CURRICULUM VITAE
Dominique SPEHNER

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Born: 30/06/1971 in Besançon, France

Citizenship: French

Family Status: single

Education

1996-2000 Ph.D. in Theoretical Physics, Université Paul Sabatier, Toulouse, France
Title: *Contributions to the theory of dissipative electronic transport in aperiodic solids* (in French)
Thesis advisor: J. Bellissard

1994 "Diplôme d'Études Approfondies" (French equivalent of Master's degree) in Theoretical Physics, École Normale Supérieure, Lyon, France
3 month research project at the Centre de Physique Théorique, Marseilles, France
Title: *Non Commutative Geometry and interactions* (in French)

1992-1994 "Licence" (French equivalent of Bachelor's degree), "Maîtrise", and "Magistère" in Physics, Université Joseph Fourier, Grenoble, France
4 month training period in mathematical physics (*solution of the wave equation in the large wavelength limit*) at the State University of St. Petersburg, Russia

Employment

2/2005-present *Maître de Conférences* (tenure track position, corresponding in France to assistant professor) at the Université Joseph Fourier, Grenoble, France
Member of 2 institutes:
- Institut Fourier, Department of Mathematics (since 2005)
- Laboratoire de Physique et Modélisation des Milieux Condensés (LPMMC), Department of Physics (since 2013)

4/2001-1/2005 Research Associate,
Department of Physics
Universität Duisburg-Essen, Essen, Germany

4/2000-4/2001 Post-doctoral fellow,
Department of Physics
Pontificia Universidad Católica, Santiago, Chile

10/1996-9/1999 Doctoral fellow,
Institut de Recherche sur les Systèmes Atomiques et Moléculaires Complexes,
Université Paul Sabatier, Toulouse, France

1/1995-4/1996 "Service National de la Coopération" (Civil Service in place of the French Military Service),
Department of Physics
Technion Institute of Technology, Haifa, Israel

Research topics

- *Quantum Information*: geometric measures of quantum correlations; time evolution of entanglement in quantum systems coupled to their environment.
- *Bose-Einstein Condensates*: dynamics in Bose-Josephson junctions, macroscopic superpositions of spin coherent states, decoherence, and high precision atom interferometry.
- *Open Quantum Systems, Decoherence*: models for quantum measurements, quantum trajectories, Markovian and non-Markovian master equations, quantum Brownian motion.
- *Quantum Optics:* dynamics of photons interacting with a beam of atoms in cavity QED.
- *Transport in Solids, Stochastic processes*: random walks in a random environment, variable range hopping conduction in disordered solids in the Anderson localization regime, kinetic models for transport, quantum noises.
- *Quantum Chaos, Mesoscopic Physics*: semi-classical analysis of spectral fluctuations in quantum systems having a chaotic classical dynamics; semi-classical spectra and edge corrections to the Landau magnetic susceptibility in magnetic billiards.
- *Aperiodic Solids and Non-Commutative Geometry:* C*-algebra approach to describe electrons in disordered or quasi-periodic solids in the second quantization framework.

Habilitation thesis

2015 "Habilitation à Diriger des Recherches", Université Grenoble Alpes, France
Title: *Measurements, decoherence, and quantum correlations in composite quantum systems* (can be downloaded from my webpage).
Members of the jury: S. Attal, R. Balian, D. Braun, S. De Bièvre, B. Douçot, A. Joye, and F. Petruccione

Fellowships

2000	Post-doctoral fellow from the Fondecyt (Chile)
1997-1999	Doctoral fellow from the French Ministry of Education, Research, and Technology

Participation to funded research projects

2014-2016	Project from the Agence Nationale de la Recherche (ANR-13-JS01-0005-01) *"Mathematical methods for the N-body problem in statistical and quantum mechanics"*
2014-2016	AGIR project from the university Joseph Fourier, *"Random quantum walks and correlations"*
2013-2015	ARC 5 project from the Région Rhône-Alpes, *"Modelizing in classrooms: scientific and practical challenges"*
2009-2016	Corresponding member of the GDR *"Quantum Dynamics"*
2012-2013	PEPS project from the CNRS *"Many-body quantum mechanics and cold atoms"*
2009-2013	ANR project (ANR-09-BLAN-0098-01) *"Dynamics and statistical physics of open quantum systems"*
2009-2011	Math-AmSud project from the CNRS, INRIA (France), and Conicyt (Chile), associate researcher to the Anillo project *"Center of Stochastic Analysis and Applications"* from the Fondecyt (Chile)
2012	Project from the university Joseph Fourier, *"Quantum walks"*
2006-2008	ANR project (ANR-05-JCJC-0107-01) *"Resonances and decoherence in quantum chaos"*
1999-2003	Associate researcher to an Ecos-Conicyt project

Students

2008-2012	Advisor of the **Ph.D. thesis** of Sylvain Vogelsberger, doctoral fellow from the Ministry of Education, Research, and Technology (other advisor: Alain Joye) Ph.D. defense: June, 2012 at the Institut Fourier, Grenoble Title: *Dynamics of open quantum systems: decoherence and entanglement losses* (in French).
2013	Supervisor of the 2-month research training of Hodei Heneriz **(Master 1)** on *quantum state discrimination.*
2012	Supervisor of the 2-month research training of Alban Lafuente-Sampietro **(Licence 3)** on *quantum information.*
2008	Supervisor of the 4-month research training of Sylvain Vogelsberger **(Master 2)** on *decoherence and quantum information.*

Teaching experience

I have a broad teaching experience in both Mathematics and Theoretical Physics.

2005-present	**Lectures in Mathematics**, universities Joseph Fourier and Stendhal, Grenoble: *Functional Analysis*, *Numerical Analysis*, *Euclidean Geometry* (for teachers), *Distributions and Partial Differential Equations* (for physicists), *Computer-assisted mathematics* (with the use of the software xcas), *Reaction-diffusion processes* (jointly with a colleague from the Physics Department), *Maths for Geology* (jointly with a colleague from the Department of Earth Sciences), *Linear Algebra*, *Functions of several variables*, *Calculus and real functions* (1^{st} year), *Maths for grade school teachers.*
2005-present	**"Travaux dirigés"** (exercises) **in Mathematics**, université Joseph Fourier *Random Schrödinger operators*, *Probability and Stochastic processes* (4^{th} year), *Functional Analysis*, *Linear algebra.*
2011-2014	Member of a working group on educational issues in mathematics and physics in high school, IREM de Grenoble.
2001-2004	Teaching assistant in physics, Universität Duisburg-Essen, Germany **One-semester lecture** on *Quantum Information* **Exercises in** *Statistical Mechanics*, *Advanced Quantum Mechanics*, *Classical Hamiltonian and Lagrangian Mechanics.*
1997-1998	Teaching assistant, École Nationale Supérieure de l'Aéronautique et de l'Espace, Toulouse, France **"Travaux dirigés"**: *Fourier Analysis*, *Analytic Functions.*
1997	Teaching assistant, Université Paul Sabatier, Toulouse, France **"Travaux dirigés"** in *Probability (1^{st} year).*

Teaching material on my web page : http://www-fourier.ujf-grenoble.fr/~spehner/teaching.htm

List of publications

(1) W. Roga, D. Spehner, F. Illuminati, *Geometric measures of quantum correlations: characterization, quantification, and comparison by distances and operations*, J. Phys. A: Math. Theor. 49 issue 23 (2016), 235301 [Publisher's pick]

(2) D. Spehner, *Quantum correlations and Distinguishability of quantum states*, J. Math. Phys. 55 (2014), 075211 (review article, 96 pages)

(3) S.A. Reyes, L. Morales-Molina, M. Orszag, D. Spehner, *Harnessing gauge fields for maximally entangled state generation*, Eur. Phys. Lett. 108 (2014), 20010 (6 pages) [Editor's choice]

(4) D. Spehner, K. Pawlowski, G. Ferrini, A. Minguzzi, *Effect of one-, two-, and three-body atom loss processes on superpositions of phase states in Bose-Josephson junctions*, Eur. Phys. J. B 87 (2014), 157 (22 pages)

(5) D. Spehner, M. Orszag, *Geometric quantum discord with Bures distance: the qubit case*, J. Phys. A: Math. Theor. 47 (2014), 035302 (20 pages)

(6) D. Spehner, M. Orszag, *Geometric quantum discord with Bures distance*, New J. of Phys. 15 (2013), 103001 (18 pages)

(7) K. Pawlowski, D. Spehner, A. Minguzzi, G. Ferrini, *Macroscopic superpositions in Bose-Josephson junctions: Controlling decoherence due to atom losses*, Phys. Rev. A 88 (2013), 013606 (6 pages)

(8) W. De Roeck, D. Spehner, *Derivation of some translation-invariant Lindblad equations for a quantum Brownian particle*, J. Stat. Phys. 150 (2013), 320 (32 pages)

(9) S. Vogelsberger et D. Spehner, *Entanglement evolution for quantum trajectories*, J. Phys.: Conf. Series 306 (2011), 012029

(10) G. Ferrini, D. Spehner, A. Minguzzi, F.W.J. Hekking, *Effect of phase noise on quantum correlations in Bose-Josephson junctions*, Phys. Rev. A 84 (2011), 043628 (18 pages)

(11) S. Vogelsberger, D. Spehner, *Average entanglement for markovian quantum trajectories*, Phys. Rev. A 82 (2010), 052327 (7 pages)

(12) G. Ferrini, D. Spehner, A. Minguzzi, F.W.J. Hekking, *Noise in Bose-Josephson junctions: Decoherence and phase relaxation*, Phys. Rev. A 82 (2010), 033621 (5 pages)

(13) D. Spehner, F. Haake, *Quantum measurements without macroscopic superpositions*, Phys. Rev. A 77 (2008), 052114 (24 pages)

(14) D. Spehner, F. Haake, *Decoherence bypass of macroscopic superpositions in quantum measurement*, J. Phys. A: Math. Theor. 41 (2008), 072002 (9 pages) [Editor's choice]

(15) R. Rebolledo, D. Spehner, *Adiabatic limits and decoherence*, in: "Stochastic Analysis in Mathematical Physics, Proceedings of a Satellite Conference of ICM 2006 (Lisbon)", Eds. G. Ben Arous, A. B. Cruzeiro, Y. Le Jan, J.-C. Zambrini (World Scientific, 2008), 94-108

(16) D. Spehner, F. Haake, *Quantum measurements without Schrödinger cat states*, J. Phys.: Conf. Series 84 (2007), 012018 (21 pages)

(17) A. Faggionato, H. Schulz-Baldes, D. Spehner, *Mott law as lower bound for a random walk in a random environment*, Comm. Math. Phys. 263 (2006), 21-64

(18) M. Turek, D. Spehner, S. Müller, K. Richter, *Semiclassical form factor for spectral and matrix element fluctuations of multi-dimensional chaotic systems*, Phys. Rev. E 71 (2005), 016210 (15 pages)

(19) D. Spehner, *Spectral form factor of hyperbolic systems: leading off-diagonal approximation*, J. Phys. A: Math. Gen. 36 (2003), 7269-7290

(20) D. Spehner, M. Orszag, *Cavity QED: a quantum trajectory point of view*, Laser Physics 13 (2003), 634-643

(21) D. Spehner, M. Orszag, *Temperature-enhanced squeezing in cavity QED*, J. Opt. B: Quantum Semiclass. Opt. 4 (2002), 326-335

(22) D. Spehner, M. Orszag, *Quantum jump dynamics in cavity QED*, J. Math. Phys. 43 (2002), 3511-3537

(23) D. Spehner, J. Bellissard, *The quantum jump approach for infinitely many states*, in: "Modern Challenges in Quantum Optics", Lecture Notes in Physics 575, Eds M. Orszag and J.C. Retamal, 355-376 (Springer, 2001)

(24) D. Spehner, J. Bellissard, *A kinetic model of quantum jumps*, J. Stat. Phys. 104 (2001), 525-566

(25) R. Narevich, D. Spehner, *Weyl expansion of a circle billiard in a magnetic field*, J. Phys. A: Math. Gen. 32 (1999), L227-L230

(26) R. Narevich, D. Spehner, E. Akkermans, *Heat kernel of integrable billiards in a magnetic field*, J. Phys. A: Math. Gen. 31 (1998), 4277-4287

(27) D. Spehner, R. Narevich, E. Akkermans, *Semiclassical spectrum of integrable systems in a magnetic field*, J. Phys. A: Math. Gen. 31 (1998), 6531-6545

Preprints and articles in preparation

(I) N. Rougerie, D. Spehner, *Interacting bosons in a double-well potential*, to be submitted

(II) J. Bellissard, R. Rebolledo, D. Spehner, W. von Waldenfels, *The quantum flow of electronic transport I: the finite volume case*, http://www.ma.utexas.edu/mp_arc

Invited talks at conferences (since 2008)

4-22/07/2016	10 lectures at the seminar of the department of mathematics of the Zhejiang university, Hangzhou (China)
28-30/10/2015	Short course at the conference *Geometric Science of Information* (GSI 2015), École Polytechnique, Paris-Saclay (France)
2-4/09/2015	*Journées de physique mathématique de Lyon: Quantum Computing*, Lyon (France)
1-2/07/2015	*Workshop on Cold Gases in Quantum Information*, Bilbao (Spain)
2-6/02/2015	*Meeting of the GDR Quantum Dynamics*, Nantes (France)
27-31/10/2014	*Quantum Optics VII*, Mar del Plata (Argentina)
15-19/09/2014	*7th Italian Quantum Information Science*, Salerno (Italy)
8-19/07/2013	Lectures at the summer school *Advances in Quantum Open Systems*, Autrans (France)
3-4/07/2013	Annual meeting of the *Société Française de Physique*, Marseilles (France)
22-23/11/2012	*Journées EDP Rhône-Alpes*, Le Bourget du Lac (France)
12-16/11/2012	*Quantum Optics VI*, Piriápolis (Uruguay)
4-7/01/2012	*Math-AmSud workshop*, Santiago (Chile)
14-19/11/2010	*Quantum Optics V*, Cozumel island (Mexico)
20-23/09/2010	Meeting of the *GDR de physique quantique mésoscopique*, Aussois (France)
24-25/11/2009	*Journées de physique théorique*, Grenoble (France)
17-19/11/2009	*Open Quantum Systems*, Cergy-Pontoise (France)
20-25/7/2009	Winter school *Análisis Estocástico y Aplicaciones*, Valparaiso (Chile)
3-7/11/2008	Lectures at the winter school *Aspects of Quantum Dynamics*, Grenoble
23-24/10/2008	*Journées Hors Murs du LPMMC*, Besse-en-Oisans (France)
10/01/2008	*Taller de Análisis Funcional y Ecuaciones de Evolución*, USACH, Santiago
3-9/01/2008	*Stochastic Analysis and Mathematical Physics VI*, Santiago (Chile)

Invited seminars (since 2008)

2016 :	School of Science, Tianjin University, China (28/06) Instituto de Física, PUC, Santiago, Chile (13/01)
2015 :	Université de Besançon, France (17/06)
2014 :	Université de Lille, France (18/03)
2013 :	Universidad de Concepción, Chile (28/01)
2012 :	Center for Theoretical Physics PAN, Warsaw, Poland (25/01)
2011 :	Pontificia Universidad Católica, Santiago, Chile (25/8)
2010 :	Pontificia Universidad Católica, Santiago, Chile (20/8 and 24/8)
2009 :	Pontificia Universidad Católica, Santiago, Chile (6/1 et 16/1)
2008 :	Institute for Theoretical Physics, Heidelberg, Germany (26/6), Pontificia Universidad Católica, Santiago, Chile (07/01)

Organization of conferences

1-5/02/2016	Co-organizer (with D. Häffner and N. Rougerie) of the annual meeting of the GDR *Dynamique Quantique*, Grenoble, France
11-12/10/2012	Co-organizer (with N. Rougerie) of the PEPS meeting *"Many-body quantum mechanics and cold atoms"*, Grenoble, France
17-19/06/2010	Main organizer of the conference *"Quantum Information with Atoms, Photons, and Solid State Systems"*, Grenoble, France
8-9/11/2007	Organizer of the session *"decoherence and quantum information"*, journées du Centre de Théorie en Physique de Grenoble, Seyssins, France

Popularizing science

2015	Talk *"What is a quantum computer and what could one do with it?"* (in French) Ateliers de l'information, Bibliothèque Universitaire Sciences, Grenoble (6/05)
2013-2015	Introductory talk on quantum computers for first year students from the Université Joseph Fourier in Valence (France)

Referee activity

- Evaluation of research proposals submitted to the Conicyt, Chile (years 2012, 2013, and 2014).
- Evaluation of a book proposal for *Grenoble Sciences* Editions.
- Member of the thesis jury for Ph.D. defenses at the Institut Fourier, Grenoble (December 2009 and June 2012), Universidad de Chile, Santiago (March 2013), and LPMMC, Grenoble (December 2014)
- Regular referee in Journal of Physics A: Math. Gen., New Journal of Physics, Physical Review Letters, Quantum Information Processing, and other scientific journals.

Spoken and written languages

French (mother tongue), *Spanish* (fluent), *English* (fluent), *German* (good), *Russian* (diploma "DEUG B Langues, littératures et civilisations étrangères : mention Russe", université Toulouse le Mirail, 1999).

RESEARCH STATEMENT (2010-2015)

My current fields of research are the theory of open quantum systems, quantum information theory, and interacting bosons in cold atomic gases.

Entanglement and more general types of quantum correlations are unique features of quantum mechanics. However, these correlations are strongly affected by the coupling of the quantum system with its environment or by experimental noises. My research focuses both on the mathematical description of quantum correlations and on the study of physical systems where such correlations may be produced dynamically even in the presence of decoherence due to the coupling with the environment.

Quantum Information Theory, Open Quantum Systems

A central question in quantum information theory is to characterize quantum correlations in composite systems. Such correlations are at the origin of the higher efficiencies of quantum algorithms and communication protocols over their classical analogs. I have studied with M. Orszag a new measure of quantum correlations defined as the Bures distance of the system state to its closest classical state. This distance is a geometric analog of the quantum discord. We have shown that its evaluation and the problem of finding the closest classical state reduce to a quantum state discrimination task, thereby demonstrating an unexpected link between the degree of quantumness of a state and the distinguishability of quantum states pertaining to an ensemble (see (6) in the list of publications). By applying this general result, I have calculated the geometric discord explicitly when one of the subsystems of the composite system is a qubit (e.g. a two-level atom) (5). I have studied recently with W. Roga and F. Illuminati the corresponding geometric discord obtained by replacing the Bures distance by the Hellinger distance (1). We have shown that this yields to the first instance of easily-computable *bona fide* measure of quantum correlations (the more popular Hilbert-Schmidt geometric discord is also easy to compute but not physically reliable). We have compared the geometric discords with two related measures of quantum correlations which have attracted a lot of attention in recent years: the measurement-induced geometric discord and the discord of response. Several explicit relations and many optimal bounds have been derived, enabling to compare the three types of measures and the measures obtained from different distances (1). I have written a survey article explaining this geometric approach to quantum correlations and its relation with the state distinguishability problem and with quantum entropies. This article has been published in a special issue of J. Math. Phys. (2).

Together with my former Ph.D. student S. Vogelsberger, I have been interested in the evolution of the entanglement for two qubits coupled to independent reservoirs. More specifically, we have studied the corresponding quantum trajectories, i.e. the random evolution of the wave function of the two qubits given by a stochastic Schrödinger equation with classical Poisson or Wiener processes. These quantum trajectories describe the Markovian dynamics of the qubits when continuous measurements are performed on the reservoirs. We have shown that the mean entanglement always decays exponentially, with a rate that only depends on the measurement scheme on the reservoirs (i.e. on the nature of the random processes appearing in the stochastic Schrödinger equation) (9), (11). This result is in strike contrast with the popular phenomenon of entanglement sudden death, which states that in the absence of measurements, the density matrix of the qubits, whose evolution is governed by a Lindblad master equation, looses completely its initial entanglement after a finite time.

In a joint work with W. De Roeck (8), I have derived rigorously the Lindblad master equation describing the dynamics of a Brownian quantum particle on an infinite lattice coupled to a free boson reservoir, starting from the Hamiltonian dynamics of the particle + reservoir and taking the weak and singular coupling limits. These limits involve a rescaling of the time and particle mass in the particle-reservoir coupling constant λ, so that time and mass go to infinity when $\lambda \to 0$. The main challenge is that one deals with a system with an infinite volume, instead of the confined systems considered so far in the Davies's weak coupling limit approach. The proof relies on a Dyson expansion and the identification of the diagrams which contribute in this expansion in the limit $\lambda \to 0$.

Cold atomic gases

Bose Josephson junctions are formed by clouds of ultracold atoms in Bose-Einstein condensates in two different modes (e.g. two internal energy levels). Because of interactions between atoms, the dynamical evolution generates quantum correlated states after a sudden quench to zero of the inter-mode tunnel energy to zero. This yields to the formation of squeezed states, and, at later times, macroscopic superpositions of coherent states, which are quite challenging due to applications in atomic interferometry. In particular, squeezed states have been shown experimentally to lead to a high precision of the interferometer. In a joint work with G. Ferrini, A. Minguzzi, and F. Hekking, I have studied the impact of decoherence on macroscopic superpositions in Bose Josephson junctions. The experimentally most relevant mechanisms of decoherence are magnetic fluctuations and atom losses. Magnetic fluctuations lead to a phase noise and can be treated exactly, beyond the usual Markov approximation. This analysis shows that the induced decoherence is not so detrimental for macroscopic superpositions and does not scale with the number of atoms (10), (12). At difference from phase noise, decoherence due to atom losses increases rapidly with the number of atoms in the junction. The effects of the various loss processes have been investigated in detail in two papers (4), (7) with K. Pawlowski, A. Minguzzi, and G. Ferrini. In particular, it has been shown that the macroscopic superpositions can be partially protected from decoherence for strongly asymmetric losses in the two modes by using Feshbach resonances to tune the interaction energies.

In a recent collaboration with S. Reyes, L. Morales-Molina, and M. Orszag (3), I have been interested in a model with two interacting species of atoms in a Bose-Einstein condensate on a ring lattice in the presence of a synthetic magnetic field. We have found that for certain values of the interactions and gauge field, there exists a robust eigenstate of the Bose Hubbard Hamiltonian with maximal entanglement between the two species. A protocol to reach this state from the ground state by varying the gauge field and an indirect way to detect it by measuring the current of particles in the ring has been proposed.