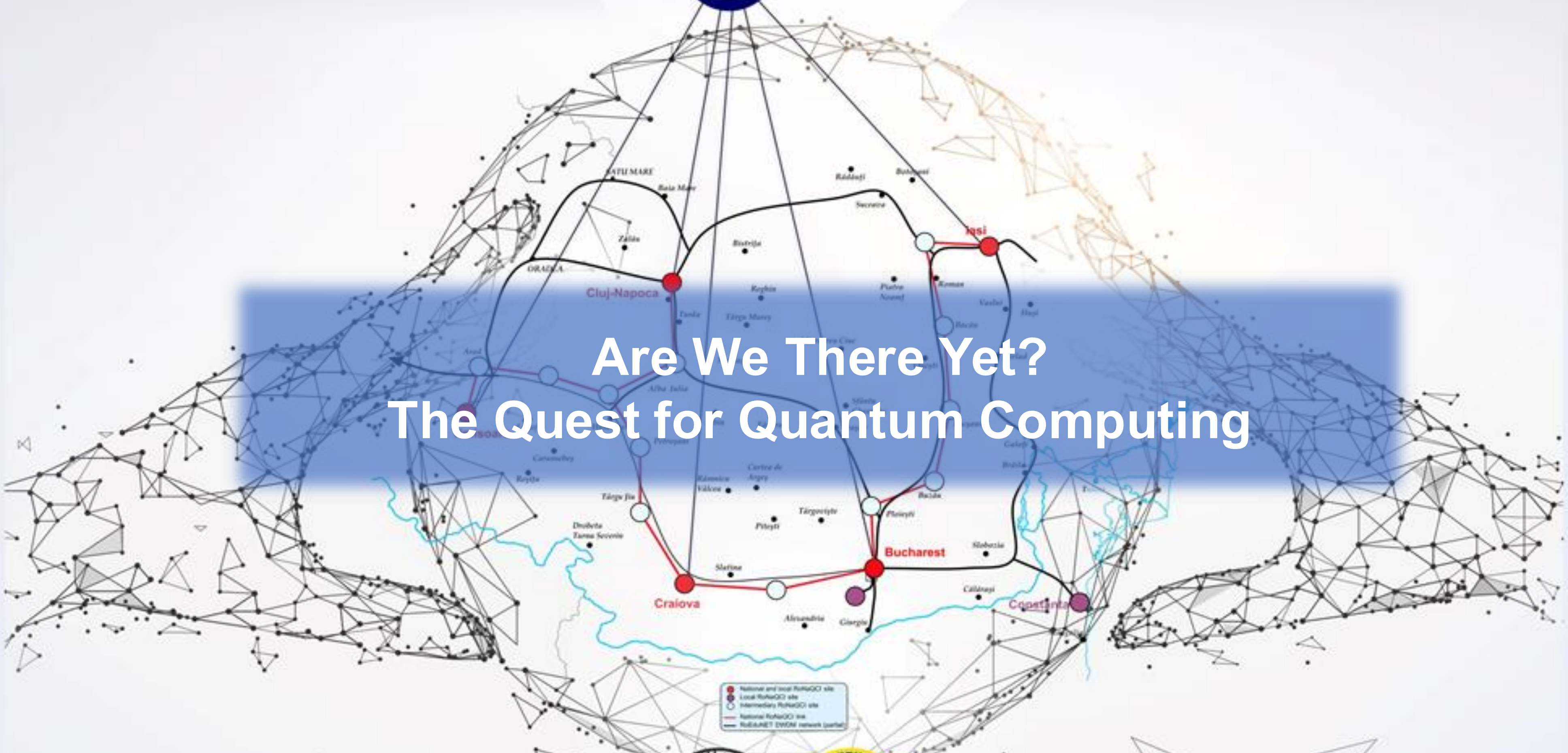
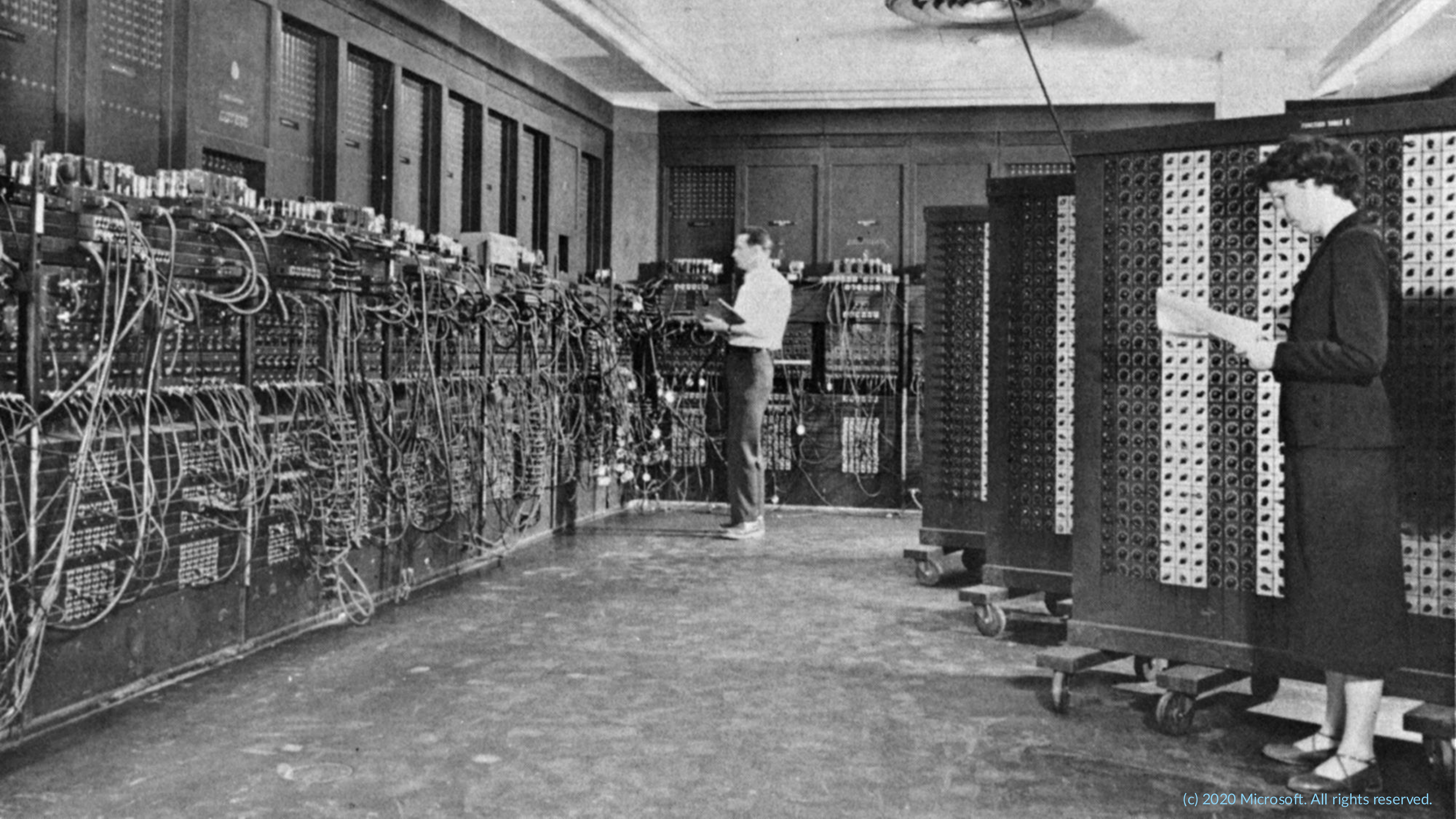
Romanian National Quantum Communication Infrastructure

ronaqci



Are We There Yet?
The Quest for Quantum Computing


Are we there yet?



Location: Lawrence Livermore National Laboratory — California, U.S.

Performance: 1,742 exaFLOPS (1.742 quintillion calculations per second)

Components: AMD 4th-Gen EPYC 24-core CPUs in AMD Instinct MI300A APUs

First online: November 2024

We’re still helpless
in face of exponential
complexity problems

RSA-2048 Challenge Problem

2519590847565789349402718324004839857142928212620403
2027777137836043662020707595556264018525880784406918
2906412495150821892985591491761845028084891200728449
9268739280728777673597141834727026189637501497182469
1165077613379859095700097330459748808428401797429100
6424586918171951187461215151726546322822168699875491
8242243363725908514186546204357679842338718477444792
0739934236584823824281198163815010674810451660377306
0562016196762561338441436038339044149526344321901146
5754445417842402092461651572335077870774981712577246
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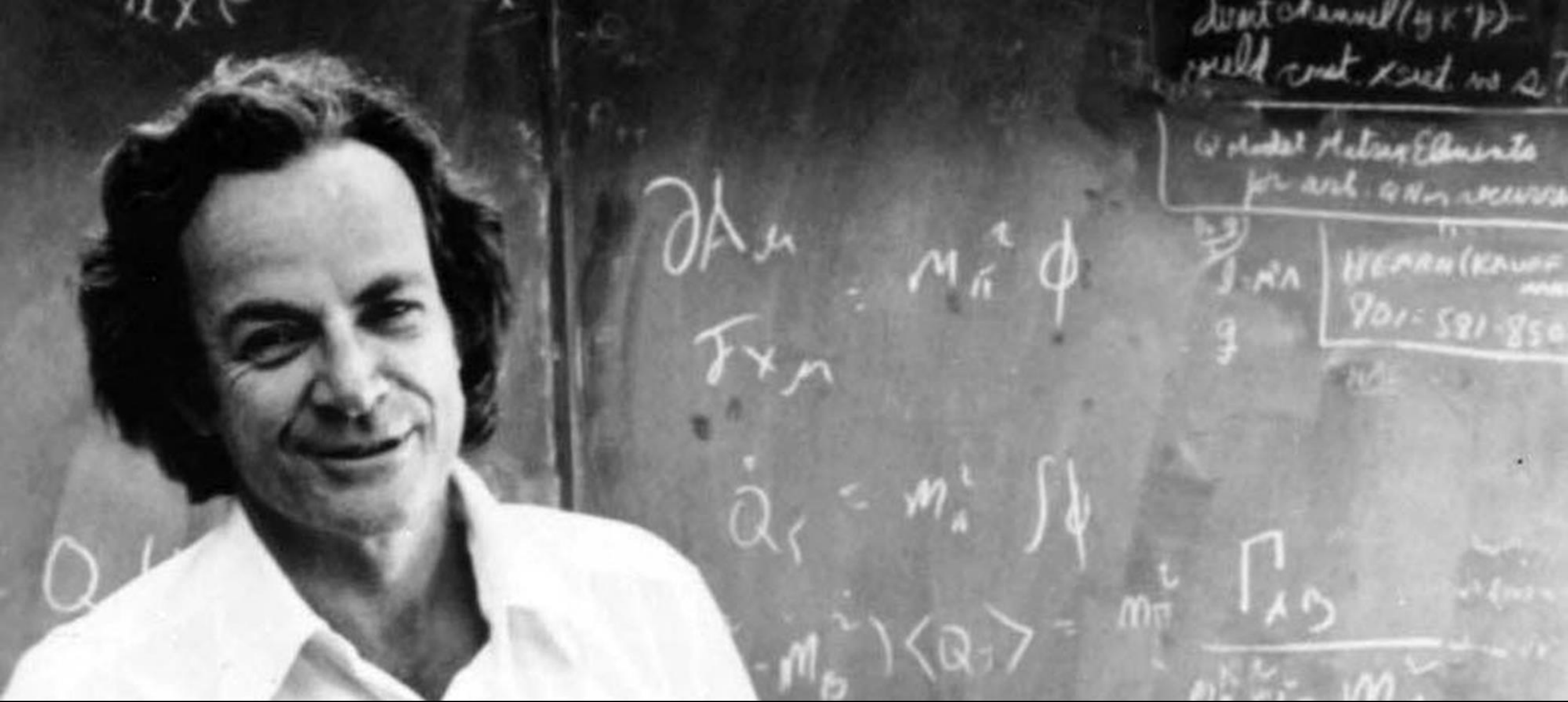


"Nature isn't classical, dammit, and if you want to make a simulation of nature, you'd better make it quantum mechanical"

MAY 15, 1935 PHYSICAL REVIEW VOLUME 47

Can Quantum-Mechanical Description of Physical Reality Be Considered Complete?

A. EINSTEIN, B. PODOLSKY AND N. ROSEN, *Institute for Advanced Study, Princeton, New Jersey*

(Received March 25, 1935)

OCTOBER 15, 1935 PHYSICAL REVIEW VOLUME 48

Can Quantum-Mechanical Description of Physical Reality be Considered Complete?

N. BOHR, *Institute for Theoretical Physics, University, Copenhagen*

(Received July 13, 1935)

PHYSICAL REVIEW VOLUME 108, NUMBER 4 NOVEMBER 15, 1957

Discussion of Experimental Proof for the Paradox of Einstein, Rosen, and Podolsky

D. BOHM AND Y. AHARONOV
Technion, Haifa, Israel

(Received May 10, 1957)

The Bit

0 / 1

WHY ?

The Qubit

$$\begin{bmatrix} \alpha \\ \beta \end{bmatrix}$$

$$\alpha, \beta \in \mathbb{C}$$
$$|\alpha|^2 + |\beta|^2 = 1$$

The Postulates

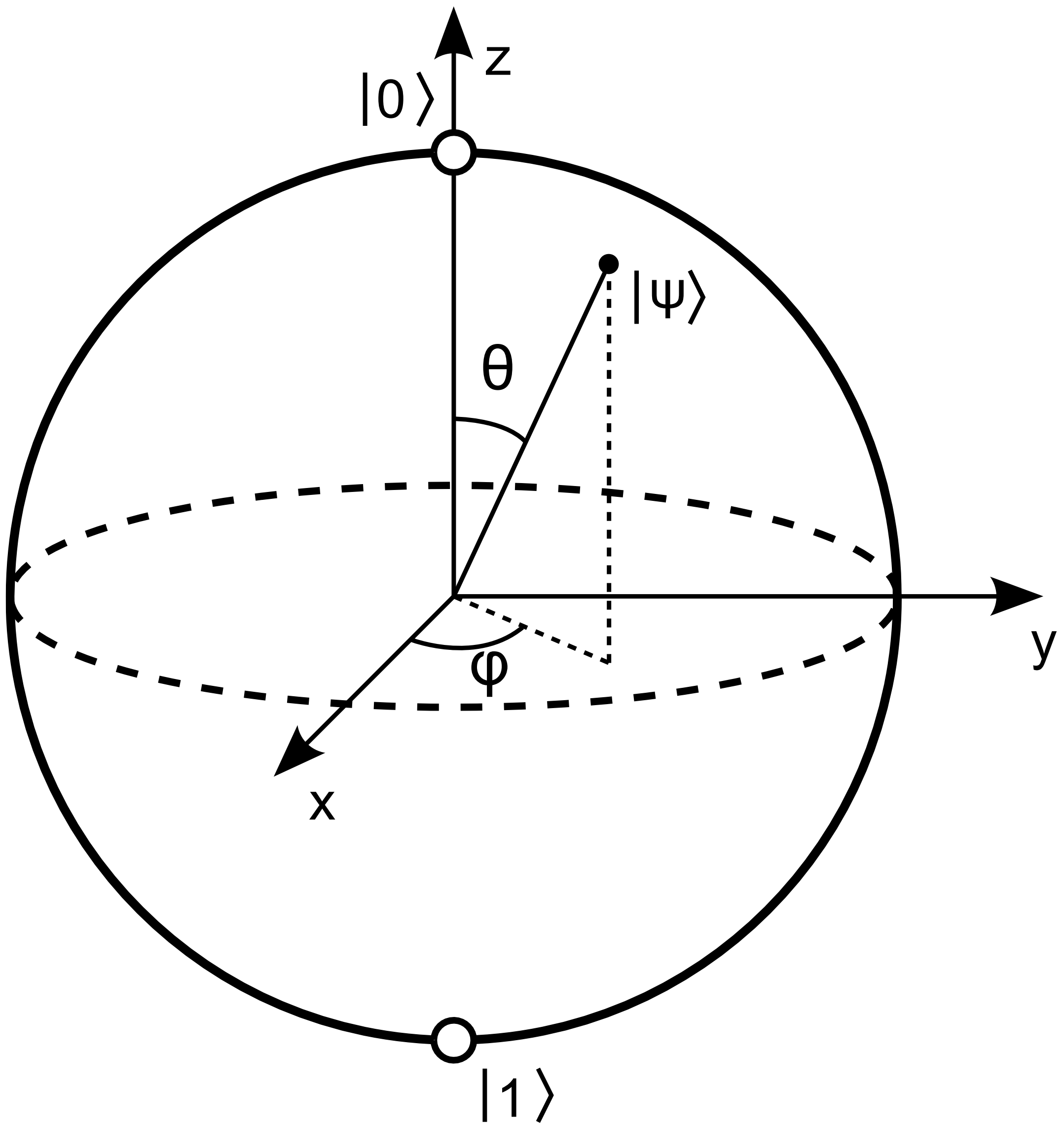
1. States in nature can be described using complex vector spaces.
2. Observable attributes can be described by using operators (unitary transformations).
3. Measurements of observables can only result in very specific values (associated with the operators).
4. Measurement results have probabilistic outcomes.
5. Any measurement determines a change of state (to the specific value mentioned in #4).
6. Time-based evolution can be described:

$$ih\frac{d}{dx} \mid \psi(t) > = H \mid \psi(t) >$$

$$|0 > = \begin{bmatrix} 1 \\ 0 \end{bmatrix}$$

$$|1 > = \begin{bmatrix} 0 \\ 1 \end{bmatrix}$$

$$| \psi > = \alpha \, | \, 0 > + \, \beta \, | \, 1 >$$



z
|0⟩
|ψ⟩
θ
φ
y
x
|1⟩

$$X \equiv \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix} \qquad Y \equiv \begin{bmatrix} 0 & -i \\ i & 0 \end{bmatrix} \qquad Z \equiv \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix}$$

$$H \equiv \frac{1}{\sqrt{2}} \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix} \qquad S \equiv \begin{bmatrix} 1 & 0 \\ 0 & i \end{bmatrix} \qquad T \equiv \begin{bmatrix} 1 & 0 \\ 0 & e^{\frac{i\pi}{4}} \end{bmatrix}$$

$$H|0> = \frac{1}{\sqrt{2}}|0> + \frac{1}{\sqrt{2}}|1>$$

Also referred as |+>
(equal superposition)

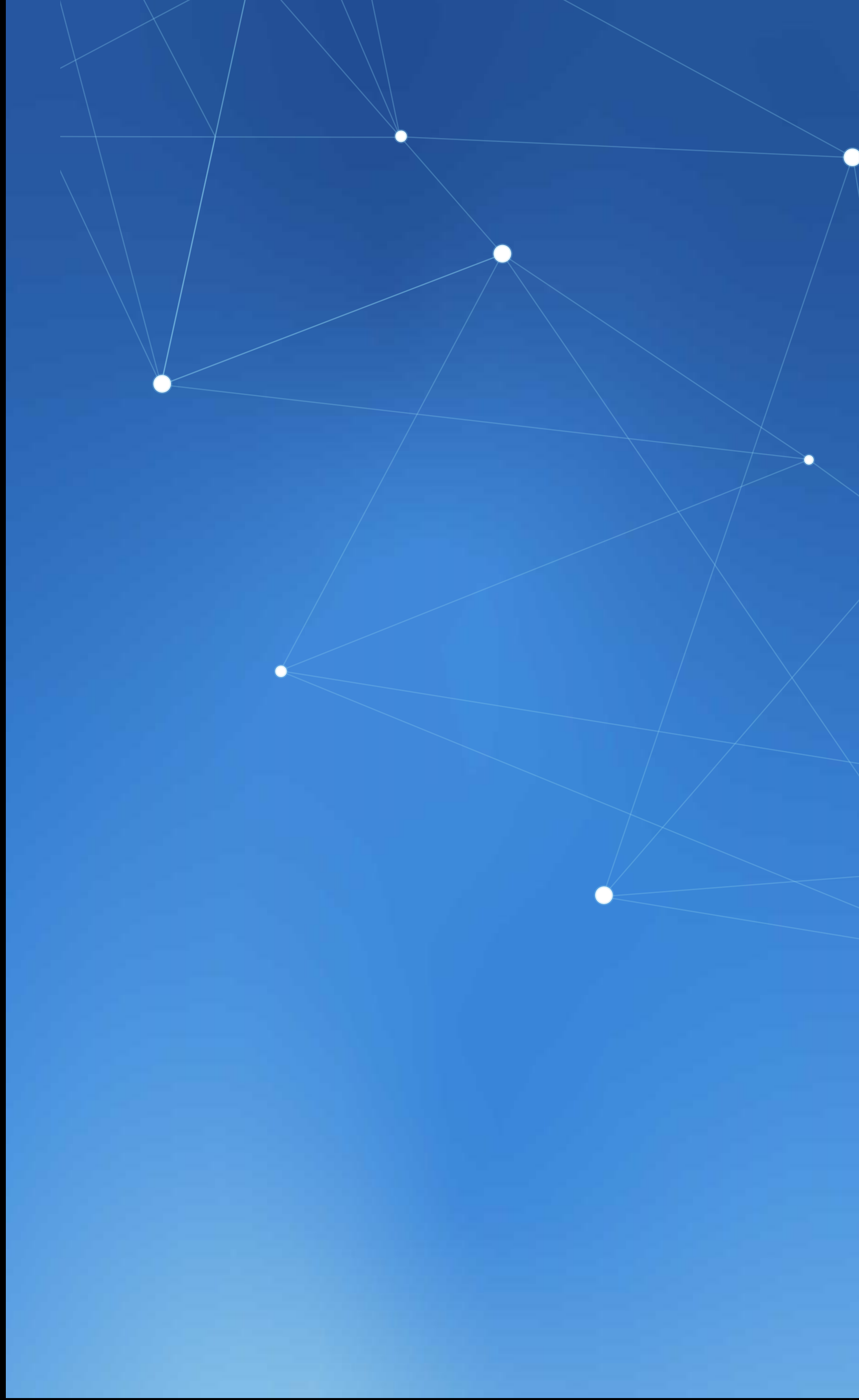
The power of Quantum Computing

$$| \psi > = \alpha_0 \, | \, 0 > + \, \alpha_1 | \, 1 >$$

$$| \psi > = \alpha_{00} \, | \, 00 > + \, \alpha_{01} | \, 01 > + \, \alpha_{10} \, | \, 10 > + \, \alpha_{11} | \, 11 >$$

…

For **n** qubits, the state vector of the system has $\mathbf{2^n}$ amplitudes!



$$CNOT \equiv \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 \end{bmatrix}$$

$$CNOT\,(\,|\,c >, |\,t >) = \begin{cases} |\,c >, |\,t > & if\,|\,c > =|\,0 > \\ |\,c >, flip\,|\,t > & if\,|\,c > =|\,1 > \end{cases}$$

$$\frac{|00> + |11>}{\sqrt{2}}$$

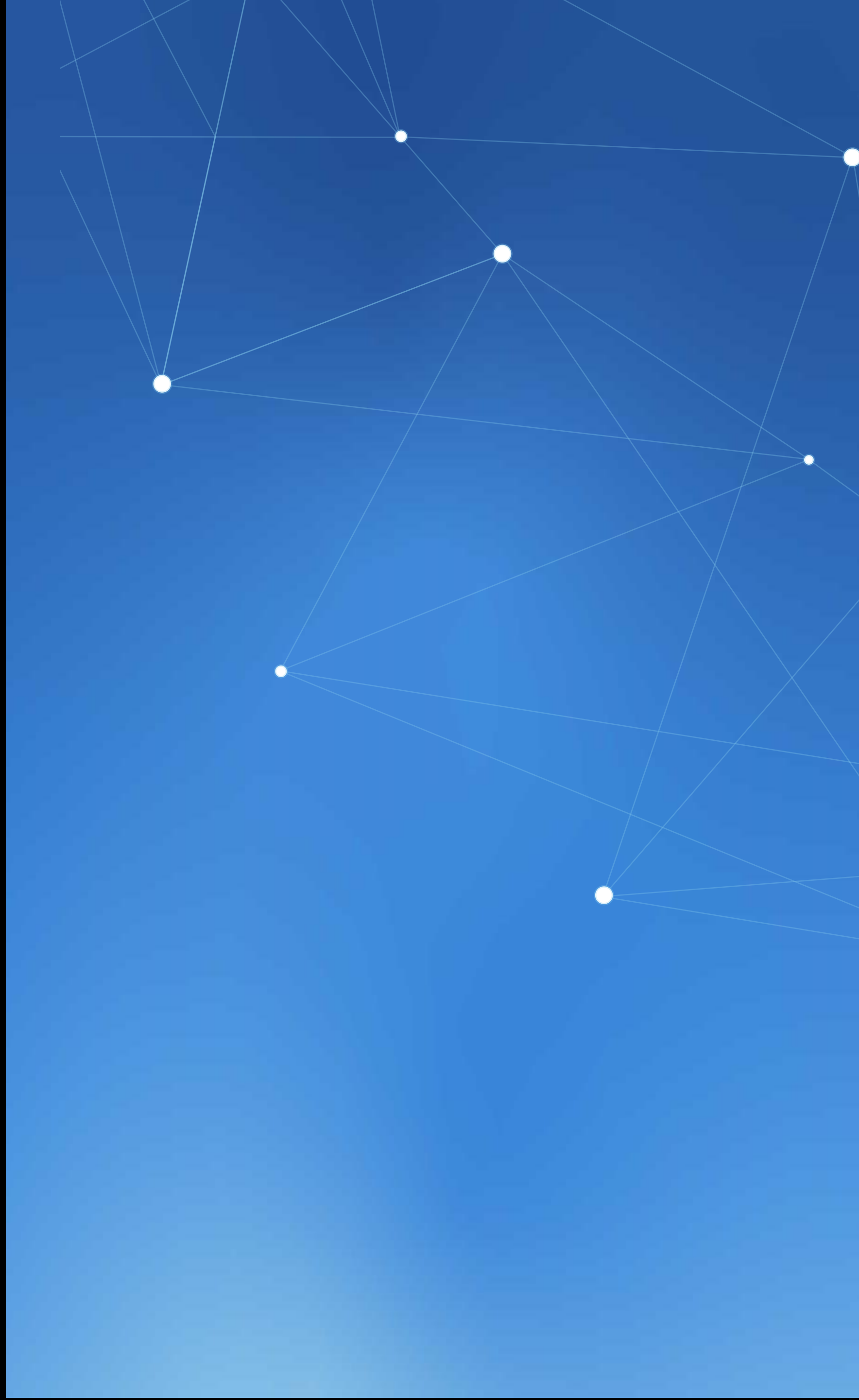
Bell state or EPR pair

a.k.a. “spooky action at a distance”

Universal Quantum Computing

Any unitary operation can be approximated to arbitrary accuracy using Hadamard (H), Phase (S), CNOT, and $\frac{\pi}{8}$ (T) gates.

H, S, CNOT, and T are universal gates



The Bit

The Qubit

HOW ?

0 / 1

$$\begin{bmatrix} \alpha \\ \beta \end{bmatrix}$$

$$\alpha, \beta \in \mathbb{C}$$
$$|\alpha|^2 + |\beta|^2 = 1$$

The Algorithms

Ciprian: This quantum computing stuff is amazing, can I build powerful algorithms to harness its power?

The Universe: Sure thing

Ciprian: Amazing!

The Universe: There’s one small caveat. You need to build your algorithms assuming you can only measure once, usually at the end. You know, it’s like building a claims analysis solution using a database to which you can write as many times as you want but only query it once. After which it’s destroyed.

Ciprian: 🤯

|0>,|0>,|0> = |000>

|0>,|0>,|1> = |001>

|0>,|1>,|0> = |010>

|0>,|1>,|1> = |011>

|1>,|0>,|0> = |100>

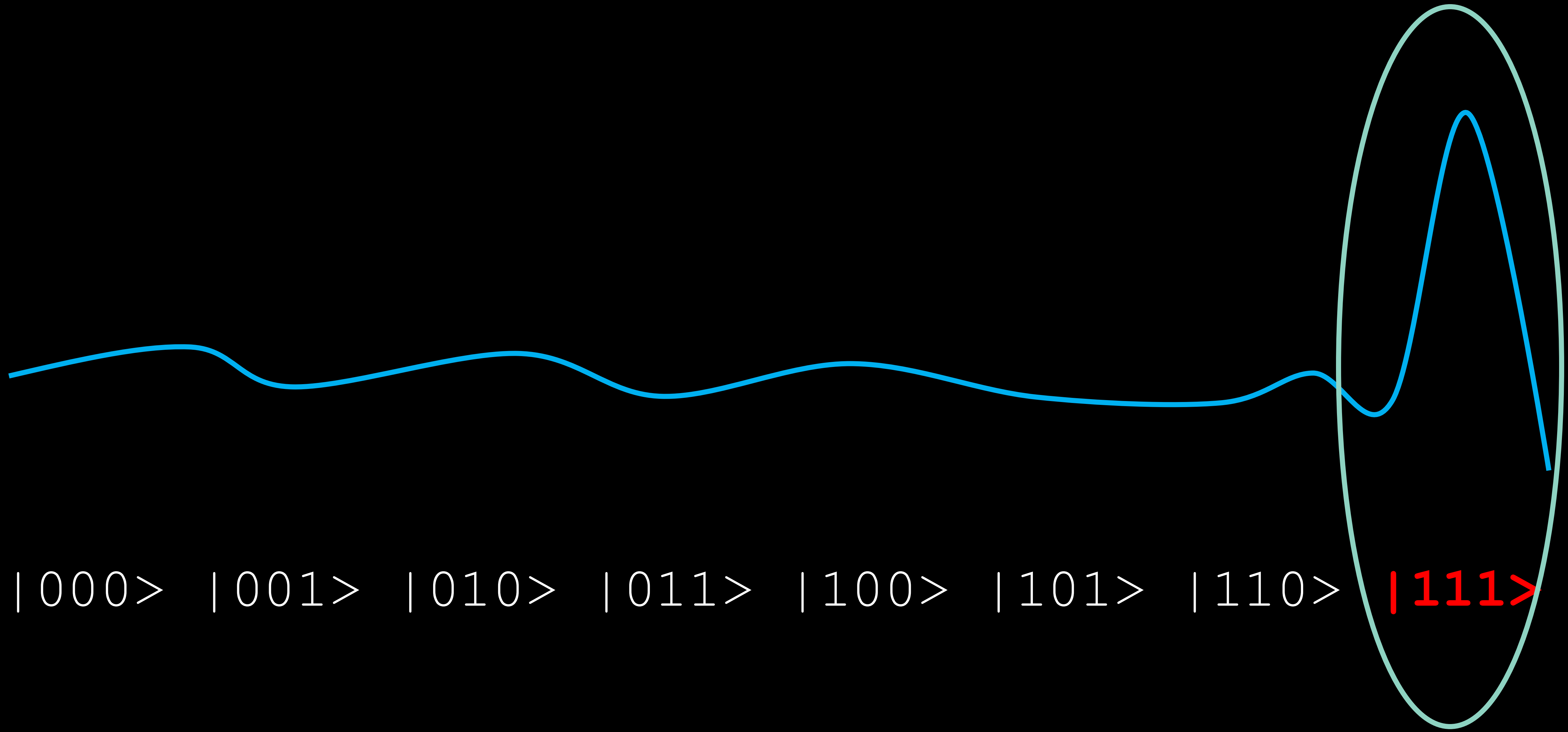
|1>,|0>,|1> = |101>

|1>,|1>,|0> = |110>

|1>,|1>,|1> = |111>

|000> |001> |010> |011> |100> |101> |110> **|111>**

Amplitude amplification



DiVincenzo Criteria

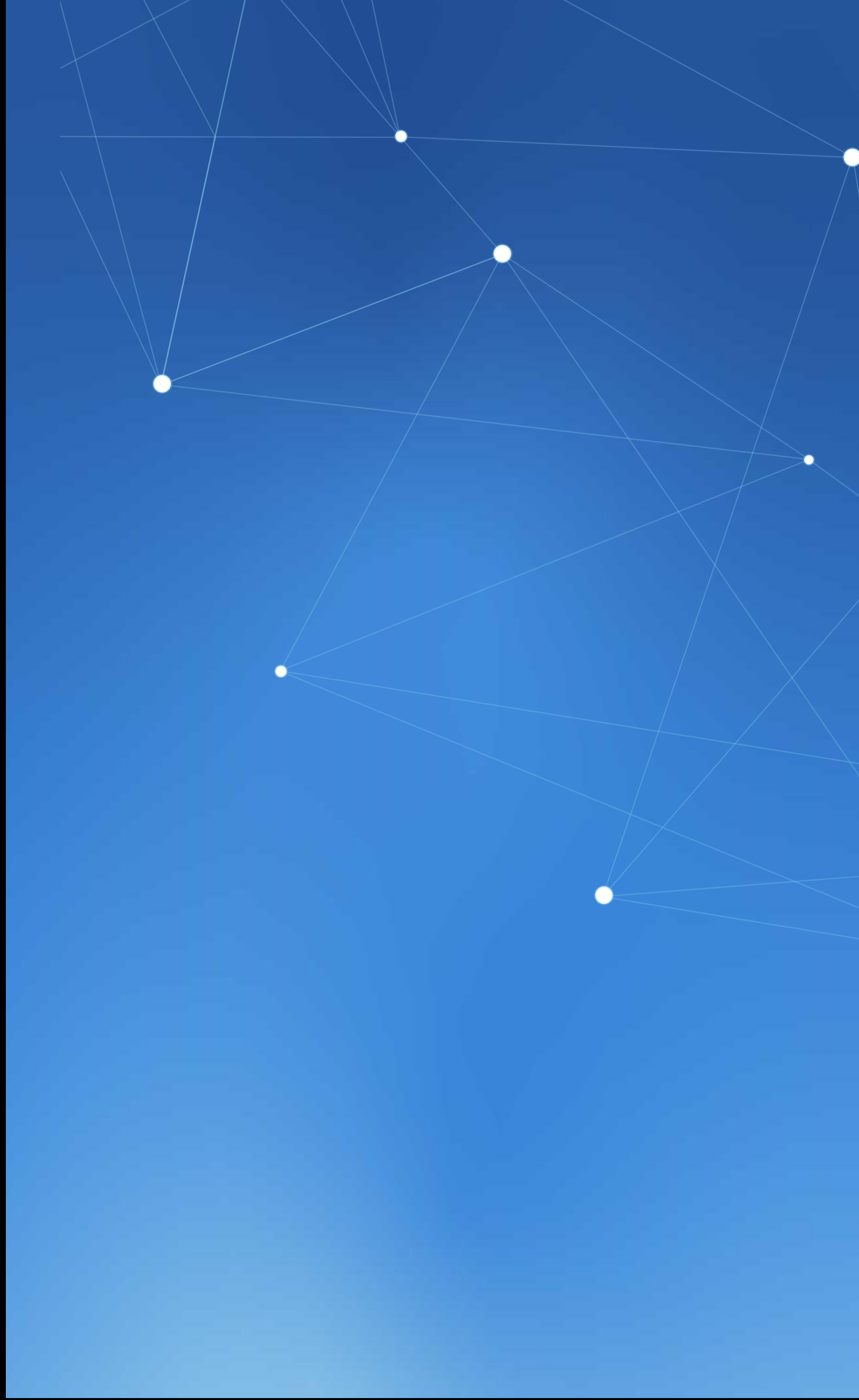
Scalability

Ability to initialize the qubits in a specific state

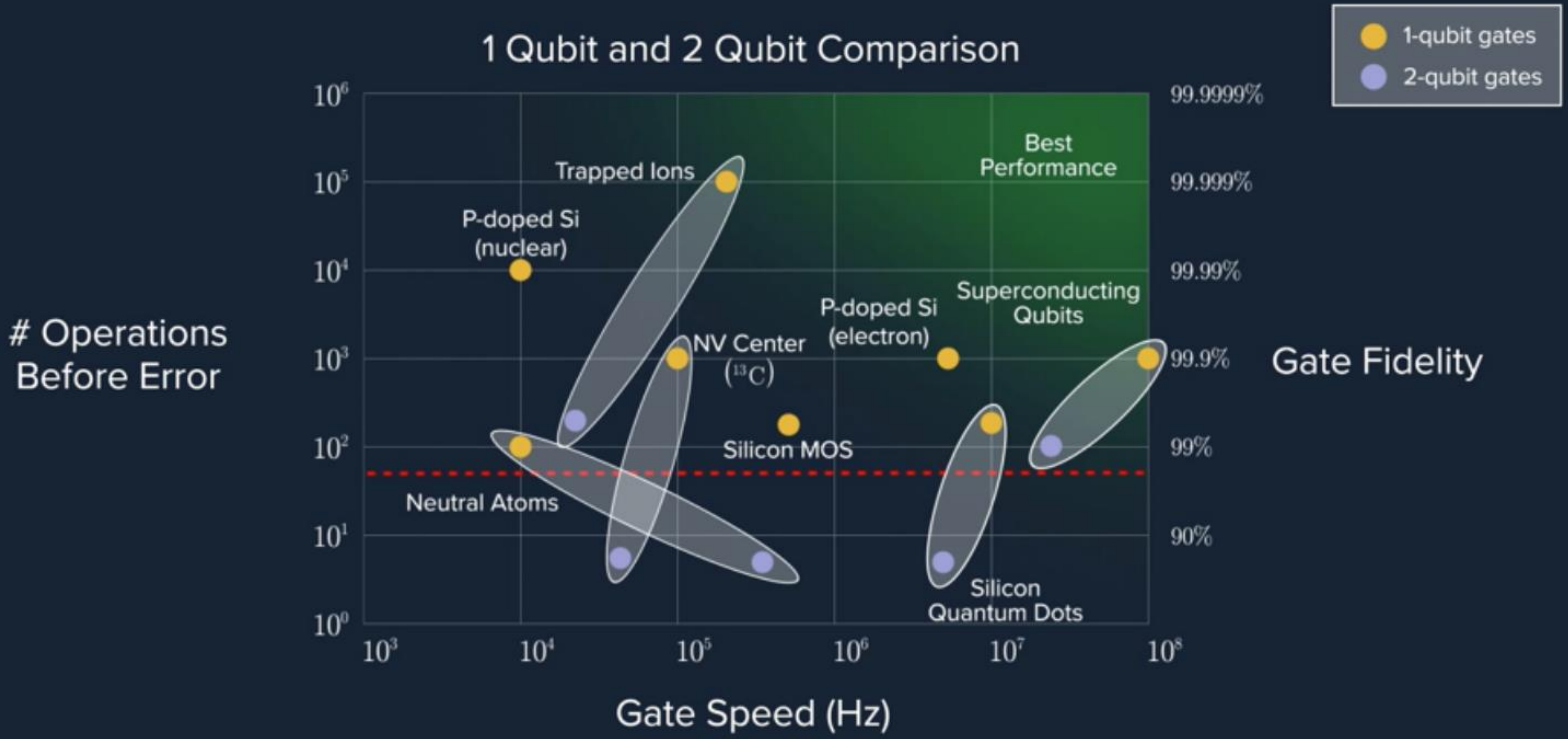
Resilient qubits

Ability to perform a universal set of operations

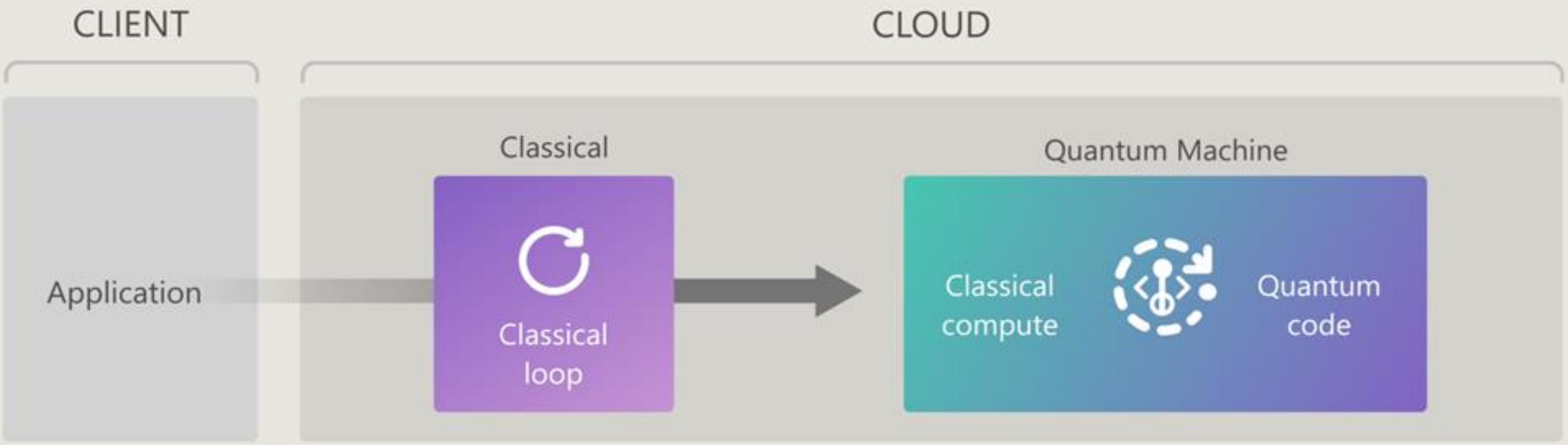
Reliable measurements

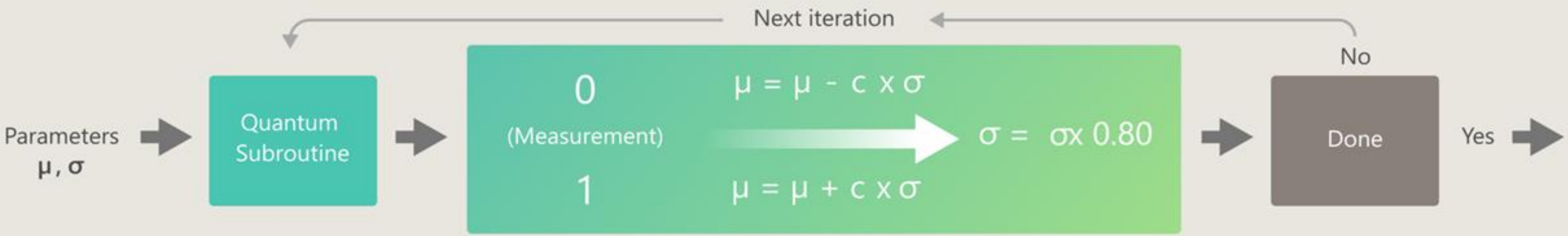


1 Qubit and 2 Qubit Fidelity and Gate Speed



Batch Interactive **Integrated** Distributed





The calculation is iterative and adaptive while qubits are coherent

Powered by

Quantum Communication

QKD initiatives

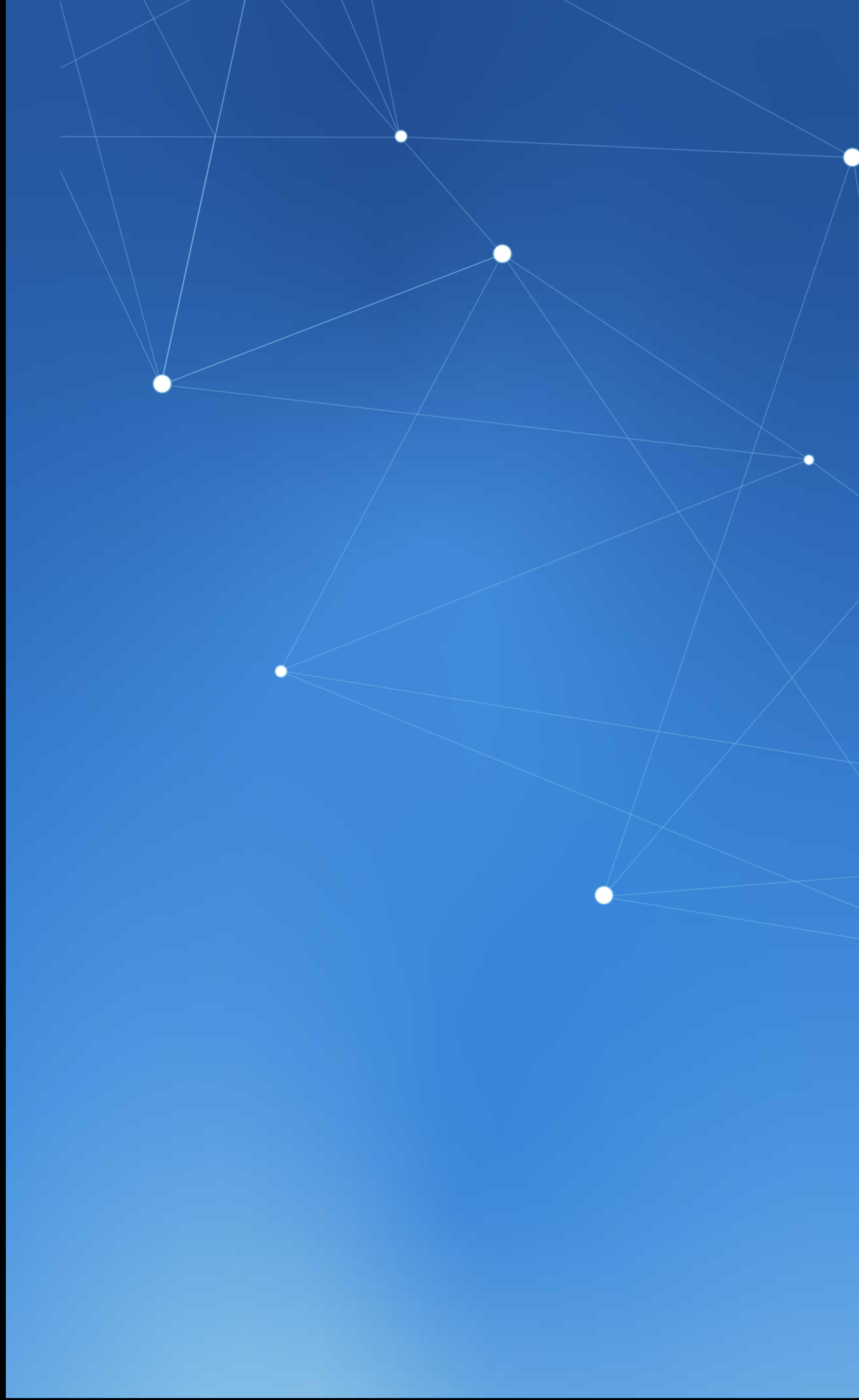
Quantum repeaters

Entangled photons sources

Frequency/wavelength mapping/conversion

(Single) photon detection

Error correction



Azure Quantum

Quantum Computing

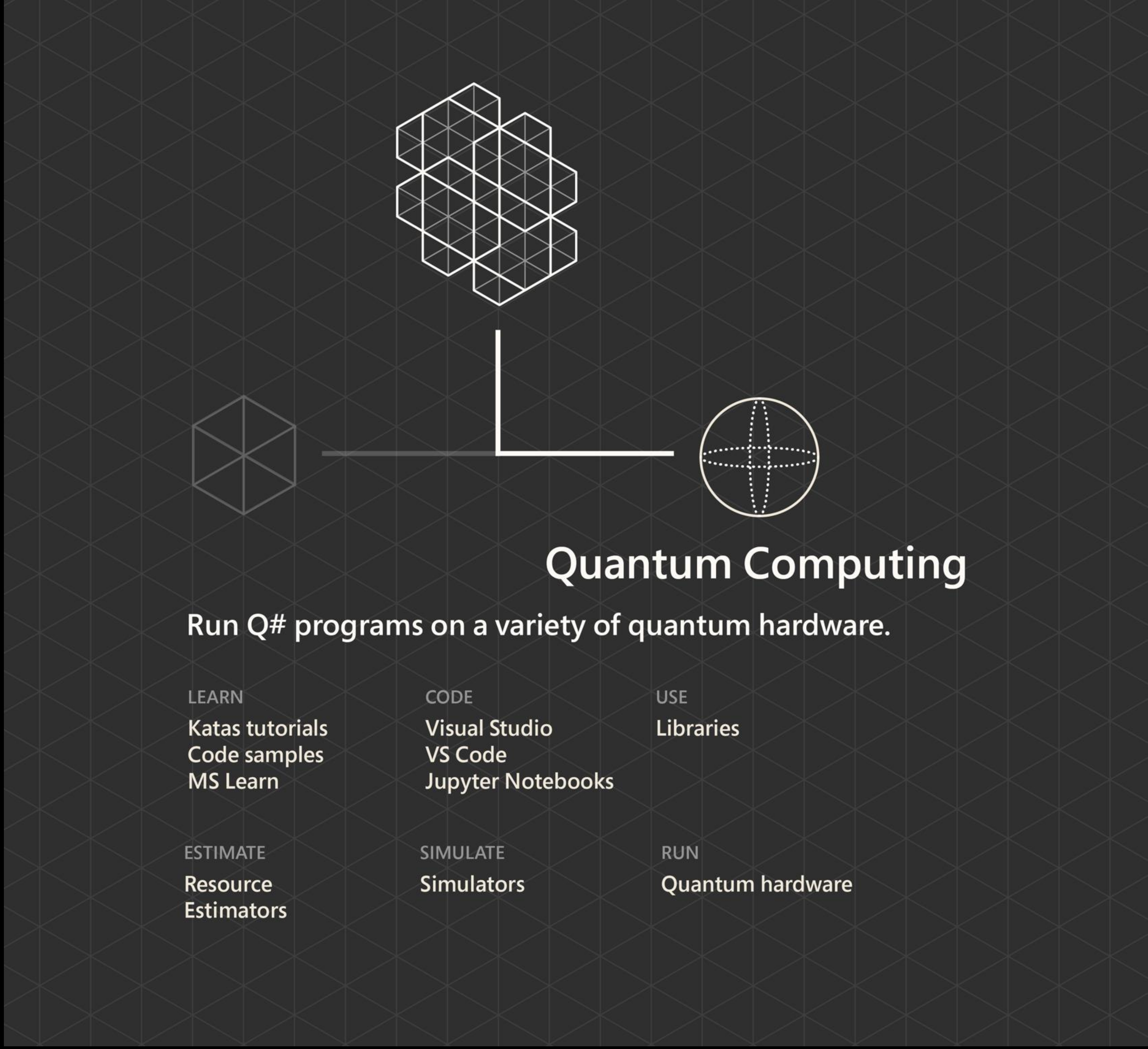


Image source: https://docs.microsoft.com/en-us/learn/modules/get-started-azure-quantum/2-azure-quantum-structure-overview

Azure Quantum

Optimization

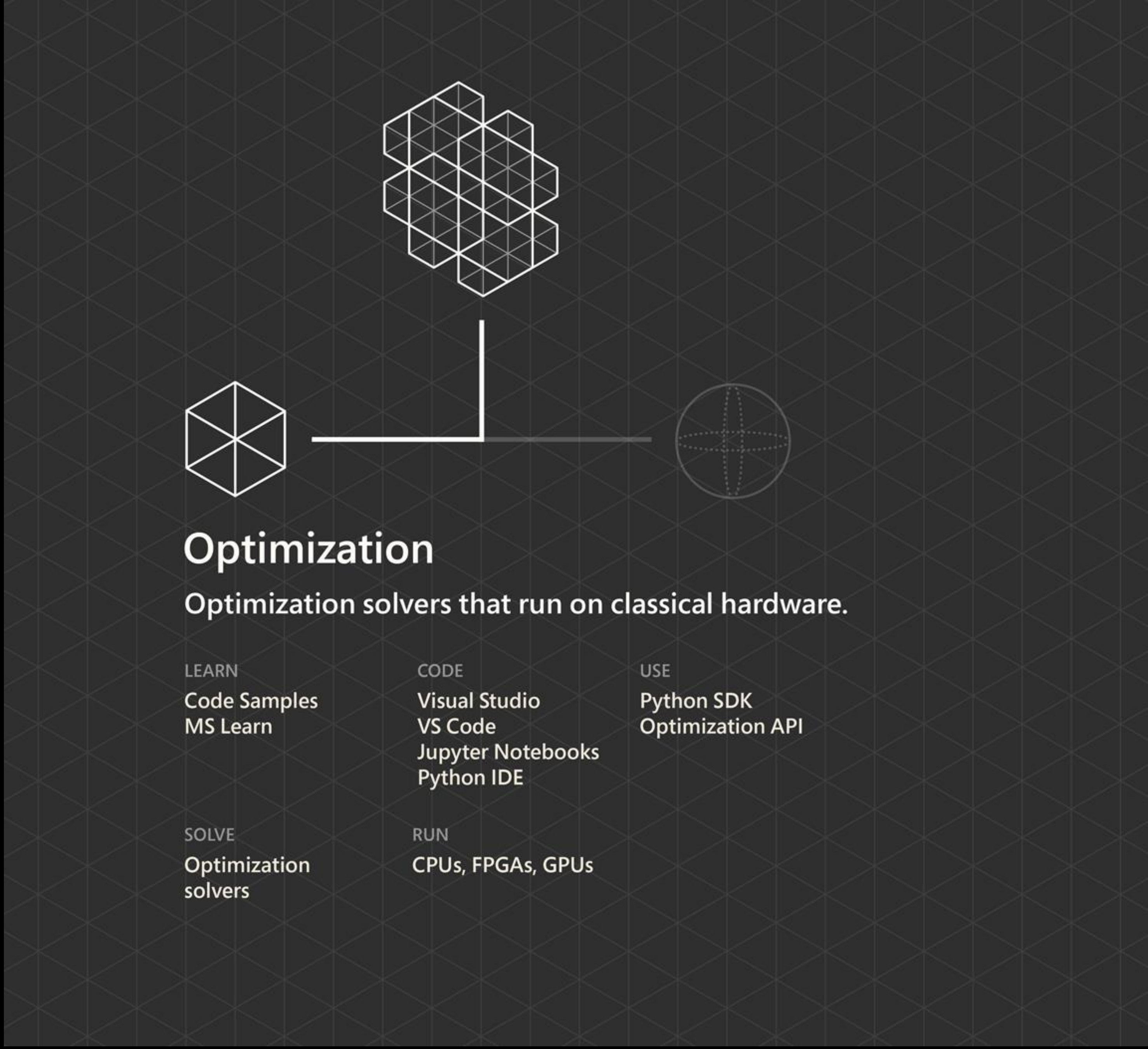
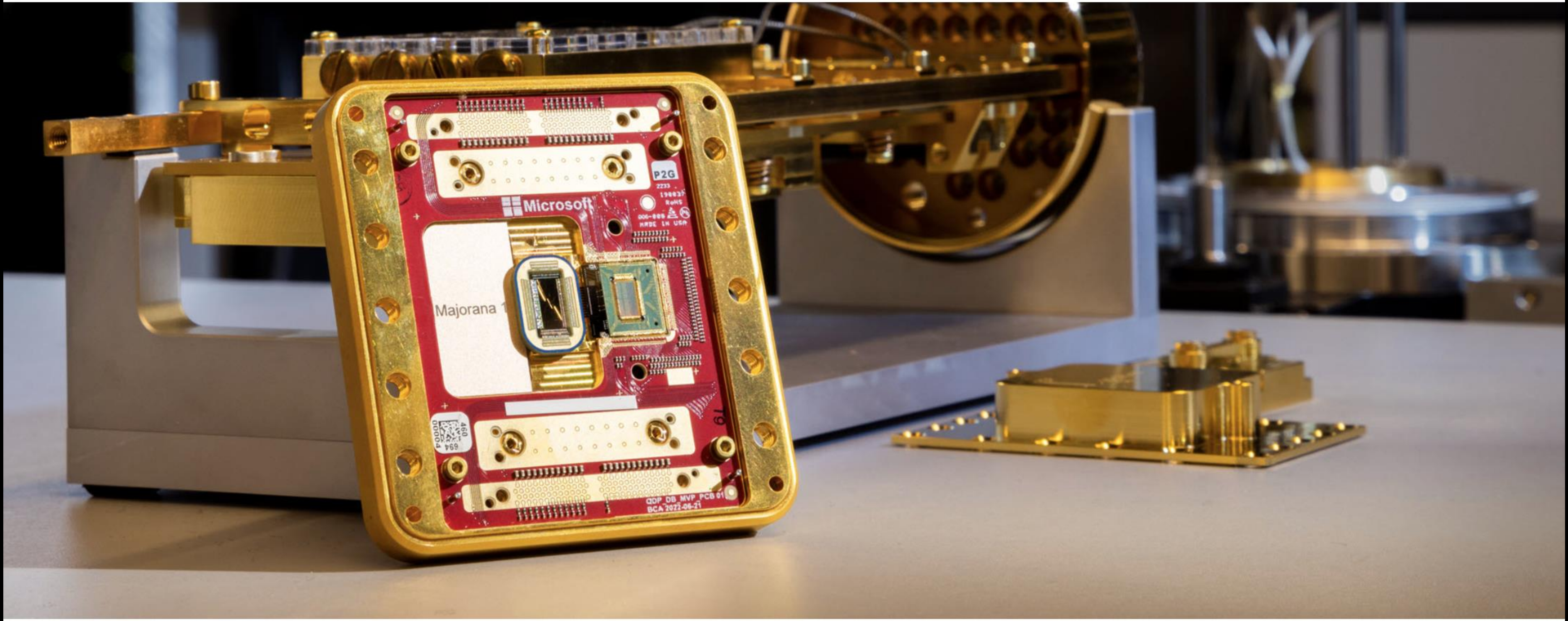
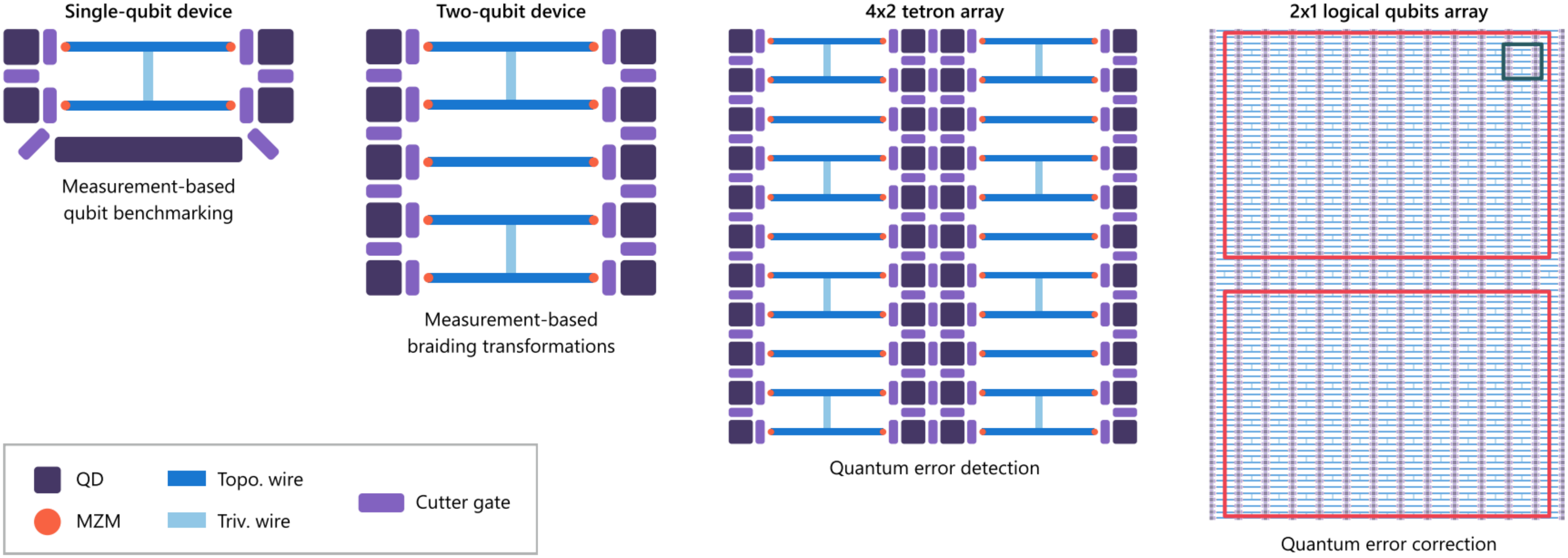


Image source: https://docs.microsoft.com/en-us/learn/modules/get-started-azure-quantum/2-azure-quantum-structure-overview



Microsoft’s Majorana 1 chip carves new path for quantum computing

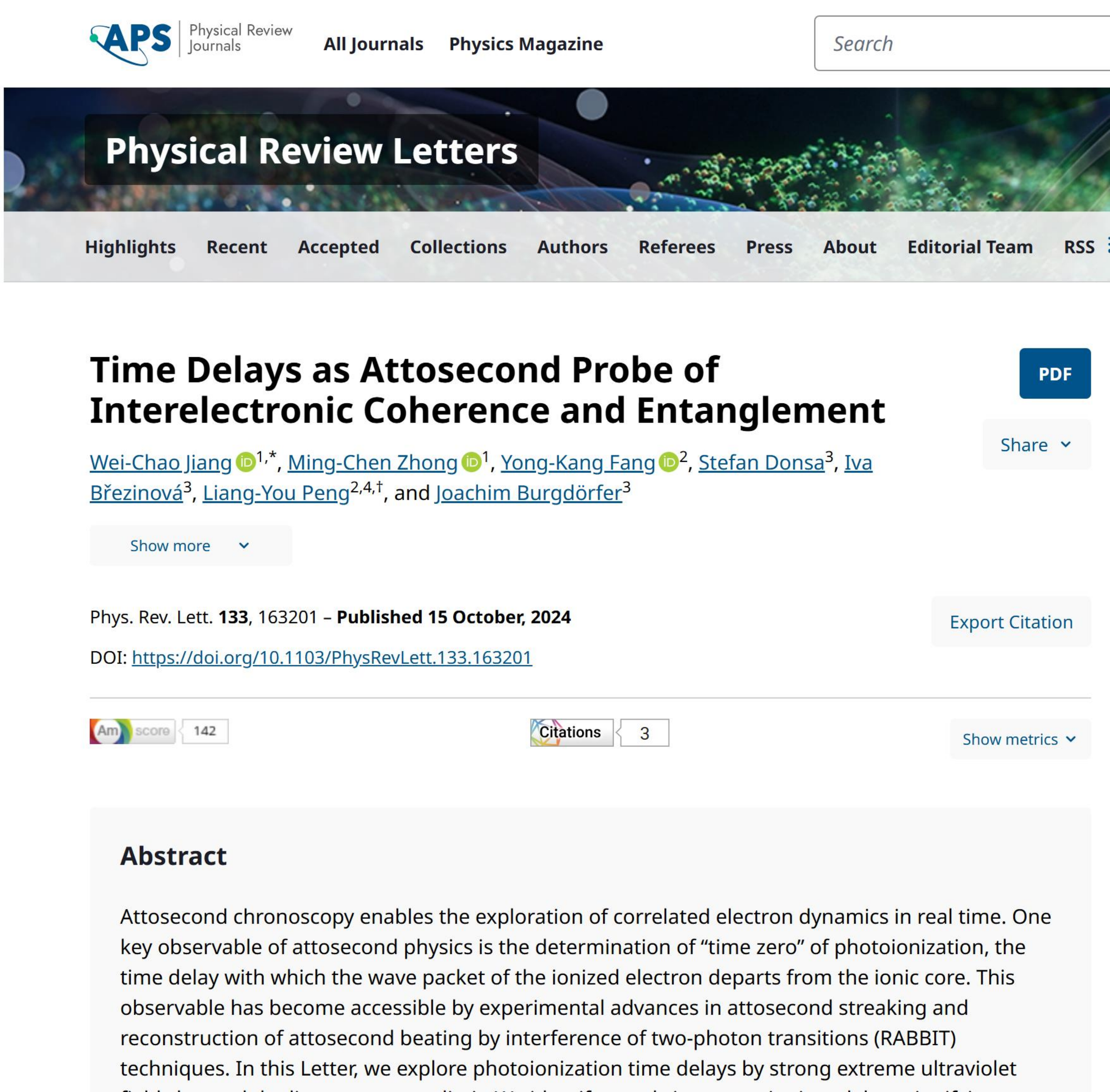


Single-qubit device
Measurement-based
qubit benchmarking
Two-qubit device
Measurement-based
braiding transformations
4x2 tetron array
Quantum error detection
2x1 logical qubits array
Quantum error correction
QD
MZM
Topo. wire
Triv. wire
Cutter gate

Attosecond = 10^{-18} sec

(one billionth of a billionth)

We're now starting to measure the time it takes for entanglement to form



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Time Delays as Attosecond Probe of Interelectronic Coherence and Entanglement

PDF

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Wei-Chao Jiang[1,*], Ming-Chen Zhong[1], Yong-Kang Fang[2], Stefan Donsa[3], Iva Březinová[3], Liang-You Peng[2,4,†], and Joachim Burgdörfer[3]

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Phys. Rev. Lett. **133**, 163201 – **Published 15 October, 2024**

DOI: https://doi.org/10.1103/PhysRevLett.133.163201

Export Citation

Abstract

Attosecond chronoscopy enables the exploration of correlated electron dynamics in real time. One key observable of attosecond physics is the determination of "time zero" of photoionization, the time delay with which the wave packet of the ionized electron departs from the ionic core. This observable has become accessible by experimental advances in attosecond streaking and reconstruction of attosecond beating by interference of two-photon transitions (RABBIT) techniques. In this Letter, we explore photoionization time delays by strong extreme ultraviolet

We're now starting to build "distributed" multi-qubit gates

nature

Article | Open access | Published: 05 February 2025

Distributed quantum computing across an optical network link

D. Main, P. Drmota, D. P. Nadlinger, E. M. Ainley, A. Agrawal, B. C. Nichol, R. Srinivas, G. Araneda & D. M. Lucas

Nature **638**, 383–388 (2025) | Cite this article

Abstract

Distributed quantum computing (DQC) combines the computing power of multiple networked quantum processing modules, ideally enabling the execution of large quantum circuits without compromising performance or qubit connectivity[1,2]. Photonic networks are well suited as a versatile and reconfigurable interconnect layer for DQC; remote entanglement shared between matter qubits across the network enables all-to-all logical connectivity through quantum gate teleportation (QGT)[3,4]. For a scalable DQC architecture, the QGT implementation must be deterministic and repeatable; until now, no demonstration has satisfied these requirements. Here we experimentally demonstrate the distribution of

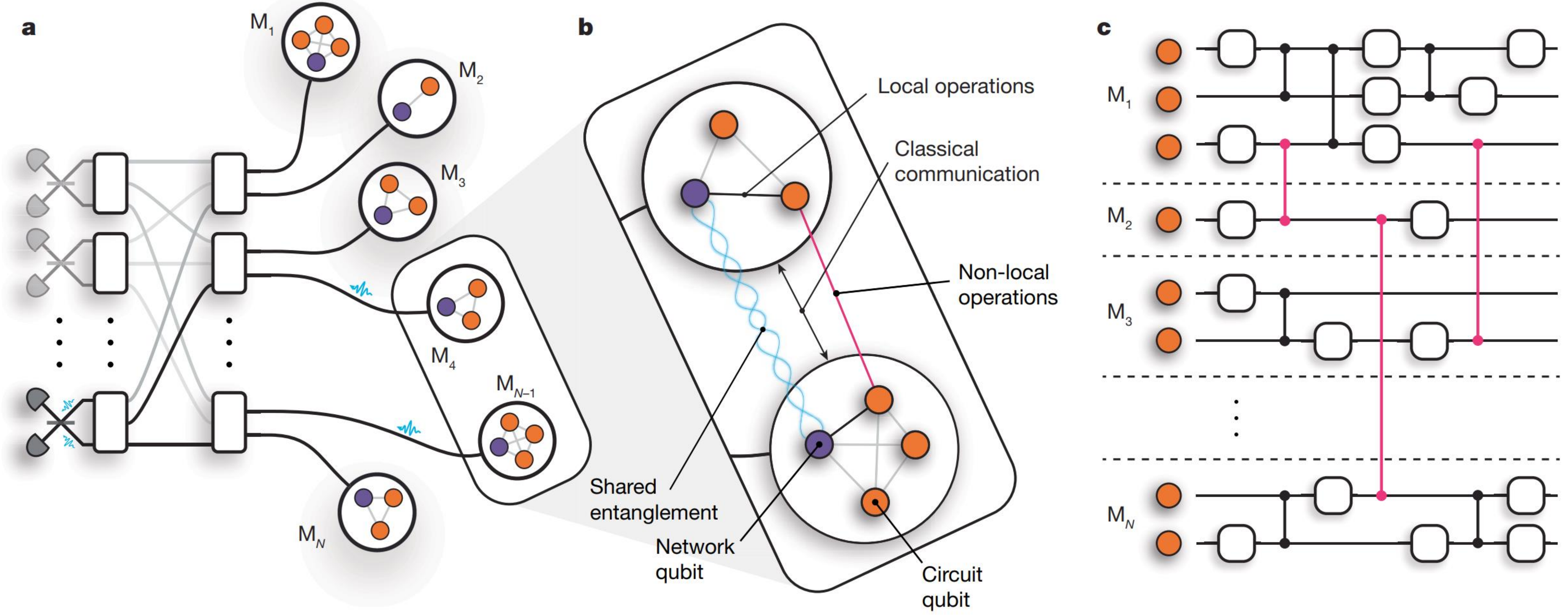

Fig. 1 | DQC architecture. a, Schematic of a DQC architecture comprising photonically interconnected modules. Entanglement is heralded between network qubits through the interference of photons on beam splitters. A photonic switchboard provides a flexible and reconfigurable network topology. **b**, The modules consist of at least one network qubit (purple) and at least one circuit qubit (orange), which may directly interact by means of local operations. QGT mediates non-local gate interactions (pink) between circuit qubits in separate modules. These protocols require the resources of shared entanglement, local operations and classical communication. **c**, A quantum circuit distributed across a network of small quantum processing modules that function together as a single, fully connected quantum computer.

https://www.nature.com/articles/s41586-024-08404-x.pdf

ENTANGLED THINGS.

YOUR HOSTS

Patrick Hynds

Security Expert

The CEO and Founder of DTS and Pulsar Security, Patrick is a recognized technology leader with expertise in Microsoft technologies, software development, network architecture, and enterprise security. Patrick has spent two decades as a Microsoft Regional Director, frequently speaking at technical events throughout the world, and is a graduate of West Point and a decorated Gulf War veteran.

Ciprian Jichici

Quantum Computing Enthusiast

The Chief Data Scientist and GM of Data & AI and Advanced Computing practices at Solliance, Ciprian is recognized internationally as a Microsoft Regional Director and a Microsoft Most Valuable Professional for Artificial Intelligence and Quantum Computing. Cloud Computing, Artificial Intelligence, and Machine Learning are some of the key areas of his expertise. Ciprian is passionate about quantum physics and consequently, quantum computing.

Ciprian Jichici is the Chief Data Scientist and the GM of Data & AI and Advanced Computing of Solliance, one of the top worldwide Microsoft AI & ML partners.

He is recognized internationally as a Microsoft Regional Director and a Microsoft Most Valuable Professional for Artificial Intelligence and Quantum Computing.

Cloud Computing, large-scale data processing, Artificial Intelligence, and Machine Learning are some of the key areas of his expertise spanning 25+ years of IT.

Ciprian is also very passionate about quantum physics and consequently, about quantum computing.

solliance

Ciprian Jichici

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Chief Data Scientist,
Solliance

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