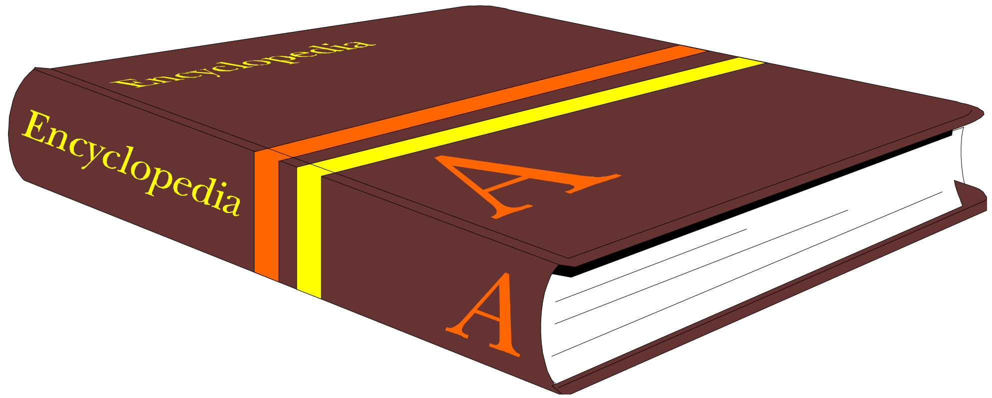
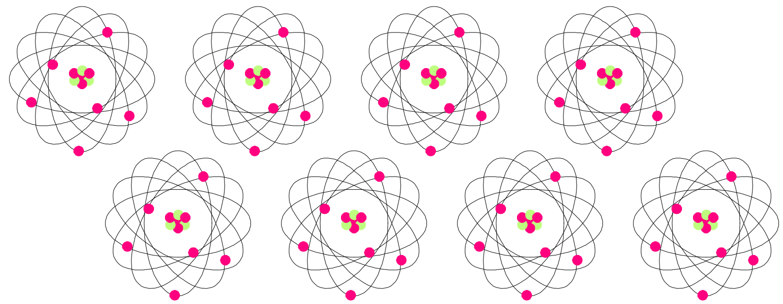
Physics Information Day

Physics of Information Day



Information

is encoded in the state of a *physical* system.



Information

is encoded in the state of a *quantum* system.

Put

Weirdness

to work!

Caltech quantum information

Jeff Kimble
Physics

John Preskill
Physics

Alexei Kitaev
Physics, Math, and
Computer Science

Leonard Schulman
Computer Science

Gil Refael
Physics

IQIM
INSTITUTE FOR QUANTUM INFORMATION AND MATTER

NSF

GORDON AND BETTY
MOORE
FOUNDATION

Big Questions

HEP:

What underlying theory explains the observed elementary particles and their interactions, including gravity?

QIS:

Can we control complex quantum systems and if so what are the scientific and technological implications?

Not the frontier of short (subnuclear) distances or long (cosmological) distances, but rather the frontier of highly complex quantum states: *The entanglement frontier*

Also: emergence of classicality, security of quantum cryptographic protocols, foundations of statistical mechanics and thermalization, information theoretic principles illuminating the foundations of quantum physics, information processing by e.g. black holes, etc.

Truism:
the macroscopic world is classical.
the microscopic world is quantum.

Goal of QIS:
controllable quantum behavior in scalable systems

Why?

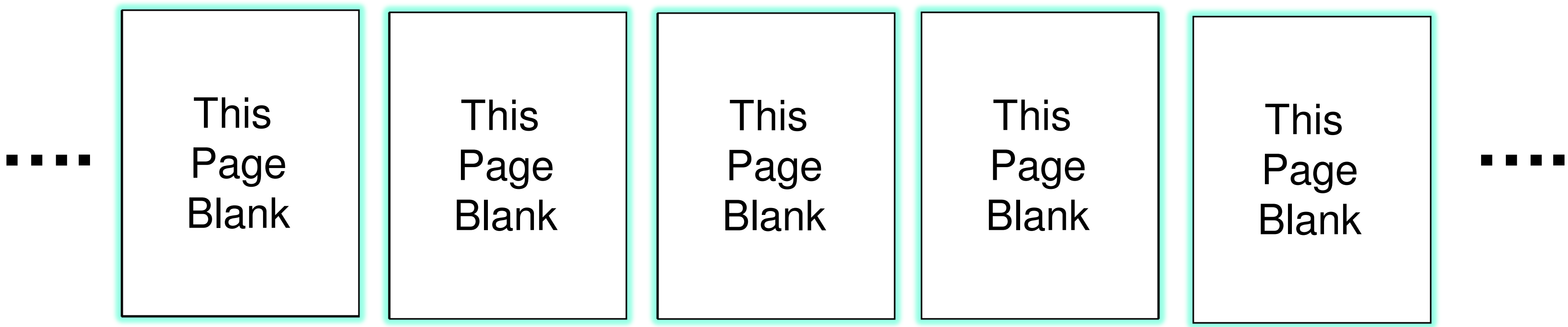
Classical systems cannot simulate quantum systems efficiently (a widely believed but unproven conjecture).

But to control quantum systems we must slay the dragon of decoherence …

Is this merely *really, really hard*?
Or is it *ridiculously* hard?

Quantum entanglement

If you read ten pages of an ordinary hundred-page book, you learn about 10% of the content of the book. But if you read ten pages of a “typical” hundred-page quantum book, you learn almost nothing about the content of the book. That's because nearly all the information in a quantum book is encoded in the correlations among the pages; you can't access it if you read the book one page at a time.



Describing “typical” quantum states with many parts requires extravagant (exponential) classical resources.

Can we verify that Nature allows states with no succinct classical description?

Toward quantum supremacy

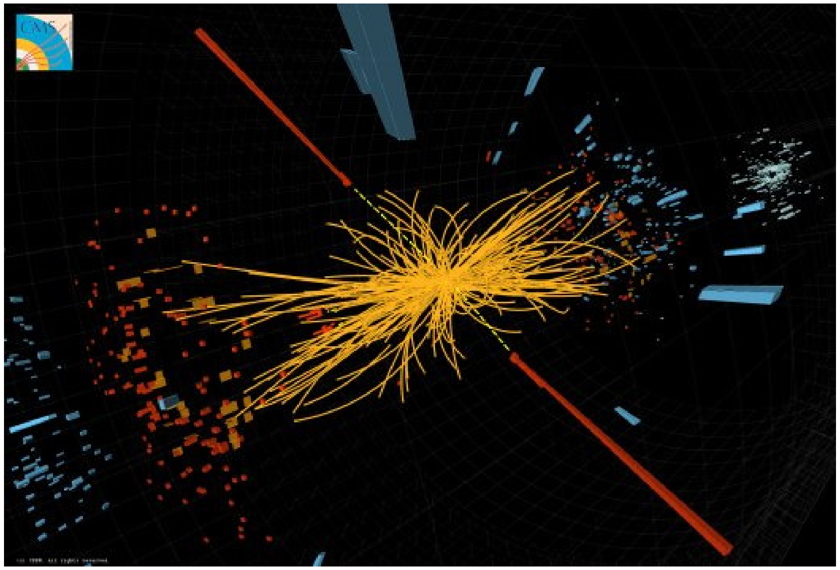
The quantum computing adventure will enter the new, more mature phase of "quantum supremacy" once we can prepare and control complex quantum systems that behave in ways that cannot be predicted using digital computers (systems that "surpass understanding" and surprise us).

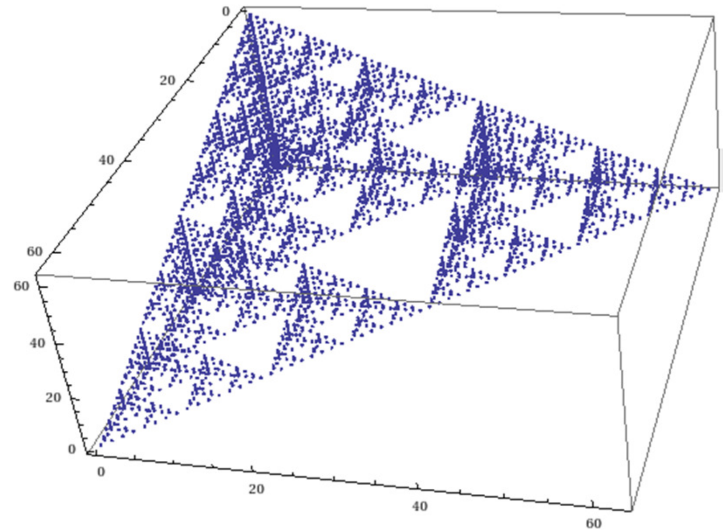
To reach that goal, it will be useful to gain a deeper understanding of two questions:

What quantum tasks are feasible?
What quantum tasks are hard to simulate classically?

Might it be that the extravagant "exponential" classical resources required for classical description and simulation of generic quantum states are illusory, because quantum states in Nature have succinct descriptions?

Quantum algorithms and quantum error correction





Jordan, Lee, Preskill: A quantum computer can simulate particle collisions, even at high energy and strong coupling, using resources (number of qubits and gates) scaling polynomially with precision, energy, and number of particles.

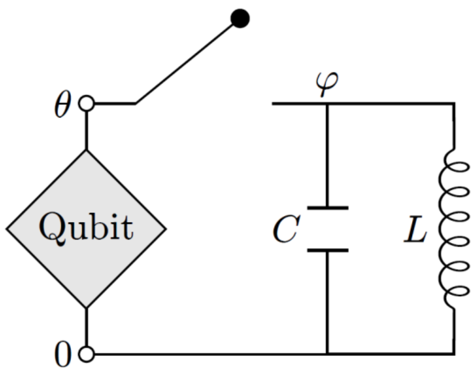
Haah: A 3D quantum code can be a robust topologically ordered quantum memory. The code admits pointlike quasiparticles, but the particles cannot move freely --- the system is a *quantum spin* glass with an enhanced memory time. To move a particle by distance R, O(log R) particles must be created.

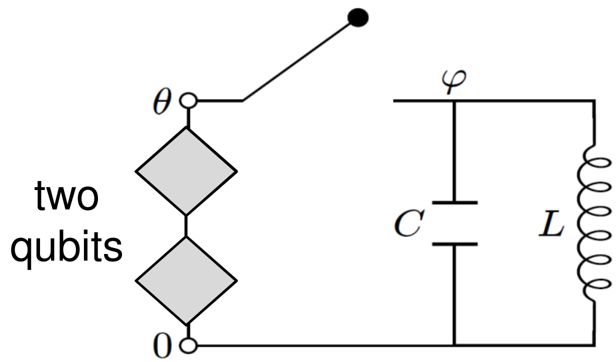
Protected phase gates

Brooks, Kitaev, Preskill

$$\exp\left(i\frac{\pi}{4}Z\right) \text{ and } \exp\left(i\frac{\pi}{4}Z_1\otimes Z_2\right)$$

Some gates are protected: we can execute Clifford group phase gates with exponential precision. This is achieved by coupling a qubit or a pair of qubits to a “superinductor” with large phase fluctuations:

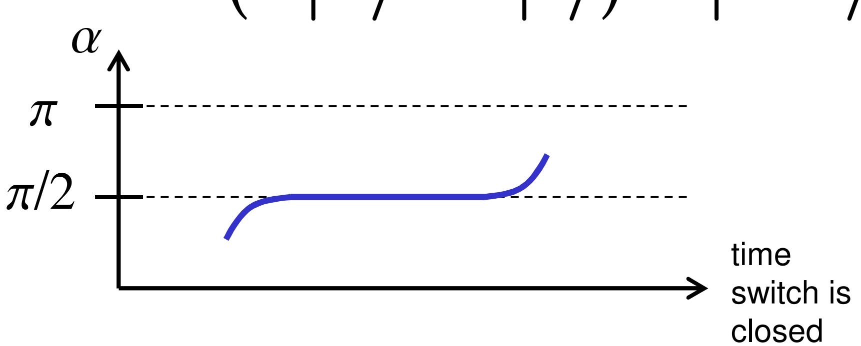




$$\sqrt{L/C} \gg 1$$

To execute the gate, we (1) close the switch, (2) keep it closed for awhile, (3) open the switch. This procedure alters the relative phase of the two basis states of the qubit:

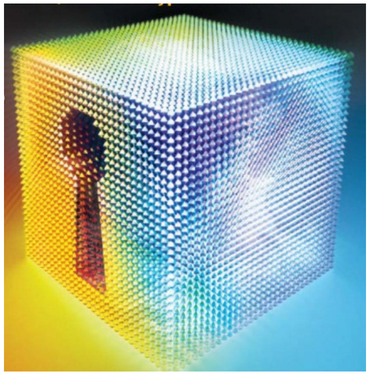
$$\left(a|0\rangle + b|1\rangle\right)\otimes|\mathrm{init}\rangle \rightarrow \left(a|0\rangle + be^{-i\alpha}|1\rangle\right)\otimes|\mathrm{final}\rangle$$



The relative phase induced by the gate “locks” at π/2. For $\sqrt{L/C} \approx 80$ phase error ~ few X 10^{-8} is achieved for timing error of order 1 percent. Why?

Quantum Information Challenges

Cryptography



Privacy from physical principles

Algorithms

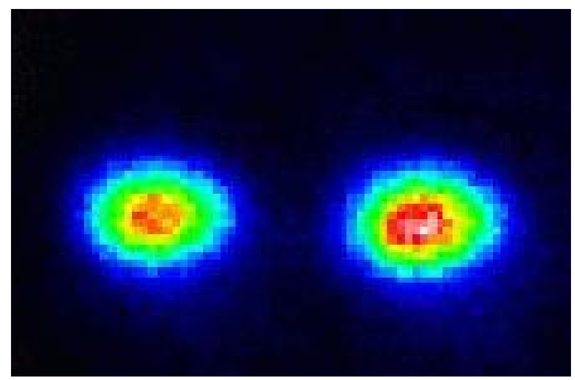
$$\sum_{x \in G} | x \rangle \otimes | f(x) \rangle$$

What can quantum computers do?

Error correction

Reliable quantum computers

Hardware



Toward scalable devices

And …what are the implications of these ideas for basic physics?

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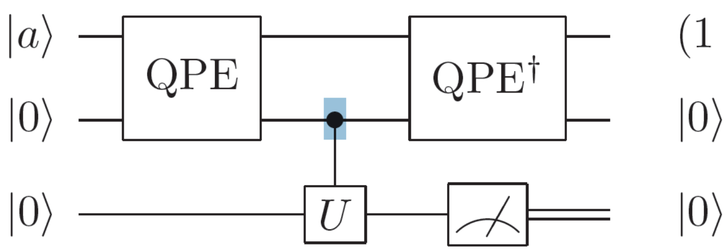
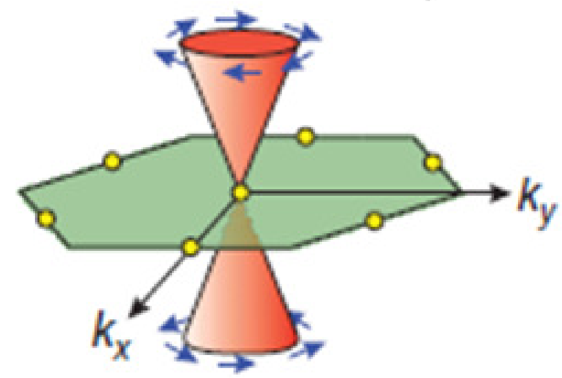
Quantum Information

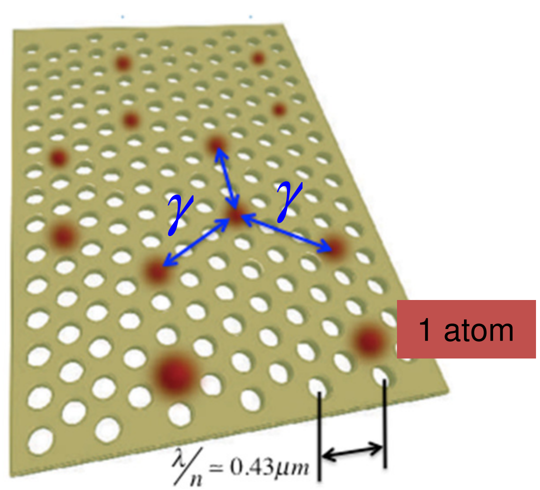


Quantum Condensed Matter

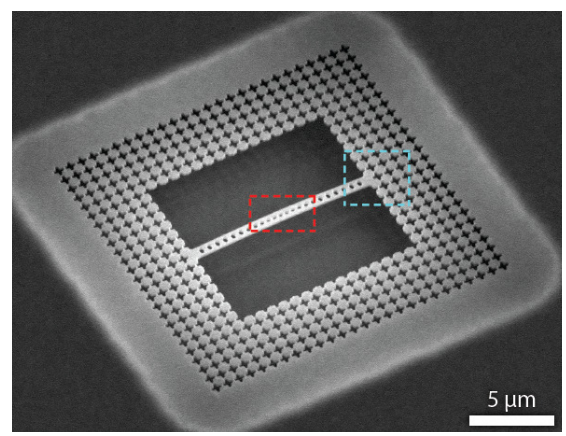


Surface-spin

Quantum Optics



Quantum Mechanical Systems



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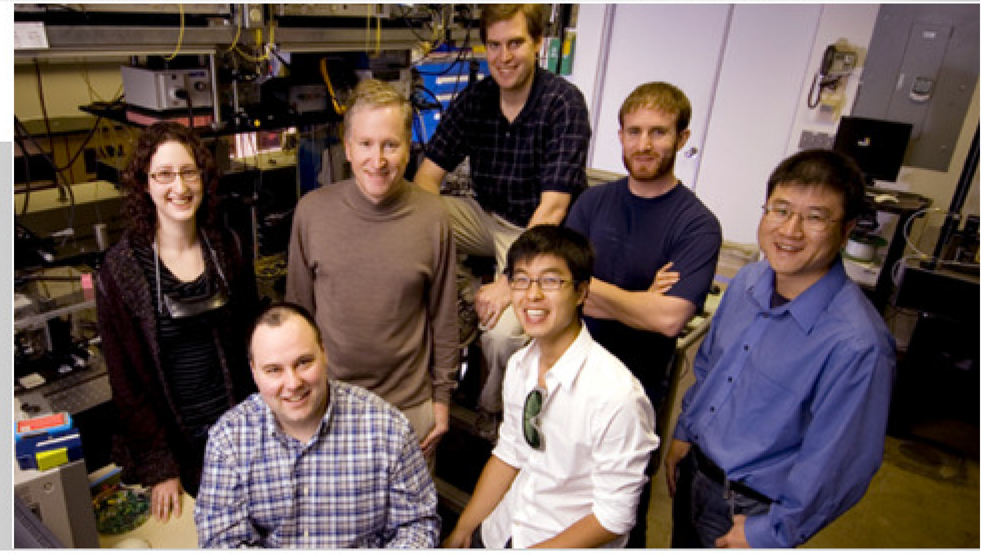


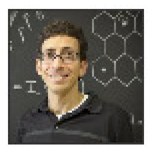
Welcome

The Institute for Quantum Information and Matter (IQIM) at Caltech is a Physics Frontiers Center supported by the National Science Foundation and the Gordon and Betty Moore Foundation. IQIM researchers study physical systems in which the weirdness of the quantum world becomes manifest on macroscopic scales. Our research programs span quantum information science, quantum many-body physics, quantum optics, and the quantum mechanics of mechanical systems.

IQIM Postdoctoral Fellowships

To apply, visit the IQIM Postdoctoral Fellowship web page

In the News



New Physics faculty, Jason Alicea, discusses his circuitous path to physicis and his current work toward developing the physics behind a quantum computer. Working with collaborators Gil Refael and Matthew Fisher, they look forward to "combining traditional conventional materials that are already available on people's shelves—to design a device that's capable of performing bona fide universal quantum computation without decoherence. We don't know how to do that, but we've made some small steps in that direction fairly recently. That's what I'm most excited about right now."
[Read the full article introducing Jason Alicea]
12.18.12

Jeff Kimble, William L. Valentine Professor and Professor of Physics, is the 2013 recipient of

Calendar

IQIM Postdoctoral and Graduate Student Seminars

Institute for Quantum Information Science (IQI) Seminars

Condensed Matter Physics (CMP) Seminars

Physics Mathematics and Astronomy Seminars

Upcoming Visitors
Keith Lee *Dec 31-Jan 18*
Stephen Jordan *Jan 6 - 19*
Stacey Jeffery *Jan 8-10*
Kejie Fang *Jan 10-11*
Steve Flammia *Jan 29*
Andrew Doherty *Jan 29*
Stephen Bartlett *Jan 29*
David Perez-Garcia *Feb 10-24*

quantumfrontiers.com

Quantum Frontiers

A blog by the Institute for Quantum Information and Matter @ Caltech

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Posted on December 3, 2012 by preskill

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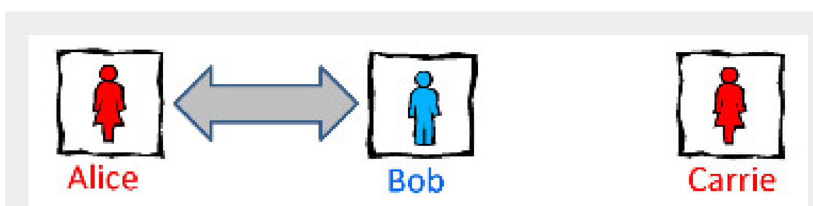
Edit

Is Alice burning? The black hole firewall controversy

19 Votes

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Annenberg Center

- Caltech IQIM Seminar Organized by & for postdocs & students

- Reception Friday 4:30-6:00 Bridge Patio

nature is subtle

Physics of Information Day

Annenberg 204
Friday, 2:00pm – 4:00 pm