From Monopoles to Fault-Tolerant Quantum Computation:

A conference in honor of John Preskill's 60th birthday

March 14-16, 2013

California Institute of Technology

Drawing by Eugenia Sangiovanni from Bob Paz photo

Schedule

Thursday, March 14

9:50 am	Introduction
10:00 am	Patrick Hayden, McGill University
10:50 am	*Break*
11:20 am	Lenny Susskind, Stanford University
12:10 pm	*Lunch*
2:00 pm	Scott Aaronson, Massachusetts Institute of Technology
2:50 pm	Debbie Leung, University of Waterloo
3:40 pm	*Break*
4:10 pm	Jeff Kimble, California Institute of Technology

Friday, March 15

9:15 am	Kip Thorne, California Institute of Technology
10:05 am	Sandip Trivedi, Tata Institute of Fundamental Research
10:55 am	*Break*
11:25 am	Paul Ginsparg, Cornell University
12:15 pm	*Lunch*
2:00 pm	Charles Bennett, IBM Research
2:50 pm	Robert Raussendorf, University of British Columbia
3:40 pm	*Break*
4:10 pm	Peter Shor, Massachusetts Institute of Technology
6:00 pm	Reception, Main Lounge, The Athenaeum
7:00 pm	Dinner, Hall of Associates

Saturday, March 16

9:15 am	Mark Wise, California Institute of Technology
10:05 am	Lisa Randall, Harvard University
10:55 am	*Break*
11:25 am	Alexei Kitaev, California Institute of Technology
12:15 pm	*Box Lunch*

Patrick Hayden, McGill University

Where and When Can a Qubit be?

One of the most important properties of quantum information is that it cannot be copied. That statement, however, is not completely accurate. While the no-cloning theorem of quantum mechanics prevents quantum information from being copied in space, the reversibility of microscopic physics actually requires that the information be copied in time. In spacetime as a whole, therefore, quantum information is widely replicated but in a restricted fashion. In this talk, I will fully characterize which regions of spacetime can all hold the same quantum information. Because quantum information can be delocalized through quantum error correction and teleportation, it need not follow well-defined trajectories. Instead, replication of the information in any configuration of spacetime regions not leading to obvious violations of causality or the no-cloning principle is allowed. This provides a simple and complete description of where and when a qubit can be located in spacetime, revealing a remarkable variety of possibilities.

After explaining the main result, I'll present some applications to quantum cryptography, including the best known "quantum secret sharing" schemes. To end, I'll speculate on possible lessons from this work for understanding the replication of quantum information when the structure of spacetime is more subtle, specifically in the presence of black holes and cosmological spacetimes.

Lenny Susskind, Stanford University

The AMPS Effect

I will discuss the pros and cons of the AMPS argument for firewalls.

Scott Aaronson, Massachusetts Institute of Technology

Hidden Variables as Fruitful Dead Ends

John Preskill is the sanest person I know. In this talk I'll examine whether, in 2013, a sane physicist should take seriously the idea of hidden variables. Attempting to unify 60+ years of work on this subject, I'll distinguish "Bohm-like" theories (where the hidden variables surf atop the wavefunction) from "psi-epistemic" theories (where the hidden variables replace the wavefunction), and "radical" theories (which make new physical predictions) from "conservative" theories (which don't). I'll summarize the outlook for all of these in light of Bell's Theorem, the Kochen-Specker Theorem, and the recent PBR Theorem. Then I'll discuss new work by Adam Bouland, Lynn Chua, George Lowther, and myself, which gives a nontrivial construction of psi-epistemic theories in any finite dimension, but also rules such theories out in three dimensions or higher if a symmetry condition is imposed. (Our impossibility proof uses measure theory and differential geometry.) Finally, I'll explore how hidden variables could either increase or decrease the power of quantum computation, and offer some open problems.

Debbie Leung, University of Waterloo

Computational and Cryptanalytic Consequences of Time Travel

We focus on two particular models of closed timelike curves.

The first is Deutsch's 1991 mixed-state-fixed-point model which abolishes the grandfather paradox. The second is due to Bennett and Schumacher, in which the grandfather paradox on certain initial states is exploited as a putative physical mechanism for post-selection.

We discuss possible consequences of the existence of such closed timelike curves on quantum information processing.

Joint work with Charles Bennett, Graeme Smith, and John Smolin

Jeff Kimble, California Institute of Technology

Quantum Optics in 1- and 2-Dimensional Photonic Crystals

John Preskill's inspiring leadership of Quantum Information Science has enabled a new future for scientists worldwide, including for my group at Caltech. I will recall some aspects of our association over the past twenty-four years, and then describe current research that would not have been possible in a parallel universe without John.

Kip Thorne, California Institute of Technology

Physics Bets and Conversations with John

I will describe the history, sociology, science, and humor behind the bets that Hawking, Preskill and I have made, and also some earlier bets that I made with Hawking, Chandrasekhar and Zel'dovich. Then I will describe how conversations with John have influenced my research over the past several decades.

Sandip Trivedi, Tata Institute of Fundamental Research

Gravity and Condensed Matter Physics: The Beginnings Of A Dialogue?

The AdS/CFT correspondence suggests that the study of gravity in Anti de Sitter space could prove useful in understanding strongly coupled systems of interest for example in condensed matter physics. This talk will review some of the developments and the promising directions in the subject. Extremal Black Holes, whose importance John Preskill emphasised in the early 1990's, will play an important role in the discussion.

Paul Ginsparg, Cornell University

A Stylometric Assessment

This non-technical talk will provide the definitive answer to an inessential question, and suggest possibilities for future progress in this direction.

Charles Bennett, IBM Research

Apocalypses, Firewalls, and the Meaning of Post-Selection

Survivorship bias is a problem in cosmology, where, among other things, it reduces confidence in our universe's likely past and future. The theory of post-selected computation elevates this bias from a bug to a feature, dramatically improving computation and state discrimination at the cost of undermining the notion of a computer as a device independent of the questions we choose to ask it. We consider survivorship bias in connection with black hole complementarity, suggesting that the question of whether or not an in-falling Alice encounters a firewall at the event horizon may be moot if neither Alice nor anyone else would notice the difference.

Robert Raussendorf, University of British Columbia

Computation by Measurement – A Tour from Quantum Optics to Quantum Foundations

In this talk I will discuss various aspects of quantum computation by measurement [1] - a computational scheme that began with the question of how ultra-cold atoms in optical lattices can be used for quantum information processing. I will briefly describe its fault-tolerant version on three-dimensional cluster states [2], which was worked out at Caltech in collaboration with Jim Harrington and Kovid Goyal, inspired by DKLP's discussion of the surface codes [3]. Finally, I will point to connections between measurement-based quantum computation and contextuality of quantum mechanics [4].

[1] R. Raussendorf and H. J. Briegel, Phys. Rev. Lett. 86, 5188 (2001).
[2] R. Raussendorf, J. Harrington, and K. Goyal, Ann. Phys. (N.Y.) 321, 2242 (2006).
[3] E. Dennis et al., J. Math. Phys. (N.Y.) 43, 4452 (2002).
[4] J. Anders and D.E. Browne, Phys. Rev. Lett. 102, 050502 (2009).

Peter Shor, Massachusetts Institute of Technology

Quantum Weirdness and Cryptography

We discuss the applications of quantum information to cryptographic protocols. In particular, we discuss quantum key distribution and quantum money.

Saturday, March 16

Mark Wise, California Institute of Technology

Unusual Sources of Baryon Number Violation

Abstract: I discuss the simplest extensions of the standard model that have baryon number violation in perturbation theory but where proton is stable. In addition to the standard model fields these models have two complex scalar fields. Some of these models allow for neutron-antineutron oscillations. The phenomenology of one of the models is discussed including generation of the baryon excess and constraints from flavor and electric dipole moments and $n \bar n$ mixing.

Lisa Randall, Harvard University

Holographically Dual Effective Field Theories With Broken Conformal Symmetry

Alexei Kitaev, California Institute of Technology

Berry Curvature for Many-body Systems

The Berry curvature is a 2-form on the parameter space of a quantum system. It describes the noncommutativity of two small deformations of the Hamiltonian. I will give a recipe to break the Berry curvature of a many-body system into local terms. If the Hamiltonian is deformed in a third direction, the change of each local term is equal to the divergence of some discrete current. On a 1-D lattice, the total current through an arbitrary cut defines a 3-form on the parameter space. For a d-dimensional system, there is a d+2-form. (The actual construction is based on the partition function in d+1 dimensions.)

Thank you

A special thank you is extended to Daniel Gottesman, Anton Kapustin and Hoi-Kwong Lo for their combined efforts over the past several months leading up to the conference in honor of John Preskill's 60th birthday. Much of the event's success is a direct result of their involvement with help from those listed below. The extra time that they dedicated to this project is truly appreciated.

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