The Quantum Times

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Newsletter of the Topical Group
on Quantum Information

American Physical Society

Inside this issue

New Perspectives on the Quantum State: A report from Waterloo

Ken Wharton

The "New Perspectives on the Quantum State" conference was held at the Perimeter Institute (Waterloo, Canada) from September 27th to October 2nd. (Videos of all the presentations are now available on pirsa.org; this review should help guide you to the ones you will find most interesting.) This was the second annual conference of the Perimeter Institute-Australia Foundations (PIAF) collaboration, which "aims to promote quantum foundations as a subject of research", and indeed these PIAF conferences have recently been the largest such gatherings outside of Europe.

That said, this conference sported a much lower attendance than last year's "The Clock and the Quantum", making it more comparable in size to the original PIAF workshop in Sydney, back in Feburary 2008. Most glaringly, the poster session dropped from over 20 posters last year to only 2 this year. I don't know the number of official attendees (not counting occasional drop-ins from PI itself), but the 26 invited and contributed speakers seemed to make up over half the audience.

If you're considering attending this conference series next year, I highly recommend it. Conferences at PI always seem to run smoothly (thanks to an amazing support staff) and the building itself seems to be dangerously conducive to idea-sparking conversations. Such opportunities were certainly helped by the leisurely schedule (less than 5 hours of talks a day, 2 hour lunches), and also by the lack of distractions you might find in a larger city.

The topical focus (on the status of the quantum state) was by and large respected, but while this provided a common theme, it also served to emphasize the complete lack of consensus on this topic in the foundational community. Indeed, many of the speakers confessed to their own uncertainty on this issue. The breadth of approaches meant that no particular viewpoint dominated the conference, although the deBroglie-Bohm (dBB) interpretation was the most-represented minority (6 out of 26 talks).

Even dBB had its share of different perspectives, however; Howard Wiseman [Griffith University] gave an excellent summary and motivation, making a particular attempt to interest non-Bohmians. He made a persuasive case that anyone working in foundations should be very familiar with dBB. Sheldon Goldstein [Rutgers University] also gave a spirited defense of dBB, assigning "nomic" (law-like) status to ψ, but I thought the most effective take was by Antony Valentini [Imperial College, London]. He argued that the dBB pilot wave should be thought of as a new type of "causal agent", and put the argument in a historical context, comparing pilot waves to the original abstractions that led to forces and fields. Another way to grapple with the pilot wave's 3N-dimensional configuration space was presented by Travis Norsen [Marlboro College]; he pointed out that one could replace it with an infinite number of fields living in 3D physical space as a step to something more palatable. More technical results were also presented -- Samuel Colin [Perimeter Institute] discussed modeling of non-equilibrium distributions, and Nelson Pinto-Neto [Centro Brasileiro de Pequisas Físicas] showed how

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dBB trajectories could be effectively used in quantum cosmology.

Other approaches to an "ontic" quantum state (one that directly describes some underlying reality) included the dynamical collapse models of Philip Pearle [Hamilton College] and the non-unitary evolution of mixed states proposed by Gian-Paolo Beretta [Università di Brescia]. Both of these talks were good, general surveys for people unfamiliar with these approaches, demonstrating how tapping into thermodynamic irreversibility allows one to insert an actual collapse into the quantum dynamics.

You might have expected that other "ontic" perspectives would have been presentations from the many-worlds camp, but there were no talks explicitly on those interpretations. The closest mark would have been Robin Blume-Kohout's [Perimeter Institute] enjoyable perspective on what quantum information and computing have to tell us about whether we might be living in what he called "the Matrix" – i.e. some perceived subset of a quantum universe. The evidence that we are, apparently, is that a quantum agent could out-perform us at certain tasks and games. Christopher Timpson [Oxford] also argued that a realistic quantum state might better be viewed as non-separable density matrices assigned to "natural subsystems" corresponding to regions of physical spacetime. (This was joint work with David Wallace [Oxford], with a many-worlds bent.)

Timpson was one of the few talks trying to smooth the divide between QM and quantum field theory; the other speakers that tried to use covariant formulations to help interpret non-relativistic QM were Daniel Terno [Macquaire University] and Ken Wharton [San José State University], both of us concluding that ascribing any firm "reality" to traditional non-relativistic quantum states was problematic at best.

Which brings us to the "psi-epistemic" perspectives, where the wavefunction isn't a faithful description of an underlying reality, but is more representative of our knowledge of that reality. (Robert Spekkens [Perimeter Institute], a strong advocate of this view, was one of the conference organizers.) The opening talk of the conference, by N. David Mermin [Cornell], argued that the measurement problem simply results from our "bad habit" of treating the wavefunction as a physical reality. The main thrust of Mermin's talk, however, was (in my opinion) a tenuous analogy to the reification of spacetime and the "problem of now". (I was intrigued by the parallels between Mermin's talk this year and Lee Smolin's [Perimeter Institute] talk at the previous PIAF conference, even though Mermin was unaware that Smolin has also been grappling with our experience of "now".)

Stephen Bartlett [University of Sydney] made a strong case that this ontic/epistemic discussion was far from being just a semantic argument. He pointed out that a 1991 paper by Deustch, concerning quantum systems in the presence of closed time-like curves, used an "ontic" quantum state to conclude that unitarity could be violated in these extreme cases. Bartlett then re-analyzed these same cases using a "psi-epistemic" perspective, and showed that most of Deutsch's original conclusions were not supported.

A case against ontic interpretations of density matrices was made by Leslie Ballentine [Simon Fraser University], pointing out that by giving different observers different knowledge of the same system, they can end up with the same "subjective density matrix" and yet still answer certain questions differently. He supported an "ensemble interpretation", where the standard wavefunction merely represents an ensemble of similarly-prepared systems. The issue of which (if any) hidden variables one would then need to describe the ontic state for an individual system was not addressed. The other speaker that explicitly supported an ensemble interpretation was Brian La Cour [University of Texas at Austin], who addressed the hidden variable issue by pointing out that experimental tests of quantum contextuality (at least, those that rely on sequential timelike-separated measurements) do allow an interpretation in terms of pre-existing ontic states, so long as each measurement both selects and dynamically changes one subset of the ensemble.

Another epistemic perspective was presented by two Quantum Bayesians (or QBists): Christopher Fuchs [Perimeter Institute] and Rüdiger Schack [University of London]. In their view, the division between the observer and the observed in QM is analogous to the division between an agent and events in probability theory, and therefore apparently not in need of an explanation at all. Using a "Dutch Book" basis for Bayesian probability theory, both Fuchs and Schack described the Bayesian updating of ones mental description of quantum states (upon measurement). In this view, the Born rule is "not a law of nature", but rather "something we should strive for" to avoid making poor decisions. Fuchs even went so far as to provide a more general Bayesian updating rule for use on both classical and quantum systems, with new meta-parameters concerning the fundamental nature of the systems in question. (No, not hidden variables; those didn't really enter into the picture, depending on what was meant by the word "Zing!".)

Howard Barnum [Los Alamos National Laboratory] started from a QBist-sympathetic perspective and then attempted to add some "meat" – aka physical significance – to the quantum state. After posing a lot of deep questions, Barnum seemed to mostly end up in the camp of relational interpretations, a la Carlo Rovelli. Interestingly, this was similar to the conclusions of Philip Goyal [Perimeter Institute]; Goyal's talk focused mostly on reconstructing quantum theory from a few basic principles (probability and

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complementarity), but then hinted that his results best implied a relational ontology. Dean Rickles [University of Sydney] surveyed the status of these relational quantum theories, where the quantum state can be epistemic without any hidden variables at all. The main idea is that there is "no absolute state of being; only correlations between subsystems" (Mermin). This reduces reality to a series of "correlations, all the way down". Rickles's final slides also beat out Howard Wiseman's valiant efforts for the best (worst?) joke of the conference.

Of course, the real challenge for psi-epistemic interpretations is to actually specify what the ontic state really is. Caslav Brukner [University of Vienna] discussed some problems with this goal, in the context of hidden variable models; he showed that such models could not have an ontic state space significantly smaller than the traditional state space, and furthermore would allow for superluminal "signaling" on the level of the hidden variables. Alberto Montina [Perimeter Institute], however, pointed out that the ontic state space could be much much smaller if one allowed non-Markovian dynamics, and then proceeded to show how this might be accomplished for both a qubit as well as for an arbitrary dimension Hilbert space. Montina also had one tantalizing slide concerning the use of time-symmetric boundary conditions (past and future) as a natural way out of Markovian dynamics, tying in nicely with Aharanov's approach (below).

Terry Rudolph [Imperial College] pointed out that a psi-epistemic model for a single qubit already exists – courtesy of Kochen and Specker – and then discussed fascinating (but so far unsuccessful) attempts to extend that general approach to a qutrit. He also made a general point that in a psi-epistemic model, if one knows all the hidden variables, one should not always be able to uniquely determine a corresponding (epistemic) quantum state. Such uniqueness would imply that the original quantum state wasn't "epistemic" at all (as defined in arXiv:0706.2881) – although for a different take, see the beginning of Travis Norsen's talk.

The "keynote" speaker -- and certainly the most renowned – was Yakir Aharanov [Chapman University]. Armed with only a pen, he gave a very nice derivation of his two-state formalism for post-selected systems, and then discussed the intriguing aspects of "weak measurements" that can be performed on ensembles of such systems at intermediate times between the (strong) pre- and post- selections. If the "strength" of the weak measurement is weighted by some parameter $a << 1$, then the information one gains from the weak measurement scales as "a", but the net effect from the weak measurement on the intermediate quantum state scales like "a^2". Aharanov concluded

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Editor

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

Editorial Board

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

that for sufficiently weak measurements one could experimentally determine what was actually happening in a quantum system without disturbing it (given a large enough ensemble). From this perspective the "ontic" state would be best described by two wavefunctions; a "history vector" determined by the initial pre-selection as well as a "destiny vector" determined by the final post-selection. Ken Wharton's talk extended such a two-state formalism into the relativistic domain, outlining a candidate psi-epistemic model in which a two-component classical field was constrained by two-time boundary conditions (corresponding to a preparation and a measurement).

There were also two panel discussions, but I confess I didn't get much out of them. More constructive discussions were to be found in the 15+ minutes of questions following each of the invited talks. I made particular note of Huw Price's questions to both Mermin and Valentini, Valentini's comments to Fuchs, Timpson's question to Rickles, and Lucien Hardy's exchange with Beretta. Goldstein also had an interesting "confession" after his talk, sparked by a question from Maaneli Derakhshani.

To summarize, there was no general agreement to be found, except perhaps that the Copenhagen (non-) Interpretation isn't tenable, and that reports of the demise of hidden variables have been greatly exaggerated. Still, such a meeting of the minds was nevertheless exactly what this field needs. Hopefully cross-pollination from all these different approaches will help us figure out what these mathematical objects in our equations actually represent -- and why nature seems to work in a way that is so fiendishly difficult for us to comprehend.

Ken Wharton *is an Associate Professor in the Department of Physics and Astronomy at San José State University. He will soon be spending an upcoming sabbatical pursuing the mysteries of quantum mechanics as a Visiting Fellow at the Sydney Centre for the Foundations of Science.*

Bits, BYTES, *and Qubits*

QUANTUM NEWS & NOTES

A programmable quantum computer

One of the main problems with existing quantum computational architecture had been, until recently, the inability to perform general computations. In other words, implementations of quantum computing devices weren't programmable - until now. A group at the National Institute of Standards and Technology in Boulder, Colorado led by Dave Wineland that includes *Quantum Times* editorial board member Didi Leibfried has constructed a programmable two-qubit quantum processor. The processor is capable of taking any one of fifteen classical inputs to realize arbitrary unitary transformations on the two qubits that are stored in trapped atomic ions. The group's work, described in a letter to *Nature: Physics* (published online on November 15th), utilized quantum state and process tomography to characterize the fidelity of the implementation for 160 randomly chosen operations. The design of the processor could be used to form the basis of a multiqubit register that would serve as the core component in a much larger scale quantum processor. So how long will it be until I can put in my order for a quantum smartphone?

So how fast will it be?

The previous news item might have hard-core gamers drooling in anticipation of the ultimate in game consoles. Processing power, usually marketed according to the speed (unless you're a Mac user), is what it's all about. Indeed, Moore's Law famously predicts the increase in processor speed as a function

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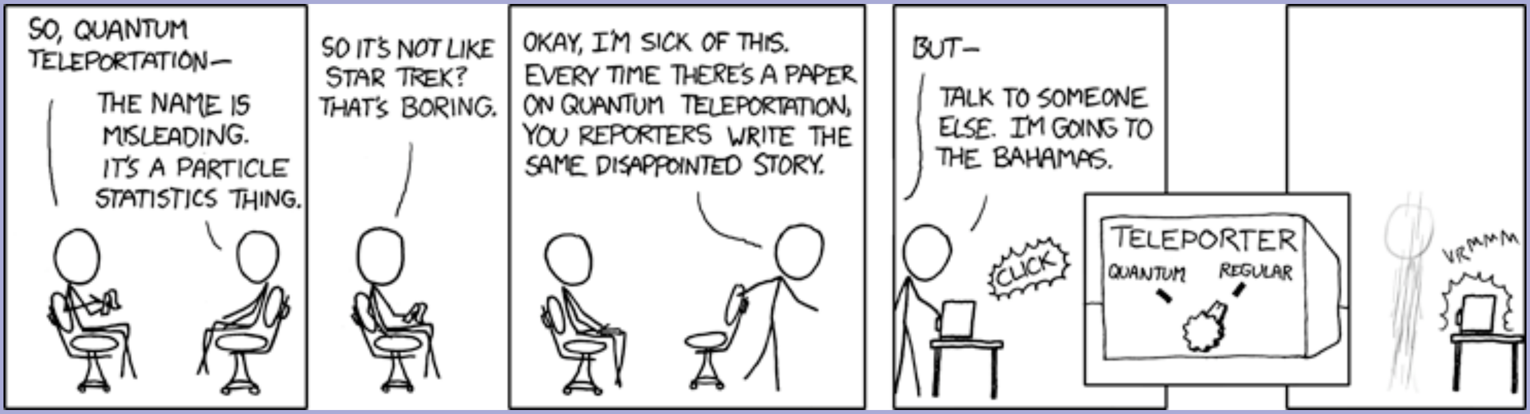
the lighter side from xkcd.com by Randall Monroe



of time as being exponential. Quantum computers promise a dramatic speed-up over their classical counterparts. But is there a fundamental limit to processing speed, whether it be classical or quantum? Indeed, Lev Levitin and Tommaso Toffoli have found a fundamental quantum limit to the rate of operation of *any* information processing system. This is actually not all that surprising when one considers the time-energy uncertainty relation. But, as they say, the 'devil was in the details.'

The assumption is that any such limit must be embodied in the processing rate of a *perfect* quantum computer. Levitin and Toffoli (publishing in *PRL*), built on the work of Mandelstam and Tamm; Fleming, Anandan, and Aharonov; and Vaidman, regarding the minimum allowable time to orthogonalize a state. They demonstrated that, for every quantized chunk of energy, a perfect quantum computer achieves ten quadrillion more operations *each second* than today's fastest classical processor. If Moore's Law is correct, reaching this limit would take 75 to 80 years, though some feel that is optimistic. As quoted on Chris Jablonski's *Emerging Tech* blog at ZDNet.com, Scott Aaronson thinks 20 years is a more realistic prediction. What will the gamers of the future do with themselves?

And they'll be useful too!

I have to apologize for shamelessly taking the theme of the title of this item from Jarek Miszczak's post on Quantiki. I just couldn't resist. At any rate, one of the more mundane tasks of computers is solving linear systems of equations. From calculating the loading forces on a bridge to developing economic forecasts, systems of linear equations are ubiquitous tools in applied mathematics and *have* been for, quite literally, thousands of years (for example, the Bakhshali manuscript, dating from roughly the second or third century BCE, includes such systems of equations).

Now Aram Harrow, Avinatan Hassidim, and Seth Lloyd have developed a quantum algorithm for solving such systems. Their algorithm runs in $\mathrm{poly}(\log N,\kappa)$ time which is an exponential improvement over the best classical algorithm. This is good news to budding Gordon Moores intent on making their first million off a viable quantum computer. Until now quantum computers showed their greatest promise in the task of factoring large numbers which, outside of cryptography, is largely useless. In particular it is becoming increasingly apparent that quantum computers won't be a whole lot better than their classical counterparts at solving problems from that infamous class known as NP-complete problems. But thanks to Harrow, Hassidim, and Lloyd, they just became far more useful.

Perhaps they'll be optical

All these interesting news items beg the question: which quantum computing architecture provides the best scalability? That's a tough question and one that won't be answered any time soon. Nevertheless, many different architectures have made great strides recently. In addition to the ion traps used by the group at NIST, optical architectures have shown some recent promise. Notably, a group at the University of Bristol led by Jeremy O'Brien, has successfully scaled up their own discovery to create the first optical 'quantum computer chip,' as it were.

In 2003, O'Brien, in conjunction with colleagues at the University of Queensland, created the first optical CNOT gate for single photons. Last year, O'Brien and his group have managed to cram hundreds of the same CNOT gate onto a piece of silicon a millimeter across using tiny coupled waveguides instead of mirrors and beamsplitters. Now, the team has carried out an actual calculation using the new chip, albeit a fairly simple one (they calculated the prime factors of 15). Nevertheless, it proves that the initial concept is scalable. The trouble, of course, is finding reliable sources of single photons, something that hasn't quite been perfected. But it's another step forward on the road toward a realistic quantum computer.

More finagling with photons

A team from the Australian National University has created a system capable of storing and 'echoing' pulses of light. The setup, which uses pulsed lasers as a source, creates a flexible optical memory system. It also has the potential to drastically increase the range over which quantum cryptographic devices can effectively operate. At the moment, such systems are limited to between 50 and 100 kilometers in range. But, in theory, some sort of quantum repeater could be employed to extend that range. This new technology might serve as the core of just such a device since it allows photons to be captured, stored, and released all on demand. The research was published in *Nature*.

Three-color entanglement

Researchers from the University of São Paolo, the Max Planck Institute for the Science of Light, and the University of Erlangen-Nuremberg have, for the first time, entangled light beams of three different wavelengths. One of the most promising applications for this effect would be the integration of information from qubits of differing types, e.g. quantum dots, trapped ions, and superconducting flux qubits, since all might conceivably produce light of differing wavelengths. The research was published in *Science*. Is it just me, or do the pieces seem to be falling into place?

-ITD

APS

Topical Group on Quantum Information

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NOTICE: GQI ELECTIONS

The 2009 election for new members of the Executive Committee is now open. The Candidates are: **John Preskill** and **Barbara Terhal** (Vice-Chair), and **Alán Aspuru-Guzik** and **Olivier Pfister** (Member-at-Large). Voting is open through Dec. 18. Links to biographical summaries, election statements, and instructions have been e-mailed to members.

A letter from the Chair-elect

We have, just this year, passed an historic landmark: the 15th anniversary of Peter Shor's paper announcing that quantum computers could efficiently factor numbers. This amazing discovery motivated many of us to begin research in quantum computing, and even today must be considered among the strongest reasons for continued funding of the discipline. The APS Topical Group on Quantum Information was founded in part because of the rise of quantum information science, and in part to give those interested in quantum theory a home within the APS (The saying "I've got some grad student. He's thinking about the meaning of quantum mechanics. He's doomed," attributed to John McCarthy, is a good gauge of what mainstream physicists thought, and still think, of those interested in thinking hard about quantum theory.) Traditionally, then, GQI has been a home for physicists interested in the physics behind quantum information experiments and foundational and theoretical investigations of quantum information. But quantum computing is much more than just these traditional domains. As incoming chair of GQI this is what concerns me the most: where are we going as a field and how can GQI best aid the field?

To take just one example of the broader applicability of quantum computing than is witnessed at APS meetings and in APS communications, we almost completely ignore the questions of engineering which must be undertaken when (not if!) we build a large scale quantum computer. These questions will explicitly not be about "physics" but will concern, say, large scale integration and quantum architectures. How will GQI respond to the coming invasion of the quantum computer engineers?

As a second example, we might consider the more theoretical, computer science side of quantum computing. Recently, for instance, it was established that PSPACE=QIP, and if you don't know what these terms stand for, well, that is exactly the point. This is a very beautiful contribution to the theory of quantum computational complexity, the classical equivalent being one of the biggest achievements in classical computational complexity. Where will we put the quantum computing theorists? Even more scary, what about the coming quantum computer *programmers* (off-shoring joke deleted)?

I'm not sure there is a good answer to this question, but it seems to me that GQI should be broadly construed and should work to make sure that the breadth of the field of quantum information science is included in its future. So this sounds like a noble goal,

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right? All goals are noble when you don't have to contribute anything besides reading a little letter and nodding your head in agreement. But what I suggest is something different. All of us know people who live on the boundaries of quantum information science. Why don't you, who are reading this, go out and, as a starting point, get one of these boundary people to join GQI (or join yourself if you're not a member)? I mean, they may be a computer scientist, engineer, mathematician, or, I dare say, even a chemist, but I'm sure they don't bite, and might actually benefit from the wisdom of the physicists who make up the majority of GQI. So go forth, GQIers, find strangers and convert them over to the fold!

Yours in incoming-chair-ness,
Dave "Pledge Drive" Bacon

***Dave Bacon**, also known as the Quantum Pontiff, is a self-proclaimed theoretical ski bum and pseudo-professor. According to the University of Washington's payroll department, he is actually a Research Assistant Professor in the Department of Computer Science and Engineering and an Adjunct Professor in the Department of Physics. He was born during a lunar eclipse in May of 1975 in Yreka (not Eureka), CA.*

letters

Quantum mechanics is local

At the same time I was giving an invited talk at the March APS meeting in Pittsburgh about the foundations of quantum information, and in particular explaining why quantum mechanics is local – which, by the way, is a very useful principle in quantum information, one of the things I will be telling my students the next time I teach a course on the topic – the newsstands were carrying the March issue of *Scientific American* in which David Albert and Rivka Galchen (Columbia) were claiming exactly the opposite: quantum mechanics is nonlocal, and this represents a threat to special relativity. "[A] fist in Des Moines can break a nose in Dallas without affecting any other physical thing ... anywhere in the heartland." The issue included a picture of Einstein on the front cover, looking perplexed.

Nonsense! Granted, *Scientific American* is not *Physical Review A*, but the public should be spared such flamboyant and misleading assertions. There was not the slightest hint anywhere in the article that their claim of nonlocality might be wrong. But wrong it is; see my arXiv:0908.2914 if in any doubt on the matter. And you who teach quantum theory to the sophomores (now I am really stepping on toes!) should at least have a twinge of conscience every time you tell the class that carrying out a measurement collapses a wave function, thus leaving the poor students with the confused idea that this is some physical process, rather than just a means of calculating a conditional probability. True, the latter sounds less exotic, and so may not help with the course enrollment, and your students will have to learn what a conditional probability is (how terrible!). But at least they won't grow up believing in *spukhafte Fernwirkungen*.

If someone doesn't like what I'm saying, he can go ahead and shake a fist – in Des Moines or Detroit or New York or wherever. I, for one, have not the slightest fear of these extremely powerful, superluminal, infinite-ranged, undetectable influences. The reason they cannot transmit information (about which we all agree) is that they don't exist (about which we should all agree). Or if shaking a fist is not enough, consider a letter to the editor....

Robert B. Griffiths
Department of Physics
Carnegie-Mellon University
rgrif@andrew.cmu.edu

A response to Griffiths

It is true that the magazine cover line (which neither the authors nor I wrote) should have been more circumspect and that the article should have been clearer that it was not talking about signaling nonlocality. Nonetheless, I find it telling that Dr. Griffiths's letter repeats the very mistake that it accuses the article of: not offering hints it may be wrong. The interpretation of the wavefunction which Dr. Griffiths's letter, book, and papers offer is hardly uncontroversial. His letter only reinforces my feeling that quantum foundations is an active field with strong personalities and intense disagreements underconstrained by data. All we editors can hope for is to achieve balanced coverage when integrated over time. Scientific American will publish other articles on quantum foundations which explore alternative interpretations, and I invite researchers in this area to contact me if they would like to contribute.

George Musser
Editor
Scientific American
gmusser@sciam.com

Editor's note: David Albert was given an opportunity to respond but had not done so by the time this issue went to press. If a response is received, it will appear in a future issue.

Letters may be sent to the Editor (Ian Durham) at idurham@anselm.edu.

TQC 2010

5th Conference on Theory of Quantum Computation, Communication and Cryptography

13-15 April, University of Leeds, UK

Quantum computation, quantum communication, and quantum cryptography are subfields of quantum information processing, an interdisciplinary field of information science and quantum mechanics. TQC 2010 focuses on theoretical aspects of these subfields. The objective of the conference is to bring together researchers so that they can interact with each other and share problems and recent discoveries. The conference will be held from April 13-15, 2010, at the University of Leeds. It will consist of invited talks, contributed talks, and a poster session.

The scope of the conference includes, but is not limited to:

* quantum algorithms
* quantum complexity theory
* quantum cryptography
* quantum estimation and measurement
* quantum coding theory
* entanglement theory
* models of quantum computation
* simulation of quantum systems
* quantum communication
* quantum noise
* fault-tolerant quantum computing

Invited Speakers:

* Julia Kempe (Tel-Aviv University)
* Frank Verstraete (University of Vienna)
* Anton Zeilinger (University of Vienna)
* Kae Nemoto (NII, Tokyo)
* Ronald de Wolf (CWI, Amsterdam)

Post Proceedings:

As has happened for previous TQCs, a post-conference proceedings volume will be published in Springer's *Lecture Notes in Computer Science*, to which selected speakers will be invited to contribute.

Conference committees:

For a complete list of members of the **Program Committee**, the **Local (University of Leeds) Organizing Committee**, and the **Conference Series Steering Committee**, please see the conference website,

http://tqc2010.leeds.ac.uk/.

Important Dates:

* Submission deadline: Monday 4th January 2010 (23:59 local time)
* Notification of acceptance/rejection: Thursday 11th February 2010
* Conference: April 13-15, 2010
* Post-proceedings submission deadline: End of May 2010
* Final copy deadline: End of August 2010
* Published: November 2010

IQC
Institute for
Quantum
Computing

The IQC invites applications for visitors all areas and of all levels of expertise in of quantum information science and technology.

Founded in 2002, the mission of the Institute for Quantum Computing (IQC) is to aggressively explore and advance the application of quantum mechanical systems to a vast array of relevant information processing techniques.

A part of the University of Waterloo, based in Waterloo, Ontario, Canada, IQC creates a truly unique environment, fostering cutting-edge research, and collaboration between researchers, in the areas of computer, engineering, mathematical and physical sciences.

At this time, IQC has 18 faculty members, 20 postdoctoral fellows and over 65 students and research assistants, as well as a support staff of 14.

IQC benefits greatly from our active visitor program.

We gladly host researchers from all areas, and of all levels of expertise, in quantum information processing. Visitors should expect to engage IQC researchers and to present their recent work.

If you are interested in a visit that is two weeks or longer, please fill in the form at:
http://www.iqc.ca/positions/visiting_researcher.php

For shorter visits, please contact the faculty member you wish to visit directly.

The Institute for Quantum Computing acknowledges the support of the Government of Canada through Industry Canada and the Government of Ontario through the Ministry of Research and Innovation.

To find out more about the Institute for Quantum Computing, please visit
http://www.iqc.ca.

Visitors should expect to engage IQC researchers and to present their recent work.