

Bob Coecke - scientific cv



Head of the Quantum Group at Oxford University Computing Laboratory
University Lecturer of Quantum Computer Science
EPSRC Advanced Research Fellow
Governing Body Fellow of Wolfson College, Oxford

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BORN:

- Willebroek, Belgium, 23 July 1968.

STUDIES:

- Candidate Architecture and Polytechnics, July 1988, Vrije Universiteit Brussel, High Distinction.
- Candidate Mathematics and Physics, July 1990, Vrije Universiteit Brussel, The Highest Distinction.
- Licentiaat Physics, July 1992, Vrije Universiteit Brussel, The Highest Distinction.
- PhD in Sciences, July 1996, Vrije Universiteit Brussel, The Highest Distinction.

EMPLOYMENT HISTORY:

- October 1992-1996: Research Assistant at Belgian's National Fund for Scientific Research (NFWO).
- October 1997-2000: Research Fellow at Flander's Fund for Scientific Research (FWO).
- October 2000-March 2001: Postdoctoral Researcher, Theoretical Physics, Imperial College.
- March 2001-October 2001: Postdoctoral Researcher, Category Theory, McGill University.
- October 2001-October 2002: Postdoctoral Researcher, DPMMS, Cambridge.
- October 2001-July 2006: Postdoctoral Researcher, Computing Lab, Oxford.
- July 2006-July 2011: EPSRC Advanced Research Fellow.
- Since June 2007: University Lecturer in Quantum Computer Science, Computing Lab, Oxford.
- Since June 2007: Governing Body Fellow, Wolfson College, Oxford.
- April 2009-July 2009: Long Term Visiting Research Scientist, Perimeter Institute for Theoretical Physics.

RESEARCH EXPERTISE:

- Conceptual and Mathematical Foundations of Physics
- High-level Methods for Quantum Information and Computation
- Ordered Structures, Category Theory, Non-monotonic Logics, Probability Theory
- Computer Science Semantics, Dynamic Epistemic Logic, Computational and Mathematical Linguistics

RESEARCH GROUP:

Since the start of my EPSRC Advanced Research Fellowship, July 2006, and my University Lectureship in Quantum Computer Science, June 2007, **I expanded the then 4 member Quantum Group at OUCL**, a multidisciplinary group jointly headed by Samson Abramsky FRS and myself, **to its present size of 35 members**. I take the larger portion of the daily management of this group on me. Since July '06, **I (co-)supervise(d) 17 DPhil students**, with backgrounds in computer science, quantum computing, foundational physics, pure mathematics and linguistics. I also supervised MSc projects, e.g. **7** in 2008-10.

Note: this document contains hyperlinks which only function on a device that is connected to the internet.

GRANT PORTFOLIO:

Expanding this group involved attracting outstanding students that were awarded Clarendon (3) and DTA (6) studentships, Postdocs on EPSRC and other fellowships (3), and in particular, by means of many successful grant applications, among which several highly prestigious ones which importantly increased the international visibility and reputation of the group. In particular, I **initiated and coordinated**:

- g*₁ EC-FP6-STREP (Coordinator) *Foundational structures for quantum information and computation (QICS)*. Started January 2007 and ran 3.5 years — value: **1.6 M EUR** of which **380 K EUR** is allocated to Oxford.

This proposal ended up **2nd out of the 487 submitted proposals** in the submission phase, **in an FET Open call**, that is, all FET subjects are allowed. This was the **1st large EU grant ever awarded with OUCL as the coordinating site**; hence know-how had to be generated on the spot, and there was no of administrative support. The three periodic reviews qualified the research as “outstanding and unique in kind”, and the coordinator as “excellent”.

Other grants obtained in the same period are:

- g*₂ EPSRC Advanced Research Fellowship *The structure of quantum information and its ramifications for IT*. Started July 2006 and runs 5 years — value: **460 K GBP**.
- g*₃ Leverhulme grant (PI¹; with Abramsky) *Where quantum meets classical: foundational structures and their ramifications*. Started January 2007 and runs 4 years — value: **70 K GBP**.
- g*₄ ONR grant (PI) *Complementary quantum observables and resulting information flows in algorithms and protocols*. Started October 2008 and runs 4 years — value: **600 K USD**.
- g*₅ EPSRC grant (PI; with Joel Ouaknine) *Complexity and decidability in unconventional computational models*. Started October 2008 and runs 3 years — value: **180 K GBP**.
- g*₆ FQXI grant (PI) *The road to a new quantum formalism: categories as a canvas for quantum foundations*. Started October 2008 and runs 1 year — value: **90 K USD**.
- g*₇ FQXI mini grant (PI) *Categories, logic and the foundations of physics*. Started March 2009 and runs 2 year — value: **7.5 K USD**.
- g*₈ PhD Plus Grant (PI) for Bill Edwards. Started October 2009 and ran for 6 month — value: **21 K GBP**.
- g*₉ JTF & NUS combined interdepartmental grant (with Briggs (PI), Benjamin (Materials), Timpson (Philosophy)) *Quantum nanoscience: fundamental physics, emerging structures, and implications for our ultimate reality*. Starts January 2011 and runs 3 years — value: **1.6 M USD** of which approx. 1/4th for OUCL.
- g*₁₀ FQXi grant (PI) *A relativistic universe of interacting quantum processes*. Starts October 2011 and runs 1.5 years — value: **110 K USD**.

The current grant portfolio of our group, including fellowships, is about **4.5 M GBP**. Earlier Grant successes are:

- g*₁' EPSRC grant (with Abramsky (PI)) *High-level methods in quantum computation and quantum information*. Started Sep 2004 and ran 3 years — value: **200 K GBP**
- g*₂' ONR Grant (with Abramsky (PI) and Martin) *Combining qualitative and quantitative theories of information*. Started Jul 2003 and ran 3 years — value: **200 K USD**
- g*₃' Travel Fellowship awarded by the Department for Research & Development of the Free University of Brussels. Started Sep 2000 and ran 1 year — value: **~ 50 K GBP**.
- g*₄' Research Associate Fellowship of Flanders' Fund for Scientific Research in Mathematics. Started Sep 1997 and ran 3 years — value: **~ 110 K GBP**.
- g*₅' Research Aspirant Fellowship of Belgium's National Fund for Scientific Research in Physics. Started Sep 1992 and ran 4 years — value: **~ 65 K GBP**.

MEDIA COVERAGE

Our work on Natural Language Processing in [CMC] (see next page and the section “Multidisciplinary research visions and vision for the future”) featured in the article “Quantum links let computers read” in the Dec. 11 2010 issue of New Scientist; it also headlined the cover page:



¹At the time of the application I was not yet eligible to be the ‘official’ PI, but I wrote the project and managed it.

PUBLISH OR PERISH DATA (31-10-2010):

- Total cites: **1573**; total cites/author: **1078**; top cited paper: **241**; top cites paper/year: **35**; h-index: **21**.²

OVERALL PUBLICATION DATA:

- Editorship of Book Series: **1**, [FTP]
- Edited Textbooks: **2**, incl. [C3]
- Edited Special Issues of Journals: **1**
- Edited Conference Proceedings: **3**
- Refereed Computer Science Conference Proceedings: **18**, incl. [AC, CD]
- Refereed Book Chapters: **13**, incl. [CP]
- Refereed Journal Papers: **36**, incl. [C2, BCM, CMC]
- Submitted Journal and Conference Papers: **3**
- Unrefereed Conference Proceedings: **6**, incl. [C1]
- Publicized Reports (with original content): **6**
- **TOTAL: 90**

NOTABLE PUBLICATIONS; the full list of publications is in Appendix 1

Publication **milestones** are:

- [AC] S. Abramsky & B. Coecke (2004) *A categorical semantics of quantum protocols*. In: Proceedings of 19th IEEE conference on Logic in Computer Science (LiCS), pages 415–425. arXiv:quant-ph/0402130.
– **1st quantum computation related paper to ever have been accepted for the prestigious IEEE-LICS conference**. It initiated the still growing field of Categorical Quantum Mechanics, the main topic in our group, has to **241 citations** on Google Scholar, and has **12 blog trackbacks**.
- [CD] B. Coecke & R. Duncan (2008) *Interacting quantum observables*. In: Proceedings of 35th International Colloquium on Automata, Languages and Programming (ICALP). arXiv:0906.4725
– **1st quantum computation related paper to ever have been accepted for the Logic and Semantics track of prestigious ICALP conference**; currently receives **35 citations/year** on Google Scholar.

My **most read** papers also include several ones that are renowned for their unique style and accessibility, in particular in making the technical content of [AC] and [CD] available to a much broader audience:

- [C1] B. Coecke (2005) *Kindergarten quantum mechanics*. Invited speaker's contribution to: Quantum Theory: Reconsiderations of the Foundations III, pages 81–98. AIP Press. arXiv:quant-ph/0510032
- [C2] B. Coecke (2010) *Quantum pictorialism*. Contemporary Physics **51**, 59–83. arXiv:0908.1787
- I produced **tutorial material** for researchers and in particular students wanting to enter the multidisciplinary area of [AC] and [CD], including, among contributions by world-leading researchers, approx. 200 pages by myself:
- [C3] B. Coecke, ed. (2010; 1000 pages): *New Structures for Physics*. Springer-Verlag.
- [CP] B. Coecke & E. O. Paquette (105 pages): *Categories for the practicing physicist*. In [C3]. arXiv:0905.3010

In **ventures into other areas** we also made a number of influential contributions:

- [CMC] B. Coecke, M. Sadrzadeh & S. Clark (2010) *Mathematical foundations for a compositional distributional model of meaning*. Invited contribution to: Linguistic Analysis - Lambek Festschrift, ta. arXiv:1003.4394
– This result (which was first publicized in 2008) forms the basis of a 1.5 M GBP multi-site EPSRC grant application which involves the leading UK Natural Language Processing groups (incl. Cambridge and Edinburgh); this work featured in the Dec. 11 2010 issue of New Scientist
- [BCM] A. Baltag, B. Coecke and M. Sadrzadeh (2007) *Epistemic actions as resources*. Journal of Logic and Computation **17**, 555–585. arXiv:math.LO/0608166
– This work has to **57 citations** on Google Scholar.

I am also **book series editor** for:

[FTP] Springer's *Fundamental Theories of Physics* Series.

²Different versions of papers with sometimes slightly modified title are taken together.

INVITED TALK DATA:

- Invited Courses and Tutorials: **13**, incl. [8]
- Invited Conference and Workshop Talks: **62**, incl. [1, 2, 3, 4, 5, 7]
- Invited Participation as Delegate: **1**
- Invited Talks at Departments, Institutes, Industry: **41**, incl. [6, 9]
- Invited Talks at Other Departments of Own University: **10**
- **TOTAL: 127**

RECENT INVITED TALKS; the full list of invited talks is in Appendix 2.

My academic standing across a variety of disciplines is best reflected by the range and number of invited talks. For example, in (roughly) November 2010 alone, I gave **7** keynote, plenary or invited addresses at:

- [1] Knots in Washington XXXI: Categorification, Quandles, Quantum knots, and Quantum computing, George Washington University, Washington DC, 3 Dec 2010.
- [2] Air Force Office of Scientific Research Cyber Science & Security Program Review, Duke Univ., 23 Nov 2010.
- [3] Simons Conference on New Trends in Quantum Computation, Simons Center for Geometry and Physics, Stony Brook, 19 Nov 2010.
- [4] Toward an Algebra of Process. A Symposium in Honor of Basil J. Hiley on the Occasion of his 75th Birthday, Helsinki, Finland, 12 Nov 2010.
- [5] 2010 Biennial Meeting of the Philosophy of Science Association, Special Session on Category Theoretical Reflections on the Foundations of Physics, Montreal, 6 Nov 2010.
- [6] Sigma Club Seminar Series, London School of Economics, 1 Nov 2010.
- [7] The Categorical Flow of Information in Quantum Physics and Linguistics, Oxford, 30 Oct 2010.

The respective areas of these events are *pure mathematics* (knot theory), *computer security*, *quantum computing*, *foundational physics*, *philosophy of science*, *philosophy of physics* and at the *interface of linguistics and physics*. I also regularly give invited courses, the most recent one being:

- [8] Plenary Tutorial on Quantum Computing for Logicians at (3x1h lectures): North American Annual Meeting of the Association for Symbolic Logic. George Washington University, Washington DC, Mar 2010. Talk slides

These lectures were discussed on the leading theoretical computer science blog, Gödel's Lost Letter and P=NP, by Richard Lipton, starting: "Bob Coecke is a lecturer from Oxford, who gave a series of three invited talks on quantum information theory at the 2010 ASL meeting. He is a terrific speaker, and has a way of using pictures to give the best explanations I have ever seen — or heard — of complex quantum concepts such as teleportation." A screenshot of this blog post is depicted in the picture gallery on page 8. There was also a course on Categorical Quantum Mechanics by my collaborators and myself at the School on Foundational Structures in Quantum Computation and Information of which the videos are available for download from our Group's video archive — as well as many other videos of talks at events that I (co-)organized. I also gave invited talks at private companies:

- [9] Google, Mountain View, California, US, Jul 2005.

OVERALL TALK DATA:

- Invited Talks: **127**
- Talks via Paper or Abstract submission: **52**
- Other (e.g. talks at own event): **26**
- **TOTAL: 205**

PRIZES:

The 2004 biennial *Prize for Meritorious Research in the Field of Quantum Structures*, awarded by the International Quantum Structures Association.

The 1992 *Prize of Sciences* awarded by the Science Faculty, Free University of Brussels, for highest final year marks.

ORGANIZED EVENTS DATA:

- Schools organized: **1**
- Conferences and workshops organized: **7+3+18 = 28**
- Seminar series initiated and organized: **1**
- Review meetings organized: **3**
- **TOTAL: 33**

ORGANIZED EVENTS LISTING:

Organizer of school:

Organizer of the Spring School which marked the end of the EU Future and Emerging Technologies Open STREP Foundational structures for quantum information and computation (QICS), Oxford, May 2010.

Organizer of workshop series:

Co-organizer (with A. Döring) of workshops *Categories, Logic and the Foundations of Physics I–VII*, Imperial college: Jan, May 2008, Jan, Aug 2009; Oxford: Aug 2008, Mar 2010; Birmingham: Sep 2010.

Organizer of workshops *Current Research in Operational Quantum Logic I, II, III*, Brussels, Jun 1998, May 1999, Apr 2000.

Organizer of conferences and workshops:

Co-organizer (with L. Hardy) of *Pictures, Quanta, Probability (CPC)*, Oxford, Aug 2010.

Organizer of *Quantum Physics and Logic VII*, Oxford, May 2010.

Co-organizer (with E. Blakey) of *Complexity Resources in Physical Computation*, Oxford, Aug 2009,

Organizer (with A. Döring and L. Hardy) of *Categories, Quanta, Concepts (CQC)*, Perimeter Institute, Jun 2009.

Local organizer of *Quantum Physics and Logic VI*, Oxford, Apr 2009.

Organizer of *Tutorial Lecture Series on Quantum Information and Computation at Mathematical Foundations of Programming Semantics*, Oxford, Apr 2009.

Co-organizer (with H.-J. Briegel) of *International Conference on Foundational Structures for Quantum Information and Computation*, Obergurgl-Austria, Sep 2008.

Co-organizer (with P. Panangaden) of *Joint Quantum Physics and Logic V & Developments in Computational Models III Workshop*, Rejkavik, Iceland, Jul 2008.

Co-organizer (with V. Kendon) of *Special Session on Quantum Algorithms & Complexity at Computability in Europe*, Athens, Jun 2008.

Co-organizer (with S. Clark) of *Quantum Interaction II*, Oxford, Mar 2008.

Organizer of *Categorical Quantum Logic*, Oxford, Aug 2007.

Co-organizer (with R. Duncan) of *First QICS workshop*, Oxford, Mar 2007.

Organizer of the four-workshop-cluster conference *Cats, Kets and Cloisters (CKC)*, Oxford, Jul 2006).

Local organizer of *Quantum Programming Languages IV*, Oxford, Jul 2006.

Co-organizer (with V. Danos) of *Mathematical Structures in Quantum Informatics*, Inst. H. Poincaré, Paris, Dec 2005.

Organizer of *Logic from Quantales*, Oxford, Jan 2005.

Organizer of *Peripatetic Seminar on Sheaves and Logic 72*, Brussels, Apr 2000.

Member of the organising team of interdisciplinary conference *Einstein meets Magritte*, Brussels, May 1995.

Organizer of seminar series

Initiator and organizer of the still running and very popular *Oxford Advanced Seminar on Informatic Structures*, Oxford, weekly during term, Oct 2004–June 2008.

Organizer of project review meeting

Organizer of 3 review meetings for FP6-STREP QICS, Inst. H. Poincaré, Mar 2008; Brussels, Mar 2009, Sep 2010.

OTHER OUTREACH:

Co-maintainer (with C. Heunen and J. Vicary) of the *Quantum Group Talks Archive*, which in contains video recordings of 150–200 talks and conferences in the areas of our groups' research.

Co-maintainer (with J. Biamonte, A. Döring and J. Vicary) of the *Categories, Logic and Foundations of Physics* web page. In its first 12 months the webpage had around 25.000 pageviews.

COORDINATORSHIP:

Coordinator of the 3.5 year EU Future and Emerging Technologies Open STREP Foundational structures for quantum information and computation (QICS). Partners were Bristol (Jozsa), Edinburgh-Paris (Danos), Grenoble (Jorrand), Hannover (Werner), Innsbruck (Briegel), York (Braunstein). (see also page 2 on grants)

PROGRAM COMMITTEE AND MEMBERSHIP DATA:

- Program committee chairing: **7**
- Program committee membership: **18**
- Council membership: **1**
- Invitation only membership: **1**

PROGRAM CHAIR AND COMMITTEE LISTING:

PC co-chair (w. F. Ablayev) of the workshop High Productivity Computations (Kazan, Russia, Jun 2010)

PC co-chair (w. P. Panangaden & P. Selinger) of the workshop Quantum Physics and Logic VII (Oxf., May 2010)

PC chair of the QICS School on Foundational Structures in Quantum Computation & Information (Oxf., May 2010)

PC co-chair (w. P. Panangaden & P. Selinger) of the workshop Quantum Physics and Logic VI (Oxf., Apr 2009)

PC co-chair (w. P. Panangaden) of the joint workshop Quantum Physics and Logic V – Developments in Computational Models IV (Rejkavik-Iceland, Jul 2008).

Workshop chair of Algebraic and Topological Methods in non-Classical Logics III (Oxf., Aug 2007)

PC chair of Cats, Kets and Cloisters (Oxf., Jul 2006)

PC member of:

- *24th and 27th Conference on the Mathematical Foundations of Programming Semantics (MFPS)* (Philadelphia & Carnegie Mellon; May 2008, May 2011).
- *Quantum Interaction I, II, III, IV, V (QI)* (Stanford, Oxford, Saarbruecken, Washington DC & Aberdeen; Mar 2007, 2008, 2009, Nov 2010, June 2011).
- *3rd International Workshop on Physics and Computation (P&C)* (on the Nile, Egypt, Aug-Sep 2010).
- *International Workshop on Categorical Logic* (Brno, Czech Republic, Aug 2010).
- *17th Workshop on Logic, Language, Information and Computation (WoLLIC)* (Brasilia, Brazil, Jul 2010).
- *6th Conference on Theory and Applications of Models of Computation (TAMC)* (Changsha, China, May 2009).
- *Interaction and Concurrency Experience '09 (ICE)* (Bologna, Aug 2009).
- *Developments in Computational Models '09 (DCM)* (Rhodes, Greece, Jul 2009).
- *Trends in Logic VI: Logic and the Foundations of Physics* (Brussels, Dec 2008).
- *3rd & 4th Workshop on Quantum Programming Languages (QPL)* (Chicago & Oxford; Jul 2005, Jul 2006).
- *6th & 7th Biennial International Quantum Structures Meeting (IQSA)* (Vienna & Denver; Jul 2002 & 2004).

Voted council member of the International Quantum Structures Association (IQSA) – Apr 2001-05, Apr 2009-13.

Member of the Foundational Questions Institute (FQXi) – membership by invitation only.

RESEARCH GRANT PANEL MEMBERSHIP AND EXAMINATION:

Examiner for 4 D.Phil. and Ph.D. theses (Université Catholique de Louvain 2003, Free Universit of Brussels 2006, Oxford 2007, McGill 2008).

Member of EPSRC's peer review college since 2006.

Member of the Foundational Questions Institute's (FQXi) expert panel for the essay competition 'What is Ultimately Possible in Physics?' in 2009.

Member of the EU Future and Emerging Technologies (FET) Open STEP evaluation panel in 2010.

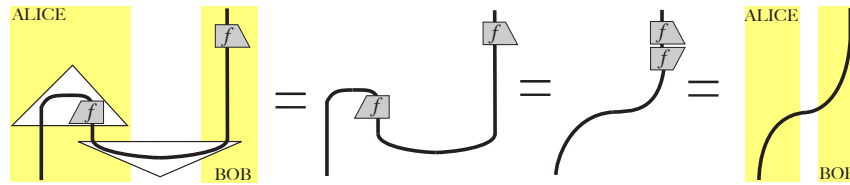
MULTIDISCIPLINARY RESEARCH VISION NOW AND FOR THE FUTURE:

Multidisciplinary is reflected in my personal track record, from physics via mathematics into computer science, the backgrounds of group members, the spectrum of my publications, the range of invited talks, the range of events that I organized, and the range of grant successes and applications.

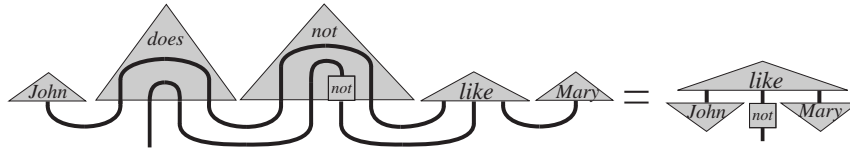
These activities are moreover interacting, and at equal footing, that is, it is not the case that one discipline is the 'slave' of another one, like it is often the case in interdisciplinary research.

I strongly believe that this kind of multidisciplinary enables the emergence of radically new approaches and concepts, which could never have seen the light within the tight constraints of the usual disciplinary boundaries. To allow for these new methods and concepts to be thoroughly developed one of course needs a sustainable and stable context, which a group of this size with a broad spectrum of funding sources offers. It also allows younger members to both be involved in the more challenging but at the same time high-risk areas, as well as the more established areas, guaranteeing a successful progress in their research.

More specifically, I think that long-standing deep fundamental questions in physics may benefit by views on reality offered by other sciences, in contrast to the rather narrow view on classicality in terms of Newtonian mechanics. An interesting example here is the structural similarity of, on the one hand, the categorical quantum mechanics description of quantum phenomena and protocols [AC, C1, C2]:



and how information flows between words generates meaning of a sentence [CMC]:



Given that logic arose from a fragment of natural language, this more profound analysis of meaning in language may provide a completely new perspective on logic, and in turns, on fundamental physics.

Besides my research in quantum information and quantum foundations, structural coincidences of this kind within a variety of disciplines will constitute an import focus of my future research, as well as their applications.

GOOD CITIZENSHIP AT OXFORD UNIVERSITY:

Since I started my University Lectureship in quantum computer science I have been holder of an **EPSRC Advanced Research Fellowship which in principle relieves me from teaching and administrative duties**. Still, I did contribute substantially to the University's and the College's needs:

- I created a new course and did a substantial amount of teaching (see below).
- Member and loyal attendant of Wolfson College's Governing Body.
- Member of Wolfson College's Fellowship and Membership Committee, Since 2008.
- Appointment committee member of the University Lectureship in Theoretical Quantum Optics, Nov 2008.
- Member Oxford University Computing Laboratory Scholarships Committee, Since Oct 2010.
- Undergraduate college admission interviewing for St John's College, Oxford, 2006
- MSc admission interviewing for Oxford University Computing Laboratory, 2007.
- Advisor for many students at Wolfson College and Oxford University Computing Laboratory.

TEACHING EXPERIENCE:

At Oxford University Computing Laboratory:

I created and provided lecture notes for the *Quantum Computer Science* course.

I lectured and set and marked exams for the *Quantum Computer Science* course in Hilary 2006, 07, 08, 09.

I created, provided lecture notes, and lectured an advanced course *Structure, Logicality and Sense in Quantum Theory*, immediately on my arrival at Oxford University Computing Laboratory, in Michaelmas 2001.

From 2001-2010 I very regularly gave parts of and guest lectures for many courses, including:

- *Domain Theory*
- *Categories, Proofs and Programs*
- *Logic and Information Flow for Multi-Agent Systems*

I was class tutor for all of the above mentioned courses, as well as for *Intelligent Systems I*.

Other teaching:

Instructor of *computer aided musical composition and performance* at two art schools, 1996–97.

Class tutor of *calculus, physics I, discrete mathematics, analytical mechanics, electro-magnetism, and projective geometry* at the Free University of Brussels, 1992–2000.

SUPERVISION DATA:

- DPhil Supervision (including ongoing): **1(pre-Oxf) + 17 = 18**
- MSc Thesis Supervision: **9**
- Licentiaats Thesis Supervision: **4**



COMPUTING LABORATORY



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Welcome



Logic Meets Complexity Theory

MARCH 21, 2010

by rjlipton

tags: Algorithms, circuits, Factoring, graphs, P=NP, Problems, Proofs, SAT, time, Turing

A summary of the 2010 ASL conference

Bob Coecke is a lecturer from Oxford, who gave a series of three invited talks on quantum information theory at the **2010 ASL meeting**. He is a terrific speaker, and has a way of using pictures to give the best explanations I have ever seen—or heard—of complex quantum concepts such as teleportation.



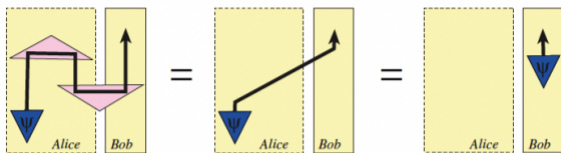
Today I will talk about his presentations, Alexander Razborov's award talk, and our complexity session given in Razborov's honor at the ASL conference. ASL is the Association for Symbolic Logic.

The ASL meeting was quite enjoyable—being in Washington D.C. during several days of beautiful weather did not hurt either. ASL is a relatively small meeting, but has a strong energy and excitement about it. I would definitely plan on going again, and anyone interested in hearing very strong talks on foundational issues should go to one of their meetings.

The ASL group does some things a bit differently from STOC and FOCS and other theory meetings. Their meeting has several invited and special one hour talks, as well as shorter 30 minute contributed talks. The latter are arranged in parallel sessions, but these sessions are very inclusive and essentially all get a chance to speak. ASL also does an interesting “trick” with their tutorials: the tutorial was broken into three one hour talks given over three consecutive days. I liked this approach very much.

A Picture is Worth a Thousand Qubits

Coecke uses pictures of a special kind to explain quantum information processing. This, in his hands, is in my opinion extremely insightful, and helped me really “get it.” I thought I would try to give an over view of what he does with his wonderful pictures. If you want to see the real thing go [here](#) for the full story. He uses pictures like these to explain quantum teleportation and other operations:

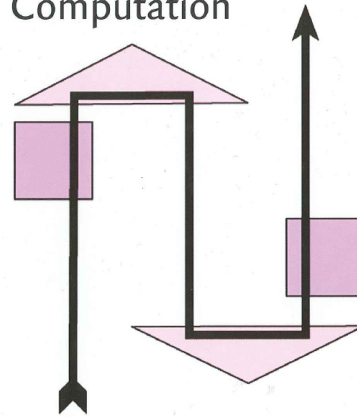


The intuition is each diagram represents a physical experiment. He has a small set of simple rules: diagrams can be changed into other ones by applying a rule. In this was he can show how a complex looking quantum setup is really equivalent to something often much simpler. This allows insight into why things work the way they do. The figure above starts out with a complex entanglement, and finally gets a simple transfer of bits. Very neat.

If any of you discover a caveman drawing looking like this: we have a problem.



Semantic Techniques in Quantum Computation



Edited by

Simon Gay and Ian Mackie

CAMBRIDGE

Pictures are central to the categorical quantum mechanics (CQM) research program, which we initiated. They constitute a ‘rigorous’ mathematical language in which we describe nature in CQM.

The screen shot at the top shows the banner of Oxford University Computing Laboratory. The prominent picture in it is drawn by me and represents pictorial reasoning within CQM.

The screen shot on the left shows an entry on the leading theoretical computer science blog, Gödel's Lost Letter and P=NP, authored by Richard Lipton. It discusses my plenary tutorial lectures on quantum computing and categorical quantum mechanics as well as Razborov's Gödel Prize lecture at the 2010 North American Annual Meeting of the Association for Symbolic Logic.

The scan above depicts the cover of a textbook. The cover picture is taken from Kindergarten Quantum Mechanics, my popular paper.

Appendix 1: publications

Book Series Editorship

1. *Fundamental Theories of Physics*, Springer-Verlag.

Textbooks Edited

2. B. Coecke, ed. (2010; 1000 pages) *New Structures for Physics*. Lecture Notes in Physics series, Springer-Verlag.
3. B. Coecke, D.J. Moore and A. Wilce, eds. (2000) *Current Research in Operational Quantum Logic: Algebras, Categories, Languages*. Foundational Theories of Physics series, Springer-Verlag.

Special Issues of Journals Edited

4. B. Coecke, P. Panagaden and P. Selinger, eds. (2011) *Foundations of Physics*. Issue on: *Quantum Physics and Logic*. To appear.

Conference Proceedings Edited

5. F. Ablayev, B. Coecke and A. Vasiliev, eds. (2011) *Proceedings of the 1st Workshop on High Productivity Computations*. Electronic Proceedings in Theoretical Computer Science. To appear.
6. B. Coecke, P. Panagaden and P. Selinger, eds. (2010) *Proceedings of Quantum Physics and Logic VI*. Electronic Notes in Theoretical Computer Science. To appear.
7. B. Coecke, I. Mackie, P. Panagaden and P. Selinger, eds. (2010) *Proceedings of Quantum Physics and Logic V and Developments in Computational Models IV*. Electronic Notes in Theoretical Computer Science. To appear.
8. P. D. Bruza, W. Lawless, K. van Rijsbergen, D. A. Sofge, B. Coecke and S. Clark, eds. (2008) *Quantum Interaction. Proceedings of the Second Quantum Interaction Symposium*. College Publications.

Refereed Computer Science Conference Proceedings

Note: in Computer Science, acceptance of a conference paper is regarded as of higher value than a journal publication

LNCS := Lecture Notes in Computer Science

ENTCS := Electronic Notes in Theoretical Computer Science

ICALP := Int. Coll. on Automata, Languages and Programming

LiCS := Annual IEEE Symposium on Logic in Computer Science

MFPS := Conf. on Math. Foundations for Programming Semantics

CTCS := Conference on Category Theory and Computer Science

CSL := EACSL Annual Conference on Computer Science Logic

QPL := Workshop on Quantum Programming Languages

QI := Quantum Interaction Symposium

LCMAS:= Int. workshop on Logic & Comm. in Multi-Agent Syst.

9. B. Coecke and S. Perdrix (2010) Environment and classical channels in categorical quantum mechanics. In: Proc. 19th CSL, pp. 230–244, LNCS. arXiv:1004.1598
10. B. Coecke and A. Kissinger (2010) The compositional structure of multipartite quantum entanglement. In: Proc. 37th ICALP, pp. 297–308, LNCS. arXiv:1002.2540
11. B. Coecke, B. Edwards and R. W. Spekkens (2010) Phase groups and the origin of non-locality for qubits. In: Proc. 6th QPL, ENTCS. arXiv:1003.5005
12. B. Coecke, Q. Wang, B. Wang, Y. Wang and Q. Zhang (2010) Graphic calculus for quantum key distribution. In: Proc. 6th QPL, ENTCS.
13. B. Coecke and B. Edwards (2010) Toy quantum categories. In: Proc. 5th QPL, ENTCS. arXiv:0808.1037
14. B. Coecke and R. Duncan (2008) Interacting Quantum Observables. In: Proc. 35th ICALP, pp. 298–310, LNCS.
15. S. Clark, B. Coecke and M. Sadrzadeh (2008) A Compositional Distributional Model of Meaning. In: Proc. 2nd QI, pp. 133–140, College Publications.
16. B. Coecke, E. O. Paquette and S. Perdrix (2008) Bases in diagrammatic quantum protocols. In: Proc. 24th MFPS, ENTCS **218**. arXiv:0808.1029

17. B. Coecke and E. O. Paquette (2008) POVMs and Naimark's Theorem Without Sums. In: Proc. 4th QPL, ENTCS **210**. arXiv:quant-ph/0608072
18. B. Coecke (2008) Axiomatic Description of Mixed States from Selinger's CPM-construction. In: Proc. 4th QPL, ENTCS **210**.
19. B. Coecke (2007) Automated Quantum Reasoning: Non-Logic \rightsquigarrow Semi-Logic \rightsquigarrow Hyper-Logic. In: Proc. 1st QI, AAAI Press. SS07-08-005.pdf
20. B. Coecke (2007) De-linearizing Linearity: Projective Quantum Axiomatics from Strong Compact Closure. In: Proc. 3th QPL, ENTCS **170**. arXiv:quant-ph/0506134
21. B. Coecke (2006) Strongly Compact Closed Semantics. In: Proc. 21st MFPS, ENTCS **155**, 331–340.
22. B. Coecke (2004) Quantum Information Flow, Concretely, Abstractly. In: Proc. 2nd QPL, pp. 57–74, P. Selinger, Ed., TUCS General Publication.
23. S. Abramsky and B. Coecke (2004) A Categorical Semantics of Quantum Protocols. In: Proc. 19th LiCS, pp. 415–425, IEEE Comp. Sc. Press. arXiv:quant-ph/0402130
24. A. Baltag, B. Coecke and M. Sadrzadeh (2004) Algebra and Sequent Calculus for Epistemic Actions. In: Proc. 2nd LCMAS, ENTCS **126**.
25. B. Coecke (2003) Entropic Geometry from Logic. In: Proc. 19th MFPS, ENTCS **83**. arXiv:quant-ph/0212065
26. S. Abramsky and B. Coecke (2002) Physical Traces: Quantum vs. Classical Information Processing. In: Proc. 9th CTCS, ENTCS **69**. arXiv:cs.CG/0207057

Refereed Book Chapters – mostly invited

27. B. Coecke (2010) A universe of quantum processes and some of its guises. In: *Deep Beauty: Mathematical Innovation and the Search for an Underlying Intelligibility of the Quantum World*, H. Halvorson, Ed., Cambridge University Press. To appear. arXiv:1009.3786
28. B. Coecke and K. Martin (2010) A Partial Order on Classical and Quantum States. In: *New Structures for Physics*, 167–271, B. Coecke, Ed., Springer-Verlag.
29. B. Coecke and E. O. Paquette (2010) Categories for the Practicing Physicist. In: *New Structures for Physics*, pp. 167–271, B. Coecke, Ed., Springer-Verlag. arXiv:0905.3010
30. B. Coecke, E. O. Paquette and D. Pavlovic (2009) Classical and Quantum Structuralism. In: *Semantic Techniques for Quantum Computation*, pp. 29–69, I. Mackie and S. Gay (eds), Cambridge University Press. arXiv:0904.1997
31. S. Abramsky and B. Coecke (2008) Categorical Quantum Mechanics. In: *Handbook of Quantum Logic and Quantum Structures*, pp. 261–324, K. Engesser, D. M. Gabbay and D. Lehmann, Eds., Elsevier. arXiv:0808.1023
32. B. Coecke and D. Pavlovic (2008) Quantum Measurements without Sums. In: *Mathematics of Quantum Computing and Technology*, pp. 559–595, G. Chen and L. Kauffman and S. Lamnaco, Eds., CRC Press. arXiv:quant-ph/0608035
33. B. Coecke (2006) Introducing Categories to the Practicing Physicists. In: *What is Category Theory?*, pp. 45–74, G. Sica, Ed., Advanced Studies in Mathematics and Logic **30**, Polimetrica. arXiv:0808.1032
34. B. Coecke, D.J. Moore and S. Smets (2004) Logic of Dynamics & Dynamics of Logic: Some Paradigm Examples. In *Logic, Epistemology and the Unity of Science*, pp. 527–556, S. Rahman, J. Symons, D. M. Gabbay and J.-P. Van Bendegem, Eds., Kluwer. arXiv:math.LO/0106059
35. B. Coecke and D.J. Moore (2000) Operational Galois Adjunctions. In *Current Research in Operational Quantum Logic: Algebras, Categories, Languages*, pp. 195–218, eds., B. Coecke, D.J. Moore and A. Wilce, Foundational Theories of Physics (series), Kluwer. arXiv:quant-ph/0008021
36. B. Coecke, D.J. Moore and A. Wilce (2000) Operational Quantum Logic: An Overview. In *Current Research in Operational Quantum Logic: Algebras, Categories, Languages*, pp. 1–36, B. Coecke, D.J. Moore and A. Wilce, Eds., Foundational Theories of Physics (series), Kluwer. arXiv:quant-ph/0008019.

37. B. Coecke and K. Verelst (1999) Early Greek Thought and New Perspectives in Quantum Mechanics: Outlines of an Approach. In *Metadebates of Science*, pp. 163–196, G. Cornelis, S. Smets, J.P. Van Bendegem, Eds., Kluwer.
38. D. Aerts, B. Coecke and S. Smets (1999) On the Origin of Probabilities in Quantum Mechanics: Creative and Contextual Aspects. In *Metadebates of Science*, pp. 299–310, G. Cornelis, S. Smets and J.P. Van Bendegem, Eds., Kluwer.
39. D. Aerts and B. Coecke (1999) The Creation-Discovery-View: Towards a Possible Explanation of Quantum Reality. In *Language, Quantum, Music*, pp. 105–116, M.L. Dalla-Chiara et al., Eds., Kluwer.

Refereed Journal Papers – some invited

40. B. Coecke and R. Lal (2011) Causal categories. *Foundations of Physics*. To appear.
41. B. Coecke and S. Perdrix (2011) Environment and classical channels in categorical quantum mechanics. *Logical Methods in Computer Science*. To appear.
42. B. Coecke and R. W. Spekkens (2011) Picturing classical and quantum Bayesian inference. *Synthese*. To appear.
43. B. Coecke and B. Edwards (2011) Spekkens’s toy theory as a category. *AMS Proceedings of Symposia in Applied Mathematics*. To appear.
44. B. Coecke and R. Duncan (2010) Interacting quantum observables: categorical algebra and diagrammatics. *New Journal of Physics*. To appear. arXiv:0906.4725
45. B. Coecke, D. Pavlovic and J. Vicary (2010) A new description of orthogonal bases. *Mathematical Structures in Computer Science*. To appear. arXiv:0810.0812
46. B. Coecke, M. Sadrzadeh and S. Clark (2010) Mathematical foundations for a compositional distributional model of meaning. *Linguistic Analysis*. To appear. arXiv:1003.4394
47. B. Coecke (2010) Quantum pictorialism *Contemporary Physics* **51**, 59–83. arXiv:0908.1787
48. A. Baltag, B. Coecke and M. Sadrzadeh (2007) Epistemic Actions as Resources. *Journal of Logic and Computation* **17**, 555–585. arXiv:math.LO/0608166
49. S. Abramsky and B. Coecke (2007) Physics from computer science. *Journal of Unconventional Computing* **3**, 179–197.
50. S. Abramsky and B. Coecke (2005) Abstract physical traces. *Theory and Applications of Categories* **14**, 111–124. arXiv:0910.3144
51. B. Coecke and S. Smets (2004) The Sasaki-Hook is not a [Static] Implicative Connective but Induces a Backward [in Time] Dynamic One that Assigns Causes. *International Journal of Theoretical Physics* **43**, 1705–1736. arXiv:quant-ph/0111076
52. B. Coecke (2002) Disjunctive Quantum Logic in Dynamic Perspective. *Studia Logica* **71**, 1–10. arXiv:math.LO/0011209
53. B. Coecke (2002) Quantum Logic in Intuitionistic Perspective. *Studia Logica* **70**, 353–382. arXiv:math.LO/0011208
54. B. Coecke, D.J. Moore and I. Stubbe (2001) Quantaloids Describing Causation and Propagation of Physical Properties. *Foundations of Physics Letters* **14**, 133–145. arXiv:quant-ph/0009100
55. B. Coecke and I. Stubbe (2000) State Transitions as Morphisms for Complete Lattices. *International Journal of Theoretical Physics* **39**, 601–610. arXiv:math.DS/0008039
56. B. Coecke and S. Smets (2000) Logical Description for Perfect Measurements. *International Journal of Theoretical Physics* **39**, 591–599. arXiv:quant-ph/0008017
57. B. Coecke (2000) Structural Characterization of Compoundness. *International Journal of Theoretical Physics* **39**, 581–590. arXiv:quant-ph/0008054
58. B. Coecke and I. Stubbe (1999) On a Duality of Quantales emerging from an Operational Resolution. *International Journal of Theoretical Physics* **38**, 3269–3281.
59. B. Coecke and I. Stubbe (1999) Operational Resolutions and State Transitions in a Categorical Setting. *Foundations of Physics Letters* **12**, 29–49. arXiv:quant-ph/0008020.
60. B. Coecke and F. Valckenborgh (1998) Hidden Measurements, Automorphisms and Decompositions in Context Dependent Components. *International Journal of Theoretical Physics* **37** 311–322.
61. H. Amira, B. Coecke and I. Stubbe (1998) How Quantales Emerge by Introducing Induction within the Operational Approach. *Helvetica Physica Acta* **71**, 554–572.
62. B. Coecke (1998) A Representation for a Spin-S Quantum Entity as a Compound System in \mathcal{R}^3 Consisting of 2S Individual Spin-1/2 Entities. *Foundations of Physics* **28**, 1347–1365. arXiv:quant-ph/0105094
63. B. Coecke (1998) A Representation for Compound Systems as Individual Entities: Hard Acts of Creation and Hidden Correlations. *Foundations of Physics* **28**, 1109–1135. arXiv:quant-ph/0105093
64. B. Coecke (1998) A Representation of Projection Lattices and their States in Euclidean Space. *Journal of Mathematical Analysis and its Applications* **220**, 603–612.
65. B. Coecke (1997) A Classification of Classical Representations for Quantum-like Systems. *Helvetica Physica Acta* **70**, 462–477. arXiv:quant-ph/0008062
66. B. Coecke (1997) Classical Representations for Quantum-like Systems through an Axiomatics for Context Dependence. *Helvetica Physica Acta* **70**, 442–461. arXiv:quant-ph/0008061
67. D. Aerts, B. Coecke, B. D’Hooghe and F. Valckenborgh (1997) A Mechanistic Macroscopical Physical Entity with a Three Dimensional Hilbert Space Quantum Description. *Helvetica Physica Acta* **70**, 793–802.
68. D. Aerts, B. Coecke, T. Durt and F. Valckenborgh (1997) Quantum, Classical and Intermediate II : the Vanishing Vector Space Structure. *Tatra Mountains Mathematical Publications* **10**, 241–266.
69. D. Aerts, B. Coecke, T. Durt and F. Valckenborgh (1997) Quantum, Classical and Intermediate I : a Model on the Poincaré Sphere. *Tatra Mountains Mathematical Publications* **10**, 225–240.
70. B. Coecke (1997) New Examples of Hidden Measurement Systems and Outline of a General Scheme. *Tatra Mountains Mathematical Publications* **10**, 63–74.
71. B. Coecke (1996) Superposition States through Correlations of the Second Kind. *International Journal of Theoretical Physics* **35**, 2339–2351.
72. B. Coecke (1995) Representation of a Spin-1 Entity as a Joint System of Two Spin-1/2 Entities on which we Introduce Correlations of the Second Kind. *Helvetica Physica Acta* **68**, 396–406.
73. B. Coecke (1995) Generalisation of the Proof on the Existence of Hidden Measurements to Experiments with an Infinite Set of Outcomes. *Foundations of Physics Letters* **8**, 437–447.
74. B. Coecke (1995) Hidden Measurement Model for Pure and Mixed States of Quantum Physics in Euclidean Space. *International Journal of Theoretical Physics* **34**, 1313–1320.
75. B. Coecke (1995) Hidden Measurement Representation for Quantum Entities Described by Finite Dimensional Complex Hilbert Spaces. *Foundations of Physics* **25**, 1185–1208.

Submitted to Conference or Journal

76. B. Coecke and Ray Lal (—) Time-asymmetry and causal structure. Submitted to: Physical Review Letters.
77. B. Coecke and Aleks Kissinger (—) The compositional structure of multipartite quantum entanglement. Submitted to: Communications in Mathematical Physics.
78. E. Grefenstette, M. Sadrzadeh, S. Clark, B. Coecke and S. Pulman (—) Concrete Compositional Sentence Spaces. Submitted to: 9th International Conference on Computational Semantics (IWCS).

Unrefereed Conference Proceedings

79. B. Coecke (2005; invited speaker's contribution) Kindergarten Quantum Mechanics. In: *Proceedings of Quantum Theory: Reconsiderations of the Foundations III*. A. Khrennikov, Ed., AIP Press. arXiv:quant-ph/0510032
80. B. Coecke (2004; invited speaker's contribution) Quantum Information Flow, Concretely, and Axiomatically. In: *Proceedings of Quantum Informatics 2004*, pp. 15–29, Y. I. Ozhigov, Ed., Proceedings of SPIE Vol. 5833. arXiv:quant-ph/0506132
81. B. Coecke and K. Martin (2004; invited speaker's contribution) Partiality in Physics. In: *Proceedings of Quantum Theory: Reconsideration of the Foundations II*, pp. 129–148, World Scientific. arXiv:quant-ph/0312044
82. B. Coecke (2001) Discretization and Determination in Quantum History Theories. In: *Quantum Probability and White Noise Analysis XIII*, pp. 85–94, World Scientific. arXiv:quant-ph/0105085
83. B. Coecke, B. D'Hooghe and F. Valckenborgh (1997) Classical Physical Entities with a Quantum Description. In: *Proceedings of Fundamental Problems in Quantum Physics II*, pp. 103–107, M. Ferrero, A. van der Merwe, Eds., Fundamental Theories of Physics, Kluwer Academic Publishers.
84. D. Aerts, S. Aerts, B. Coecke, B. D'Hooghe, T. Durt and F. Valckenborgh (1997) A Model with Varying Fluctuations in the Measurement Context. In: *Proceedings of Fundamental Problems in Quantum Physics II*, pp. 7–9, M. Ferrero, A. van der Merwe, Eds., Fundamental Theories of Physics, Kluwer Academic Publishers.

Theses and Publicized Reports (with original content)

85. B. Coecke and B. Edwards (2010) *Three qubit entanglement analysed with graphical calculus*. PRG-RR-09-03
86. B. Coecke, E. O. Paquette and D. Pavlovic (2008) *Classical and quantum structures*. PRG-RR-08-02
87. B. Coecke (2007) *Complete positivity without positivity and without compactness*. PRG-RR-07-05
88. B. Coecke (2004) *The Logic of Entanglement*. (short version of following) arXiv:quant-ph/0402014
89. B. Coecke (2003; 160 pages) *The Logic of Entanglement. An Invitation*. PRG-RR-03-12
90. B. Coecke (1996; 99 pages) *Hidden Measurement Systems*. Ph. D. Thesis, Free University of Brussels.

Appendix 2: invited talks

Links to events are available from:

users.comlab.ox.ac.uk/bob.coecke/Events.html

Invited courses and tutorials

1. Tutorial on Quantum Computing (CQ) for Logicians at (3x1h lectures): *North American Annual Meeting of the Association for Symbolic Logic*. Washington DC, Mar 2010. Talk slides
2. Tutorial on Categorical Quantum Mechanics (CQM) at (3x1.5h lectures): Beihang University of Aeronautics and Astronautics, Beijing, China, Nov 2009.
3. Tutorial on Category Theory (CT) in CQ at (2h lecture): *3rd Summer School on Quantum Computation and Information*. Mexico City, Jun 2009. [CANCELLED due to swine flu]
4. Tutorial on Quantum Theory (CT) for Computer Scientists (CS) at (2h lecture): *25th Conference on the Mathematical Foundations of Programming Semantics*. Oxford, Apr 2009.
5. Tutorial on CQM at (5x1.5h lectures): *Expository Quantum Lecture Series 2: Foundations of Quantum Science and Technology*. University of Putra, Malaysia, Nov 2008.
6. Tutorial on CT for Physicists (Ph) at (2h lecture): *International Conference on Foundational Structures for Quantum Informatics*. Obergurgl, Austria, Sep 2008.
7. Tutorial on QT for CT at (2h lecture): *Categories, Logic and Found. Physics III*. Oxford, Aug 2008. QGvideo:0808002

8. Tutorial on CQM at (2h lecture): *Logic, Physics and Quantum Information Theory*. Workshop at Bellairs Research Centre, Barbados, Mar 2008. QGvideo:0803001
9. Tutorial on CQM at (3x1.5h lectures): *Peripatetic seminar on sheaves and logic 84*. Braunschweig, Oct 2006.
10. Tutorial on CT for Ph at (2h lecture): *Quantum Information, Computation and Logic: Exploring New Connections*. Perimeter Institute for Theoretical Physics, Jul 2005.
11. Tutorial on CQM at (5x2h lectures): *Logical and Semantical Methods in Quantum Computation*. Workshop at McGill's Bellairs Research Centre, Barbados, Apr 2004.
12. Tutorial on CQM at (4h lectures): *Quantum Optics and Laser Science Group*, Imperial College, Feb 2004.

Invited conference and workshops talks

13. *Knots in Washington XXXI: Categorification, Quandles, Quantum knots, and Quantum computing*. George Washington University, Washington DC, Dec 2010.
14. *AFOSR Cyber Science and Security Program Review*. Duke University, North Carolina, Nov 2010.
15. *Simons Conference on New Trends in Quantum Computation*. Simons Center for Geom. and Phys., Stony Brook, Nov 2010.
16. *Basil Hiley Fest (75th birthday)*. Helsinki, Finland, Nov 2010.
17. *2010 Biennial Meeting of the Philosophy of Science Association*. Montreal, Nov 2010.
18. *The Categorical Flow of Information in Quantum Physics and Linguistics*. Oxford, Oct 2010.
19. *Quantum Physics and the Nature of Reality – John Polkinghorne 80th birthday conference*. Oxford, Sep 2010.
20. *Workshop on High Productivity Computations*. Kazan, Russia, Jun 2010.
21. *The Semantics of Information*. Dagstuhl, Germany, Jun 2010.
22. *ASL Special Session on Logic & Foundations of Physics*. Washington DC, Mar 2010.
23. *Quantum and Combinatorics*. Zakopane, Poland, Nov 2009.
24. *2nd Annual Informatic Phenomena Workshop*. Tulane University, New Orleans, Oct 2009.
25. *Conference on Representation Theory, Quantum Field Theory, Category Theory, Mathematical Physics and Quantum Information Theory*. University of Texas at Tyler, Oct 2009.
26. *Theory & Practice of Meaning Composition in Natural Languages*. Wolfson College, Oxford, Sep 2009.
27. *Reconstructing Quantum Theory*. Perimeter Institute, Aug 2009. pirsas:09080013
28. *Logical Aspects of Fault Tolerance*. UCLA, Los Angeles, Aug 2009. [I cancelled due to accidental double-booking]
29. *Mathematics in Foundations of Physics*. Askloster, Sweden, Jul 2009.
30. *The 2nd International Conference on Foundational Questions in Physics and Cosmology*. Ponta Delgada, Azores, Jul 2009.
31. *Categories, Quanta, Concepts*. Perimeter Institute, June 2009. pirsas:09060013
32. *Workshop on Quantum Computation and Information*. Mexico City, Jun 2009.
33. *Quantum Logic Inspired by Quantum Computation*. Indiana University, May 2009.
34. *1st Annual Informatic Phenomena Workshop*. Tulane University, New Orleans, Oct 2008.
35. *Mathematical developments in foundational physics*. Askloster, Sweden, Jul 2008.
36. *New Directions in the Foundations of Physics*. American Center for Physics, College Park, Apr 2008.
37. *2008 Clifford Lectures*. Tulane Univ., New Orleans, Mar 2008.
38. *Symposium on Logic and Physics*. Utrecht, Holland, Jan 2008.
39. *Structure and Identity*. Royal Academy, Brussels, Dec 2007.
40. *Operational Approaches to Quantum Theory*. CREA, Paris 5, Oct 2007.
41. *Deep Beauty: A conference in honor of John von Neumann's contributions to the mathematical foundations of quantum mechanics*. Princeton University, Oct 2007.

42. *The first International Iran Conference on Quantum Information*. Kish Island, Iran, Sep 2007.
 43. *Mathematical developments in foundational physics*. Askloster, Sweden, Jul 2007.
 44. *International Category Theory Conference 2007 (CT)*. Carvoeiro, Portugal, Jun 2007.
 45. *Quantum Theory: reconsideration of foundations-4*. Vaxjo, Sweden, Jun 2007.
 46. *Physics, Information and Computation*, special session of the *23rd Conference on the Mathematical Foundations of Programming Semantics (MFPS)*. University of Tulane, New Orleans, Apr 2007.
 47. *Mathematical Methods for Reasoning about Security*. Workshop at *Bellairs Research Centre*, Barbados, Mar 2007.
 48. *Mathematical developments in foundational physics*. Askloster, Sweden, Jul 2006.
 49. *The 21st Summer Conference on Topology and its Applications*. Georgia Southern University, Jul 2006.
 50. *Foundations of Probability and Physics-4*. Vaxjo, Sweden, Jun 2006.
 51. *The 2006 Association of Symbolic Logic Annual Meeting*. Montreal, May 2006.
 52. *Logical and Semantical Methods in Quantum Computation II*. Workshop at *Bellairs Research Centre*, Barbados, Apr 2005.
 53. *Computational Structures for Modelling Space, Time and Causality*. Dagstuhl, Germany, Aug 2006.
 54. *Mathematical Theory of Quantum Computation and Quantum Technology*. Texas A&M University, Nov 2005.
 55. *The Impact of Categories: 60 Years of Category Theory in Historical and Philosophical Retrospect*. Ecole Normale Supérieure, Paris, Oct 2005.
 56. *Quantum Information, Computation and Logic: Exploring New Connections*. Perimeter Institute for Theoretical Physics, Jul 2005. `pirsa:05070118`
 57. *Quantum Theory: Reconsideration of the Foundations III*. Vaxjo, Sweden, Jun 2005.
 58. *Quantum Computing*, special session of the *Twenty-first Conference on the Mathematical Foundations of Programming Semantics (MFPS XXI)*. University of Birmingham, May 2005.
 59. *Causality, Spacetime Topology & Domain Theory*. Workshop at *Bellairs Research Centre*, Barbados, Apr 2005.
 60. *Mathematical Structures for Quantum Computation*. Université Paris 7, Dec 2004.
 61. *Workshop on Probabilistic Semantics*. Imperial College, London, Nov 2004.
 62. *Quantum Informatics 2004*. Moscow, Russia, Oct 2004.
 63. *Spatial Representation: Discrete vs. Continuous Computational Models*. Dagstuhl, Germany, Aug 2004.
 64. *Perspectives workshop "Quantum Computing"*. Dagstuhl, Germany, May 2004.
 65. *Philosophical Logic meets Mathematical Logic: from Classical to Quantum*. Free University of Brussels, Feb 2004.
 66. *Joint Mathematics Meetings. AMS Special session on The Many Lives of Lattice Theory and Theory of Ordered Sets, with Connections to Combinatorics*. Phoenix, Jan 2004.
 67. *Ramifications of Category Theory. A workshop Dedicated to F. W. Lawvere*. Florence, Nov 2003.
 68. *Applications of Lattice Theory and Ordered Sets to Computer Science. Center for Discrete Mathematics and Theoretical Computer Science (DIMACS)*. Rutgers, New Jersey, Jul 2003.
 69. *Causality in Computer Science and Physics*. Workshop at the *IEEE Symposium on Logic in Computer Science (LiCS)*. University of Ottawa, Jun 2003.
 70. *Quantum Programming Languages*. Workshop at the *Fields Institute Summer School on Logic and Foundations of Computation*. University of Ottawa, Jun 2003.
 71. *Quantum Theory: Reconsideration of the Foundations 2*. Vaxjo, Sweden, Jun 2003.
 72. *Seminar on Logic and Informatics 2003*. Free University of Brussels, Mar 2003.
 73. *Quantaes and their Applications*. Instituto Superior Técnico, Lisbon, Jul 2002.
 74. *Categorical Methods in Algebra and Topology*. Nassogne, Belgium, Jun 1999.
- Invited participation as delegate**
75. *International Microsoft Research Workshop: The Grand Challenge in Non-Classical Computation*. York, UK, 2005.
- Invited talks at departments, institutes, industry**
76. Dept. Seminar, Compt. Lab., Cambridge, Feb 2011.
 77. Sigma Club, London School of Economics, Nov 2010.
 78. Dept. Appl. Math. & Theor. Phys., Cambridge, Apr 2010.
 79. Quantum Foundations Seminar, Perimeter Institute for Theoretical Physics (PI), Mar 2010. `pirsa:10030058`
 80. Quantum Information Seminar, PI, Mar 2010. `pirsa:10030114`
 81. Tsinghua University, Beijing, Dec 2009.
 82. Capital Normal University, Beijing, Nov 2009.
 83. University of Aeronautics and Astronautics, Beijing, Nov 2009.
 84. Quantum Foundations Seminar, PI, May 2009. `pirsa:09060013`
 85. Colloquium, PI, Apr 2009. `pirsa:09040001`
 86. Joint Logic & Quantum information seminar, Leeds, Nov 2008.
 87. Theory Seminar, School of Comp. Sc., Birmingham, Nov 2008.
 88. Geometry Seminar, Dept. of Maths, Manchester, Dec 2007.
 89. Maths Colloquium, Sheffield, Nov 2007.
 90. Dept. of Comp. Sc., Nottingham, May 2007.
 91. Dept. of Comp. Sc., Masaryk university, Brno, Nov 2006.
 92. Maths Colloquium, Masaryk University, Brno, Nov 2006.
 93. Dept. of Comp. Sc., York, Dec 2006.
 94. Google, Mountain View, California, Jul 2005.
 95. Kestrel Institute, Palo Alto, California, Jul 2005.
 96. Dept. Maths and Stats, McGill, Apr 2005.
 97. Dept. Comp. Sc., Leicester, Jan 2005.
 98. Logic & Semantics Sem., Compt. Lab., Cambridge, Dec 2004.
 99. School of Comp. Sc., Birmingham, Aug 2004.
 100. Laboratoire des Preuves, Programmes et Systèmes (PPS-CNRS), Paris 7, May 2004.
 101. Dept. Maths and Stats, Ottawa, Mar 2004.
 102. Logic & Foundations of Maths Research Seminar, Université de Québec a Montréal, Mar 2004.
 103. Dept. Maths and Stats, McGill, Mar 2004.
 104. Quant. Opt. & Laser Sc. Group, Imperial College, Dec 2003.
 105. Laboratoire d'Informatique Théorique et Quantique, Université de Montréal, Nov 2003.
 106. Quant. Opt. & Laser Sc. Group, Imperial College, Oct 2003.
 107. Theor. Phys. Group, Imperial College, London, Jun 2002.
 108. Dept. Maths and Stats, Ottawa, Apr 2002.
 109. Dept. Maths and Stats, McGill, Dec 2001.
 110. Dept. Maths and Stats, Ottawa, May 2001.
 111. Art Institute of Chicago (title: Waves, Quantum and Space: Blending Physics, Music and Language), Apr 2001.
 112. Dept. of Pure Maths and Math. Stats, Cambridge, Feb 2001.
 113. Centro de Matemática, Coimbra, Portugal, Jun 2000.
 114. Theor. Comp. Seminar, Instituto Superior Técnico, Jun 2000.
 115. Dept. Alg. & Geom., Masaryk University, Brno, Nov 1999.
 116. Dept. Phys., Utrecht, The Netherlands, Dec 1994.
- Invited talks at other departments of own institute**
117. Oxford Quantum Information Meeting. Merton, Mar 2010.
 118. Philosophy of Physics Research Seminar, Oxford, Feb 2009.
 119. Logic Seminar, Mathematical Institute, Oxford, Nov 2008.
 120. QIP Seminar, Materials Dept., Oxford, Jul 2008.
 121. Quantum Field Theory Seminar, Math. Inst., Jan 2008.
 122. Analytic Topol. in Maths & Comp. Sc., Math. Inst., Apr 2006.
 123. Analytic Topol. in Maths & Comp. Sc., Math. Inst., Apr 2003.
 124. Philosophy of Physics Research Seminar, Jun 2002.
 125. Oxford Society for Physics and Philosophy Seminar (honorary: single malt Scotch Whisky), Oxford, Nov 2001.
 126. *Centre for Logic and Philosophy of Science*, Free University of Brussels, Nov 1996.