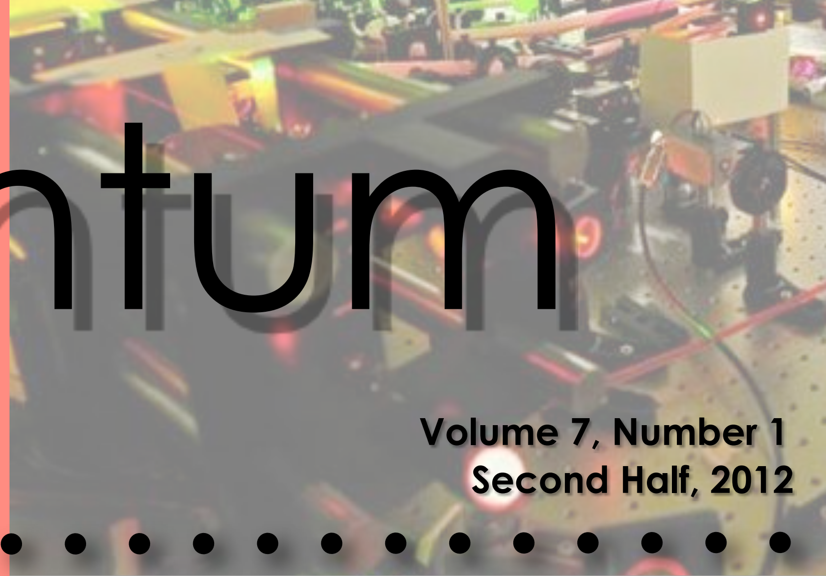
The Quantum Times



Volume 7, Number 1
Second Half, 2012

Newsletter of the Topical Group on Quantum Information

American Physical Society

s•p•e•c•i•a•l i•s•s•u•e

Prizes 2012

Editor's Note

Ian T. Durham

In what could be viewed as a watershed moment for quantum information, foundations, and computation, this year's Nobel Prize has been awarded to two of our field's experimental pioneers: **Serge Haroche** of Collège de France and École Normale Supérieure, both in Paris, and **David Wineland** of the National Institute of Standards and Technology (NIST) in Boulder, Colorado. In honor of both Serge and Dave, we have commissioned profiles on each from people who know them well, both on a professional and a personal level.

There were several other recent awards and recognitions given to members of the quantum information community including the addition of four APS fellows under the GQI banner and Rob Spekkens' First Prize in the FQXi Essay Contest. We highlight those on subsequent pages and include the latest FQXi Large Grant RFP which is specifically aimed at the physics of information.

On a more practical note, this issue also includes information on the current GQI election. Biographies and candidate statements for the Vice Chair and Member-at-Large positions begin on p. 8 Please take the time to vote!

We also note that, for the time being, *The Quantum Times* will move to a twice-per-year format. If submissions are such that four issues once again become possible, we will return to the quarterly schedule.

Inside

Serge Haroche

by
Jean-Michel Raimond and Michel Brune

The 2012 Nobel prize in physics has been jointly attributed to Dave Wineland and to Serge Haroche, for “ground-breaking experimental methods that enable measuring and manipulation of individual quantum systems.” This joint award recognizes the strong conceptual links between Dave's and Serge's works. They were performed on radically different systems, but with the same underlying concepts.

Serge Haroche was born in Casablanca, at a time when Morocco was still a French protectorate. He received there an excellent high-school education, continued in Paris when his family settled in there. He was already fascinated by science in high school. He often tells of his wonder when he found that his high-school maths and physics enabled him to correctly predict the orbit of the first artificial satellites. After two years of intensive training in maths and physics in the “grandes écoles” preparatory classes, he was admitted in 1963 to the two top-ranking schools, École Polytechnique (first rank) and École Normale Supérieure (ENS). At the time, École Polytechnique was leaning preferentially towards industry or administration. Serge thus joined the physics curriculum at ENS, dedicated to research.

He met there two remarkable professors, Alfred Kastler (Nobel 1966) and Claude Cohen-Tannoudji (Nobel 1997), who led him through the fascinating quantum landscape. The life at the physics laboratory was rather exciting, with the exploration of all avenues opened by optical pumping, recently discovered by

Continued on next page

David Wineland

by
Dietrich Leibfried

Photo by Dietrich Leibfried

"In the first place it is fair to state that we are not experimenting with single particles, any more than we can raise Ichthyosauria in the zoo" wrote Erwin Schrödinger in 1952. Exactly 60 years later, David Wineland of NIST in Boulder, Colorado, USA and Serge Haroche of Ecole Normale Supérieure in Paris, France win the Nobel Prize for their seminal experiments with single quantum particles. A theoretical description of these experiments is not hard, two-level (spin-1/2) systems, harmonic oscillators and their mutual coupling are sufficient, all fixtures of a modern beginners course in quantum mechanics. To cleanly implement these deceivingly simple elements in a laboratory and then make their messages accessible to human senses requires a degree of experimental sophistication that seemed impossible to Schrödinger. Nevertheless, these experiments are reality now, not in a small part due to Dave Wineland’s and Serge Haroche’s work.

Dave Wineland grew up in Sacramento, California. Early on he showed perseverance and a knack for perfection when practicing riding on the back wheel of his bike for essentially arbitrary distances in 7th grade. This earned him an early big award as "wheelie champion" of Howe Grammar School. Biking, mostly on both wheels but sometimes completely airborne, remained dear to his heart until today. He honed his technical skills by building model airplanes (American champion in two classes of free flying engine powered models 1980 and 1981) and by fixing used cars and

Continued on next page

Kastler and Jean Brossel. Serge decided to embark in this exploration and started a "State Thesis" work under the supervision of Claude Cohen-Tannoudji, about whom he once said "[he] taught me how to juggle with atoms and photons and gave me a lasting passion for research and teaching". In this pioneering work, he explored the dressed atom model, which he later used as a guide in all his research.

After a post-doc with A. Schawlow at Stanford, he returned to ENS in 1973 with a position at Centre National de la Recherche Scientifique (CNRS), followed by a professorship at Université P. et M. Curie in 1975. Jean Brossel, then the head of the physics department and of the "laboratoire de spectroscopie Hertzienne" suggested he set up his own team. He started studies of quantum beats in high-lying levels of sodium. Quite logically, even though the logical link might not be evident at first sight, this led to the experiments on cavity QED recognized by the Nobel committee.

The first experiments forked into two directions: microwave spectroscopy of high-lying Rydberg states and superradiance, a collective emission phenomenon, which was then the focus of a great deal of interest. It was quite natural to wonder if Rydberg levels could undergo a superradiant emission in the millimeter-wave range. We observed it in 1979 with a few million atoms. Soon, Serge proposed to use a resonant cavity to reinforce the atom-field coupling. Using rather low-Q microwave cavities, we observed transient masers, with a few thousand atoms only. In an insightful remark concluding a paper describing these experiments, Serge envisioned reducing the number of atoms even further, down to the single atom level, implementing the dream of Purcell, who proposed in 1946 to tailor spontaneous emission by changing the limiting conditions imposed on the field. Four more years were needed to achieve this goal. In a superconducting Fabry Perot cavity (Q factor of 10^6), the spontaneous emission on a Rydberg transition was sped up by a factor over 500! Almost simultaneously, Dan Kleppner and G. Gabrielse independently observed the spontaneous emission inhibition and H. Walther realized the micromaser, a device entering for the first time the "strong coupling" regime in which the atom-field interaction overwhelms dissipative processes. Modern cavity quantum electrodynamics was born.

From 1984 to 1993, Serge was a part-time professor at Yale University. A major contribution of the group he led there with E. Hinds was the observation of the spontaneous emission inhibition in the infrared domain and the exploration of the atom-surface interaction. Yet, having two offices separated by 4000 miles is not easy, and Serge returned full time in ENS when he was offered a position at the newly created Institut Universitaire de France, before joining Collège de France in 2001, the most coveted academic position in France.

After the realization of a two-photon micromaser, the ENS team proposed in 1990 to perform an ideal,

Continued on next page

bikes. "I would go for anything that had an engine" remembers Dave. A physics class in his senior year in high school directed his interest towards that subject and he became fully immersed in it while studying at the University of California at Berkley and during his thesis work at Harvard supervised by Norman Ramsey. His experimental skills were already obvious to his peers, as the parts of an apparatus he built had vanished from their original places and reemerged in other setups within a few days after they were declared fair game.

During his postdoctoral studies with Hans Dehmelt, Dave pioneered experiments on single electrons in a Penning-trap that eventually lead to a series of spectacular tests of quantum electrodynamics and are still being refined to this day. Ideas from this time have shaped whole research fields and still bear fruits today, as the proposal to use single ions as frequency standards, but most prominently the idea of laser cooling of atoms discussed by Wineland and Dehmelt and independently Hänsch und Schawlow in 1975. Soon other institutions became interested in the gifted postdoc and the story goes that Dehmelt hung up on one of the callers with a curt "Dave Wineland is not available!" He must have known quite well that this was nothing short of a glowing recommendation.

Eventually Dave decided to join the fledgling branch of the National Bureau of Standards in Boulder, Colorado (now National Institute of Standards and Technology, NIST). Dave remains at NIST to this day, despite several offers to go elsewhere during his career. After initial work on the cesium beam standard Dave got the chance to set out and make the ideas from his postdoc time a reality. Together with Bob Drullinger and Fred Walls he succeed in the first experimental demonstration of laser cooling on a cloud of magnesium ions in 1978, at about the same time as Neuhauser, Toschek, Hohenstett and Dehmelt saw cooling in a cloud of barium ions at the University of Heidelberg, Germany. During the following years Jim Bergquist, Wayne Itano and John Bollinger joined what was now the Ion Storage Group, and soon single ions were trapped in isolation (1981). The group kept adding to their record with a number of original and elegant experiments in Penning and later also radio frequency traps. Ion based frequency standards saw a steady stream of improvements and in 1989 the group succeeded to cool the harmonic motion of a single mercury ion to its quantum mechanical ground state. This experiment motivated a flurry of theoretical work that explored the quantum control of single trapped ions. Many of these ideas were inspired by cavity QED with the harmonic motion of the ion taking the role of the cavity field. Chris Monroe joined the group and the year 1995 saw several groundbreaking experiments. A single beryllium ion was cooled to the ground state in all three normal modes of motion and from this starting point the team demonstrated quantum control of internal states and motion by coupling them with Raman

Continued on next page

Raimond & Brune, continued

quantum non-demolition measurement of the photon number in a cavity. The idea was to measure by Ramsey interferometry the quantized light shifts experienced by an atom in the non-resonant cavity field. This would allow us to infer the photon number without changing the field state more than required by the projection postulate. The key technical elements in this proposal were circular Rydberg atoms, with a lifetime long enough to allow using them in a Ramsey interferometer, and open Fabry-Perot microwave cavities (circular atoms are incompatible with closed cavities). This proposal was the start of a seventeen-year journey of technological progress on microwave cavities.

The first important step was performed in 1996 with the observation of the quantum Rabi oscillation of a single atom in a weak field, directly revealing the strong coupling regime and field quantization. Quite remarkably, the ion traps in Dave's group produced very similar results at the same time, illustrating the duality between these experiments. In both cases, an oscillator (the field or the ion motion) is coupled to a “spin” (the circular atom or the internal ionic states).

The year 1996 also marked the emergence of quantum information ideas in the quantum optics community. Dave's ion traps led to the first demonstration of a gate and rapidly to more complex entanglement manipulations. The quantum Rabi oscillation at ENS was used in the following years for a series of demonstrations of elementary quantum information processing functions, combining a few one and two-qubit quantum gates.

Another interesting potential use of both ion traps and CQED is to study the boundary between the quantum and the classical worlds. Coherent states are tunable mesoscopic objects which can exhibit quantum or classical features depending upon the number of quanta. Both experiments simultaneously produced Schrödinger cat states: quantum superpositions of coherent states with different classical amplitudes. The ENS team could in addition monitor for the first time the decoherence of these states, rapidly transformed in a statistical mixture through their coupling to the environment.

All these experiments were still far from the original objective. It was only in 2006 that we finally realized a cavity with a photon storage time long enough (130 ms) to perform a real QND photon number counting. We could witness in real time the birth, life and death of individual photons, monitor the quantum jumps of light, and observe the quantum Zeno effect for a light field. We turned the method into a full determination of the field quantum state, allowing us to take a “movie” of the real time decoherence of a Schrödinger cat state. This sheds new light onto the the fuzzy transition between quantum and classical behaviors. Finally, we could use this QND information to prepare and protect non-classical field states from decoherence in real time, by operating for the fist time a quantum feedback loop.

Continued on next page

Leibfried, continued

-transitions. It became possible to generate coherent states, squeezed states and number states of the motion and observe collapses and revivals in their Rabi-flopping in close analogy to cavity QED experiments that were pursued with the micro-maser in Serge Haroche’s group at the same time. Next, Schrödinger-cat states were produced where internal electronic states of the atoms mimicked the nucleus in limbo and superpositions of coherent states of the motion with different phases stood in for the cat. Soon the complete density matrices of the motion and negative Wigner functions of a non-classical number state were reconstructed experimentally. All these experiments had direct analogies in the micro-maser that were subsequently realized in Serge Haroche’s group.

Despite these successes, the nineties saw a crisis in ion trapping with some of the traditional strongholds phasing out and very few upstart groups picking up the slack. This has profoundly changed in the last 15 years as Ignacio Cirac and Peter Zoller have (in Dave’s own words) “resurrected the field from its deathbed” with their seminal proposal for quantum information processing (QIP) with trapped ions in 1995. In most part as a consequence of Cirac and Zoller’s paper and a timely demonstration of the essential features of the proposal by the Ion Storage Group in the same year, quantum information processing with trapped ions and closely related fields are booming with more than 20 groups setting out in the field to date. QIP with trapped ions has enjoyed steady progress over the last 15 years, with quantum control expanding to ever larger numbers of ions and more degrees of freedom. However (and maybe for a reason), the Nobel committee only mentioned this development in passing. The first practically useful spin-off of this work, the quantum logic ion clock, is featured in more detail. This clock uses a close relative of Cirac and Zoller’s quantum logic gate to read out the state of aluminum ions with a helper ion to yield 17 digits of frequency accuracy. This makes the clock sensitive to minute shifts described by special and general relativity. The ticks of such clocks reveal their relative position in the gravitational potential to less than a meter, making them essentially “space-time standards”.

If you ask Dave about his greatest accomplishment, he answers “The group we built here at NIST”. His office door is always open, no matter whether the grad student in his first week or a group member of many years seeks him out. Dave rarely insists on a course of action, but everyone quickly learns to take his advice seriously. In long lab nights Dave often returned to the lab after dinner. If seating was limited, he would turn an empty grey government trash bin upside-down and take a seat. Whether a squeaky fan needed replacement or a complicated signal lacked proper interpretation, nothing was too trivial or too complex. In his talks Dave rarely dwells on the importance of a certain result. Instead he will address the limitations and imperfections with such

Continued on next page

Raimond & Brune, continued

There is a beautiful duality between Dave's and Serge's experiments. In the former, trapped quantum matter is probed and manipulated by light. In the latter, trapped quantum light is probed and manipulated by matter. Both led to similar achievements, sometimes nearly simultaneously, and both have contributed to the considerable development of experimental quantum physics. There are even more similarities between the two laureates. Both have painstakingly and patiently followed a clear path through the difficulties of experimental physics, only driven by their curiosity for fundamental quantum phenomena. Both have been supported by institutions which allowed them to pursue these lines without excessive pressure for immediate results, publications and returns on investments. Both, finally, have had the charisma and leadership to gather around them permanent teams, accumulating knowledge through the years, working in a fruitful synergy to train generations of skilled students.

Jean-Michel Raimond *holds the rank of Professor at Université P. et M. Curie (UPMC) and* ***Michel Brune*** *is Directeur de Recherches, CNRS. Both are affiliated with the Laboratoire Kastler Brossel which is jointly operated by ENS, CNRS, and UPMC-Paris6.*

Leibfried, continued

brutal honesty that one is sometimes wondering whether the audience might fail to appreciate the achievement. Some skeptics held that this matter-of-fact style would never suffice to "sell" Dave's work to the Nobel Foundation. It is fortunate for Dave and for physics that they turned out to be wrong.

Dietrich Leibfried *is a researcher in the Ion Storage Group at the National Institute of Standards and Technology in Boulder, Colorado. He serves on the Editorial Board of The Quantum Times.*

Nobel Museum, Stockholm
Photo by Dietrich Leibfried

FQXi
FOUNDATIONAL QUESTIONS INSTITUTE

Physics of Information

The Foundational Questions Institute (FQXi) invites proposals for research on "Physics of Information". Info and instructions available here: http://fqxi.org/grants/large/initial

FQXi will award a total of $3 million to one- and two-year grants for topical, innovative, and unconventional research and outreach projects on Physics of Information. Topical projects might tackle questions such as:

What is the precise relationship between information and reality? Can information exist without matter, and vice versa, or are they two sides of the same coin? Are there fundamental limits to information processing by physical systems? What can information reveal about black holes, singularities, physics at the Planck length, and the origins and fate of our universe? (For more, see: http://fqxi.org/grants/large/initial/examples)

We will award grants ranging from $50,000 to $200,000. All grants will have a start date of September 1, 2013 and run through August 31, 2014 (one-year grants) or August 31, 2015 (two-year grants). Initial application must be submitted online at: http://fqxi.org/grants/large/initial/application by January 16, 2013 (this is a fairly simple initial form and is *not* a full proposal).

In addition to projects in physics, this RFP is open to related fields such as cosmology, astrophysics, mathematics, computer science, complex systems, biology, and neuroscience.

Please share this RFP with friends, colleagues, and any likely applicants. (The RFP site even has a widget that enables easy sharing through email or social media: http://fqxi.org/grants/large/initial). If you have any questions about the RFP please contact us at mail@fqxi.org.

FQXi essay contest winners include quantum information scientists

Ian T. Durham

The quantum information and foundations community was well-represented among winners of this year's FQXi essay contest whose theme was "Questioning the Foundations." GQI member Rob Spekkens was awarded First Prize in the fourth annual essay competition for his essay entitled "The paradigm of kinematics and dynamics". Included among Third Prize winners was Giacomo D'Ariano for his essay entitled "Quantum-informational Principles for Physics" and occasional *Quantum Times* contributor Ken Wharton for his essay entitled "The Universe is not a Computer". (The Editor of this newsletter also won a Fourth Prize for his essay entitled "Rethinking the scientific enterprise: in defense of reductionism".)


Rob Spekkens by Rob Spekkens

Spekkens' essay argues that the usual dichotomy of *kinematics* and *dynamics* in physical theories should be replaced. Briefly, the kinematics of a physical theory describe the space of physical states that are allowed by that theory, whereas the dynamics of the theory describe how those states evolve. For at least four-hundred years we have labored under the assumption that the two are an inseparably integral part of any physical theory – every valid physical theory must include both. However we don't always consider them as being inextricably linked. Spekkens cites, for example, the fact that the Everett interpretation of quantum mechanics shares the same kinematics with dynamical collapse theories but they have different dynamics. Similarly, the Newtonian formulation or classical physics, in which the kinematics is given by configuration space, shares (obviously) the same dynamics as the Hamiltonian formulation in which the kinematics is given by phase space.

What Spekkens proposes in his essay is that we must accept the kinematics and dynamics as a sort of 'package deal' – any two theories that are empirically equivalent should be treated as *exactly* equivalent. This is akin to Einstein's strong equivalence principle in which inertial motion free space produces the same empirical results as free-falling motion in a gravitational field. Spekkens further argues that such a stance does *not* equate to operationalism which is the view that we should only concern ourselves with the outcomes of experiments. As he notes in the essay

> [f]or instance, if one didn't already know that the choice of gauge in classical electrodynamics made no difference to its empirical predictions, then discovery of this fact would, by the lights of the principle, lead one to renounce real status for the vector potential in favour of only the electric and magnetic field strengths. It would not, however, justify a blanket rejection of any form of microscopic reality.

In other words, Spekkens does not rule out hidden ontologies by fiat. Rather, he says that "[t]he principle tells us to constrain our model-building in such a way that every aspect of the posited reality has some explanatory function." He proceeds to give several examples of physical theories in which one can alter the dynamics slightly giving "wildly" different kinematics while producing the same empirical predictions. Thus he concludes that the connection between kinematics and dynamics is purely conventional and that the entire concept should be replaced by the more holistic notion of *causal structure*, a concept that has already been explored by a number of authors as he points out.

To read all the essays, go to http://www.fqxi.org/community/essay/winners/2012.1. Also note that in its upcoming large grant round of funding, FQXi is focusing on the physics of information. A detailed solicitation is given on the previous page.

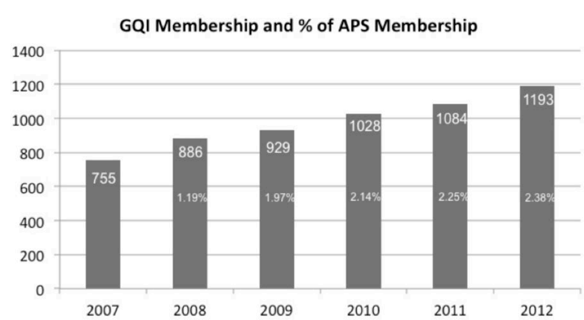
Ian T. Durham *is an Associate Professor of physics (and sometimes mathematics) at Saint Anselm College in Manchester, New Hampshire and the founding Editor of The Quantum Times, now in its seventh year. He has won three FQXi essay prizes and appears as a guest on the December edition of FQXi's podcast. His current work in quantum information focuses on resource theory, in particular the study of quantum reference frames and superselection rules.*

LETTER FROM INCOMING CHAIR

Since Danny Greenberger and Anton Zeilinger petitioned APS to establish a "Topical Group on Quantum Information, Concepts, and Computation" in 2002, and since its founding in 2005, GQI has played an increasingly important role in advancing the interests of the quantum information community. To name a few accomplishments, Physical Review Letters has been listing papers in a special Quantum Information category since July 2004 (volume 93, issue 1), the APS March Meeting has hosted bigger and better QI sessions every year since 2005 (more on this below), and 21 QI researchers have already been elected Fellows of the APS since 2007.

The future looks bright: 2012 was the year of the first Nobel prize in Experimental Quantum Information (well, the Nobel committee used slightly different terminology), awarded to David Wineland and Serge Haroche. Their theory counterparts, Ignacio Cirac and Peter Zoller, were just awarded the Wolf Prize, which is a strong predictor of the Nobel prize… and Alexei Kitaev won the multi-million dollar Fundamental Physics Prize.

Yet, grand challenges loom ahead. While postdocs and graduate students in QI have been experiencing a mildly improving job market, the vast majority cannot find permanent positions and many are forced to switch. A common occurrence, which I have personally witnessed (and probably experienced), is that a QI job applicant ends up falling between the cracks. An effective way to change the hiring climate is to firmly establish QI as a legitimate and equal player in the culture of Physics departments. To this end we must grow GQI from Topical Group to Division. To see why, here are the current Divisions of APS: Atomic Molecular & Optical, Astrophysics, Biological Physics, Computational Physics, Condensed Matter Physics, Chemical Physics, Fluid Dynamics, Polymer Physics, Laser Science, Materials Physics, Nuclear Physics, Physics of Beams, Particles & Fields, Plasma Physics.



You'll notice a strong correlation between these topics and the way in which many Physics departments are traditionally organized. Achieving Division status will certainly help us break down remaining hiring barriers.

So what do we need to do? Simply increase our membership above a threshold, currently equal to 1,450 members. And where do we stand? Our historic growth pattern is shown in the chart below, along with our percentage of total APS membership. For comparison, the largest Division is Condensed Matter Physics, with about 6,100 members (11.4%). We are already larger than one of the current Divisions (Physics of Beams), and have been the largest Topical Group since 2012, when we surpassed Gravitation [1]. Yet, at the current growth rate it will take us until 2015 before we cross the threshold. And here is where you can help: check out the members list at http://www.aps.org/membership/units/listings/upload/GQI.pdf, find a least one friend or colleague who isn't yet a member, and ask them to join!

And now to our signature event: the annual APS March meeting, which will take place in Baltimore, March 18-22. A special treat this year will be a Nobel symposium featuring Wineland and Haroche. Another treat is a "lunch with the experts" hosted by John Preskill and John Martinis, open on a first-come first-serve basis to students. Actually, the meeting starts already on Sunday March 17 with tutorial sessions, and this year GQI will have a tutorial on "Quantum Information and Computation for Quantum Chemistry", organized by Purdue's Sabre Kais. Anyone can register and attend.

One of my responsibilities as Chair-Elect in 2012 was to act as GQI Program Chair, and thus to oversee the quantum information sessions at the March Meeting, a job I could not have properly done without sage advice from my predecessor, John Preskill, who ran a flawless meeting in Boston last year. This year we are sponsoring or co-sponsoring six invited symposia:

C11, Monday 2:30: Quantum communication and cryptography (Smith, Leverrier, Vidick, Makarov, Sciarrino)
F3, Tuesday 8:00: Quantum computing in AMO (Saffman, Calarco, Furusawa, O'Brien, Gaebler)
N1, Wednesday 11:15: Quantum computing with diamond (Wrachtrup, Awschalom, de Leon, Jacques, Hanson)
R10, Wednesday 2:30: New platforms for non-Abelian statistics: Majoranas and beyond (Beenakker, Heiblum, Clarke, Lindner, Barkeshli)
T10, Thursday 8:00: Superconducting qubits (Chow, Devoret, Martinis, Fowler, Blais)
U4, Thursday 11:15: Quantum Reservoir Engineering and Feedback (Murch, Hatridge, Vijayaraghavan, Brune, Schindler)

Continued on next page

W3, Thursday 2:30: Quantum foundations (Renner, Gisin, Mueller, Brukner, Rudolph)

We are also sponsoring six focus sessions, most with sub-sessions:

A27, B27: Adiabatic quantum computing
M27, R27: Quantum error correction and decoherence control
A26, C26, J26, M26, T26, U26, W26: Semiconductor qubits
W27: Superconducting Qubits: Quantum Computing Architectures
T27: Superselection and quantum reference frames
B6, G26: Quantum characterization, verification, and validation

You can find all of this information in greater detail at meeting.aps.org/Meeting/MAR13/APS_epitome.

And don't miss the **GQI business meeting on Tuesday at 5:45 in room 327**, where you can meet and greet your fellow quantum informationalists, hear about the latest and greatest GQI developments, and enjoy free pizza and beer.

GQI's current Vice-Chair Andrew Landahl is now responsible for the quantum information sessions at the 2014 March Meeting in Denver. He will welcome your suggestions on how to make next year's meeting even better.

Many thanks to all of you who have helped with organizing GQI's participation in this year's March Meeting, especially Invited Session organizers Jason Alicea, Ivan Deutsch, Steven Girvin, Ronald Hanson, Terry Rudolph, Matthias Steffen, and Mark Wilde; Focus Session organizers Sergio Boixo, Ken Brown, Ian Durham, Thaddeus Ladd, Richard Harris, and Charlie Tahan; and Session Sorters Taeyoung Choi, Qiuzi Li, Brian Neyenhuis, Ben Palmer, Sergey Pershoguba, Rusko Ruskov, Yun-Pil Shim, Charlie Tahan, and Haitan Xu. Because of your efforts a great program awaits us in Baltimore!

–Daniel Lidar, Incoming Chair

[1] Data junkies can find much more here: http://www.aps.org/membership/units/statistics.cfm

NEW GQI FELLOWS

Congratulations to the newest APS (GQI) Fellows!

Markus Aspelmeyer, Universität Wien: "For outstanding contributions to experimental quantum information, quantum optics, and quantum foundations, including the first experimental realization of a one-way quantum computer using 4-photon entangled cluster states and the first demonstration of radiation-pressure based cavity cooling of a micromechanical system."

Alán Aspuru-Guzik, Harvard University: "For his contributions at the interface of quantum information and chemistry and biology, including theory and experiment on quantum simulation for molecules, the development of the understanding of quantum coherence in photosynthesis, and density functional theory for open quantum systems."

Christopher Fuchs, Perimeter Institute for Theoretical Physics: "For powerful theorems and lucid expositions that have expanded our understanding of quantum foundations, through his illuminating reformulation of the view that quantum states are states of knowledge, merging the Copenhagen interpretation with the interpretation of probabilities as degrees of belief."

Daniel Gottesman, Perimeter Institute for Theoretical Physics: "For his pioneering theoretical work on quantum computation and cryptography, in particular laying the foundations of quantum error correction and rigorously extending the theory of fault tolerant quantum computation."

GQI ELECTIONS

Candidates for Vice Chair

Alan Aspuru-Guzik, Harvard University

Biography:
Alán Aspuru-Guzik is currently Associate Professor of Chemistry and Chemical Biology at Harvard University, where he began his independent career in 2006. Alán received his undergraduate degree in Chemistry in 1999 from the National Autonomous University of Mexico (UNAM). After receiving his PhD in Physical Chemistry from the University of California, Berkeley in 2004, he was a postdoctoral scholar at UC Berkeley from 2005-2006.

Alán carries out research at the interface of quantum information and chemical physics. In particular, he is interested in the use of quantum computers and dedicated quantum simulators and quantum algorithms for chemical systems. He has worked on quantum algorithms and analog simulation schemes for the simulation of molecular electronic structure, quantum dynamics and protein folding. Alán has collaborated with several experimental quantum information groups in the realization of experimental

Continued on next page

demonstrations of these. Alán has studied the role of quantum coherence in excitonic energy transfer in photosynthetic complexes. In particular, he introduced quantum process tomography and witnesses for electronic coherence to the field of ultrafast chemical spectroscopy.

In 2009, Alán received the DARPA Young Faculty Award for his work in quantum simulation, the Camille and Henry Dreyfus Teacher-Scholar Award and the Sloan Research Fellowship. In 2010, he received the Everett-Mendelsson Graduate Mentoring Award and received the HP Outstanding Junior Faculty Award by the Computers in Chemistry Division of the American Chemical Society. In the same year, he was selected as a Top Innovator Under 35 by the Massachusetts Institute of Technology Technology Review magazine. In 2012, Alán became a fellow of the American Physical Society, nominated by the Topical Group of Quantum Information.

Candidacy Statement:
I am excited to run for Vice Chair of the executive committee of the Topical Group of Quantum Information (GQI). Quantum information is a growing and dynamic field where several theoretical and experimental developments keep many of us on our toes each morning as we open the new postings of the quant-ph/ section of the arXiV. During the past couple of years, I served as a member at large of GQI, and in this capacity I have participated in decision making and contributed ideas for the advancement of GQI. With your support, in the role of Vice Chair, I will continue to work to seek ways of increasing membership and participation in GQI so that we become a full division of APS and to advocate for graduate students, postdoctoral researchers and young faculty by creating novel opportunities for showcasing their work during the APS meeting. In particular, I am interested in creating an academic employment session at APS where postdoctoral researchers on the job market can present their work and where attendees from interested institutions can hear the candidates in a single place and meet them in person. In a similar fashion, I will strive to create more spaces for undergraduate students and graduate students to present their work, such as a poster session with awards to the best poster in each category. These ideas are modeled after similar successful efforts carried out by the American Chemical Society. As someone who works at the interface of quantum information and chemical physics, I will continue to support the interdisciplinary nature of GQI and its interactions with other fields such as atomic and molecular physics, condensed-matter theory, mathematical and chemical physics, etc. I also would like to promote the presence of GQI online and the use of novel technologies in order to facilitate interaction between members. And finally, I am interested in continuing to work with the current and new members of the committee in helping to fundraise and establish GQI-based awards for senior researchers. In summary, having learned the ropes during the past two years, I look forward to receiving your support to continue serving the community and advocating for quantum information as Vice Chair. Please e-mail me with any questions and suggestions during the campaign and, if elected, during my time on the committee.

Jacob Taylor, NIST (Gaithersburg)

Biography:
Jake Taylor is a Physicist at the National Institute of Standards and Technology, a JQI Fellow at the Joint Quantum Institute, and Adjunct Assistant Professor of Physics at the University of Maryland. His interest in quantum information began as an undergraduate, working with Alex Dalgarno and Jim Babb at ITAMP at the Center for Astrophysics at Harvard. He proceed to an AB summa cum laude in Astronomy & Astrophysics and Physics at Harvard in 2000, and followed with a year in Japan as a Luce Scholar at the University of Tokyo studying black hole growth. Taylor returned to Harvard, finishing his PhD in the group of Mikhail Lukin in 2006, working on approaches to quantum computing and fault tolerance using spins in quantum dots and nitrogen-vacancy centers in diamond. He went on to become a Pappalardo Fellow at MIT. In 2009 Taylor started his group at the Joint Quantum Institute, investigating hybrid quantum systems, quantum-assisted metrology, and the fundamental limits to quantum devices for computation and communication. The author of more than 60 peer reviewed publications, Taylor is the recipient of the 2006 Newcomb Cleveland Prize of the AAAS, the 2010 Presidential Early Career Award for Science and Engineering, and the 2012 Samuel J. Heyman Service to America "Call to Service" medal. For more information: http://groups.jqi.umd.edu/taylor.

Candidacy Statement:
Quantum information research enables deep connections between apparently disparate fields of physics, from topological order to complexity theory to fundamental limits to measurement and computation. Indeed, long-standing paradoxes of the previous century have largely fallen due to the framework quantum information provides for understanding quantum phenomena, as well as the pioneering experiments it inspires to observe such effects.

In this regard, members of the APS Topical Group on Quantum Information (GQI) represent a diverse group who are willing to engage in dialogue outside of their field. While this represents a key strength of our Topical Group, it also presents a distinct challenge to the continued growth of the field. I will pursue the continued recruitment of GQI members to develop and

Continued on next page

encourage a wider discussion across field boundaries, while providing a framework to further enable quantum information-focused contributions to other fields to be seen in a broader context. This will tie in with current efforts to see the Topical Group raised to division status, as well as the potential establishment of prizes to highlight the best contributions to the field.

Candidates for Member-at-Large

Markus Aspelmeyer, University of Vienna

Biography:
Markus Aspelmeyer is a Professor of Physics at the University of Vienna and Speaker of the recently founded Vienna Center for Quantum Science and Technology (VCQ). His current research focus is the investigation of the quantum regime of nano- and micromechanical devices, where he aims to combine the development of new quantum technologies with fundamental quantum experiments. Markus received his Bachelor in philosophy from the Munich School of Philosophy in 2000 and his PhD in solid state physics from LMU Munich in 2002. Following his postgraduate studies he switched to the field of quantum optics and held postdoctoral positions in Anton Zeilinger's group at the University of Vienna, Austria, and at the Institute for Quantum Optics and Quantum Information (IQOQI) of the Austrian Academy of Sciences. Since 2009 Markus is a Full Professor at the Faculty of Physics of the University Vienna. His awards include the Fresnel Prize 2007 of the European Physical Society, the Ignaz-Lieben Prize 2008 of the Austrian Academy of Sciences and the Friedrich Wilhelm Bessel Research Award 2010 of the Alexander von Humboldt-Foundation. He is a member of the Young Academy of the Austrian Academy of Sciences, a member of the European Academy of Sciences and Arts and a Fellow of the APS.

Candidacy Statement:
Times couldn't be more exciting for quantum science! The last 8 years saw 2 Nobel Prizes in Physics directly linked to quantum optics, quantum information and quantum control. In parallel, a multitude of new technologies is being developed that keeps improving our abilities to control and exploit quantum properties of light and matter. And in many cases, these developments are being driven by the challenges and prospects of quantum information processing. It is fascinating to see where this is going: from new fundamental tests of quantum physics over first applications of complex quantum processors to an increasing number of "real-world" quantum technologies. I am not aware of many arenas in science where research on deep fundamental questions is so intimately linked to the development of new technologies as is the case in our quantum optics and quantum information community. We have been generating new opportunities for physics and we need to make sure that they are being used, in particular by continuing to attract talented young researchers and by disseminating our know-how across the boundaries of scientific disciplines. As I said: it is fascinating to see where all of this is headed. And it is even more fascinating to participate in it!

Graeme Smith, IBM Research (Yorktown Heights)

Biography:
Graeme Smith is a Research Staff Member in the Physics of Information group at IBM's TJ Watson Research Center. He was previously a postdoc at both IBM and Bristol. He received a PhD in physics from Caltech in 2006, supervised by John Preskill. Graeme is interested in computation and communication in noisy settings, quantum Shannon theory, coding theory, cryptography, geometry and packing, quantum estimation and detection, optical communications, and the physics of information.

Candidacy Statement:
As quantum information continues to grow into a mature and recognized field, it is essential to maintain good communication and cross-fertilization between different subgroups of the community. Our field is characterized by a radical diversity of interests, motivations, and techniques, ranging from deep philosophical questions about the nature of reality to the everyday challenges of microwave engineering. The APS topical Groups on Quantum Information can act as a center of gravity for the various interests of its members by organizing timely sessions at APS conferences that will also serve to attract non-members at the periphery who may be interested. It is crucial that we include information theorists and computer scientists who may not consider themselves physicists as well as experimental and theoretical physicists who do not yet realize they have been doing quantum information for ages. By embracing the diversity inherent in the community, we can continue to grow the GQI in ways that enhance the experience for current members while absorbing new and exciting avenues as they arise.

Zoller and Cirac win Wolf Prize

As this issue was going to press, it was announced that Peter Zoller (Innsbruck) and Ignacio Cirac (MPQ) have won the 2013 Wolf Prize in Physics "for groundbreaking theoretical contributions to quantum information processing, quantum optics and the physics of quantum gases." We hope to have a more extensive article on this in a future issue. Congratulations Peter & Ignacio!

BOOK REVIEW

The Mathematical Language of Quantum Theory: From Uncertainty to Entanglement
by Teiko Heinosaari and Mario Ziman
Cambridge University Press, 2012, **$85.00**
ISBN-13: 9780521195836 (hardcover)

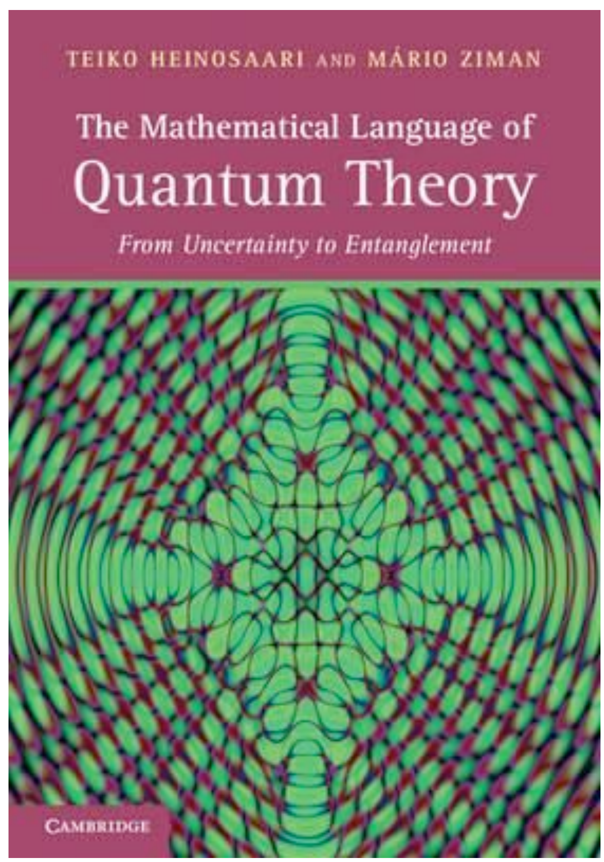
Back in the dark days of early 2000, when I was first starting my Ph.D., it was not very easy to learn about the generalized quantum formalism of density operators, Positive Operator Valued Measures, and Completely Positive maps. Difficult as it may be to believe in this post Nielsen and Chuang age, most books on these topics were long out of print and university libraries were not well stocked in them. Most of us had to rely on John Preskill's lecture notes and, excellent though these are, the generalized formalism is covered in a bit of a hurry in order to move on to all the exciting new results in quantum information and computation.

When Nielsen and Chuang appeared at the end of 2000, it was a revelation. For the first time, the formalism was explained cleanly, simply and accessibly. Still, Nielsen and Chuang's treatment is not unproblematic. For one thing, it is restricted to finite dimensional Hilbert spaces. This is not ideal for those who want a bit more mathematical sophistication, or those who are working primarily with continuous variable systems. It is also fairly odd that we have to rely on a quantum information textbook to learn this material, since the generalized formalism is applicable to a wide variety of other subjects, such as the theory of open quantum systems, quantum statistical mechanics, algebraic quantum field theory, and the foundations of quantum theory. What is needed then is a book that covers the generalized formalism with more care and attention to detail, that is not also burdened with the task of covering all of quantum information and computation, and that is accessible to novices. The short version of this review is that Heinosaari and Ziman have written this book, and it would have made my life much easier had it been available when I was a Ph.D. student. I will be recommending it to any research student that works with me in the future as the first thing that they should read.

Heinosaari and Ziman have struck the right note with regard to mathematical rigour. They present most of the material in a way that is applicable to infinite dimensional Hilbert spaces, but do not shy away from specializing to finite dimensions or to discrete observables when the general proofs would involve heavy functional analysis. In this way, the book is very readable for people from a variety of backgrounds, provided they have a reasonable understanding of the basics of quantum theory. The book is well referenced, so it is very easy to look up the more general proofs as and when necessary. This is a significant plus point for the book, as most books on this topic either require a sophisticated knowledge of functional analysis or they restrict themselves entirely to the finite dimensional case.

The structure of the first five chapters of the book is coherent and logical, starting with a review of Hilbert space and then building up the formalism in increasing generality, from states and effects (yes/no measurements) to general observables to quantum channels and finally quantum instruments, which describe the most general way of updating a quantum system after a measurement. I particularly liked the chapter on quantum instruments and its careful treatment of how these are related to the description of measurements in terms of unitary evolution and POVMs. The text provides proofs of several fundamental theorems that are usually just stated or omitted in most quantum information texts, such as the proof that all mixture-preserving automorphisms of the set of density operators are unitary or anti-unitary. This level of thoroughness is very useful for those interested in the foundations of quantum theory. The

Continued on next page



book also touches on topics of recent research that are not covered in other texts, such as the coexistence of POVMs and the existence of Symmetric-Informationally-Complete POVMs. Given the scope of the book, the treatment of these topics is necessarily introductory, but it does serve to give the reader a flavor of current research.

Although this is a very good book, it is not completely perfect, and there are three main areas in which it could be improved. Firstly, there are many exercises for the student within the text, and these usually come with helpful hints of how to go about solving them. However, in many cases reading the hints makes the exercises completely trivial to solve. This would not be so bad if the hints were collected at the end of the book, but in fact they appear immediately after the exercises themselves, so it is very difficult to stop yourself from reading them before thinking about the problem. Hopefully these can be moved to the back in future editions, or at least made a little more cryptic. The book's website states that a collection of problems and solutions are in preparation, which may also help with this problem.

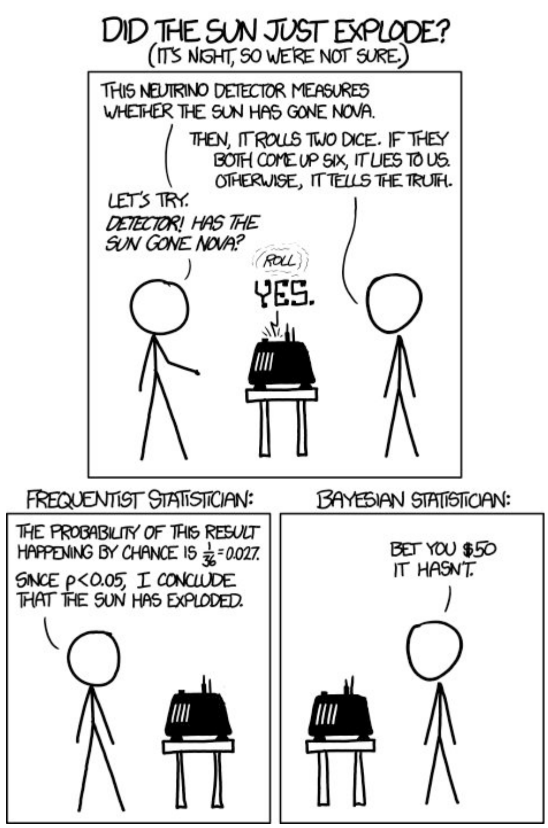
Secondly, whilst there is obviously a subjective element to the selection of material for a textbook, there are some topics that I would definitely add to it if I were teaching a course on this subject. The first is the proof of the Stinespring dilation theorem, which is used, for example, to prove that all quantum channels can be represented as unitary evolutions on a larger Hilbert space. The book states the theorem, but does not provide a proof. This strikes me as an odd omission given the central importance of the theorem and the fact that it is not too hard to prove it in finite dimensions (perhaps it was omitted because the general version is rather more difficult). Secondly, there is some discussion of the fixed point sets of some specific quantum channels, e.g. phase damping channels, but the general characterization of the fixed-point sets of quantum channels is not given. This is a shame as it is a very useful theorem in many applications, such as quantum error correction. It also allows for a simple proof of the no-broadcasting theorem, which is another significant omission. Although the no-cloning theorem is discussed, it would have been good to have a proof of no-broadcasting given that the book emphasizes mixed states.

Finally, the book ends with what the blurb describes as "a separate chapter on entanglement". It really is quite separate, in the sense that it does not really follow the logical development of the rest of the book. One has to wonder whether it was included simply because entanglement it is a trendy topic (and whether it will be replaced by a chapter on quantum discord in the second edition). This would not be so bad if it was a good review of entanglement, but unfortunately I do not think it is up to the excellent standard of the rest of the book. First of all, it does not do a good job of explaining why we should care about entanglement in the first place. Teleportation is not covered until the end of the chapter in a section entitled "Additional topics in entanglement theory". This belies its status as perhaps the key example of using entanglement as a resource for quantum communication. Similarly, the discussion of Bell's theorem is relegated to almost a side-note after the discussion of entanglement witnesses. Both of these things should be discussed up front as motivation for the more detailed discussion of entanglement. Secondly, I think that any review of entanglement really ought to include the asymptotic theory of conversion between bipartite pure states, and the consequent identification of the entanglement entropy as the unique measure of entanglement. It is hard to understand why ersatz facts about isolated classes of mixed entangled states, LOCC channels, and separability criteria are considered more important than this. In fact, I consider most of the material covered in the main body of the chapter to be "additional topics",

THE LIGHTER SIDE

from xkcd.com by Randall Monroe

(Chris Fuchs: this one's for you)



Continued on next page

Review, continued

of interest mainly to specialists, whilst the main points of entanglement theory have been entirely missed or skirted over very quickly.

Given that I have ended with the negatives, let me remind you that the first five chapters of this book are excellent. Beginning graduate students should definitely read it and it provides an essential reference for those teaching courses that involve the generalized quantum formalism. Just maybe tear out chapter six before lending it to your students.

__Matt Leifer__ is one of the two people behind the innovative new online quantum information and foundations seminars known as Q+ (the other is Daniel Burgarth). He is also on the Editorial Board of the very publication you are now reading.

The Quantum Times

Volume 7, Number 1
Second Half, 2012

The Quantum Times is a publication of the Topical Group on Quantum Information of the American Physical Society. It is published twice per year, usually in early January and late June.

Editor
Ian T. Durham
Department of Physics
Saint Anselm College
Manchester, NH
idurham@anselm.edu

Contributions
Contributions from readers for any and all portions of the newsletter are welcome and encouraged. We are particularly keen to receive

- **op-ed pieces and letters** (the APS is *strongly* encouraging inclusion of such items in unit newsletters)
- **books reviews**
- **review articles**
- **articles describing individual research** that are aimed at a broad audience
- **humor** of a nature appropriate for this publication

Submissions are accepted at any time. They must be in electronic format and may be sent to the editor at idurham@anselm.edu. Acceptable forms for electronic files (other than images) include LaTeX, Word, Pages (iWork), RTF, PDF, and plain text.

Editorial policy
All opinions expressed in *The Quantum Times* are those of the individual authors and do not represent those of the Topical Group on Quantum Information or the American Physical Society in general.

REQUEST FOR NOMINATIONS FOR THE 2013 JOHN STEWART BELL PRIZE FOR RESEARCH ON FUNDAMENTAL ISSUES IN QUANTUM MECHANICS AND THEIR APPLICATIONS:

Dear friends and colleagues:

We are pleased to announce the 2013 John Stewart Bell Prize, and ask for your assistance in identifying deserving candidates for the award.

The John Stewart Bell Prize for Research on Fundamental Issues in Quantum Mechanics and their Applications (short form: "Bell Prize") is awarded every other year, in particular again in 2013, for significant contributions first published in the 6 years preceding January 1st of the award year. The award is meant to recognize major advances relating to the foundations of quantum mechanics and to the applications of these principles – this covers, but is not limited to, quantum information theory, quantum computation, quantum foundations, quantum cryptography, and quantum control. The award is not intended as a "lifetime achievement" award, but rather to highlight the continuing rapid pace of research in these areas. It is intended to cover even-handedly theoretical and experimental research, both fundamental and applied.

The award is funded and managed by the University of Toronto, Centre for Quantum Information and Quantum Control (CQIQC), but the award selection will be handled by an arms-length selection committee. The membership of the 2013 committee is

* Nicolas Gisin (chair, and winner of the inaugural Bell Prize, 2009)
* Aephraim Steinberg, ex officio vice-chair
* Sandu Popescu (winner of the 2011 Bell Prize)
* John Preskill
* Eugene Polzik

The award will be presented as part of the biennial CQIQC conference, during which the awardee will be invited to deliver a prize lecture. This year's conference will additionally be a celebration of the upcoming 50th anniversary of Bell's Inequalities, making it a particularly special occasion. (The meeting will run August 12-16, 2013 at the Fields Institute, University of Toronto. The conference web page is under development, but the previous conference program can be viewed at http://www.fields.utoronto.ca/programs/scientific/11-12/CQIQCIV)

To nominate a candidate for this award, please email your nomination to Anna Ho, CQIQC administrative assistant, at aho@chem.utoronto.ca. The nomination should include the name and affiliation of the nominee, a 1-2 paragraph statement of the importance of the contribution on the basis of which you are making the nomination and the principal literature citations to this work (which must have been published between January 2007 and December 2012). Self-nomination is prohibited.

All nominations received prior to January 31, 2013 will be considered (although the committee will not be bound to restrict itself to these nominations).

Thank you in advance for your assistance,

Nicolas Gisin
on behalf of the Bell Prize selection committee