

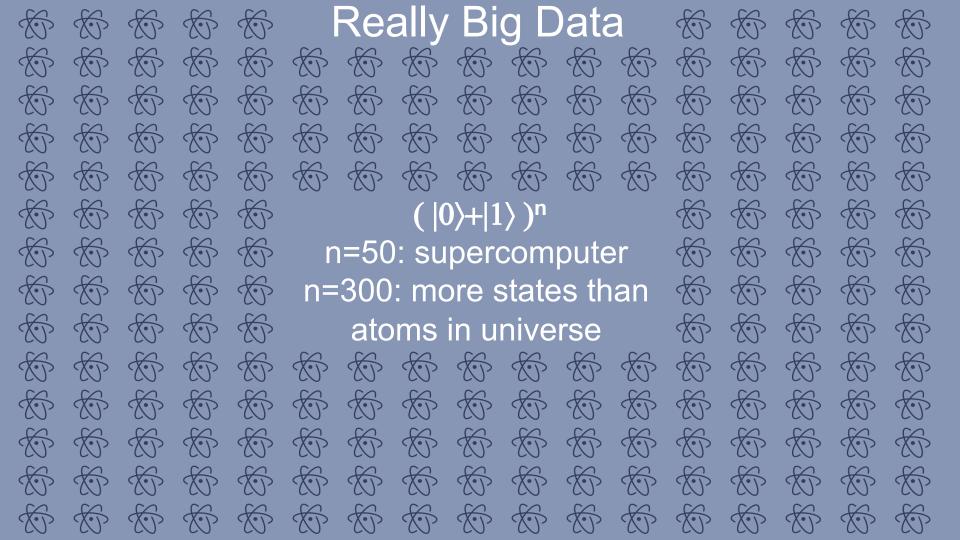
Quantum Data



$$|0\rangle$$
+ $|1\rangle$

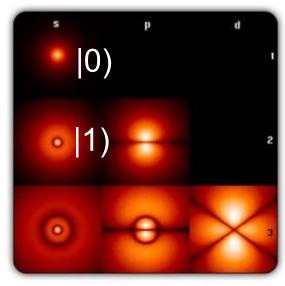
Quantum Data

$$(|0\rangle + |1\rangle)^2 = |00\rangle + |01\rangle + |10\rangle + |11\rangle$$



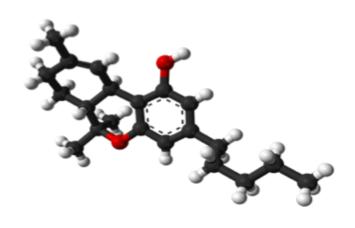
Qubit Systems

H atom:



orbitals

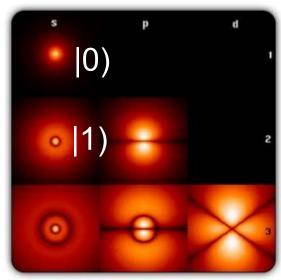
atom circuit:



Problemlight is 1000x bigger

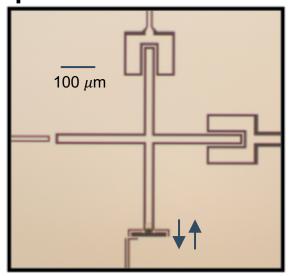
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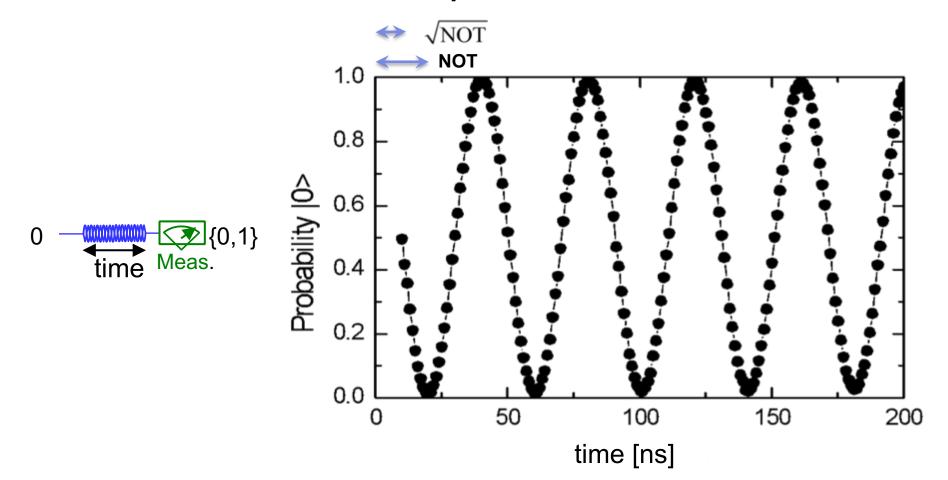
quantum circuit:

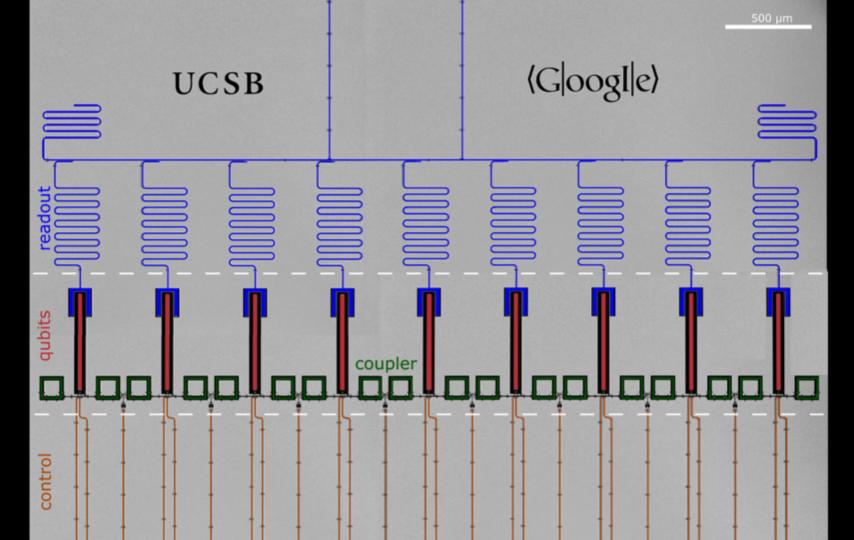


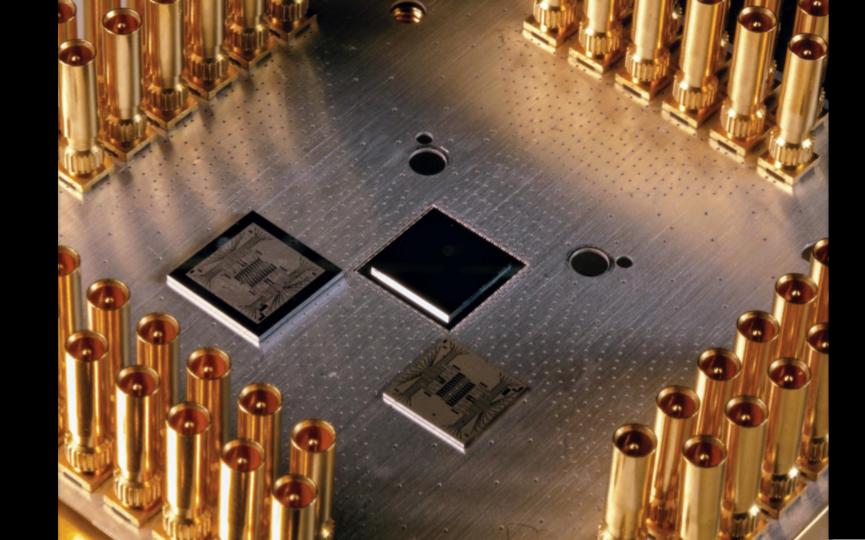
6 GHz microwave oscillator

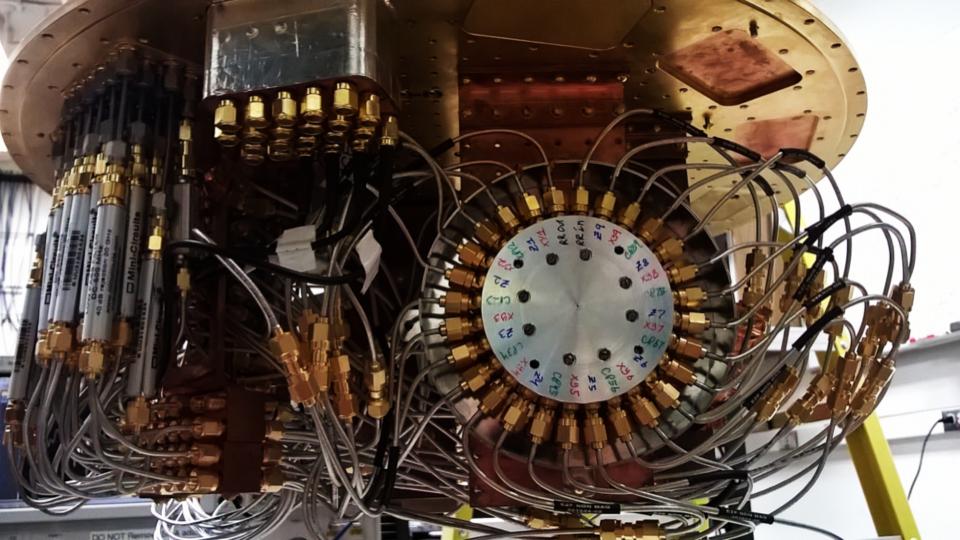
Easier control for large size

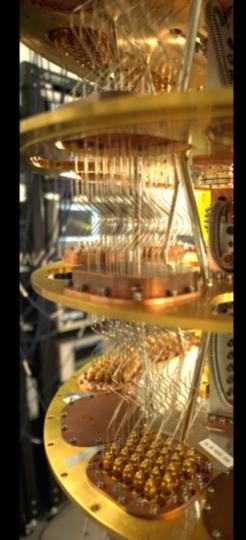
Qubit Operation

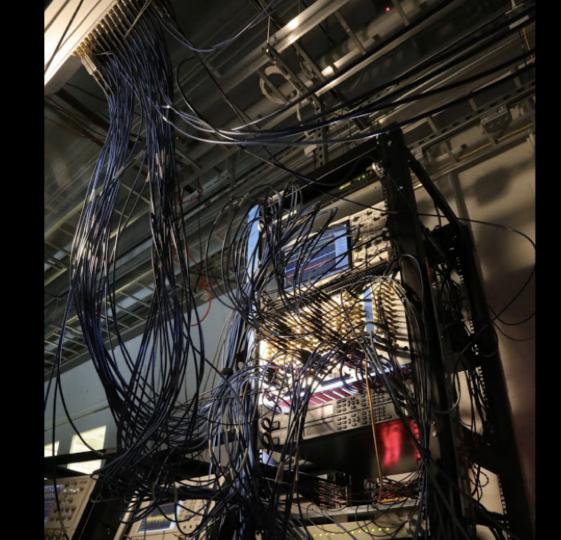




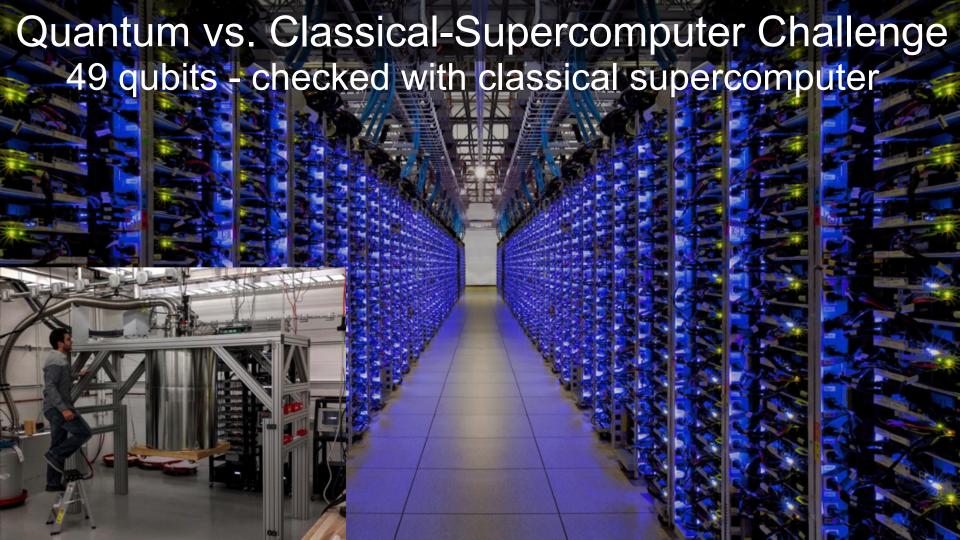






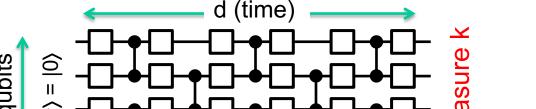






Quantum Supremacy Algorithm: Qubit Speckle

1) Choose 1 instance, randomly from gateset





Clifford

Non-Clifford

(Random guess: any outcome k has probability
$$p_{cl} = 1/2^n$$
)

3) Calculate $|\psi\rangle$, $p(k) = |\langle k|\psi\rangle|^2$ store in lookup table

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4) Correlation: cross entropy
$$S = \langle \ln p(k)/p_{cl} \rangle$$

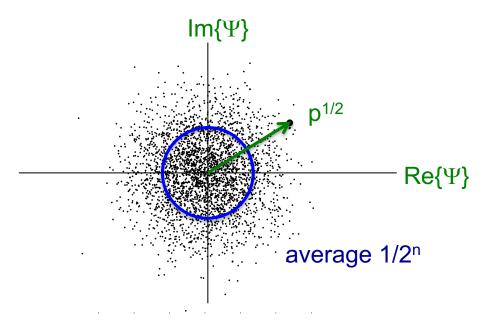
5) Compare to theory
$$S_{qu} = 0.42$$
 quantum

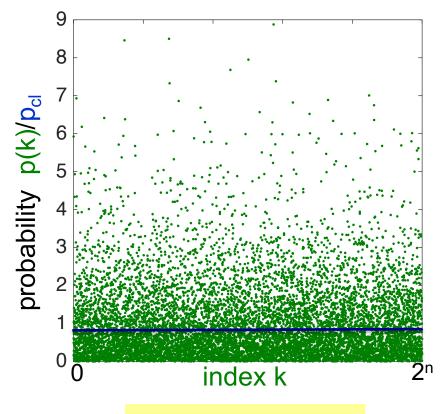
≅ -0.58 classical 6) Try another instance

speckle = coherence predict = fidelity

How Does it Work?

 Gaussian distribution Re{Ψ} & Im{Ψ} gives Porter-Thomas (exponential) distribution

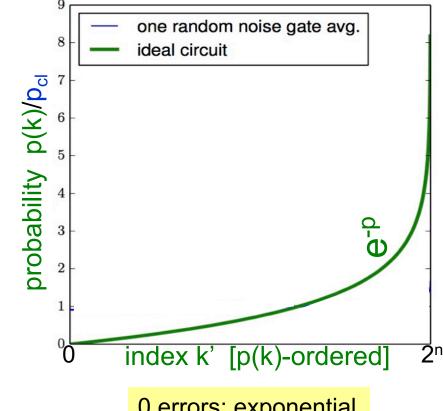




0 errors: exponential

How Does it Work?

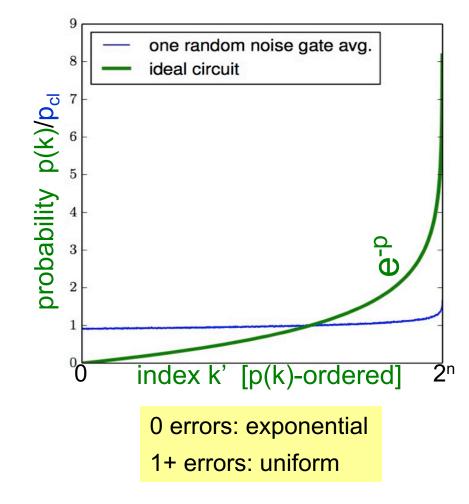
Gaussian distribution $Re\{\Psi\}$ & $Im\{\Psi\}$ gives Porter-Thomas distribution (exponential)



0 errors: exponential

How Does it Work?

- Gaussian distribution Re{Ψ} & Im{Ψ} gives Porter-Thomas distribution (exponential)
- Uniform distribution with <u>one</u> error (lose speckle)



Windows

- A fatal exception 0E has occurred at 0028:C562F1B7 in UXD ctpci9x(05) + 00001853. The current application will be terminated.
- * Press any key to terminate the current application.
- Press CTRL+ALT+DEL again to restart your computer. You will lose any unsaved information in all applications.

Press any key to continue _

Intrinsic Errors in Quantum Computation

$$S_{tot} \cong P_0 S_{qu} + (1-P_0) S_{cl}$$

Probability of no error:

$$P_0 = \exp[-N_a \varepsilon_a]$$

Average number of errors:

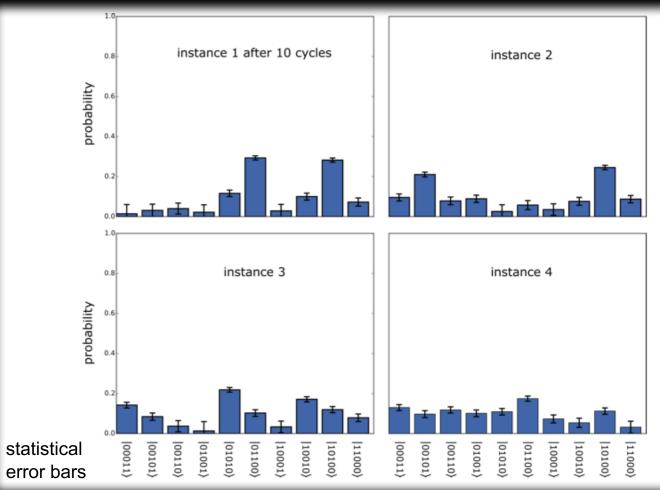
$$N_{q} \epsilon_{q} = 49 \times 7 \times 0.005 = 1.7$$



Need: scaling with low

orrore

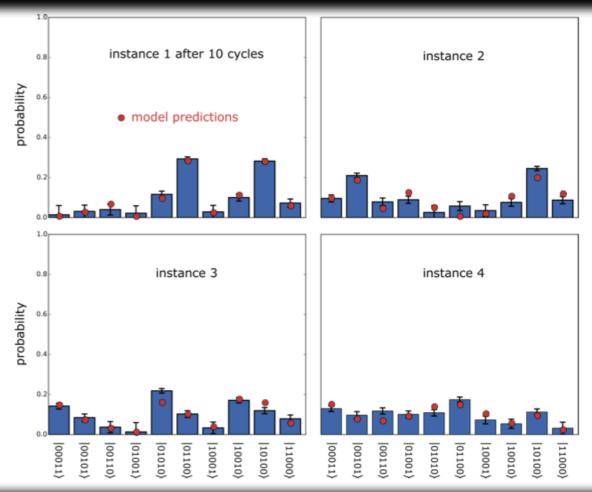
Typical dataset with 5 qubits



quantum info just from prob. histograms

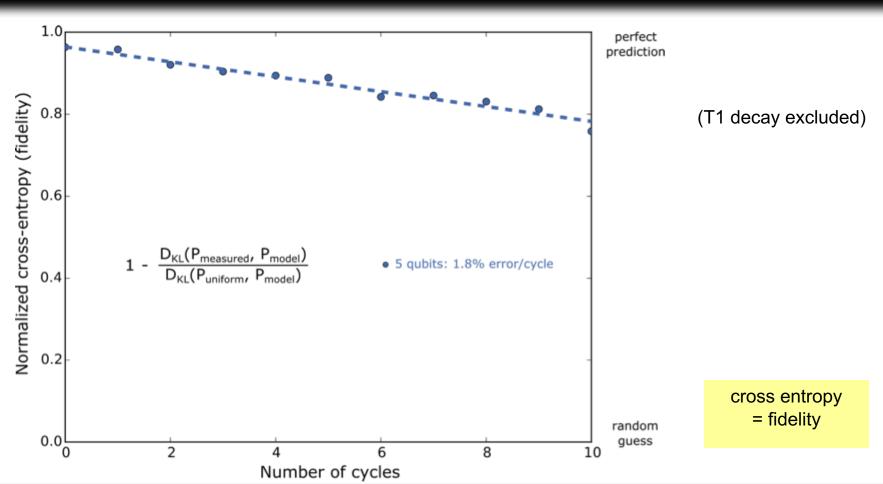
photon conserving states

Compare probabilities of experiment and theory

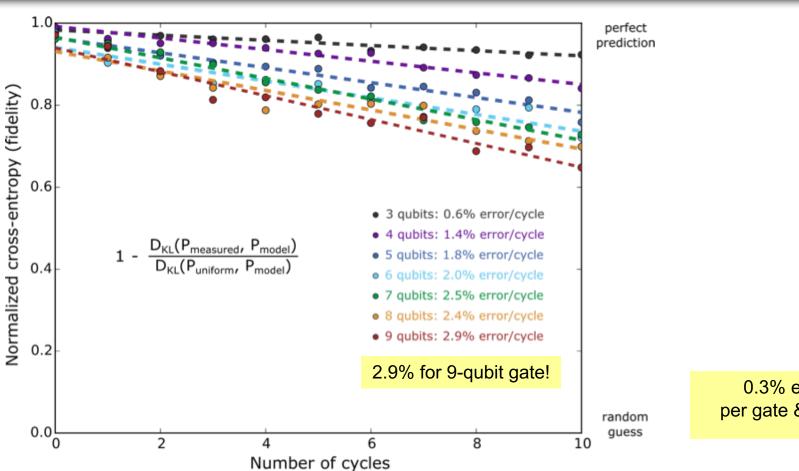


speckle pattern matches theory

Measuring fidelity

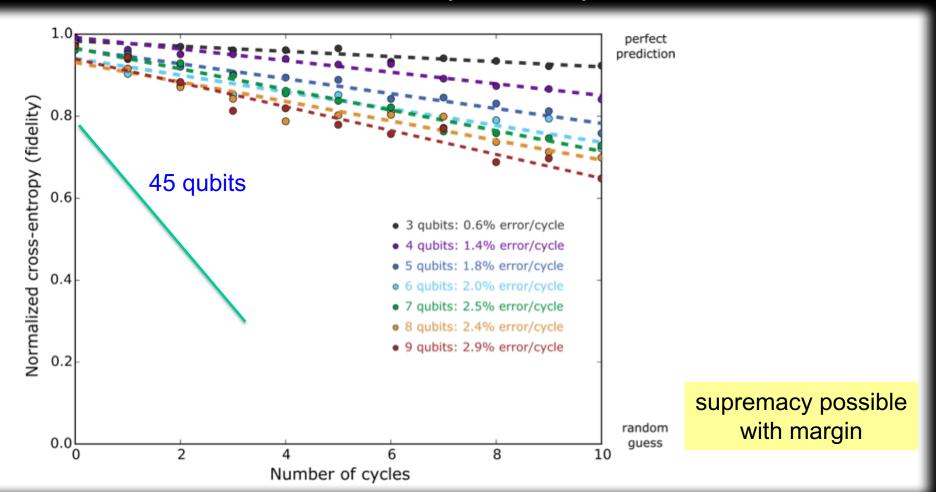


Measuring fidelity



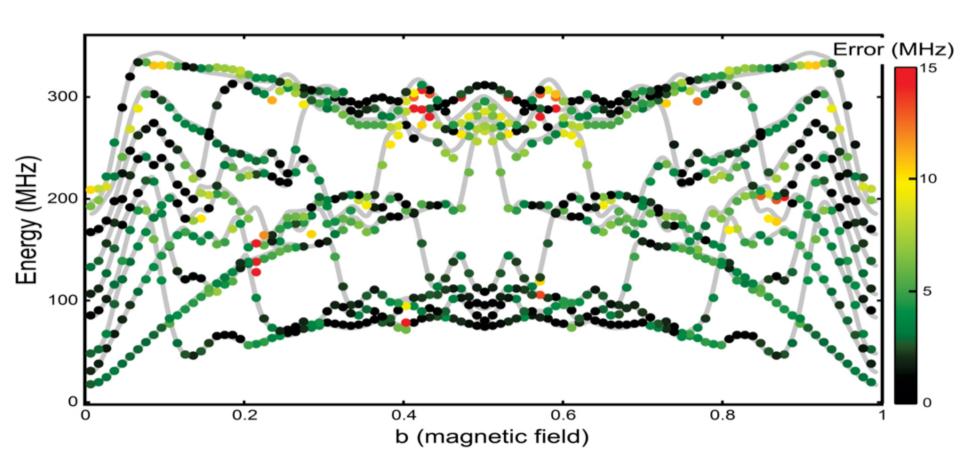
0.3% error per gate & cycle

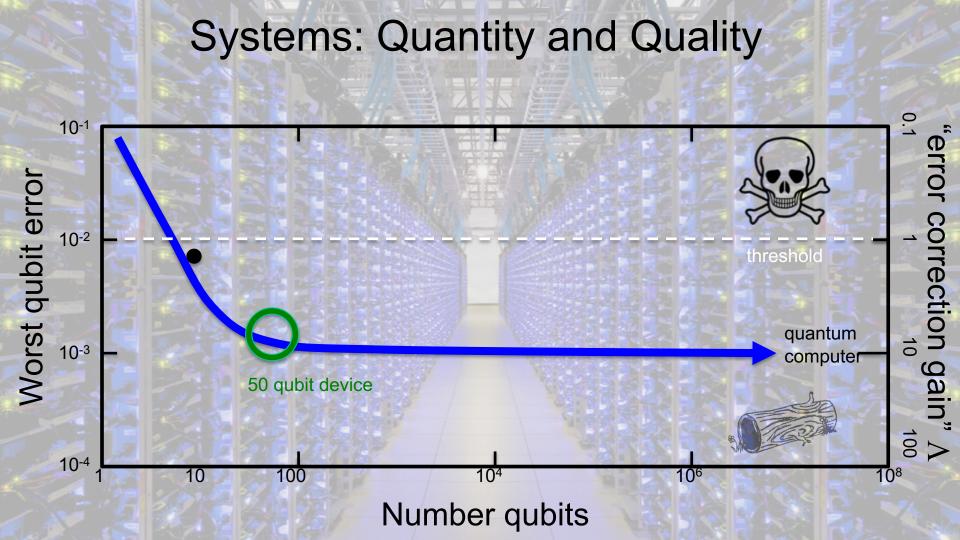
Scaled fidelity for 45 qubits



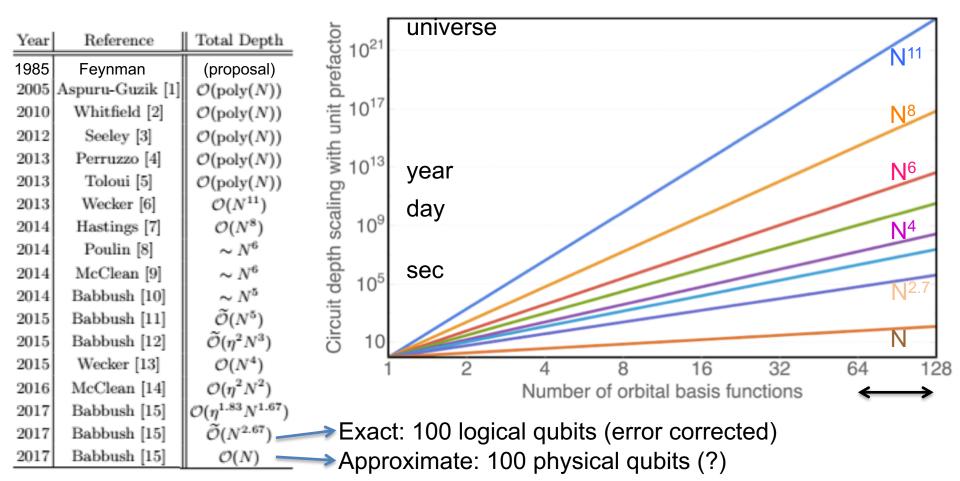
Quantum Materials (theory) 9 lattice sites 10000 T 300 Energy (MHz) 100 0.2 0.6 8.0 0.4 b (magnetic field)

Quantum Materials (theory + experiment)

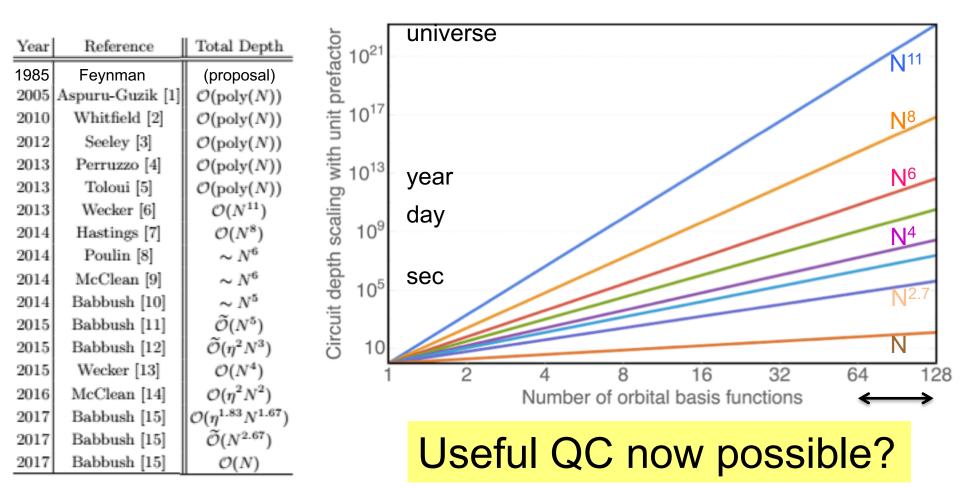




Huge Progress in Algorithms (Quantum Chemistry)



Huge Progress in Algorithms (Quantum Chemistry)



Google Hardware Plans

- 1) 9 qubit devices, both gate based and continuous (gmon) 1 qubit: 0.05-0.1% error 2 qubit 0.5-1%
- 2) 22 qubit device in test (2x11 array)
 Single and 2 qubit performance similar to 9 qubit device
- Quantum supremacy device ready to fabricate (square array)
 By end of year
 Working towards Quantum Cloud offering

