CURRICULUM VITAE

Name	Nilanjana Datta
Profession	Affiliated Lecturer in Mathematics, Faculty of Mathematics, University of Cambridge, U.K. and Fellow of Pembroke College, Cambridge.
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Academic Career

July 1995: **Ph.D thesis** entitled *"Low-temperature phase diagrams of quantum lattice systems and Properties of the edge of the Laughlin liquid,"* completed under the supervision of Prof. Jürg Fröhlich of ETH Zurich and Dr. Rudolf Morf of the Paul Scherrer Institute, Zurich.

October 1995 – a post-doctoral fellow at the Dublin Institute of Advanced Studies in Dublin, Ireland.

January 1996 - June 1996 – a visiting scientist at the Centre de Physique Théorique in C.N.R.S Marseille, France.

July 1996 - August 1997 – a post–doctoral fellow at the University of Strathclyde, Glasgow, U.K..

September 1997 to December 2000 – a Senior Research Assistant at the Institut de Physique Théorique, in the École Polytechnique Fédérale de Lausanne (EPFL).

Since January 2001 – an affiliated lecturer of the Faculty of Mathematics, and a Fellow of Pembroke College, University of Cambridge, U.K.

SUMMARY OF RESEARCH

Since 2002, my research has primarily been in the field of Quantum Information Theory. I have been working on various aspects of this field, e.g., data compression for sources with memory, perfect transfer of quantum states and entanglement over spin networks, proof of the additivity conjectures of the Holevo capacity and the minimum output entropy for various models of quantum channels, complementary channels, entanglement manipulation, and the evaluation of the optimal rates of various quantum information protocols using the quantum information spectrum method.

Before moving into the field of Quantum Information Theory, my research was primarily in the field of Quantum Statistical Mechanics. Part of my PhD thesis was also on the Quantum Hall Effect. Below, I give brief summaries of certain selected topics of my research.

Brief summary of research on memory effects in Quantum Information Theory

Optimal rates of quantum information protocols, such as compression and transmission of information, were initially obtained under the assumption that the information source, or the channel used in the protocol, was memoryless. A memoryless quantum information source is one for which successive signals emitted by it are independent of each other. A quantum channel is said to be memoryless if the noise acting on successive inputs to the channel is uncorrelated.

In real world communication systems, the assumption of sources and channels being memoryless is not always justified. Hence memory effects need to be taken into account. In 2002, with Yuri Suhov of the University of Cambridge, I proved that the optimal data compression limit for a quantum information source with memory, modelled by a lattice system of interacting qubits governed by a suitable Hamiltonian, is given by its von Neumann entropy rate.

Classical and quantum capacities in the presence of memory, have been established only for a sub-class of channels, the so-called forgetful channels. A forgetful channel is one for which the correlation in the noise acting on successive inputs dies out after a finite number of uses. Capacities of channels with long-term memory, however, had remained an open problem. Along with T.C.Dorlas of the Dublin Institute of Advanced Studies, I studied the transmission of classical information through a class of channels with long term memory. A channel in this class is given by a convex combination of memoryless channels. Hence, the memory of such a channel can be considered to be given by a Markov chain which is aperiodic but not irreducible. We obtained an expression for both the classical capacity and the entanglement-assisted capacity of such a channel. We also generalized our methods to obtain the classical capacity of quantum channels with general Markovian correlated noise.

With Garry Bowen of the University of Cambridge, I employed the quantum information spectrum method, which is a powerful mathematical tool in understanding information theory beyond the memoryless scenario, to compute the classical capacity of any arbitrary quantum channel. The latter work was an important step in the direction of establishing a unifying mathematical framework for obtaining the optimal rates of various quantum information protocols, without making specific assumptions about the nature of the sources or channels involved.

We have used this method further, to obtain optimal rates of entanglement manipulation protocols of bipartite pure states, such as entanglement concentration and entanglement dilution. We have also been able to go beyond pure states and evaluate the entanglement cost of sequences of *arbitrary* quantum states.

Brief summary of research on perfect transfer and mirror inversion of quantum states

Quantum information is encoded in quantum mechanical states of a physical system. Hence, reliable transmission of quantum information from one location to another entails the perfect transfer of quantum mechanical states between these locations. We considered the situation in which the underlying system used for this information transmission is a system of N interacting spins and addressed the problem of arranging the spins in a network in a manner which would allow perfect state transfer over the largest possible distance. The network is described by a graph G, with the vertices representing the locations of the spins and the edges connecting spins which interact with each other. State transfer is achieved by the time evolution of the spin system under a suitable Hamiltonian. This can be equivalently viewed as a continuous time quantum walk on the graph G. We obtained the maximal distance of perfect state transfer and proved that the corresponding quantum walk exhibited an exponential speed-up over its classical counterpart.

We could also go beyond state transfer and achieve the more general operation of mirror inversion of quantum states of a linear register, in each excitation subspace, with respect to the centre of the register. The appealing feature of our construction was that it required no dynamical control over individual inter-qubit interactions. This work was done with a host of collaborators from Cambridge, Imperial College London and MIT, namely, C.Albanese, M.Christandl, T.Dorlas, A.Ekert, A.Kay and A.Landahl.

Brief summary of research on the additivity and multiplicativity conjectures

The capacity of a memoryless quantum channel for transmitting classical information, under the constraint that successive inputs to the channel our independent of each other, is given by the so-called *Holevo capacity*. An important open question is whether the capacity of the quantum channel can be increased by lifting this constraint, i.e., by using entangled inputs. This question is related to the conjecture that the Holevo capacity is additive. Along with Alexander Holevo of Moscow and Yuri Suhov of Cambridge, I proved this conjecture for different classes of quantum channels.

We also obtained a sufficient condition for additivity of the minimum output entropy for a pair of given channels and an analytic verification of this condition for specific quantum channels for which a closely related multiplicativity property was violated. This validated the additivity conjecture for these channels.

Along with Mary Beth Ruskai, I studied the additivity conjecture, as well as the associated multiplicativity conjecture for the maximal output p-norm, for quantum channels which are generalizations of the depolarizing channel.
Of course, the globabl additivity of the Holevo capacity is no longer an open problem since Matthew Hastings has provided a counterexample arXiv:0809.3972.

Brief summary of research on Quantum Statistical Mechanics

As a graduate student, in 1994, along with C.Albanese, I studied a family of Hamiltonians describing a system of spin polarized, itinerant lattice fermions with short range repulsive interactions in the strong coupling limit. We proved rigorously that this family of Hamiltonians exhibit a Mott transition at zero temperature. We developed a convergent cluster expansion algorithm to study the system at low temperatures. By means of this expansion, we could avoid the difficulties related to the *sign problem* of Fermi systems.

Along with R.Fernandez and J.Fröhlich, I developed contour expansion methods to study the effect of thermal fluctuations and quantum perturbations of classical lattice interactions of a system in $d \geq 2$ dimensions. The classical Hamiltonian was required to have a finite number of periodic ground states and yield a regular zero-temperature phase diagram. Our analysis was based on an extension of the well-known Pirogov Sinai theory of classical phase transitions to quantum lattice models. We proved that the only effect of the quantum perturbation was to cause small deformations of the classical phase diagram and does *not* lead to any drastic new effects. Hence it provides a "no–go" theorem which narrows the search for new quantum effects.

Subsequently, we developed a convergent perturbation scheme, with the aim of extending the applicablity of the (above mentioned) low temperature analysis to systems in which quantum perturbations have the more drastic effect of breaking the degeneracies of the classical ground states. A classical Hamiltonian with an infinitely degenerate ground state was considered. It was proved that if the quantum perturbation reduced the degeneracy to a finite number in the nth order of perturbation theory then there existed a unitary operator which block diagonalized the Hamiltonian to order n in the perturbation parameter. The transformed Hamiltonian has a new classical part with finitely many degenerate ground states and a new quantum perturbation which is "small" with respect to the classical part in such a way that the low temperature expansion methods can be used.

We also made a rigorous analysis of the low temperature phases of two variants of the Hubbard model, namely, the Falicov Kimball model and the asymmetric Hubbard model. We established a mathematically controlled perturbation expansion which enabled us to show how – as a consequence of the Pauli principle – *effective exchange interactions* are generated, even though the interactions of the intial Hamiltonian are *spin–independent*.

Along with Bruno Nachtergaele of UC Davis, USA, and Alain Messager of C.N.R.S. Marseilles, I studied the problem of rigidity of interfaces in the Falicov-Kimball model in a cubic lattice, under mixed boundary conditions. We developed a technique to evaluate the low temperature properties of such a system by means of a low temperature contour expansion, while treating the long range tail of the potential by a high temperature expansion. This transformed the problem from that of an interacting contour model to a model of non-interacting "decorated" contours, the decorations resulting from the long range of the potential. The latter model could then be analysed by the method of cluster expansions. We proved that both the 100– and the 111 interfaces of the Falicov Kimball model are rigid at low temperatures. Moreover, the rigidity of the 111 interface results from a phenomenon of "ground state selection" and is a consequence of the Fermi statistics of the electrons in the model.

I further investigated properties of interfaces in quantum lattice models with Tom Kennedy of Tucson, Arizona. We proved that at zero temperature, interfaces in the highly anisotropic XZ and XXZ quantum spin chains are not stable. This is in contrast to the ferromagnetic XXZ chain, for which the existence of localized interface ground states has been proved, for any amount of anisotropy in the Ising-like regime.

LIST OF PUBLICATIONS

(1) N.Datta, G.Ghosh and M.H.Engineer, *Exact integrability of the two-level system, Berry's phase and non-adiabatic corrections*: Phys.Rev.**A40**, 526 - 529, 1989.

(2) N.Datta and G.Ghosh, *Berry's phase for anharmonic oscillators*: Phys.Rev.**A46**, 5358 - 5362, 1992.

(3) C.Albanese and N.Datta, *Quantum criticality, Mott transition and Sign Problem for a Model of Lattice Fermions*: Commun. Math. Phys., 167:571-591, 1995.

(4) N.Datta and R.Ferrari, *Investigations of the Laughlin state*: **MPI-Ph/92-16**, March 1992.

(5) N.Datta, R.Fernandez and J.Fröhlich, *Low temperature phase diagrams of quantum lattice systems. I. Stability for quantum perturbations of classical systems with finitely-many ground states.*: J.Stat.Phys. **84**, 455 - 534, 1996.

(6) N.Datta, R.Morf and R.Ferrari, *Edge of the Laughlin droplet*: Phys. Rev. **B53**, 10906 - 10915, 1996.

(7) N.Datta, R.Fernandez, J.Fröhlich and L.Rey Bellet, *Low temperature phase diagrams of quantum lattice systems. II. Convergent perturbation expansions and stability in systems with infinite degeneracy.* : Helv. Phys. Acta **69**, 752 - 820, 1996.

(8) N.Datta, R.Fernandez and J.Fröhlich, *Effective Hamiltonians and Phase Diagrams for Tight-Binding Models*: J.Stat.Phys. **96**, 545-611, 1999.

(9) N.Datta, A. Messager and B. Nachtergaele, *Rigidity of interfaces in a model of crystalline matter*: 163-183 in *Mathematical Results in Statistical Mechanics*, World Scientific Publishing, 1998.

(10) N.Datta, A.Messager and B. Nachtergaele, *Rigidity of interfaces in the Falicov Kimball model* : J. Stat. Phys., **99**, 461-553, 2000.

(11) N.Datta and Y.Suhov,*Data compression limit for an information source of interacting qubits* : Quantum Information Processing, **1(4)**, 257-281, 2002.

(12) N.Datta and T.Kennedy, *Expansions for one quasiparticle states in spin 1/2 systems* : J. Stat. Phys., **108**, 373-399, 2002.

(13) N.Datta and T.Kennedy, *Instability of interfaces in the antiferromagnetic XXZ chain at zero temperature* : Communications in Mathematical Physics, **236**, 477–511, 2003.

(14) N.Datta and H.Kunz, *Random Matrix approach to the crossover from Wigner to Poisson statistics of energy levels*: Journal of Mathematical Physics, **45**, 870–886, 2004.

(15) M.Christandl, N.Datta, A.Ekert and A. Landahl, *Perfect transfer in quantum spin networks*: Phys. Rev. Lett. **92**, 187902, 2004.

(16) N.Datta and T. Dorlas, *Random walks on a complete graph: a model for infection*: Journal of Applied Probability, **41**, 1008–1021, 2004.

(17) C.Albanese, M.Christandl, N.Datta and A.Ekert, *Mirror inversion of quantum states in linear registers*: Phys. Rev. Lett. **93**, 230502, 2004.

(18) N.Datta, A.S.Holevo and Y.M.Suhov,*On a sufficient condition for additivity in quantum information theory*: Problems in Information Transmission, **41**, 76–90, 2005.

(19) N.Datta, *Additivity in Isotropic Quantum Spin Channels*: International Journal of Quantum Information, **4**, no. 3, 473–485, June 2006; e-print: *quant-ph/0410034*.

(20) N.Datta, *Multiplicativity of Maximal p-Norms in Werner-Holevo channels for* $1 \leq p \leq 2$: *quant-ph/0410063*.

(21) M.Christandl, N.Datta, T.Dorlas, A.Ekert, A.Kay and A.Landahl *Perfect Transfer of Arbitrary States in Quantum Spin Networks* Phys. Rev. A **71**, 032312, 2005 .

(22) M. Christandl, N. Datta, A. Ekert and A. J. Landahl, *Information processing in quantum spin systems,*: in Proceedings of the 7th International Conference on Quantum Communication, Measurement and Computing, S. M. Barnett, E. Anderson, J. Jeffers, P. Ohberg, and O. Hirota, Eds., (AIP Press, 2004), pp. 215–218.

(23) N.Datta, A.S.Holevo and Y.M.Suhov, *Additivity for transpose depolarizing channels*: International Journal of Quantum Information, Asher Peres Memorial Issue, **4**, no. 1, 85–98, February 2006.

(24) D. Bruss, N.Datta, A. Ekert, L.C. Kwek and C. Macchiavello, *Multipartite entangle-*

ment and quantum phase transitions: Phys. Rev. A **72**, 014301, 2005.

(25) N.Datta and T. C. Dorlas, *"Source Coding in Quantum Information Theory"* in: Encyclopedia of Mathematical Physics, Vol. 4, (Jean-Pierre Francoise, Gregory L. Naber, and Tsou Sheung Tsun, eds.), Elsevier 2006, pp. 609–617.

(26) N.Datta and M.B. Ruskai, *"Maximal output purity and capacity for asymmetric unital qudit channels"*: J. Phys. A : Math. Gen. **38**, 9785–9802, 2005.

(27) N.Datta and A.S.Holevo, *"Complementarity and additivity for depolarizing channels"*: *quant-ph/0510145.*

(28) N.Datta, *"Quantum Entropy and Quantum Information Theory,"* Proceedings of Les Houches, Session LXXXIII, 2005, Mathematical Statistical Physics, Elsevier.

(29) N.Datta, M. Fukuda and A.S. Holevo, *"Complementarity and additivity for covariant channels"*: Quantum Information Processing. **5**, no. 2, 179–207, June 2006.

(30) G. Bowen and N. Datta, *"Beyond i.i.d. in Quantum Information Theory"* : Proceedings of the International Symposium on Information Theory, ISIT 2006, 451.

(31) N.Datta and T. Dorlas, *"Quantum Feinstein's Lemma and its application to channel coding* : Proceedings of the International Symposium on Information Theory, ISIT 2006, 441–445.

(32) N.Datta and T.C.Dorlas, *"Coding Theorem for a Class of Quantum Channels with Long-Term Memory"*: J. Phys. A: Math. Theor. 40, 8147-8164, 2007.

(33) G. Bowen and N.Datta, *"Asymptotic Entanglement Manipulation of Bipartite Pure States"*: *quant-ph/0610199* (accepted for presentation at the *QIP Workshop,* 30^{th} *Jan –* 3^{rd} *Feb, 2007, Brisbane, Australia*)

(34) G. Bowen and N. Datta, *"Quantum Coding Theorems for Arbitrary Sources, Channels and Entanglement Resources"*: *quant-ph/0610003.*

(35) G. Bowen and N.Datta, *"Entanglement Cost for sequences of arbitrary quantum states"*: *arXiv:0704.1957*, submitted to Journal of Mathematical Physics.

(36) N.Datta, T.C.Dorlas and Y.M. Suhov, *"Entanglement Assisted Classical Capacity of a Class of Quantum Channels with Long-Term Memory,"* Quantum Information Processing. **7**, no. 6, 251–262, December 2008.

(37) N.Datta and T.C.Dorlas, *"Classical capacity of quantum channels with general Markovian correlated noise,"* accepted for publication in the Journal of Statistical Physics; to appear in the Special Issue dedicated to J.Froehlich and T.Spencer; *arXiv:0712.0722.*

(38) N.Datta and R. Renner, *"Smooth Renyi Entropies and the Quantum Information Spectrum,"* accepted for publication in IEEE Trans. Inf. Theory; to appear in June 2009; *arXiv:0801.0282*.

(39) N.Datta, *"Min- and Max- Relative Entropies and a New Entanglement Monotone",* accepted for publication in IEEE Trans. Inf. Theory; to appear in June 2009; *arXiv:0803.2770*.

(40) N.Datta, *"Max- Relative Entropy of Entanglement, alias Log Robustness",* submitted to International Journal of Quantum Information; Int. Jour. Quant. Info. **7**, no.2, 475-491, 2009; *arXiv:0807.2536*.

(41) M.Mosonyi and N.Datta, *"Generalized relative entropies and the capacity of classical-quantum channels,"* submitted to Journal of Mathematical Physics, *arXiv:0810.3478*.

(42) F.Buscemi and N.Datta, *"The quantum capacity of channels with arbitrarily correlated noise"*: submitted to IEEE Trans. inf. Theory; e-print of a shorter version *arXiv:0902.0158*

INVITED LECTURES AND SEMINARS

"Quantum Hall effect as a topological invariant" at the Conference of the Swiss Physical Society, held in Verbier, Switzerland, in September 1993.

"Quantum criticality and Mott transition in a system of lattice fermions" at the Conference of the Swiss Physical Society, held in Bern, Switzerland, in March 1994.

"Low temperature phase diagrams of quantum lattice systems," in the Theoretical Physics Department of the University of Oxford, England in August 1995.

"Stability of classical lattice systems under quantum perturbations" in the Dublin Institute of Advanced Studies in Dublin, Ireland, in September 1995.

"Edge of the Laughlin droplet" in the Department of Physics, in the University of Strathclyde in Glasgow, Scotland, in October 1995.

"Quantum selection vs. thermal fluctuations" in the Centre de Physique Théorique, in C.N.R.S. Marseille, in March 1996.

"Towards a devil staircase - in a variant of the Hubbard model" in ETH Zurich, Switzerland, in June 1996.

"Quantum perturbations of classical lattice systems" in the University of Rutgers, New Jersey, U.S.A. in September 1996.

“Ground state selection” in the University of California, Davis, California, U.S.A., in September 1996.

“Convergent perturbation expansions for quantum lattice systems” in the University of Arizona, Tucson, Arizona, U.S.A. in October 1996.

“Quantum Pirogov Sinai theory” (a series of invited lectures) in the Autumn School on *The Mathematics of Phase Transitions* in Prague, Czech Republic, in October 1996.

“Phase transitions in the Falicov Kimball model” in the Dublin Institute of Advanced Studies in Dublin, Ireland, in November 1996.

“Ordering by disorder,” in the Centre de Physique Théorique, in C.N.R.S. Marseille, in December 1996.

“Stability of interfaces in a quantum lattice model,” at the *Annual Conference of Statistical Mechanics* in Kings College, London, in May 1997.

“Stability of interfaces in a model of crystalline matter,” in the Satellite Conference on *Mathematical Results in Statistical Mechanics* in Marseille, in August 1998.

“Ground state selection in a quantum lattice system, ” in the Department of Mathematics at the Heriot-Watt University, Edinburgh, Scotland, in August 1997.

“Thermodynamic stability in quantum lattice systems with infinite degeneracy” at the IV^{th} International Conference on *Problems of Modern Mathematical Physics* in Armenia, in September 1997.

“The 111-interface in the Falicov Kimball Model,” in the Institut de Physique Theórique, EPFL, Switzerland, in December 1997.

“The Quantum Hall Effect,” at C.E.R.N., Geneva, in March ’99.

“Fractionally charged quasiparticles in the Quantum Hall Effect,” (a review talk) in the University of Lausanne in April ’99.

“Rigidity of interfaces in a quantum lattice model,” at ETH Zurich, in May ’99.

“Excited state wavefunctions of quantum transverse Ising models,” at the Satellite meeting on *Statistical Mechanics* in the University of Cambridge, in August 2000.

“Existence of spectral gaps in a class of quantum spin-1/2 systems,” at the Statistical Laboratory in the University of Cambridge, in March 2001.

“One quasiparticle excitations in quantum spin-1/2 systems,” at the Workshop on *Quantum Many-Body Systems* in the Dublin Institute for Advanced Studies, in September 2001.

“Data compression limit for an information source of interacting qubits,” at the Cambridge–Massachusetts–Institute (CMI) workshop in the University of Cambridge in June 2002.

"Instability of interfaces in the anisotropic, antiferromagnetic Heisenberg chain," at the International Meeting on *Mathematical Analysis of Quantum Systems* in the Dublin Institute for Advanced Studies, in September 2002.

"Stability of interfaces in quantum spin systems," at the third European workshop on *Stochastic Models in Statistical Physics* held at EURANDOM in Eindhoven, Holland from 7th to 11th of October 2002.

"Interfaces in the XXZ Heisenberg chain," at the Mathematical Institute of the University of Oxford on the 21st of October 2002.

"Extension of Schumacher's theorem to non-i.i.d. quantum information sources," at the Department of Applied Mathematics and Theoretical Physics of the University of Cambridge on 19th of November 2002.

"Data compression limit for a class of non-i.i.d quantum information sources," at the *Simons Conference on Quantum and Reversible Computation*, in SUNY at Stony Brook, May 28-31, 2003.

"Quantum source coding for a class of sources with memory" at a conference on *Mathematical aspects of Quantum Information Theory* held in the University of Paris, Cergy-Pontoise in January 2003.

"von Neumann Entropy in sources with memory" in the *Cambridge–MIT Quantum Information Meeting* in Cambridge, in June 2003.

"Mathematical Aspects of Data Compression," (a series of seven lectures) at the Prague Summer School on *Mathematical Statistical Mechanics* in July 2003.

"Perfect state transfer in quantum spin networks," at the *Third Annual MIT–Cambridge Quantum Information Workshop*, held at MIT, October 2-3, 2003.

"Spin chains as quantum channels," in the National University of Singapore on the 30th of March 2004.

"Werner–Holevo channels," at the Mathematics Department of the University of Bristol on the 12th of May 2004.

"A quantum channel with additive minimum output entropy," at the *XXXVI Symposium on Mathematical Physics: Open Systems and Quantum Information* held in Torun, Poland from June 9–12, 2004.

"A sufficient condition for additivity in quantum channels," in Berlin on the 29th of June 2004, as part of the seminar series jointly organised by the Weierstrass Institute and the Technical University of Berlin.

"Transfer of Quantum States," and "Additivity of the minimum output entropy," (two lectures) at the *Ringberg Meeting* of the Max Planck Institute in Tegernsee, Germany, July 5–9, 2004.

“Entanglement in Quantum Wires” at Imperial College on the 30th of November 2004.

“Entanglement transfer in quantum spin networks,” at the conference on *Quantum entanglement in physical and information sciences* held in Pisa, December 14–18, 2004.

“Information transmission through quantum spin systems,” in the Mathematical Physics group of the University of York on the 24th of February 2005.

“Quantum Entropy and Quantum Information Theory,” (a series of six lectures) at the Summer School on *“Mathematical Statistical Physics”* in Les Houches in July 2005.

“Quantum Feinstein’s Lemma and its application to channel coding,” at the *IEEE International Symposium on Information Theory*, held in Seattle, USA in January 2006.

“Quantum Entropy and Information”, (a series of three lectures) at the Summer School on *Theory and Technology in Quantum Information,* held in Trieste between 12th-16th June, 2006.

“Classical capacity of an arbitrary quantum channel,” at the workshop on *Theory and Technology in Quantum Information, communication, computation and cryptography*, held in Trieste, between 19th-23rd June, 2006.

“Quantum Channels and the Additivity Conjecture,” at the Department of Theoretical Physics, ETH Zürich, in December 2006.

“Perfect transfer of quantum information across graphs,” at the workshop on *Graph models of mesoscopic systems, wave-guides and nano-structures*, at the Isaac Newton Institute in April 2007, as part of a six-month programme entitled *Analysis on Graphs and its applications.*

“Quantum Information Theory,” (a series three lectures) at the school entitled *Theoretical and Technological Perspectives of Quantum Information and Communication*, held at CIRM, Marseilles in March 2007.

“Quantum state transfer, ”(a colloquium) at the Max Planck Institute for the Physics of Quantum Systems, in Dresden, Germany, on the 23rd of July, 2007.

“Entanglement manipulation of arbitrary quantum states,”, at the conference *QMath10* to be held in Romania in September 2007.

“Quantum Channels which do not forget,” at the conference on *Noise, Information and Complexity at a Quantum Scale*, to held in Erice, Italy in November 2007.

“Beyond independence in Quantum Information Theory,” at the *TQC 2008* in Tokyo, in January 2008.

“Quantum Information Spectrum,” at Imperial College, London, in April 2008.

“Quantum channels with long term memory,” at the International Workshop :*Quantum 08* in Torino, in May 2008.

“Min- and Max relative entropies and a new entanglement monotone,” at the conference *Information and Communication*, in Budapest, in August 2008.

“Low temperature phase diagram in Quantum Lattice Models,” at IBM, Yorktown Heights, New York in October 2008.

“Generalized relative entropies and entanglement monotones,” at the *GSIS Workshop on Quantum Information Theory* in Sendai, Japan in November, 2008.

“One-shot entanglement manipulation,” at *ETH Zurich* in Switzerland in March 2009.

“Correlated noise errors in Quantum Information Theory,” at *Imperial College,* London, in April 2009.

TEACHING EXPERIENCE

Responsible for teaching the “Quantum Hall Effect” to undergraduate students of Physics, in ETH Zurich, in the summer semester of 1992.

Tutored undergraduate students of Physics, in ETH Zurich, in preparation for a series of seminars on “Quantum Optics”, in the summer semester of 1993.

Teaching assistant for a course on Electrodynamics given by Prof.J.Fröhlich to undergraduate students of ETH Zurich, in the summer semester of 1994.

Trained undergraduate students of Physics, in ETH Zurich for a series of research seminars on “Many-body effects in Condensed Matter Physics” in the winter semester of 1994.

Instructed final year students of the Physics Department, in EPF Lausanne for their Travaux Pratique on “Green’s functions in quantum mechanics”. in the winter semester of 1997.

Trained two final year students of the Physics Department, in EPFL for their Travaux Pratique on “Random Matrix Theory” and “Bose Einstein Condensation” respectively, in the summer semester of 1998.

Responsible for teaching “Functional Integral Methods” to the final year undergraduate students of Physics in EPFL, in the winter semester of 1999-2000.

Gave three introductory lectures on *Probability* to the students of four colleges in Cambridge (including Pembroke) in the first week of October, 2001.

Gave a Part III (postgraduate) lecture course on *Quantum Information Theory* in the Department of Mathematics, University of Cambridge in the Lent term of 2002 (jointly with Prof. Y.M.Suhov), 2003 (jointly with Dr. O. Johnson), and 2004 (jointly with Prof. Y.M.Suhov).

Gave three introductory lectures on *Probability* to the students of four colleges in Cambridge (including Pembroke) in the first week of October, 2002 and 2003.

Have been supervising students of Mathematics in the University of Cambridge in Probability, Quantum Mechanics, Statistics, and Markov Chains since 2001.

Since 2004, giving a Part III (postgraduate) lecture course on *Quantum Information Theory*, in the Department of Mathematics, University of Cambridge every year.

Have supervised three postgraduate students, each of whom who wrote an essay entitled *"Capacities of quantum channels,"* in 2006.

Gave series of lectures on *Quantum Information Theory* at summer schools in Prague (July 2003), Les Houches (July 2005) and Trieste (June 2006).

OTHER COLLEGE AND UNIVERSITY DUTIES

(1) Member of the Teaching Committee of Pembroke College since the Michaelmas Term of 2002.

(2) University Examiner for the Computational Projects (CATAM) of Part IB and Part II for the years 2001 and 2002.

(3) University Examiner for the Part III course on Quantum Information Theory for the years 2001–2007.

(4) Interviewed students for admission to Pembroke College in December 2001, 2002 and 2003, 2005 and 2006.

(5) Director of Studies in Mathematics, for Pembroke College since Michaelmas 2003.