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A sea change for weak-value amplification

George C. Knee, Joshua Combes, Erik Gauger, and Christopher Ferrie

Weak values arise in quantum theory when the result of a weak measurement is conditioned on a subsequent strong measurement. The majority of the trials are discarded, leaving a few that give rise to a kind of signal amplification. Weak values have received attention for their alleged potential to improve the performance of quantum sensors, and their profile has been raised by a number of impressive experiments. By contrast, recent theoretical studies have shown the opposite: the weak-value technique generally worsens metrological performance. This document summarizes the implications of those studies, which call for a reappraisal of weak values' utility.

Weak measurements vs. weak values

A quantum weak measurement is a procedure whereby only a little bit of information about a quantum system is obtained [1]; as a consequence, the system is only disturbed a little. This is in contrast to the usual strong measurements, which give a lot of information but inject a large disturbance into the system. Imagine the needle on a poor-quality analogue voltmeter, which twitches or deflects in response to an electrical signal. In a weak measurement, the amount of deflection is only loosely correlated with the true voltage—because the needle also twitches about randomly, for example. The expected value of the deflection, however, is precisely the true voltage: over many trials the average deflection will reveal the true voltage with increasing precision.

Weak measurements have become part of the standard toolbox in the modern field of quantum control: they can be a useful method of stabilizing a quantum computation, where information must be prevented from leaking into the environment [2]. However, if a weak measurement is repeated on a single system enough times to provide the same information as a strong measurement, a comparable back action will be imparted.

A weak value, like the expected value, is a well- defined quantity that arises from applying standard quantum mechanics to a particular measurement protocol [3,4]. The procedure to obtain a weak value is explained in detail in Ref. [5], but we sketch the idea here (see Figure 1): First, the system of interest is prepared in a known initial state (e.g., a predetermined voltage). It is measured weakly (for example, by using a poor quality voltmeter) and then measured again, this time strongly (with a good quality meter) [6]. Finally, the data from the poor voltmeter are culled, a step known as postselection; only those instances where the second measurement reported a particular unlikely result are kept. The weak value is approximately proportional to the expected value of the surviving data

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from the first measurement. When the reading on the second meter is a very rare one, the weak value can become quite large. Intuitively, the anomalously large deflection seems to indicate the potential to increase or amplify the precision of measuring devices—why live with a small signal when a large one can be arranged? Intuition, however, is notoriously unreliable.

The cost of amplification

The larger-than-expected average deflection is not just a theoretical oddity—it is borne out in experiments. Many studies have been motivated by the idea that the weak-value technique can convert tiny effects into larger ones. The first such study was Onur Hosten and Paul Kwiat's 2008 experiment, which detected the spin-Hall effect of light (a coupling between the polarization and transverse momentum of light at an interface between media with different refractive indices) with postselected weak measurements [7]. In most experiments with weak values, the polarization of a beam of light plays the role of the quantum system and the deflection of the beam replaces the twitching of the meter needle. The weak- value formalism has also been applied in a range of physical systems, usually with the aim of estimating the coupling between two quantum degrees of freedom.

There are two reasons why the apparent amplification provided by weak values is not a 'silver bullet' for precision measurements, however. The first is that the measurements are necessarily extremely noisy: for the measurement to truly qualify as weak, the needle on the measuring device is continually wandering under quantum fluctuations. Any systematic deflection of the needle is, by design, hidden by the fundamental quantum uncertainty in any given run. Detecting the signal necessitates the use of a statistical approach. In any weak measurement, postselected or otherwise, a very large number of trials is vital for a significant conclusion to be reached. Only a strong measurement can provide a precise estimate after a single trial.

The second reason is that the anomalously large deflections are very rare. The larger the 'amplification' that is desired, the more trials are required before an experiment succeeds . In optical experiments, a low success probability translates into a much reduced photon detection rate. Therefore, the effect leads to an attenuation as much as it leads to an amplification.

For these reasons, and despite the experimental successes being reported, a question mark has hung over the utility of weak values. In the last year, a number of researchers working independently have proved theorems with the same broad conclusion: weak values do not improve estimation accuracy or precision. In order to understand these results, we briefly describe the formalism of parameter estimation.

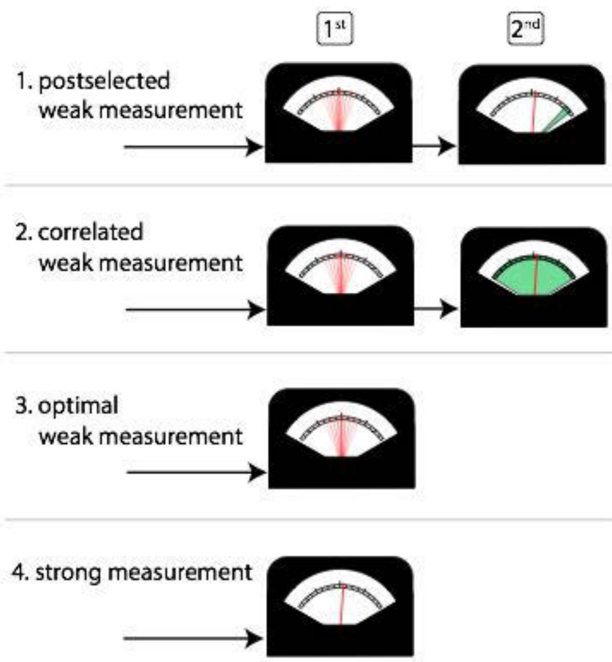

Figure 1: *When one wishes to estimate a property of a quantum system, various measurement schemes can be employed. The experimenter can choose the amount of uncertainty (depicted here by a fluctuating meter needle), and also whether to correlate the first measurement with a second one. The green areas on the second meter depict a value that must occur for the experiment to be successful – otherwise it is rejected. It has recently been shown that a postselected weak measurement (1.) will give less information than all three alternatives, despite its association with large meter readings known as 'weak values'. It is better to either (2.) keep all of the data from both measurements, or (3.) dispense with the second measurement altogether. A single strong measurement (4.) gives the most information of all.*

Parameter estimation

Gathering and interpreting data is the very essence of empirical science. For results to be meaningful, they should correspond accurately to those predicted by a theoretical model, and a statement about their uncertainty must be made. This concept is familiar to anyone who has taken part in a high school laboratory class. When writing up the results of an experiment, one states the estimate of the measured quantity along with an uncertainty – the voltage was

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5.0V ±0.1V. Both numbers are the output of statistical calculations. Consider estimating the voltage of a constant signal using a noisy voltmeter. The true voltage is denoted by x_{true}. Typically one looks at the voltmeter and records the (random) value x_i, the needle deflection in the i'th experiment. An estimator is a function of the data that produces an estimate for the true voltage. Often, the average of x over N trials is a good choice, $x_{\text{est}} = (1/N)\sum_i^N x_i$.

If the experimenter happens to be sitting at an angle to the voltmeter dial, she might consistently over- or underestimate the deflection. This will result in a biased estimate of the voltage. An unbiased estimator, on the other hand, is perfectly accurate on average $\mathbb{E}[x_{\text{true}} - x_{\text{est}}] = 0$, where the symbol $\mathbb{E}$ denotes the expected value. Aside from accuracy, the quality of the estimation procedure is characterized by the precision, defined as the variance of the estimator. See Figure 2 for a simple illustration.

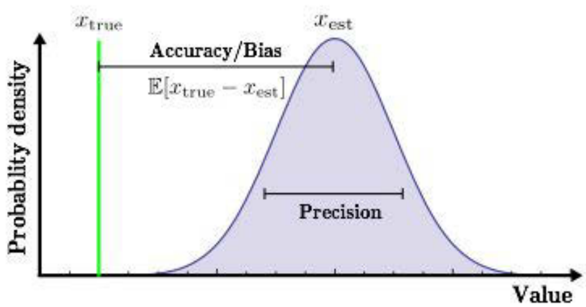

Figure 2: *An unbiased estimator has the property that in an infinite number of trials its average value will equal the true value. The quality of an estimator is characterized by the variance of the estimator. The smaller the variance the more precise the estimator is.*

In many instances it can be difficult to directly calculate the precision theoretically. A mathematical tool known as the Fisher information [8,9] allows one to place an upper bound on the variance of an estimator. The Fisher information gives a single number F, providing a powerful link between theory and experiment. If one processes the data from the experiment with the best possible, or optimal estimator, the variance will be given by the inverse of the Fisher information. That means the experimenter will report e.g. 5.0V ±(1/ $\sqrt{NF}$) V . Clearly a higher F is better because it implies a lower uncertainty in the estimate. The magnitude of the Fisher in- formation depends on exactly how the experiment is performed. It thus provides an excellent way of comparing different approaches to parameter estimation. The dependence on N means that, as long as the experiment is repeatable, the uncertainty can become arbitrarily small by increasing the number of trials.

An estimation inequality

Weak values have been hailed as remarkably useful, and as opening a new avenue for high-resolution parameter estimation. Such accolades have inspired researchers in the quantum metrology community to investigate. The conclusion reached when applying the Fisher information to weak values is that, given the same number of input resources, a weak-value strategy cannot outperform the standard metrology strategy [10-15]. This is captured in an inequality constraining the expected Fisher information:

$$F_{\text{standard}} \geq p(\checkmark) F_{\text{weak value}} \tag{1}$$

where $p(\checkmark)$ is the probability of postselection succeeding. The standard Fisher information could be one of a number of alternatives (see Figure 1). For example, keeping all of the data (rather than discarding most of it) will give higher Fisher information [11,14]; similarly, choosing an optimal initial state and not performing the second measurement at all will out-perform a postselected weak measurement [13]. A strong measurement, if available, provides the highest precision of all [10,11,13-15]. It is possible, however, for $p(\checkmark)F_{\text{weak value}}$ to approach equality with F_{standard} in a restricted parameter regime.

Furthermore, a simple estimator based upon the approximate weak value (rather than the true average of the postselected weak measurement) is not unbiased: there is a systematic error in the estimate in any real experiment. Accuracy and precision are thus both worse when postselection is used. These facts scupper the hope that weak-value amplification offers an improvement over standard metrology.

Scope for a new track?

Given these recent results, the community has started to investigate other ways in which weak values might prove useful. Whether a truly advantageous effect can be found, unlike the chimerical advantage of post-selected signal amplification, remains an open question. We will briefly summarize some of the ongoing lines of research.

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Get Lucky. Because sometimes $F_{\text{weak value}} \geq F_{\text{standard}}$, postselection might temporarily provide more information, because the inequality in (1) only applies when the number of trials is large. However, the probability of a windfall persisting decreases exponentially as more trials are performed [11].

Technical noise. Despite weak values not improving optimal estimation, many researchers have conjectured that the situation might be different when the estimation process is imperfect. We have shown that the estimation inequality (1) holds in the presence of a broad class of noise before, during, and after the weak measurement [10-13]. Together these articles treat the most prevalent types of noise, and a similar approach can be used to analyze other imperfections [16].

Imaginary weak values occur when the postselected weak measurement is performed in a certain way: the amplification is then seen in Fourier space, rather than real space. Whether or not imaginary weak values merit special consideration depends on what is meant by 'postselection': this can be understood as a physical step (e.g. the inclusion of a polarizing filter) or alternatively as the rejection of certain events from a larger dataset.

Under the first definition, the appropriate benchmark for case 1 is given by case 3 in Figure 1, and the two cases being compared correspond to (slightly) different physical setups. Altering the apparatus in such a fashion may allow an experiment to be tailored to better fit the available hardware [16,17]. In a time-domain experiment, for example, a frequency analyser is sometimes preferred to a stop- watch. However, unless there is a severe mismatch between the quality of detection in the two variables, imaginary weak values will not provide a significant advantage [13].

Taking the second definition, one compares case 1 with case 2 in Figure 1. Here the experimental setup remains identical and postselection cannot improve estimation under the most general evolution allowed by quantum theory [10]. This latter analysis therefore covers experiments involving any defined quantities, including imaginary and even complex weak values.

The true cost of estimation. It is interesting to consider the different notions of the cost associated with an investigation. One must spend time and energy to perform the experiment; there is a financial cost accompanying the hardware; and a computational cost associated with data processing and estimation.

Weak value estimators have been conjectured to offer a computationally simpler alternative than standard techniques, despite the extra apparatus required [16]. Although this is an appealing idea, standard methods are equally cheap to compute as the weak-value estimator, and are more precise [11]. Further, if one wishes to perform unbiased estimation with weak values, the postselection makes the required postprocessing much harder.

Another type of cost arises uniquely in optics experiments. Lasers can easily emit 10^{10} photons per nanosecond, making the creation-cost per photon almost negligible. The detection-cost of a photon, by contrast, is often effectively much higher [18], especially if the photodetector saturates very quickly. A variant accounting philosophy, which weighs out- put resources more heavily than input resources, could well give rise to a different conclusion to the one reached above. Interestingly, it is in exactly these special circumstances (those of large numbers of cheap input photons) that the weak-value phenomenon is known to have a classical explanation. By contrast, genuinely quantum-enhanced metrology typically exploits effects involving single quanta [19], and then the number of input resources becomes the limiting factor.

Conclusion

For a number of years, weak-value experiments, proceeding on the intuition that an 'amplified' signal is always a good thing, have outpaced the theory. The recent results have enabled theorists to catch up, and the hunt is on for a true advantage for weak values. If such an advantage is avowed, the onus will be on the claimant to fathom out its precise origin—simply quoting an 'amplification factor' is not enough.

***George Knee** recently completed his DPhil under Andrew Briggs and Simon Benjamin in the Department of Materials at the University of Oxford. **Josh Combes** is a Postdoctoral Fellow at the Center for Quantum Information and Control at the University of New Mexico. **Erik Gauger** is a Research Fellow in the Department of Materials at the University of Oxford. **Chris Ferrie** is a Postdoctoral Fellow at the Center for Quantum Information and Control at the University of New Mexico.*

Notes and references on p. 5

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Notes

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THE LIGHTER SIDE from xkcd by Randall Monroe http://xkcd.com/465/

ELECTIONS 2014

AMERICAN PHYSICAL SOCIETY
TOPICAL GROUP ON QUANTUM INFORMATION

Overview

This year marks the beginning of a new three-year cycle for GQI. That means that in addition to electing a new Vice-Chair and Member-at-Large, we elect a new Secretary-Treasurer. Each Vice-Chair goes on to become Chair-elect, Chair, and Past Chair in turn, all of whom serve on the Executive Committee. Each Member-at-Large serves a two-year term. There are two Members-at-Large and their terms are staggered. Secretary-Treasurer serves a three-year term and may serve no more than two consecutive terms. This year we are lucky to have a wonderful set of candidates from a wide range of backgrounds who are running for the three open positions. Their biographies and candidate statements are given below.

If you are an eligible voter (which means you are a member in good standing of both the APS and GQI) **you will receive an e-mail with instructions regarding the voting procedure** which is done online unless you have requested a paper ballot.

We would like to thank the candidates for their participation and we would like to encourage you to vote and become more involved in GQI. We are very close to becoming a Division within the APS which is quite an accomplishment given the fact that we did not exist ten years ago. But we are only effective if we have an active membership. We are (to the best of our knowledge) the only group in the world dedicated *solely* to quantum information. So please participate and encourage your colleagues to do so as well!

Summary of Candidates

Vice-Chair
Michelle Simmons (*ARC/New South Wales*)
Birgitta Whaley (*Berkeley/LBNL*)

Secretary-Treasurer
Mark Byrd (*Southern Illinois-Carbondale*)
Fred Strauch (*Williams*)

Member-at-Large
Lily Childress (*McGill*)
Tracy Northup (*Innsbruck*)
Graeme Smith (*IBM*)
Frank Wilhelm-Mauch (*Saarbrücken*)

Candidate Biographies and Statements

Michelle Simmons (Vice-Chair)

Biography

Scientia Professor Michelle Simmons is the Director of the Australian Research Council Centre of Excellence for Quantum Computation and Communication Technology, heading a large international team to develop scalable quantum computing technology and secure communication systems. As a Laureate Fellow and a Professor of Physics at the University of New South Wales in Sydney, she is realizing atomic-scale devices in silicon for quantum and classical computing. She was a Research Fellow at the Cavendish Laboratory in Cambridge, UK, working with Professor Sir Michael Pepper FRS in GaAs-based quantum electronics. In 1999, she was awarded a QEII Fellowship and came to Australia as a founding member of the Centre of Excellence for Quantum Computer Technology where she established a large research team dedicated to the realization of a scalable quantum computer in silicon. In 2005 she was awarded the Pawsey Medal by the Australian Academy of Science and in 2006 became the one of the youngest elected Fellows of this Academy. Professor Simmons is one of a handful of Australians to have twice received a Federation Fellowship and now a Laureate Fellowship, the Australian Research Council's most prestigious award of this kind. In 2012 she was named the NSW Scientist of the Year and most recently has been elected to the American Academy of Arts and Sciences. She has recently been appointed the Editor-in-Chief of a new *Nature* journal – *Quantum Information*.

Statement

I believe Quantum information is the future of information technology. Having served as a Director of a large, multi-disciplinary research Centre I am conscious of the intense overlap between different devices working at the same length scales all exploring quantum states of matter. By combining research at the forefront of quantum optics, atomic physics, semiconductor physics, superconducting physics and computer science with breakthroughs in

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instrumentation we have shown we manipulate matter at the smallest scales: at the level of single atoms of matter or single photons of light. There has also been an explosion in thinking about revolutionary new ways of processing information using quantum physics and computer science. I believe these advances will lead to future changes in the way we process and transfer information. At present advances in this field are reported across a range of conferences and across multiple disciplines. Discovery across the underlying fields, however, is converging. As GQI Vice-Chair I hope my experience as a Director of a large quantum information group and my role as Editor-in-Chief of a new *Nature* journal in quantum information will bring together researchers across these disparate fields for the advancement and dissemination of knowledge in this rapidly developing discipline.

Birgitta Whaley (Vice-Chair)

Biography

Birgitta Whaley is Professor of Chemistry, Director of the Berkeley Quantum Information and Computation Center at the University of California, Berkeley, and Faculty Scientist at the Lawrence Berkeley National Laboratory. After obtaining her undergraduate degree at Oxford University (1978), she had a Kennedy Fellowship at Harvard University before obtaining a Ph.D. in Chemical Physics at the University of Chicago (1984). This was followed by two years postdoctoral work in Israel (Tel Aviv and Hebrew Universities), after which she moved to Berkeley as Assistant Professor (1986). Her research is broadly focused on quantum information and quantum computation, control and simulation of complex quantum systems, and quantum effects in biological systems. Fellow of the American Physical Society and former chair of the Division of Chemical Physics, professional honors include Bergmann and Sloan Foundation fellowships, an Alexander von Humboldt research award, and Miller Institute Professor for Basic Research in Science (Berkeley). Service activities include advisory committees for the National Academy of Sciences, the Perimeter Institute for Theoretical Physics and the Kavli Institute for Theoretical Physics.

Statement

Quantum information science has grown enormously over the past years, touching ever more disciplines as it continues to usher in exciting new developments in quantum science and associated technologies. Advances in the core areas of computing, communications, measurement, fundamental concepts and foundations are receiving world-wide recognition and generating increasing public interest in the quantum world. At the same time, more and more physicists are turning to quantum information for insights into and tools to study complex quantum system. There are many wonderful things about the quantum information community – the genuinely interdisciplinary nature of this, with members coming from physics, computer and information science, chemistry and materials science, as well as engineering, is one of these. Another is that quantum information is growing and maturing, yet doing so while continuing to maintain its original fresh attitude to interdisciplinary dialogue and investigation. The GQI at APS has played a key role in enabling this unique maturation. At this time the GQI is nearing the threshold for transitioning to a Division of the APS, which will bring many additional benefits to the field. I shall campaign to increase the membership to achieve this goal as soon as possible, reaching out to those interested and 'looking in' to the field from other areas in physics and related disciplines, as well as to the many younger scientists coming in to the field. As we move towards to this goal, it is also timely to consider our priorities for moving forward, given both the increasing breadth of the field and the continuing need for professional opportunities for younger scientists. GQI provides a valuable forum for discussion and dissemination of community ideas on such issues. I look forward to serving the quantum information community as Vice-Chair in this exciting time.

Mark Byrd (Secretary-Treasurer)

Biography

Mark Byrd is Professor of Physics at Southern Illinois University in Carbondale Illinois and is cross-appointed in the Department of Computer Science. He was perhaps the first quantum computing theorist hired to a tenure-track position in the US. (He'll hear arguments to the contrary.) He was a postdoc with Daniel Lidar at the University of Toronto and a postdoc with Navin Khaneja at Harvard University. He received an NSF Career award in 2006, was co-organizer of QEC11 at USC in December 2011, and was part of a QCS IARPA team until recently. He has a wikibook that is an introduction to quantum computation and error prevention methods and that is free to read (http://qunet.physics.siu.edu/wiki). Keeping with this service to the community, he would be happy to help with the GQI.

Statement

As Secretary/Treasurer of GQI, I would look to carry on the excellent work of the two previous office holders by pushing towards Division status. Ian

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Durham and I have discussed some ideas for this. Several other ideas were discussed at the GQI meetings. First on the list is to get those already at the March meeting to sign up if they have not already. A booth would help with this as it does for contacting our representatives. Second is to ensure those giving talks in GQI sessions are members. Similarly, we should target DAMOP. There are many AMO people who also apply their research to QI. Offering an incentive should help with recruitment at these meetings. This should be announced at all talks, especially invited talks. We also want to have a sustained effort in order to grow as large as we should be. I believe as secretary of the GQI, I will be better able to help with these tasks and to push for increased membership.

Frederick Strauch (Secretary-Treasurer)

Biography

Frederick Strauch is Associate Professor of Physics at Williams College in Williamstown, Massachusetts. He holds a PhD from the University of Maryland and a BS from Loyola College. Prior to joining the Williams faculty, he held a postdoc at the National Institute of Standards and Technology (NIST). His research focuses on the design and study of "artificial atoms" made of superconducting devices operating in the quantum limit at very low temperatures and with very low electrical noise. His other interests include quantum computing with ultracold neutral atoms, quantum computing algorithms, and computational and mathematical physics in general. The common focus of his work is to develop methods to efficiently and robustly store, transfer, and manipulate quantum information using simple, experimentally accessible control protocols. He is currently working on the design of "artificial solids" capable of demonstrating novel quantum transport, with potential application to quantum computers.

Statement

At Williams College, I have been involved in guiding student research and education in quantum information processing, and would be honored to serve the Group on Quantum Information of the APS. I believe my background in the fundamentals of quantum computation and control of superconducting circuits places me at the interesting intersection of quantum foundations and the experimental frontier that the GQI represents. While I would bring a primarily undergraduate focus to the committee, I would also be interested in more general outreach, such as the possibility of a doctoral thesis award. Of course, my main priority as Secretary Treasurer would be to assist in the general business of the group and the activities spearheaded by the leadership.

Lilian Childress (Member-at-Large)

Biography

Lilian Childress is currently an Assistant Professor at McGill University in Montreal, Quebec. She received her B.S. in Physics summa cum laude from Harvard College in 2001 after undergraduate studies that included a year-long stint at Oxford University as a visiting student. She stayed at Harvard for her PhD (2007), where she worked on a broad range of projects including theoretical proposals for circuit QED with quantum dots and Rydberg atoms, as well as experimental studies of quantum memory in atomic vapor, before finally beginning work with optically-active defects in diamond. As a graduate student teaching assistant, she prepared a text on quantum optics and atomic physics (based on a course taught by Mikhail Lukin) that is still used at Harvard and elsewhere. She received a Hertz Fellowship (2002-2007), the Maurice and Gertrude Goldhaber prize (2005) and the Hertz Foundation Thesis Prize (2007) over the course of her graduate work. In 2007, she joined the faculty of Bates College in Lewiston, Maine as an Assistant Professor, where she taught for four years while continuing research on techniques to control single nuclear spins in diamond. In 2011, she spent a sabbatical working with the group of Ronald Hanson in T.U. Delft, where she collaborated on a series of experiments that led to the demonstration of long-distance entanglement between solid-state spins. She then took a postdoc at Yale University in the group of Jack Harris, where she started a project to examine interactions between superfluid excitations and cavity-confined photons and was awarded the L'Oreal USA Postdoctoral Fellowship for Women in Science. She joined the faculty at McGill in 2013, where her current research explores mechanisms for engineering interactions between solid-state spins. She is an active member of the Quebec strategic group for quantum information, l'Institut Transdisciplinaire d'Information Quantique (INTRIQ), for which she has organized a workshop; she also serves on their scientific committee, and as director of the Devices research axis.

Statement

It is an exciting time for quantum information science. Technologies and devices based on quantum principles are on the marketplace; quantum simulations are starting to push into classically uncalculable territory; ideas from quantum information science have improved classical computational algorithms and

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informed our understanding of black holes; the advances in experimental platforms and theoretical algorithms for universal quantum computation are converging towards each other. Nevertheless, it is far from a bygone conclusion that physical devices will achieve the full promise of quantum speedup or real cryptographic security. At this point, it is not even clear what the ultimate quantum analogue of the transistor will look like.

There is a clear role for the GQI to play in this arena, both from a scientific perspective and a public relations one. Scientifically, quantum information science has grown to encompass fields from computer science to materials growth to string theory, and the percolation of ideas between these areas is as challenging as it is important. GQI should work to help encourage these difficult cross-disciplinary conversations, and increase the diversity of quantum information science. This encompasses both encouraging scientists new to quantum information to engage with our community and facilitation of multidisciplinary sessions with an emphasis on accessibility.

Quantum information science also faces a public relations challenge that GQI should tackle by supporting outreach efforts. With the advent of commercial devices, quantum computing has received a lot of often misleading press, and it is our responsibility to communicate to the public not just the promise of quantum information science but also the substantial difficulties that remain, the avenues for overcoming them, and the potential for a broad spectrum of quantum technologies.

I remember learning about superconducting qubits early in graduate school, and wondering how anything could possibly be built from devices with coherence times measured in nanoseconds. But now both hardware and algorithms have progressed far beyond what I could have imagined then. Time and again, I am astounded by how quickly our community advances, and I look forward to the new developments of the coming years.

Tracy Northup (Member-at-Large)

Biography

Tracy Northup is a senior scientist at the University of Innsbruck's Institute for Experimental Physics. She received her A.B. in Physics from Harvard and Radcliffe Colleges and her Ph.D. in Physics from Caltech, supervised by Jeff Kimble. In 2008, she joined Rainer Blatt's group in Innsbruck as a postdoc, where she received a Marie Curie International Incoming Fellowship from the European Commission. She currently holds an Elise Richter Fellowship from the Austrian Science Funds. Her research focuses on optical cavities as quantum interfaces between ions and photons. In particular, her interests include exploring the dynamics of open quantum systems, implementing building blocks for quantum networks, and realizing cavity-QED-based quantum simulators.

Statement

Quantum information science encompasses a dizzying range of experimental and theoretical approaches — from atoms to photons to superconducting qubits, from cryptographic protocols to foundational questions. This diversity is a real strength of our field: it challenges us to make connections and to think about our own research in new ways. GQI provides a space for the ongoing dialogue within our community that is crucial for its growth. Through dedicated sessions at the March meeting, the nomination of APS fellows, and the *Quantum Times* newsletter, GQI offers a forum for discussion and collaboration and for recognition of our work within the larger physics world.

We are tantalizingly close to achieving division status — just a few hundred members away! Division status within APS will bring immediate tangible benefits, including more March meeting sessions and fellow nominations. In the long term, it will provide quantum information science with visibility as a stand-alone field. I've worked in Austria since completing my Ph.D. in 2008, and as a Member-at-Large, I would strive to increase the membership and participation of European researchers within GQI. In addition, something that's especially striking about the membership statistics is the percentage of students in our topical group: it's higher than in any other topical group or division. I would like us to consider the various ways in which GQI can actively support its younger members. In particular, an award for young researchers has been under discussion, and I would like to help bring that to fruition. Finally, as the *Quantum Times* transitions to a web-based format, it offers a new space for us to exchange ideas, and I hope we can make it a vibrant forum that reflects the exciting diversity of our community.

Graeme Smith (Member-at-Large)

Biography

Graeme Smith is a research staff member in physical sciences at IBM's TJ Watson Research Center. He was an undergraduate at the University of Toronto, and earned a PhD in physics from Caltech as a member of the Institute for Quantum Information. After postdocs at the University of Bristol and IBM, he began his current position in 2010. He was named a Kavli fellow in 2014. Graeme's research interests range from information theory, channel capacities, and error correction to methods for evaluating and characterizing

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quantum computing experiments. He discovered unexpected synergies as noisy quantum resources interact, in the form of superactivation of quantum channel capacity. More recently, he has studied potentially quantum effects in noisy quantum annealers like the D-wave machine and found simple classical models that capture their large-scale behavior. Earlier this year, he organized a conference entitled, "What can we do with a small quantum computer?" and believes we should all spend at least an afternoon thinking about this crucial question.

Statement

It's a remarkable time to be working in quantum information : on the experimental side, gate fidelities are approaching the fault-tolerance threshold and the number of qubits we can carefully control is getting to the point that classically modeling their behavior is intractable. On the theoretical side, studies of Hamiltonian complexity, quantum memories, and matrix product states are changing the way we think about condensed matter systems while entanglement and quantum error correction are key topics for discussions of black hole physics.

Foundations ideas like Bell inequalities have enabled device independent QKD and the delegation of quantum computing, while the classical capacity of thermal noise channels has finally been found. These highlights illustrate the radical diversity of our field that may be unique in the APS: our interests, motivations, and techniques range from the deeply philosophical to the highly pragmatic. This diversity is fundamental to our field and while it is unquestionably a strength, it also means that we have to make extra efforts to maintain communications among our various subfields and avoid balkanization. The GQI can help by acting as a center of gravity for the various interests of its members that organizes timely sessions to present multiple perspectives on topics of broad appeal both to GQI members and the APS at large. Jointly sponsored sessions on quantum simulation with Divisions like DAMOP and DCOMP have been done before, and we should do even more.

Because of our diversity, we to need make sure rank-and-file GQI members have a voice in the planning of invited and focus sessions — for example, DCMP solicits suggestions for invited speakers and sessions for each March meeting, and GQI should do the same. By embracing the diversity inherent in our community, we can continue to grow the GQI in ways that enhance the experience for current members while absorbing new and exciting directions (and members) along the way.

Frank Wilhelm-Mauch (Member-at-Large)

Biography

I studied Physics and went to graduate school at the University of Karlsruhe (now called the Karlsruhe Institute of Technology) in Germany, where I received my PhD in 1999 under Gerd Schön on mesoscopic supercondictivity - no quantum computing yet! I was a Postdoc from 1999-2001 at Delft University of Technology in the Netherlands under J.E. (Hans) Mooij, first encounter with qubits as a theorist in an experimental group. I was a Senior postdoc/lecturer 2001-2005 at Ludwig-Maximilians-University, Munich in Germany, (Habilitation in 2004 under Jan von Delft). I was Associate Professor at the Institute for Quantum Computing and Department of Physics and Astronomy, University of Waterloo, Canada, 2006-2011; Full Professor on leave 2011-13; Adjunct Professor since 2013. I am now Full Chair Professor, Saarland University in Saarbrücken, Germany since 2013. I am also currently a Divisional Associate Editor for Quantum Information at *Physical Review Letters*.

Statement

When I go to the APS March Meeting I am attending a five day conference with wall-to-wall talks on superconducting qubits which leaves me inspired and slightly firehosed. It is clear that this community makes up a large and very visible part of GQI, yet, we seem to be hesitant to help running and co-ordinating the group. As a member-at-large I hope to change that. Now is the right moment to do this because superconducting qubits have reached the point where a connection to quantum information science more broadly is possible and useful, hence we are at this time re-defining our role. I hope that this also encourages people from my field to make sure they are in GQI on its way to division status, and to connect to DCMP.

News brief

Dagomir Kaszlikowski of the Centre for Quantum Technologies in Singapore recently won First Prize in the first FQXi Video Contest. His entry, starring Vlatko Vedral as an ex-convict version of himself, imagines the Elitzur-Vaidman bomb test scheme as an anti-terrorist tool used by Vlatko to help the Singaporean cops investigate a bomb threat. Watch the video and see the comments here:

http://fqxi.org/community/forum/topic/2190

LETTER FROM INCOMING CHAIR

Tequila & Tacos to celebrate 10 years of GQI

Dear *Quantum Times* readers and members of the Topical Group on Quantum Information (GQI) of the American Physical Society (APS).

Let me begin by discussing some of the activities undertaken this past year by the GQI executive committee. Our current chair, Andrew Landahl, has had a great year as our leader. He has focused on activities that increase our membership base. Our past chair, Daniel Lidar, has been working hard to establish a new GQI Award for young scientists and has been working with APS in the implementation of this. We now have in place **an official GQI Unit Award**, which will hopefully be given out for the first time at the upcoming March Meeting. Former Chair John Preskill, was instrumental in getting this started. Ken Brown, our Vice-Chair, led the APS Fellowship Committee. Our Secretary-Treasurer, Ian Durham, continues to be the soul of GQI and has led many efforts including the continued publication of the *Quantum Times*[1]. Our two Members-at-Large, Markus Aspelmeyer and Charles Tahan, have helped in many aspects of the above. In my role as Chair-Elect, and with the help of many volunteer session organizers, session chairs and especially the session sorters, I helped to put together the program for the upcoming APS meeting that will be held in San Antonio, Texas. I want to especially emphasize the amazing work that the sorters did this year in an effort to have an exciting program for San Antonio.

This year is a special year. It will be the tenth anniversary of the creation of GQI. Since then, GQI has served as one of the most important organizations to advocate for quantum information science. As this issue of *The Times* "goes to press," GQI has 1364 members which is 2.7% of the overall APS membership of 50,820. We grew to this number from 1028 members in 2010. We are presently the second-largest Topical Group. Membership is crucial. If our growth continues as extrapolated, with the much-needed help from you towards recruiting new members, we are on the verge of becoming a division in the next couple of years. [*Editor's note*: We are eligible to apply for Division status on January 5th, i.e. next month, *if* we can eclipse the 3% mark. That would require getting a *minimum* of 161 new members by that time.]

In addition, during the past ten years, APS has awarded 25 GQI-sponsored fellows. This does not include the additional fellows we will be naming this year in San Antonio.

At the next APS meeting, people will assume their new roles. Ken Brown will become the Chair-Elect, Andrew Landahl will become Past-Chair, and I will assume the role of Chair. I will focus on fundraising efforts for our proposed GQI Award as well as on continuing Andrew's efforts on member recruitment. I welcome suggestions from any of you by e-mail (aspuru@chemistry.harvard.edu) about anything related to GQI during next year.

As it is always a tradition, we will have a Business Meeting where I will be presenting more details of what I wrote above. At the meeting, we will also have the opportunity of hearing a short presentation from Yaakov Weinstein, who is the new editor of the journal *Quantum Information Processing* about where he wants to take the journal. We have had a tradition of celebrating our Business Meeting with pizza and beer, but because we are in San Antonio, Texas and because you got a Mexican to organize the meeting this year, we will have Tequila and Tacos. See you there! ¡Arriba GQI!

Alán Aspuru-Guzik
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[1]Editor's note: This is despite the Editor's valiant attempt to resign.

Topical Group on Quantum Information
APS

Executive Committee
Andrew Landahl (Sandia), Chair
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Nominating Committee
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The Future of *The Quantum Times*

As regular readers know, over a year ago I attempted to find a replacement for me as Editor of *The Quantum Times*. I felt that, after seven (now coming up on nine) years as Editor, it was time for some fresh ideas and new blood. As I was (and still am for a few more weeks) GQI's Secretary-Treasurer, the by-laws put me squarely in charge of finding my own replacement as it is the Secretary-Treasurer's job to oversee the newsletter. I clearly have failed on two counts: resigning and finding a replacement (though one could argue it was really only a single failure).

When it became obvious that I wouldn't be leaving any time soon, I spoke with my Editorial Board and set about finding a better solution to some of the issues faced by *The Times.* The solution that was agreed upon and approved by the Executive Committee was to develop an online component of the newsletter that might, eventually, entirely supersede the PDF version. The online version would be more like a general website of GQI-related material that would include articles, job announcements, conference and workshop information, and, perhaps even a discussion forum eventually.

Matt Leifer, who is a long-time member of the Editorial Board (and contributed to the very first issue back in 2006!), graciously agreed to assist in getting this up and running. Given recent constraints on my time, we are running a bit behind on this effort. However, we would welcome assistance from anyone familiar with setting up a complex website. Please contact me directly if you are willing and able.

With that said, I wish to give my heartfelt thanks to Barry Sanders of the University of Calgary for all his help and support over the years. Barry was the first elected Secretary-Treasurer of GQI and was in that position when I offered my assistance to the new group. Barry suggested I handle the newsletter, and the rest is history. Through the years, Barry has served as both an official and an unofficial member of *The Times*' Editorial Board. Suffice it to say that much of what *The Quantum Times* has become is due to Barry. Barry has decided to take a much-deserved break from helping to edit *The Times* (unlike me, he did not fail at detachment). Since we are research collaborators, I will still be privy to Barry's amazing editing skills, and for that I am grateful. Thank you Barry!

Finally, I would like to thank Didi Liebfried and David Craig, our other Editorial Board members, for their work over the years. They may have attempted to resign, but I changed the settings on my spam filter and any e-mails from them that contain words like "resign" are immediately trashed…

Here's to a great tenth year of GQI and I hope to see many of you in San Antonio!

-Ian T. Durham, Editor

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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)
- **book 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.