The Quantum Virtual Machine

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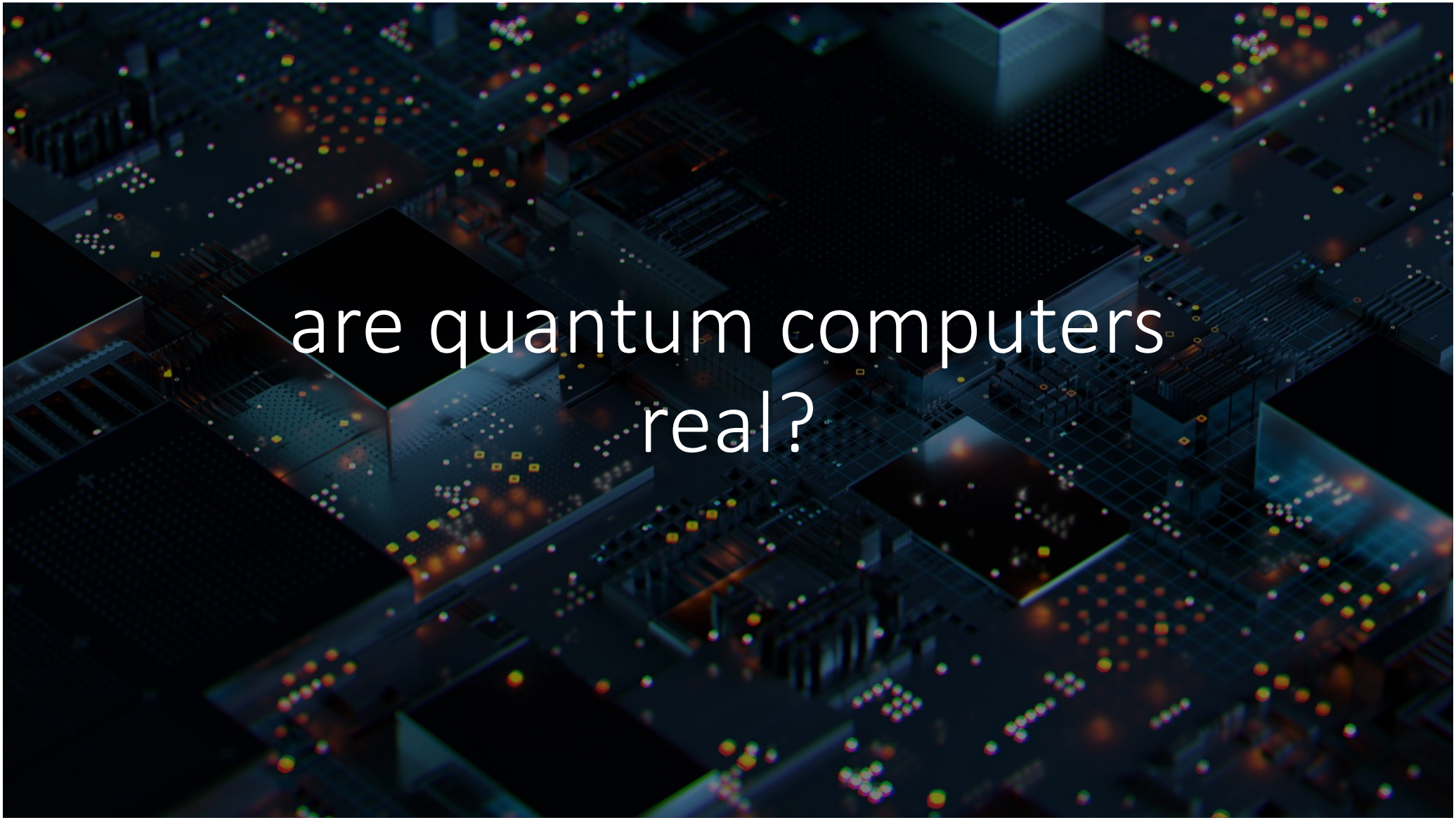
Quantum Computers

$$|\phi\rangle = \alpha_0|0\rangle + \alpha_1|1\rangle = \begin{bmatrix}\alpha_0\\ \alpha_1\end{bmatrix}$$

$$\alpha_i \in \mathbb{C} \qquad\qquad |\alpha_0|^2 + |\alpha_1|^2 = 1$$


are quantum computers
real?

yes!

- IBM – Heron 133 qubit processor
- Google – Bristlecone 72 qubit processor

- IonQ – Forte 32 qubit processor
- Quantinuum – H2 32 qubit processor
- Rigetti – Ankaa 84 qubit processor

- QuEra – Aquila 256 qubit processor

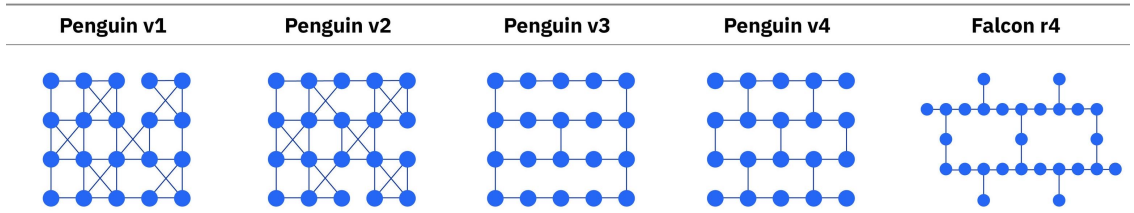

but there is a catch...

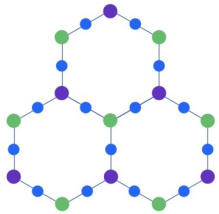
instruction set

- each device implements a different instruction set:
  - ibm: U1(λ), RX(π/2), CX
  - iong: GPI(φ), VirtualZ(θ), MS(φ0,φ1), ZZ(θ)
  - quantinuum: U1(λ, φ), RZ(π/2), ZZ(), RZZ(θ)

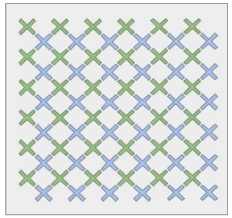
connectivity

- ibm

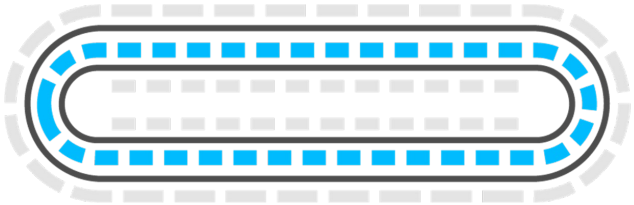




- google



- quantinuum:



noise

- ibm: 99.812 (avg), 93.21 (readout)
- google: 99.9 (1q), 99.4 (2q), 99 (readout)
- ionq: 99.98 (1q), 99.3 (2q)
- quantinuum: 99.997 (1q), 99.8 (2q)


QVM

a formal definition

- A QVM is triplet (I, N, T) where:
  - $\boldsymbol{I}$ **is the instruction set**: the set of supported instructions
  - $\boldsymbol{N}$ **is the noise model**: a random variable that given an instruction, returns another instruction representing the noise based on some probability distribution
  - $\boldsymbol{T}$ **is the topology**: a graph representing connectivity among qubits

benefits

- theoretical complexity calculations
- provides definitions for compilers
- create software emulators
- model fault-tolerant devices

thanks!

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