The Quantum Times

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Newsletter of the Topical Group on Quantum Information

American Physical Society

Inside this issue

Complex quantum simulation will need collective effort

D. Leibfried

In 1981, at the 1st conference on Physics and Computation held at MIT, Richard Feynman delivered a groundbreaking keynote lecture where he famously pointed out why quantum systems with a large number of degrees of freedom become exponentially hard to simulate with a classical computer [1]. He then proposed simulation of such systems with a "quantum mechanical machine", that we today call a quantum computer or if it is a more specialized implementation, a quantum simulator. The ideas expressed in Feynman's lecture were among the important seeds of quantum information research and meanwhile quantum simulation has grown into one of the cornerstones of our topical group.

Especially in the last few years, several technologies that could ultimately spawn quantum simulators with the capacity to tackle problems that are too complex for classical simulation have been proposed and are currently developed. Of course a universal quantum computer could tackle almost any physics simulation [2] and it would also be possible to certify results, for example by using ideas from blind quantum computation [3, 4]. However, even before a universal machine is available, we might be able to perform meaningful simulations on quantum devices with restricted capabilities.

While proponents of quantum simulation are very excited about the prospects that are just starting to emerge, critics have rightly pointed out that, because of the restrictions in the devices used, it is not straightforward to establish the credibility of results of a quantum simulation. Are such results demonstrating true properties of the simulated model or are they due to unrelated features of the simulator? At first glance this seems to be an unsolvable conundrum because the same complexity that drives one to attack the problem on a quantum simulator in the first place will thwart any easy verification. No analytical calculation or simulation on regular computers can prove that the quantum simulation result is correct.

One way to break this impasse might follow our tried-and-true approach for testing physical laws: Since the times of Galileo Galilei physical hypotheses are tested by experiments that try to confirm the predictions in as many ways as possible. If the hypothesis stands the test we keep it, but if it fails even once, we have to refine or abandon it. Hypotheses that stand a wide enough variety of such tests are typically elevated to a "physical law". In analogy, if the same physics are simulated on a quantum simulator based on superconducting devices and another one based on cold atomic gases, it is quite likely that common aspects of both results are due to the model and not caused by unchecked systematic problems and imperfections of the machines. To get further evidence one might want to use additional simulators, maybe based on quantum dots, single photons, trapped ions or other suitable physical systems. Just as the applicability of Newton's gravitational law was so convincing because it could predict trajectories of

Continued on next page

Leibfried, continued

falling apples as well as the motion of celestial bodies, such different tests should bring out the universal features of the model under study.

This approach could bring the results of quantum simulation nicely into the fold of all other physics research where "laws" are adopted as the result of a finite number of experimental verifications and the "truth" can be changed by one experiment with a credibly negative outcome. Despite this natural appeal, such an approach has (to my knowledge) not been proposed or discussed in the literature on quantum simulation so far. If this idea is useful, everybody involved in quantum simulation, scientists and people making decisions on funding, should keep in mind that success will come from a collective effort rather than a single "winning" technology. We will "win" by developing as many complementary "quantum mechanical machines" as possible. Besides solving the problem sketched above, other unforeseen breakthroughs in our mastery and understanding of complex quantum systems will very likely follow suit.

A shorter version of this comment has appeared in the February 4, 2010 correspondence section of *Nature*. The author wants to thank Manny Knill, Anne Broadbent, Joe Fitzsimons and Elham Kashefi for fruitful discussions.

[1] Richard P. Feynman, Simulating Physics with Computers, *Int. Jour. Theor. Phys.* **21**, 467 (1982).
[2] Seth Lloyd, Universal Quantum Simulators, *Science* **273**, 1073 (1996).
[3] Anne Broadbent, Joseph Fitzsimons and Elham Kashefi, Universal Blind Quantum Computation, *Proceedings of the 50th Annual IEEE Symposium on Foundations of Computer Science* (FOCS 2009), 517 (2009).
[4] Dorit Aharonov, Michael Ben-Or and Elad Eban, Interactive Proofs For Quantum Computations, *Proceedings of Innovations in Computer Science 2010* (ICS 2010), 453 (2010).

***Dietrich Liebfried** runs the NIST-Boulder group studying quantum information with trapped ions, jointly with Dave Wineland. He is an APS fellow and is on the editorial board of this rag (but don't complain to him - all problems related to Quantum Times quality control should be addressed to Werner Heisenberg).*

THE LIGHTER SIDE

First to translate the following gets a drink courtesy of the editor at the 2011 APS March Mtg. GQI Execs. and *Times* board are ineligible.

$$[\hat{I}, \widehat{\mathrm{Work}}] = 0$$

Bits, BYTES, *and Qubits*

QUANTUM NEWS & NOTES

Quantum soccer (er, football)

In honor of the 2010 World Cup, presently taking place in South Africa, we bring you word of *quantum soccer* (with apologies to those for whom it should be 'football'). Its creator is none other than science fiction author, computer scientist, and one-time John Baez collaborator, Greg Egan. As Egan's website puts it, the aim is to 'shape' the wave function of a quantum mechanical 'ball' such that the probability of it being in one of the goals rises above a certain threshold. Shaping of the wave function is accomplished by moving the players around on the field. Moving a player enables an energy transition to occur between two modes of the wave function where these two modes depend on the player's velocity. Those readers interested in trying their hand at quantum soccer can do so here: http://www.gregegan.net/BORDER/Soccer/Soccer.html. Closing with a joke about the state of American soccer (football) would seem natural here if it weren't for the fact that the Yanks have played relatively well so far despite some interesting officiating.

The world's first 'quantum' stadium

Sticking with our World Cup theme, of the many new stadiums that have been built in South Africa for the event, the new Moses Mabhida Stadium in Durbin claims to be the world's first *quantum* stadium. No, the stadium does *not* exist a state of superposition, perhaps to the disappointment of some of the sides who have played there. The reason FIFA, in a recent article on its webpage, referred to the stadium as such is because it claims to be the first stadium in the world that utilizes quantum encryption to secure certain data. The effort to incorporate these methods in the new stadium were undertaken by the University of KwaZulu Natal's (UKZN) Centre for Quantum Technology and were dubbed the quantumStadium project, part of a larger initiative called quantumCity aimed at making Durbin the world's first 'quantum city.' The system will provide protection to data being transmitted along a fiber optic cable between the stadium and the World Cup's Joint Operations Centre. While the efficacy of existing cryptographic protocols has led some to question the need for quantum cryptography, the vast majority of traffic over the world's growing fiber optic networks remains unencrypted due to bandwidth limitations (since the encryption adds bits). Quantum cryptographic systems do not have this limitation. Unfortunately, this won't help the US recover its disallowed goal in the match against Slovenia.

Continued on next page

Quantum dot transistors get smaller

A team of physicists led by Michelle Simmons at the University of New South Wales in Australia has created a transistor using quantum dots that is ten times smaller than any other. The researchers accomplished this by replacing exactly seven atoms in a silicon crystal with phosphorous atoms (isn't it incredible that humans have the ability to do this, by the way?). To date, the smallest transistor (prior to this new discovery) was 42 atoms across (does this mean the meaning of life, the universe, and everything is no longer 42?). The research was published in a recent edition of *Nature Nanotechnology*.

Quantum random networks

Theorists at the Max-Planck-Institut für Quantenoptik (MPQ) in Garching, Germany and ths Institut de Ciències Fotòniques (ICFO) at Parc Mediterrani de la Tecnologia in Barcelona, Spain, have proposed a new type of quantum network. In quantum networks, links between nodes are typically represented by the entanglement between the physical representation of those nodes, e.g. atoms. Most previous theoretical studies of quantum networks have modeled them as lattices which translate mathematically to periodically structured graphs. Such graphs have a regular structure in that enlarging them does not change their topology since the unit cell is simply continuously repeated.

Random graphs are different, however. In such graphs every node has a non-zero probability of being connected to any other node. Depending on the connection probability and in the limit of infinite size, these networks display several interesting properties. In particular, if the connection probability is high enough, nearly all nodes will be part of one giant cluster whereas if it is too small, only sparse groups of connected nodes will be present. In the classical case this means that, for low probabilities, only trivial connections exist. Higher probabilities bring about more complex sub-graphs such as triangles, squares, and stars.

The work carried out by the MPQ theorists set the amount of entanglement between two nodes of a quantum network to be equal to the connection probability of a classical random graph. What they discovered was that even for the lowest non-trivial connection probability, i.e., if the entanglement between the nodes is just sufficient to create simple connections, it is actually possible to generate communication subgraphs of *any* complexity, unlike in the classical case.

The work, whose authors included Sébastien Perseguers (MPQ), Maciej Lewenstein (ICFO), Antonio Acín (ICFO), and Ignacio Cirac (MPQ), appeared in a recent issue of *Nature Physics*.

High-NOON at the quantum corral

Physicists at the Weizmann Institute of Science in Israel have, for the first time, entangled five photons in a NOON state, that is a superposition of two extreme quantum states. In Schrödinger's infamous thought experiment, his unfortunate/fortunate cat was in a superposition of two extreme states - dead and alive (that's dead *and* alive, not dead *or* alive). In a lab, an analogous state could be, for example, splitting a pulse of N photons and sending all N photons down one of two orthogonal paths. As such, the photons are in a superposition of both paths. Such a situation is referred to as a NOON state due to the way it is written mathematically.

NOON states are of particular interest in quantum metrology since, if the beams are recombined in an interferometer, the uncertainty in the resulting measurement scales as $1/N$ whereas in conventional photon pulses it scales as $1/N^2$. Another benefit of NOON states is that their diffraction limit is $1/N$ times that of conventional light, making them useful for optical microscopes and other such devices.

The problem, to date, has been that *making* NOON states of more than a few photons has been incredibly difficult. In fact, until now, the largest NOON state created had been four photons and the methods for creating these states were specific to the number of photons being used.

Now, however, Itai Afek, Oron Ambar and Yaron Silberberg at the Weizmann Institute have developed a general way to make NOON states (for any value of N) and have so far demonstrated that it works for up to five photons. The catch is (there's always a catch) that it's not quite perfect. Specifically, they found a minimum fidelity of 92% which, as the old saying goes, is close enough for horseshoes and hand grenades (i.e. good enough for practical applications). The work was published in a recent issue of *Science*.

–ITD

letters

Spin rotation and control

It's always fun to read the *Quantum Times*, so first of all I want to thank you for your efforts.

I must say, though, that I was rather surprised to read your summary of the recent work by Petta et al. It suggests that they have controlled (for the first time? - this is implied) a single electron spin in a quantum dot, whereas in fact:

(1) Petta did not rotate a single spin. It is a beautiful experiment, but their rotation is about some axis in the Hilbert space of two electron spins

(trapped in a double quantum dot). This could be useful for certain types of encoded qubits.

(2) There have been a number of reports of actual single spin rotations in quantum dots similar to those used by Petta, including two publications from my group (Koppens et al, *Nature* 2006, used magnetic resonance and Nowack et al, *Science* 2007 used oscillating electric fields), and recently by the Tarucha group (*Nature Physics* 2009, also with electric fields). In addition, ultrafast control of single spins has been achieved with optical pulses in self-assembled quantum dots by several groups, including Awschalom and Yamamoto.

Furthermore, the *Times* article says that the next question is whether interacting spins can be coherently controlled. Ironically, this is an experiment that Petta *did* do, back in 2005 as a postdoc with Charlie Marcus (*Science* 2005).

At present, our field is putting together all elements in a single experiment. In addition, we have learned to extend electron spin coherence times to more than 200 microseconds, using highly accurate multiple-pulse spin echo sequences (Yacoby group, unpublished).

I appreciate your efforts to cover all fields across QIP, which is increasingly difficult, but just wanted to set the record straight.

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More on a bachelor's in QIS

I have to agree with Mr. Florjanczyk that quantum information science (QIS) is not likely to be a bachelors' degree anytime soon. Dr. Wilde thinks it can be introduced to even freshmen and mentions the graduate program at Waterloo. I will make the case that any QIS program will be even more difficult if done correctly! I believe that there are some points to make, both experimentally and mathematically.

Let us begin with Quantum Computation and Quantum Information (QC&QI) by Michael Nielsen and Issac Chuang, 2000, which was the text chosen here for an undergraduate/beginning graduate course. It made sense to have this as a pure math course, but would have made only weak sense as an applied physics course. Why? Because there was no basis for thinking that electrons behave simply as spins. Let me suppose that they are for the present, and see where that brings us. It still requires a curriculum that includes the POVM's that are usually ignored in a typical quantum mechanics course. It also puts you in a finite dimensional Hilbert space; so, a linear algebra course would be appropriate in the curriculum. But POVM's are not the last word on what you need. The work on completely positive linear maps in this context is, and then the work (ICCM 2007, "What Sort of Non-commutative Analysis is Needed in Quantum Computing") is very relevant. This is by Man-Duen Choi of the Mathematics Department in Toronto. His work is not often quoted. And experimentally, where is the physical motivation for this supposed finite dimensional Hilbert space, and how could one build an n-qubit computer? Reading QC&QI simply won't tell you. Also, in general, from where does the so-called need for quantum correction arise? From the interaction with the "outside world"? What interaction? This list of questions goes on and on.

All this ignores the fact that there is more to the electron than spin. It has also momentum and position which interacts with the spin! It is not just having the spin added on as if it were an afterthought. In particular, the phase space of spinning, massive particles arises from the condition that, relativistically or non-relativistically, the momentum of the particle is orthogonal to the spin. (Think about what happens in the Stern-Gerlach experiment, for example.) In any event, you cannot just take the direct product of the momentum (and position) space times the spin space. Now, having momentum, position and spin brings us into the realm of (Lie) group theory in general (and the Galilei and Poincaré groups in particular). This implies that the curriculum would have to have at least part of a course in (Lie) groups, (Lie) algebras, and representations thereof. This is fairly standard in graduate courses in mathematics, as far as it goes. But where are the phase spaces in all this?

You would have to know about the operators that occur in these representation spaces, which are in general infinite dimensional. So, you would have to know what is self-adjointness of unbounded operators, what is a general density operator, what is a POVM and a completely positive map in this context, etc. This would be another course.

The Hamiltonian formalism in classical mechanics is also necessary in quantum information theory. It appears as follows: You have a physical system exhibiting a certain Lie group of symmetries. From this group and its Lie algebra, you do some group cohomology and extract the only phase spaces (symplectic spaces in mathematical terminology) on which the group can act symplectically. This is part of another course. But this phase space is a classical phase space, and by a phase space I definitely mean a space on which you can have a Hamiltonian dynamics. Then, and only then, may you pass to a quantum mechanical representation of wave functions over any of these phase spaces. (The quantum mechanical representation of the group is made by the (projective) left-regular action on the classical phase space.) Now you may claim to have the quantum particles in

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interaction, but only if you have the Hamiltonian formalism in the first place! Without the interactions, the particles cannot function as a computer! The group of symmetries and the phase space thus play an essential role in obtaining the way a quantum mechanical computer may work. It is not just "take a state ρ and see what the effect is when applying an arbitrary operator to it." The operators are a reflection of what is allowed in an interaction; i.e., with a Hamiltonian.

Then we have to input the data and extract from the computer what the "answer" is to the question put to it. This is done by either inputting the particular state you begin with, or by reading the instrument, which is another quantum mechanical problem, one that introduces another layer of uncertainty in a quantum computer. But this leads to a theory in which you have no non-trivial projection operators at your disposal! This is a subject which does not appear at all in QC&QI, but is essential. Notice that all we have said so far deals with the essential uncertainties of a quantum computer by the very nature of the particles with which they are built. Any additional uncertainties will have to be handled by error correction codes, etc.

Getting a Hamiltonian theory for massive spinning particles is comparatively easy non-relativistically. But what about in the future? For massless particles with their helicities you must consider a relativistic theory. Are there any quantum computers considered for these particles?

One last thought: If one has a logical theory, then one may consider approximations to the solutions when dealing with it appropriately. In the case of a quantum computer, this means we first obtain a "correct" theory, or as correct as we may get it. Then, where appropriate, we might approximate the POVM's by projection valued measuresor by allowing any particular unitary operator instead of the one given by a particular Hamiltonian, etc. When doing this, we may then consider what we are doing to the theory with these approximations. But first, we must have a logical theory.

In summary, if you want to offer an ideal curriculum on quantum computers and quantum information theory and do so rigorously, then the subjects listed above will have to be included either in separate courses or by including them in a hodge-podge selection of courses. It definitely will have to be a graduate curriculum for the average student.

I believe, furthermore, that it is premature having a curriculum for a degree in quantum computing. After all, having such a degree in this implies that the necessary bases for it would all be covered. Let us see. The concept of the quantum computer was first conceived about 40 years ago. It was given a simplified "physical" basis at that time. Since then there has been a lot learned about quantum everything, but the quantum computing theorists have only adopted the POVM formalism in that time. And still, there has not been a working quantum computer! You would think that the other advances might hold essential keys to how a quantum computer could work, or maybe prohibit them from working at all.

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op-ed

The sterilization of science

The greatest professional complement I have ever received was from a former student who had taken my introductory physics course as part of the requirements for a life sciences degree (she is now a practicing nurse). At the end of my course, which is well-known for being hard, she told me that my physics course had taught her to question *everything* (her emphasis). Most physicists likely share this penchant for skepticism, at least to a degree. After all, the process of formulating a theory or carrying out an experiment involves constant revision, which naturally entails questioning our own results. As Mike Fortun and Herb Bernstein (yes, *that* Herb Bernstein) put it, science can be "messy" and the process of doing science is often simply an act of "muddling through."

That said, two things recently caught my eye that deserve mention. The first was an excellent post by GQI Chair Dave Bacon on his blog The Quantum Pontiff concerning the paper review process. Dave writes,

> Science is dynamic. Sometimes this means that science is wrong, sometimes it means that science is messy. Mostly it is very self-correcting, given the current state of knowledge. At any given time the body of science knows a lot, but could be overturned when new evidence comes in. What we produce through all of this, however, at the end of the day, are polished journal articles.

This is more than just an issue of transparency. As someone who has done a fair amount of research in the history of science, I have noticed that one of the things we have lost in the digital age is "rough notes." For papers more than about thirty years old, notes - from scraps of paper to entire notebooks - frequently can be

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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)
- **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

Op-ed, continued

found in archives and private collections that detail the "messy" process of science. The other thing we have lost, particularly with the advent of e-mail, is written letters as a record. Some of the best ideas have come out of these letters (I cited several in my PhD thesis) and they often included hand-drawn diagrams, equations that were often easier to read, and other items not found in the limiting form of an e-mail.

We also, often individually (i.e. with no real consensus), place limits on the questions we think science can legitimately ask. While this may be necessary, it is, to some degree, arbitrary and can have the effect of quenching legitimate scientific progress. Combined with the issues I raised above, it is also quenching what could be legitimate scientific *dialogue*.

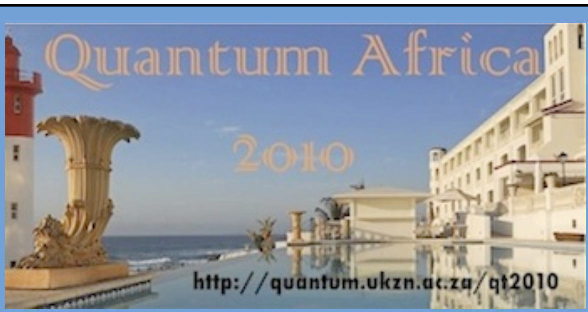
That brings up the second thing that caught my eye recently. A letter was forwarded to me this spring in which a Nobel Physics Laureate was disinvited to a conference in Italy due to their apparent interest in the "paranormal." The letter goes on to say that "it would not be appropriate for someone with such research interests to attend a scientific conference." While I agree that certain aspects of the paranormal do not belong at a scientific conference, where, precisely, do we draw the line? Would we disinvite the late Georges Lemaître, a student of Einstein and a father of modern cosmology, because he was a Jesuit priest and, as such, took vows that ostensibly implied his belief in transubstantiation, a rite he likely performed regularly? There was never any evidence that implied that the disinvited person would make their paranormal beliefs a centerpiece of conversation. Did Lemaître babble on about Catholic theology at cosmology conferences?

Both these points beg the question of whether or not some of the founding papers in our own discipline would get published in a leading journal today. Bohr's writing, for example, was notoriously philosophical (and some might say impenetrable).

The end result is that science, which should rise above such things, is increasingly *being shaped by* modern society rather than *shaping* modern society. The "culture wars" are forcing upon science a narrowing of purpose while the digital age is destroying its transparency and making its development appear black and white. More than simply unfortunate, this is dangerous.

Thus, I call on you to *question everything*, including your strongest beliefs, and *be open and transparent about it*. Science is beautiful and powerful but it isn't perfect. We should stop pretending it is.

Ian T. Durham *is the editor of this rag. In his day job, he is Associate Professor and Chair of the Department of Physics and Director of the Computational Physical Sciences Program at Saint Anselm College in Manchester, New Hampshire. He lives on the coast of Maine and blogs about quantum empiricism at http://quantummoxie.wordpress.com.*



Quantum Africa is a new series of conferences planned to take place consecutively in several African countries. The start of the series will be hosted in Durban by the Centre for Quantum Technology with a conference on progress in quantum technologies. Just as a successful preceding conference, it will feature many international renowned speakers and experts in quantum information processing, quantum optics, ultra-cold atoms and other relevant areas of quantum technologies. We hope to welcome many guests from Africa as well as from overseas.

http://quantum.ukzn.ac.za/qt2010

Upcoming Quantum Information-related Conferences and Workshops

The links below are active in most PDF viewers.

July 12-16: The Seventh Annual Canadian Quantum Information Students' Conference, Calgary, Canada.
July 17–23: 10th Canadian Summer School on Quantum Information, Vancouver, Canada.
July 19–23: The 9th International Conference on Quantum Communication, Measurement, and Computing (QCMC 2010), Brisbane, Australia.
July 23–25: Workshop on Quantum Algorithms, Computational Models, and Foundations of Quantum Mechanics, Vancouver, Canada.
Aug 1–14: Frontiers in Open Quantum Systems and Quantum Control Theory, Harvard, USA.
Aug 16–20: ARO/NSA/IARPA Quantum Computing & Quantum Algorithms Program Review, Cincinnati, USA.
Aug 16–20: School and conference on Spin-based quantum information processing, Konstanz, Germany.
Aug 28–31: 10th Asian Conference on Quantum Information Science (AQIS'10), Tokyo, Japan.
Aug 29–Sep 3: Quantum Technologies Conference: Manipulating photons, atoms, and molecules, Toruń, Poland.
Sep 1–Dec 15: Institute Mittag-Leffler Program in Quantum Information Theory, Stockholm, Sweden.
Sep 6–17: Coherence and Decoherence (AQIS'10), Benasque, Spain.
Sep 11–14: International Iran Conference on Quantum Information - 2010 (AQIS'10), Kish Island, Iran.
Sep 20–23: Recent Progress in the Theoretical & Experimental Foundations of Quantum Technology, Durban, South Africa.
Sep 23–25: International Meeting on Engineering, Manipulation, and Characterization of Quantum States of Matter and Light (EMALI2010), Barcelona, Spain.

Information on additional conferences may be found at http://quantum.info/conf/.

APS
Topical Group on Quantum Information

US NSF Travel Grant Program for Nordita/Mittag-Leffler Conference on Quantum Information Theory 4-8 Oct. 2010

Funds are available to support travel and lodging for US scientists to participate in the aforementioned conference. Information on the conference is available at

http://agenda.albanova.se/conferenceDisplay.py?confId=1440

The program is contingent on funding expected from the US National Science Foundation and will be administered by Tufts University. It is intended to cover most of the costs of travel and lodging. In addition, funds are available to cover lodging for 1-2 weeks before or after the conference to participate in the fall programs at Nordita and Mittag-Leffler or to engage in collaborative research at other institutes in Scandanavia. For information on these programs see

http://www.nordita.org/ http://www.mittag-leffler.se/programs/current/1011f/

Those not constrained by teaching obligations are encouraged to take advantage of this opportunity.

Eligibility: Open to US scientists, i.e., US citizens or those affiliated with a US institution.

- Preference will be given to junior scientists (advanced graduate students and recent PhD's) and faculty at undergraduate (PUI) institutions. Members of under-represented groups are especially encouraged to apply.
- In general, those who have current grants with travel funds are not eligible. Partial institutional support is permissible.
- US scientists participating in the Nordita or Mittag-leffler programs in Sept. or Oct. who wish to extend their stay to include the conference week are eligible for lodging support that week.
- Transatlantic travel must use US flag carriers (even if more expensive).

Application process: Applications must be submitted by e-mail to Chris King c.king@neu.edu. Send a CV with a cover letter containing a brief description of research interests. Those who want to extend their stay should also describe their plans and/or interest in this. Graduate students and new PhD's should arrange for one (at most two) letters of recommendation to be sent separately.

Application Deadline: 15 July 2010

Selection Process: Applications will be reviewed by a selection committee of Charles H. Bennett, Alan Aspuru-Guzik, Julio Gea-Banacloche, Christopher King (chair), Marius Junge, Mary Beth Ruskai (PI) and Wim van Dam. We expect to notify applicants by the start of August.

Questions: Contact the PI, Mary Beth Ruskai, by e-mail at marybeth.ruskai@tufts.edu.

UNIVERSITY OF CALGARY

FACULTY OF SCIENCE

institute for biocomplexity & informatics

The mission of the IBI: *to understand the living state from the perspective of integrative systems biology, creating a unified picture of the flow of matter, energy, entropy and information on all scales from atoms to cells and from cells to organisms.*

Joint Postdoctoral position in Stuart Kauffman and Dennis Salahub groups

IBI – Institute for Biocomplexity and Informatics, University of Calgary, Canada

Quantum Decoherence: from nonadiabatic chemical reactions to the poised realm between order and chaos

A project funded by iCORE – the informatics Circle Of Research Excellence (http://www.icore.ca)

In collaboration with Gabor Vattay (Eötvös University, Budapest), Barry Sanders (University of Calgary) and Aurélien de la Lande (CNRS, Orsay)

Applications are invited for a postdoctoral position to work on a collaborative two-year project aimed at conceptual and methodological developments around the theme of quantum coherence, decoherence, and induced coherence. We are mounting a broad-based interdisciplinary initiative to explore the fundamental nature of decoherence and induced coherence phenomena. Possible subjects include decoherence times and rates for electron transfer between proteins, quantum coherence in photosynthesis, "decoherence via measurement", dephasing, the quantum Zeno and anti-Zeno effects, sudden death of entanglement and its revival, and the kicked quantum rotor in the "poised realm", to name only a few. The successful candidate will contribute his/her own topics in consultation with other members of the collaboration.

The ideal candidate will have experience in both development and applications to complex systems of chemical physics methodology, including nonadiabatic effects, quantum information and/or quantum chaos.

Interested candidates should email their c.v. and have two or three letters of reference sent to:

Prof. Stuart Kauffman: stukauffman@gmail.com

Prof. Dennis Salahub: Dennis.salahub@ucalgary.ca