Häppölä, Gábor B. Halász, A.H.
Revivals of a closed quantum system and Lieb-Robinson speed
<http://arxiv.org/abs/1011.0380>
Citations: 4
7. I. Prémont-Schwartz, A.H., I. Klich, F. Markopoulou-Kalamara
Lieb-Robinson bounds for commutator-bounded operators
Phys. Rev. A **81**, 040102(R) (2010); arXiv:0912.4544
Citations: 4
8. A.H, Fotini Markopoulou, Seth Lloyd, Francesco Caravelli, Simone Severini, Klas Markstrom
A quantum Bose-Hubbard model with evolving graph as toy model for emergent spacetime
Phys. Rev. D **81**, 104032 (2010); arXiv:0911.5075
Citations: 10
9. S. Flammia, A.H., T. Hughes, X.-G. Wen
Topological Entanglement Rényi Entropy and Reduced Density Matrix Structure
Phys. Rev. Lett. **103**, 261601 (2009); arxiv:0909.3305
Citations: 22

10. D.I. Tsomokos, A. H., W. Zhang, S. Haas, R. Fazio
Title: Topological Order Following a Quantum Quench
 Phys. Rev. A **80**, 060302(R) (2009); arXiv:0909.0752
Citations: 9
11. A.T. Rezakhani, W.-J. Kuo, A. H., D.A. Lidar, P. Zanardi
Quantum Adiabatic Brachistochrone
 Phys. Rev. Lett. **103**, 080502 (2009), arXiv:0905.2376
also selected for publication in Virtual Journal of Quantum Information
Citations: 22
12. A.H., D. A. Lidar, S. Severini
Entanglement and area law with a fractal boundary
 Phys. Rev. A **81**, 010102 (R) (2010) , arXiv:0903.4444
Citations: 0
13. A.H., C. Castelnovo, and C. Chamon
The toric-boson model: Toward a topological quantum memory at finite temperature
 Phys. Rev. B **79** (Physical Review Editors Suggestions), 245122 (2009); arXiv:0812.4622
also selected for publication in Virtual Journal of Quantum Information
Citations: 15
14. D. Lidar, A. Rezakhani, A.H.
Adiabatic approximation with better than exponential accuracy for many-body systems and quantum computation
 J. Math. Phys **50**, 102106 (2009); arXiv:0808.2697v2
also selected for publication in Virtual Journal of Quantum Information
Citations: 15
15. A.H, I. Prémont-Schwartz, S. Severini, F. Markopoulou-Kalamara
Lieb-Robinson Bounds and the speed of light from topological order
 Phys. Rev. Lett. **102** , 017204 (2009); arXiv:0808.2495v2
also selected for publication in Virtual Journal of Quantum Information
Citations: 16
16. G. Campagnano, A.H., U. Weiss
Decoherence and Entanglement Dynamics of Coupled Qubits
 Physics Letters A **374** (2010) pp. 416-423 (doi:10.1016/j.physleta.2009.10.081);
 arXiv:0807.1987v1
Citations: 3
17. A.H., T. Mansour and S. Severini
Diffusion on an Ising Chain with Kinks
 Physics Letters A **373**, 2622 (2009); arXiv:0806.4812v1
Citations: 0
18. M. Arzano, A.H., and S. Severini
Hidden entanglement at the Planck scale: loss of unitarity and the information paradox
 Modern Physics Letters A **25**, 437 (2010) arXiv:0806.2145v1
Citations: 9
19. D. Abasto, A.H. and P. Zanardi
Fidelity analysis of topological phase transitions
 Phys. Rev. A **78**, 010301(R), (2008); arXiv:0803.2243
also selected for publication in Virtual Journal of Quantum Information
Citations: 28

20. A.H., W. Zhang, S. Haas, D. Lidar
Entanglement, fidelity and topological entropy in a quantum phase transition to topological order
 Phys. Rev. B **77**, 155111 (2008); arXiv:0705.0026
also selected for publication in Virtual Journal of Quantum Information
Citations: 42
21. A.H., D. Lidar
Adiabatic Preparation of Topological Order
 Phys. Rev. Lett. **100**, 030502 (2008); quant-ph/060714v3
also selected for publication in Virtual Journal of Quantum Information
Citations: 27
22. A.H.
Berry Phases and Quantum Phase Transitions
 quant-ph/0602091
Citations: 34
23. A.H., R. Ionicioiu, P. Zanardi
Quantum entanglement in states generated by bilocal group algebras
 Phys. Rev. A **72**, 012324 (2005); quant-ph/0504049.
also selected for publication in Virtual Journal of Quantum Information
Citations: 14
24. A.H., P. Zanardi, X.-G. Wen
String and Membrane condensation on 3D lattices
 Phys. Rev. B **72**, 035307 (2005); cond-mat/0411752.
Citations: 19
25. A.H., R. Ionicioiu, P. Zanardi
Bipartite entanglement and entropic boundary law in lattice spin systems
 Phys. Rev. A **71**, 022315 (2005); quant-ph/0409073.
also selected for publication in Virtual Journal of Quantum Information
Citations: 62
26. A.H., R. Ionicioiu, P. Zanardi
Ground state entanglement and geometric entropy in the Kitaev's model
 Phys. Lett. A **337**, 22 (2005); quant-ph/0406202.
Citations: 51
27. A.H., P. Zanardi
Quantum entangling power of adiabatically connected Hamiltonians
 Phys. Rev. A **69**, 062319 (2004); quant-ph/0308131.
also selected for publication in Virtual Journal of Quantum Information
Citations: 6

CONFERENCE
PUBLICATIONS

1. A. Hamma
Topological order and entanglement
 Advances in Quantum Computation, Edited by Kazem Mahdavi and Deborah Koslover
 American Mathematical Society Contemporary Mathematics, Vol. 482 , p. 221-226 (2009)

2. R. Ionicioiu, A. Hamma, and P. Zanardi
Entanglement, area law and group theory
 Proceedings of the NATO Advanced Study Institute, Quantum Computation and
 Quantum Information, 2-13 May 2005 Chania, Crete, Greece

PAPERS IN
 PREPARATION

- D. Mazac, A.H.
Topological Entropy in the 4D toric code
- G. Halasz, J. Happola, A.H.
Exact results for the stability of topological entropy
- S. Montes Valencia, A.H.
Cluster phases in and out of equilibrium

INVITED TALKS

- November 7th 2001, Colloquium, Institute for Quantum Computing, Waterloo ON
 Canada
Quantum Entanglement in Random Physical States
- 26-28 October 2011 Invited speaker at Emergence and Effective Field Theories,
 Perimeter Institute for Theoretical Physics, Waterloo On Canada
Entanglement and the Emergence of Thermalization
- 18-21 October 2011 Invited speaker at Workshop on Quantum Information in Quantum
 Many-body Physics, Centre de Recherches Mathématiques, Montreal QC Canada
Entanglement in physical states
- 16-17 May 2011 Invited speaker at workshop *Topological Quantum Information*,
 Scuola Normale Superiore, Pisa, Italy
Topological order at finite temperature and the quest for quantum memory
- 9-11 March 2011 Invited speaker at International Conference on Frontier Topics in
 Nanostructures and Condensed Matter Theory, London Ontario, Canada
Topological order at finite temperature and the quest for quantum memory
- 5-10 June 2010 Invited speaker at Quantum Engineering of States and Devices:
 Theory and Experiments, Universitätszentrum Obergurgl, Obergurgl, Austria
Topological Renyi Entropy
- 06/05/2009 Invited speaker at Theory Canada 5, University of New Brunswick,
 Fredericton NB, Canada.
Quantum Adiabatic Brachistochrone
- 09/19/2008 Invited speaker at the conference GRAVTUM II, Amorgos, Greece
 September 15-20, 2008.
Quantum evolution of space and matter
- 08/25/2008 Invited speaker at conference on Emergent Gravity, Massachusetts Institute
 of Technology, Center for Theoretical Physics
Lieb-Robinson bounds and the speed of light from topological order
- 09/2007 Invited speaker at Conference on Representation Theory, Quantum Field
 Theory, Category Theory, Mathematical Physics and Quantum Information Theory,
 September 20 - 23, 2007, Tyler, TX
Topological order and entanglement

OTHER
PRESENTATIONS
AND TALKS

- May 2011 Scuola Normale Superiore di Pisa, Italy
Short course on topological order
- 04/2011 University of Illinois Urbana Champaign
Lieb-Robinson bounds and the structure of correlations in quantum many body systems
- 18/11/2010 Stony Brook, NY
Simons Conference on New Trends in Quantum Computation
Topological entanglement Renyi entropy and reduced density matrix structure
- 6/10/2010 Santa Fe Institute, Santa Fe NM
Revivals of a closed quantum system and Lieb-Robinson speed
- 29/09/2010 Boston University, MA
Revivals of a closed quantum system and Lieb-Robinson speed
- 11/03/2010 University of Toronto, Canada
Lieb-Robinson bounds and the structure of correlations in quantum many body systems
- 02/2010 Albert Einstein Institute -Potsdam, Germany
Short course about quantum phase transitions, entanglement, and topological order.
- 23/10/2009 Quantum Information and Condensed Matter Physics Seminars series at the University of Southern California
How sound can protect quantum memory: The Toric-Boson model
- 17/09/2009 University of Virginia
The Toric-Boson model and quantum memory at finite temperature
- 04/29/2009 Colloquium at Sherbrooke University, Quebec, Canada.
Topological Quantum Memory at Finite Temperature
- 12/16/2008 Università di Perugia, Italy.
Stable quantum memory at finite temperature
- 10/31/2008 Talk at Boston University.
Lieb-Robinson Bounds and The Speed of Light
- 12/19/2007 Contributed Talk at the First International Conference on Quantum Error Correction QEC07, USC Los Angeles CA
A new error estimate for Adiabatic Quantum Computation
- 11/13/2007 IQI, California Institute of Technology, Pasadena, CA
Topological entropy and the entanglement description of Topological Order
- 11/02/2007 USC Quantum Information and Condensed Matter Physics Seminars
Entanglement description of topological order
- 10/30/2007 UC Berkeley
Entanglement in topologically order
- 03/2007 Talk at APS March meeting, Denver USA
Quantum phase transition from magnetic to topological order
- 03/2007 Talk at APS March meeting, Denver USA
Adiabatic Preparation of Topological Order
- 03/2007 Talk at APS March meeting, Denver USA
Adiabaticity in Open Quantum Systems

- 11/2006: Lectures at Università di Napoli Federico II
Three lectures on Quantum phase transitions, lattice gauge theories, and quantum order
- 10/2006: Perimeter Institute, Waterloo, Canada
The transition from magnetic to topological order
- 9/2006: StationQ at university of Santa Barbara, USA.
Topological adiabatic quantum computation
- 9/2005: Max Planck Institute for Quantum Optics, Munich, Germany
String/Membrane condensed states and Topological Order
- 8/2005: Contributed talk at Quantum computing 2005, Algorithms, Physical Realizations and Beyond, Kinki University, Osaka, Japan
Topological order with membrane condensation
- 8/2005: Contributed talk at EQIS 2005, ERATO conference on Quantum Information Science, Tokyo, Japan
Group theoretic methods, entanglement, area law
- 7/2005: Università di Napoli Federico II
Group Theoretic Methods, Entanglement and Area Law
- 6/2005: University of Innsbruck, Institute for Theoretical Physics, quantum information group
Group Theoretic Methods, Entanglement and Area Law
- 5/2005: Workshop on: Quantum Measurements and operations for cryptography and information processing, University of Pavia, Italy
Bipartite entanglement and area law with group-theoretic methods
- 3/2005: TU Delft, Holland
Bipartite entanglement and area law
- 3/2005: University of Barcelona, Spain
Bipartite entanglement and entropic boundary law in lattice spin systems
- 11/2004: Perimeter Institute, Waterloo, Canada
Topological order, string/membrane condensation, and entanglement
- 06/2004: TOPQIP workshop, Institute for Scientific Interchange, Torino, Italy
Ground state entanglement in Kitaev's model
- 04/2004: Poster session XXIII Meeting of theoretical physics and structure of matter, Fai della Paganella, Italy
String and membrane condensation on 2D and 3D lattices
- 12/2003: Talk at MIT Quantum reading
Entangling Power in adiabatically connected hamiltonians