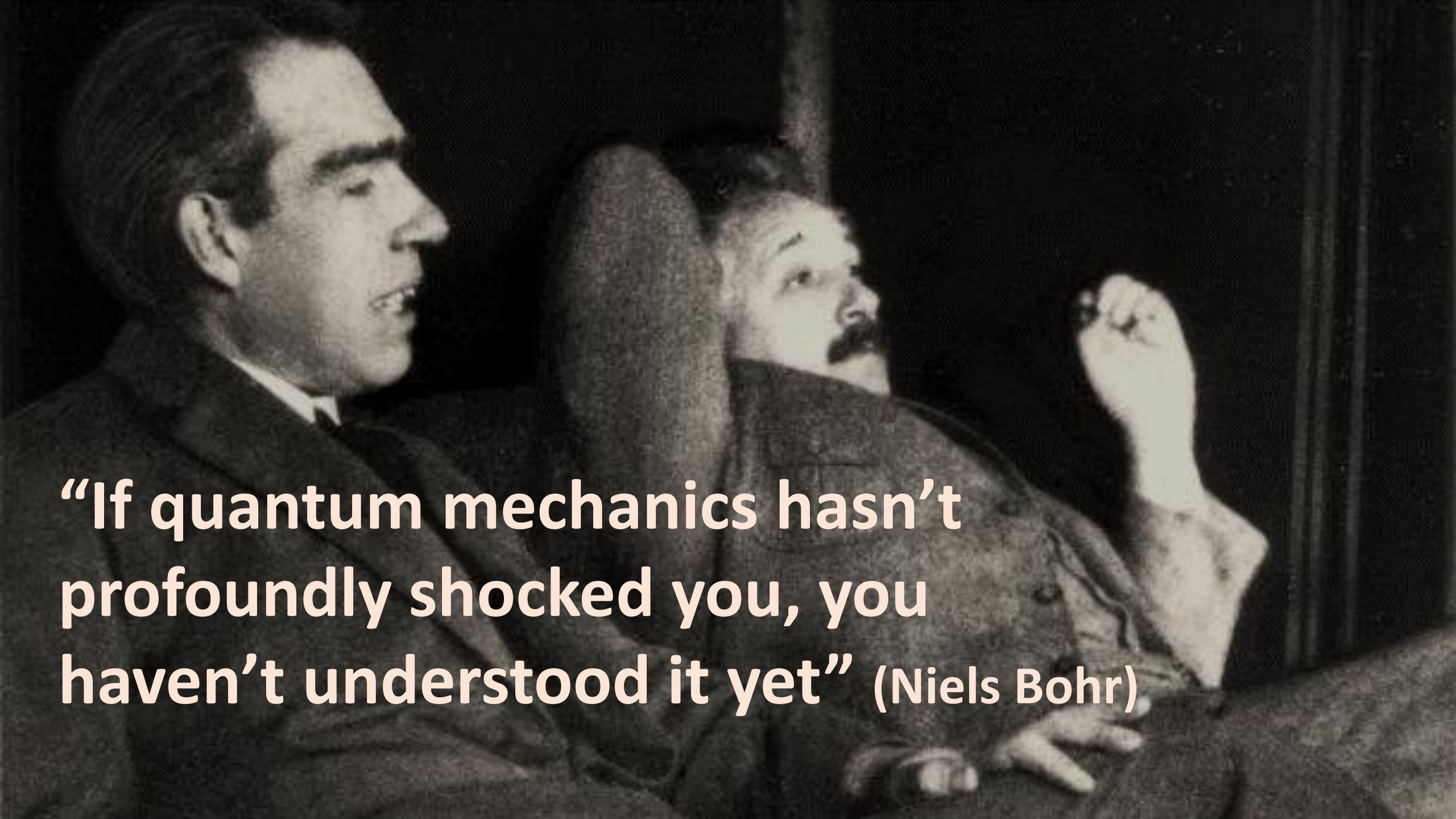
“If quantum mechanics hasn’t profoundly shocked you, you haven’t understood it yet” (Niels Bohr)


IBM
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GOOGLE, ALIBABA SPAR OVER TIMELINE FOR 'QUANTUM
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QUANTUM COMPUTING
49 QUBITS
The race for quantum supremacy
QM
operate
control
quantum

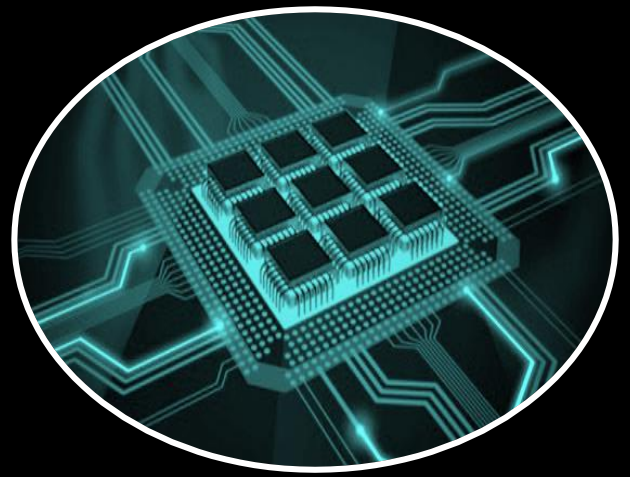
# Classical Computer

# THE BIT

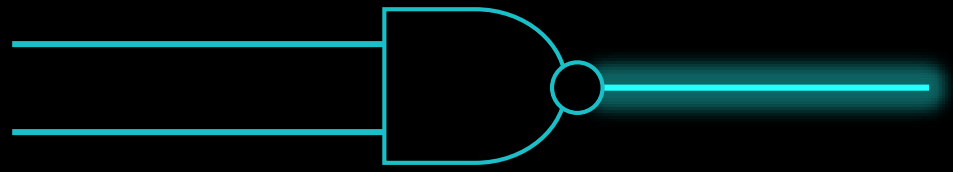
$|0\rangle$ OR $|1\rangle$

0V

5V



# THE GATE

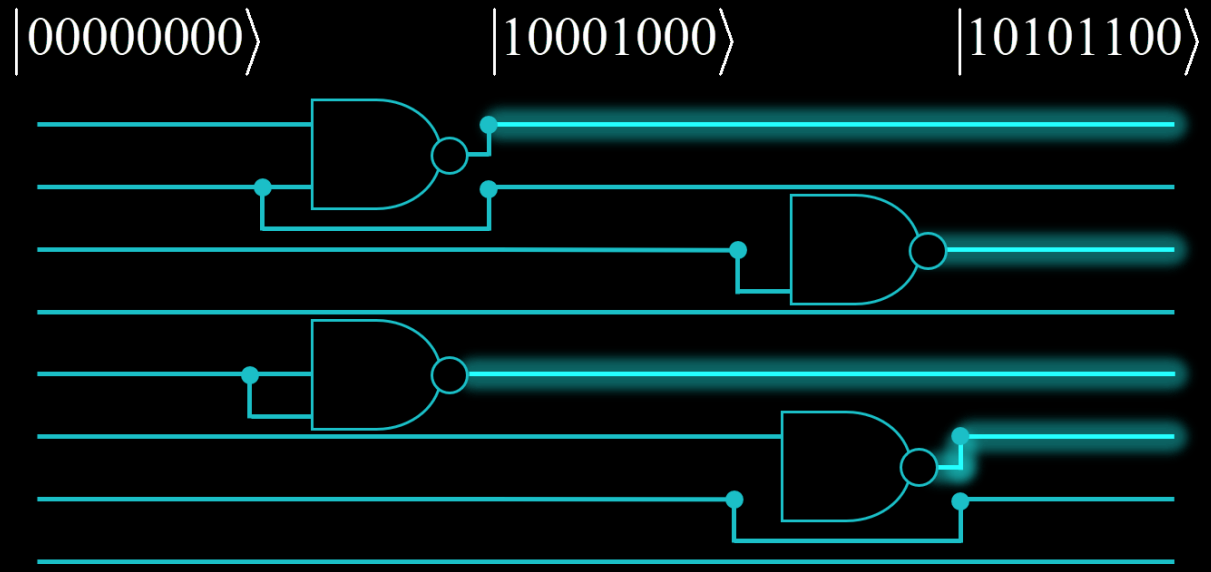


Nand Gate

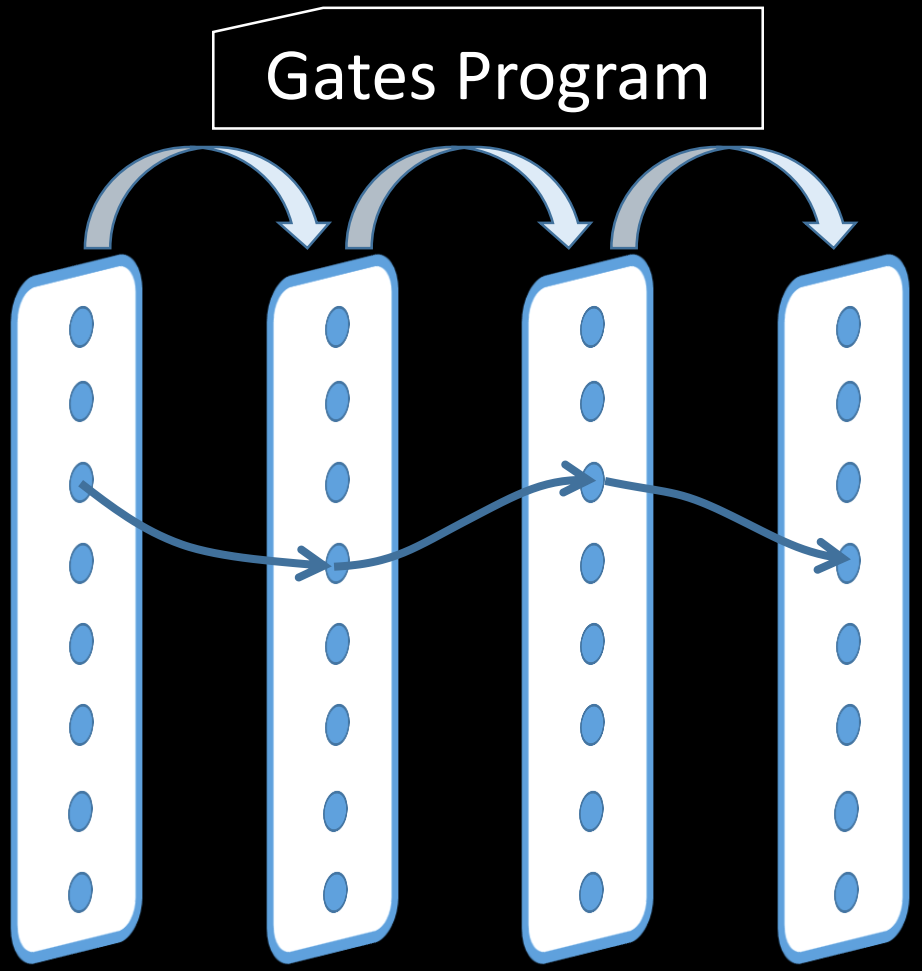
| In1 | In2 | Out |
|---|---|---|
| 0 | 0 | 1 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 0 |

Universal Gate

# UNIVERSAL GATE



# CLASSICAL COMOUTER



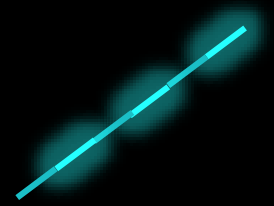
# Quantum Computer

# THE BIT

$$|0\rangle \quad OR \quad |1\rangle$$

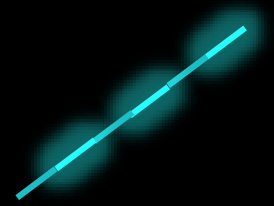
# THE QUBIT

$$|0\rangle \ AND \ |1\rangle$$



# THE QUBIT

$$\alpha_0|0\rangle + \alpha_1|1\rangle$$

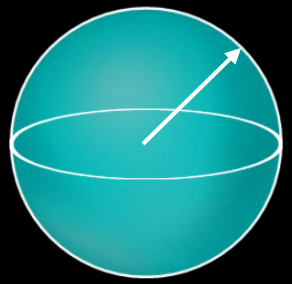


$$\begin{pmatrix} \alpha_0 \\ \alpha_1 \end{pmatrix}$$

$$\alpha_0^2 + \alpha_1^2 = 1$$

## THE QUBIT

$$\alpha_0|0\rangle + \alpha_1|1\rangle$$

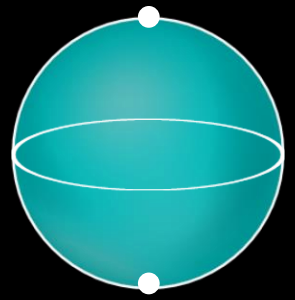


$$\begin{pmatrix} \alpha_0 \\ \alpha_1 \end{pmatrix}$$

$$\alpha_0^2 + \alpha_1^2 = 1$$

## BIT

$$|0\rangle \quad OR \quad |1\rangle$$



$$\begin{pmatrix} 1 \\ 0 \end{pmatrix} OR \begin{pmatrix} 0 \\ 1 \end{pmatrix}$$

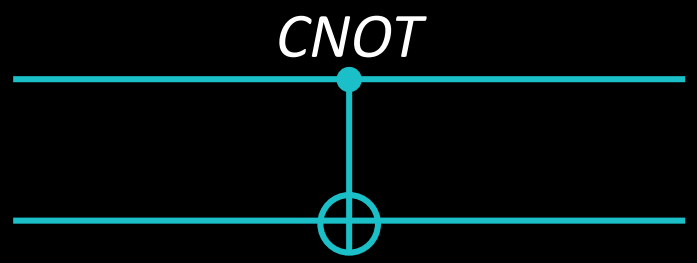
# QUANTUM GATES


$$\begin{pmatrix} \alpha_0 \\ \alpha_1 \end{pmatrix} \xrightarrow[\begin{pmatrix} u_{00} & u_{01} \\ u_{10} & u_{11} \end{pmatrix}]{U} \begin{pmatrix} \alpha'_0 \\ \alpha'_1 \end{pmatrix}$$

# QUANTUM GATES


$$\begin{pmatrix} \alpha_0 \\ \alpha_1 \end{pmatrix} \xrightarrow[\frac{1}{\sqrt{2}}\begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix}]{H} \begin{pmatrix} \alpha'_0 \\ \alpha'_1 \end{pmatrix}$$

# QUANTUM GATES

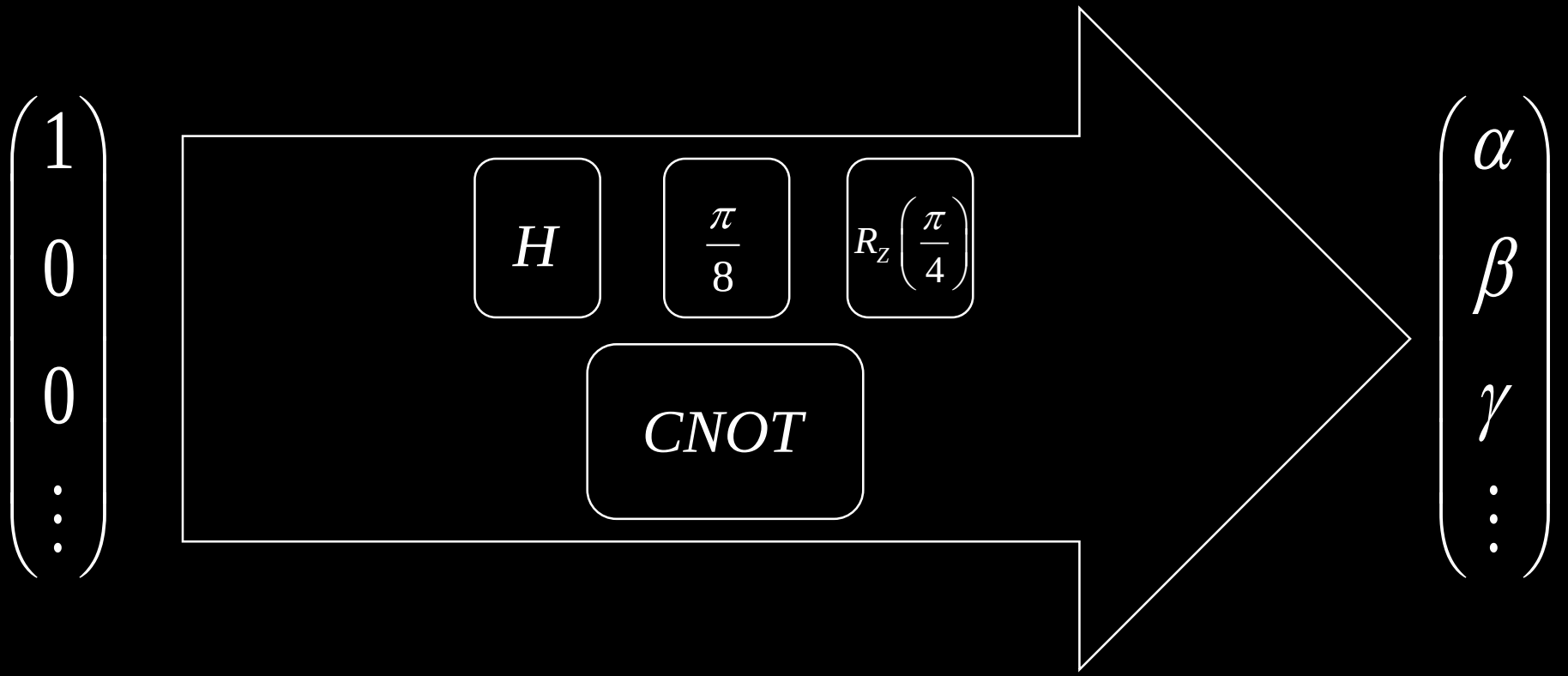



$$\begin{pmatrix} \alpha_0 \\ \alpha_1 \\ \alpha_3 \\ \alpha_3 \end{pmatrix} \xrightarrow{CNOT} \begin{pmatrix} \alpha'_0 \\ \alpha'_1 \\ \alpha'_2 \\ \alpha'_3 \end{pmatrix}$$

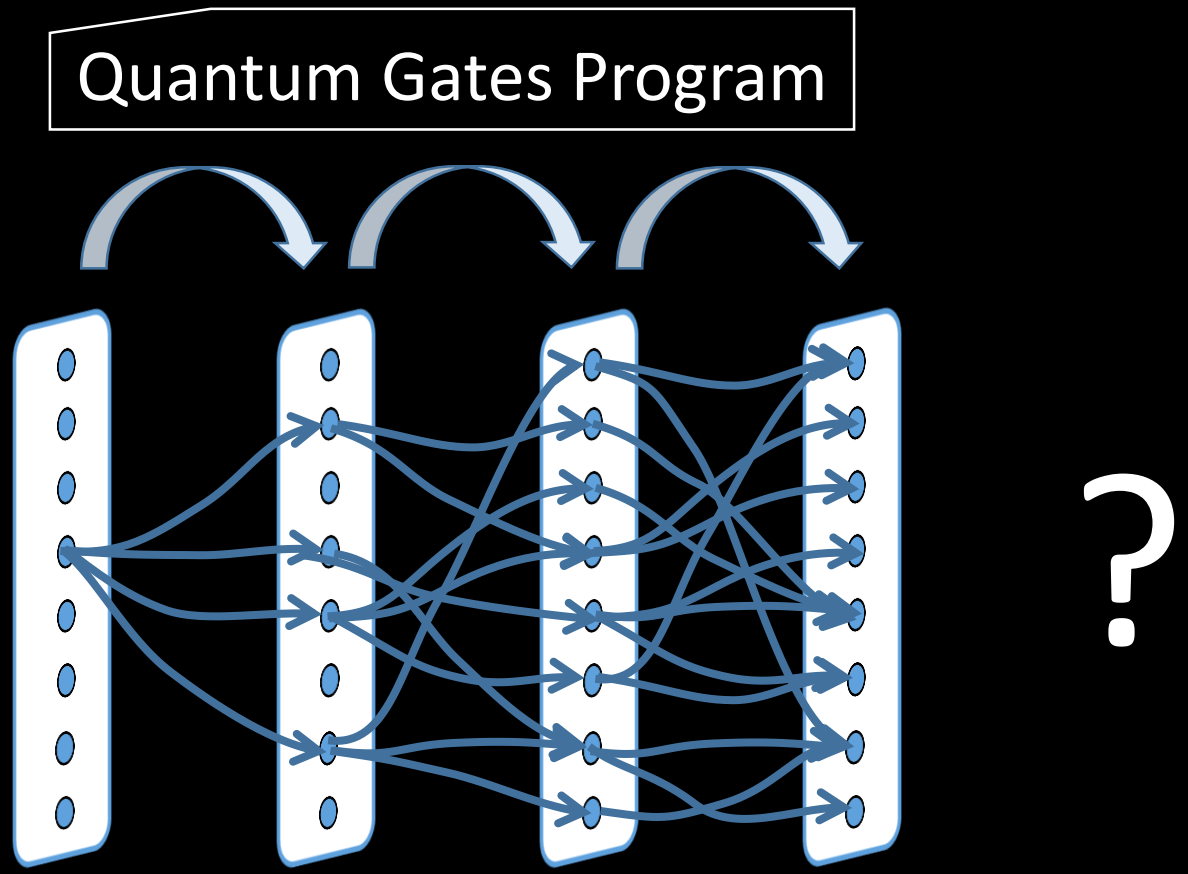
$$\begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 \end{pmatrix}$$

$$\alpha_{00}|00\rangle + \alpha_{01}|01\rangle + \alpha_{10}|10\rangle + \alpha_{11}|11\rangle$$

# Universal set of gates

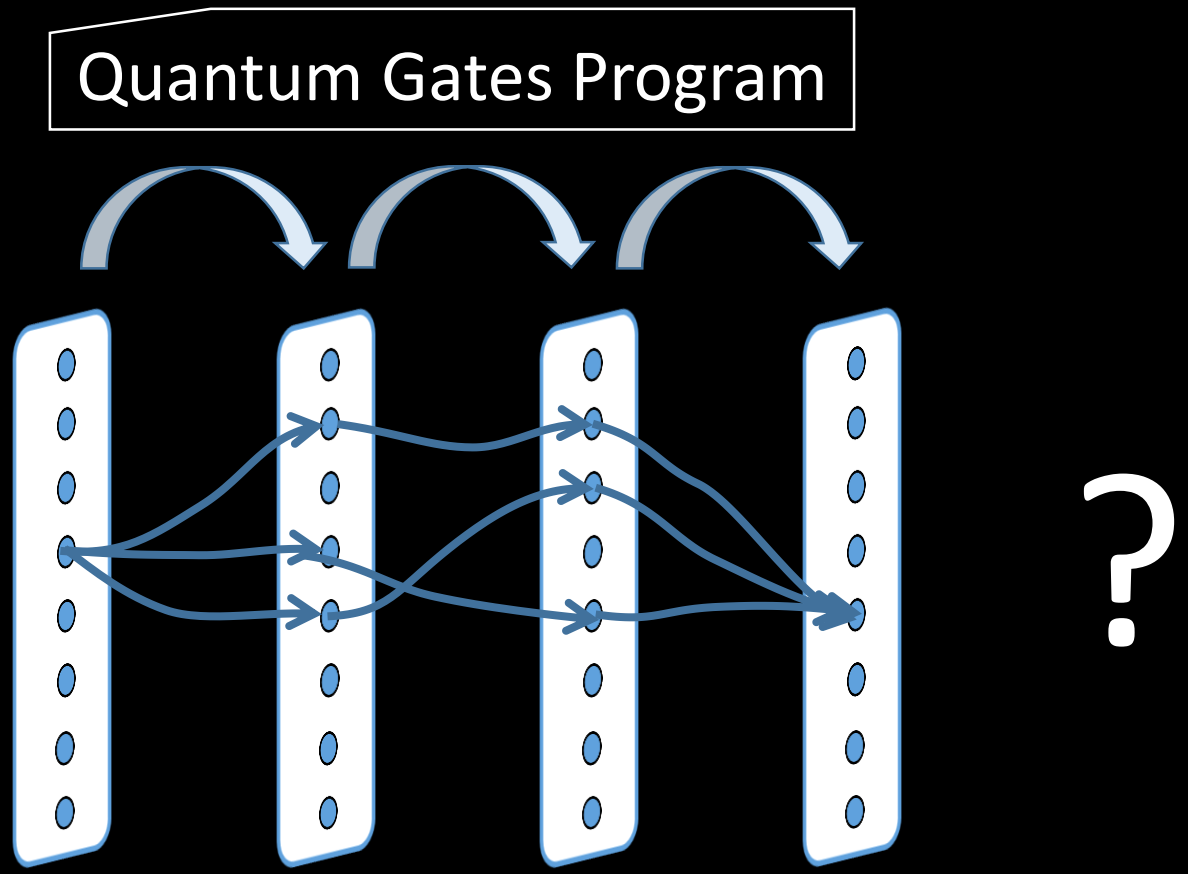


# QUANTUM COMOUTER




?

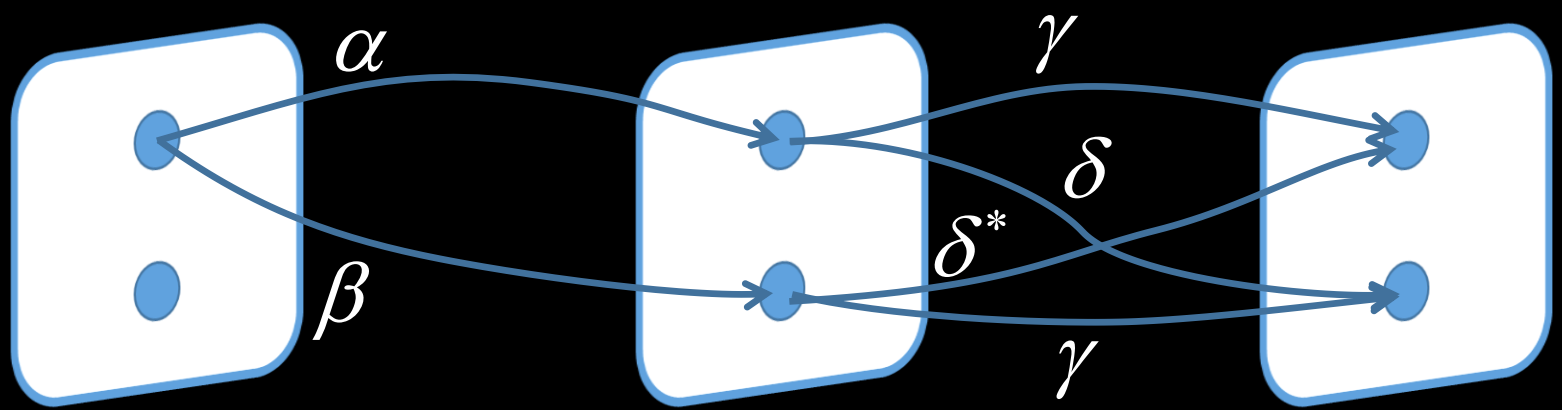
# QUANTUM COMOUTER




?

# Quantum Algorithm

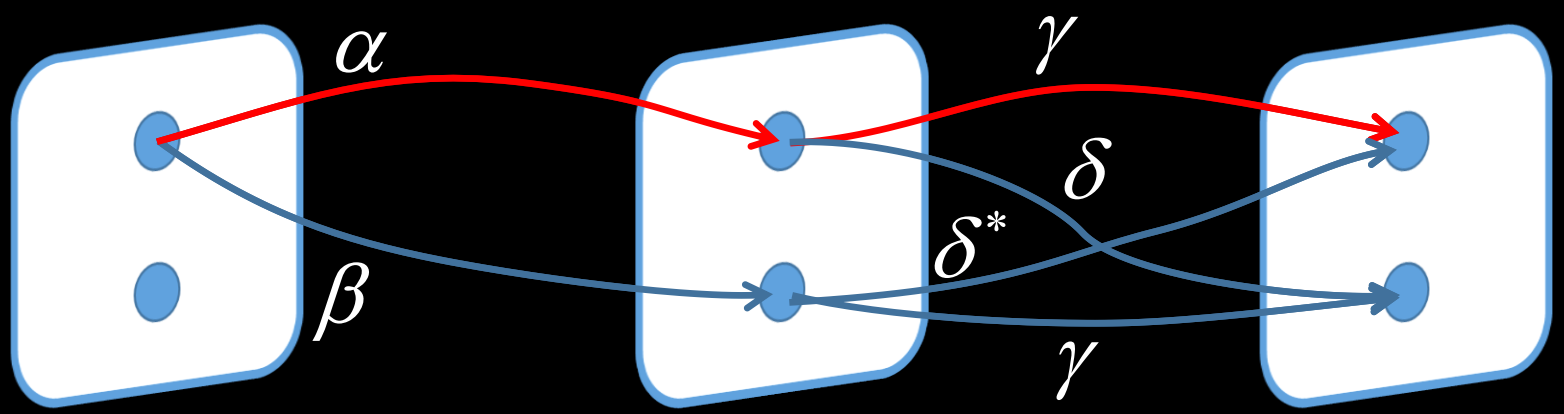
$$\begin{pmatrix} 1 \\ 0 \end{pmatrix} \xrightarrow{\begin{pmatrix} \alpha & \beta^* \\ \beta & \alpha \end{pmatrix}\begin{pmatrix} 1 \\ 0 \end{pmatrix}} \begin{pmatrix} \alpha \\ \beta \end{pmatrix} \xrightarrow{\begin{pmatrix} \gamma & \delta^* \\ \delta & \gamma \end{pmatrix}\begin{pmatrix} \alpha \\ \beta \end{pmatrix}} \begin{pmatrix} \gamma\alpha + \delta^*\beta \\ \delta\alpha + \gamma\beta \end{pmatrix}$$




QM operate control quantum

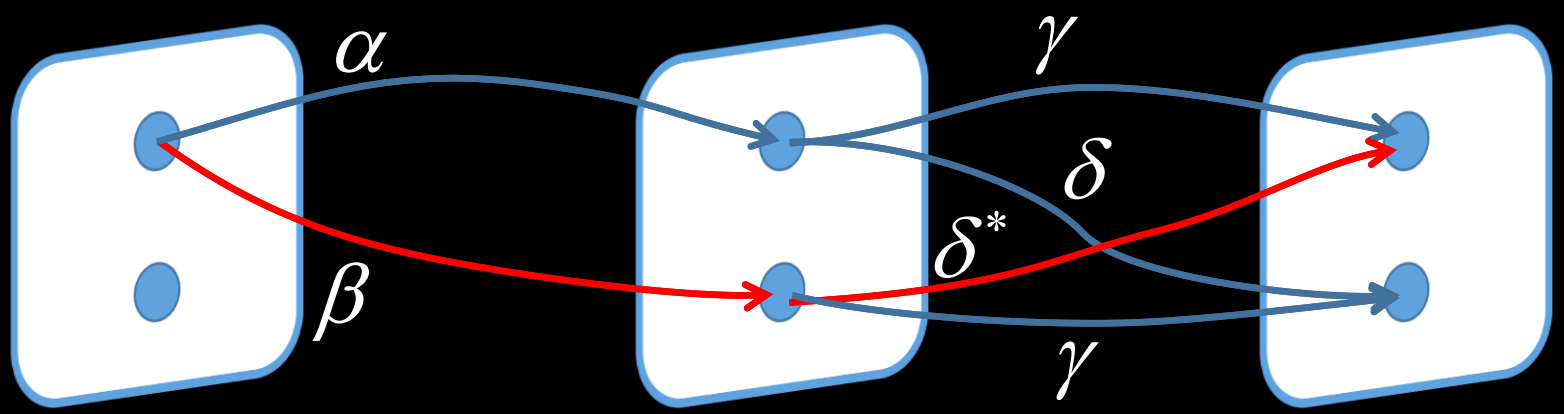
# Sum of paths

$$\begin{pmatrix}1\\0\end{pmatrix} \xrightarrow{\begin{pmatrix}\alpha & \beta^*\\ \beta & \alpha\end{pmatrix}\begin{pmatrix}1\\0\end{pmatrix}} \begin{pmatrix}\alpha\\ \beta\end{pmatrix} \xrightarrow{\begin{pmatrix}\gamma & \delta^*\\ \delta & \gamma\end{pmatrix}\begin{pmatrix}\alpha\\ \beta\end{pmatrix}} \begin{pmatrix}\gamma\alpha+\delta^*\beta\\ \delta\alpha+\gamma\beta\end{pmatrix}$$



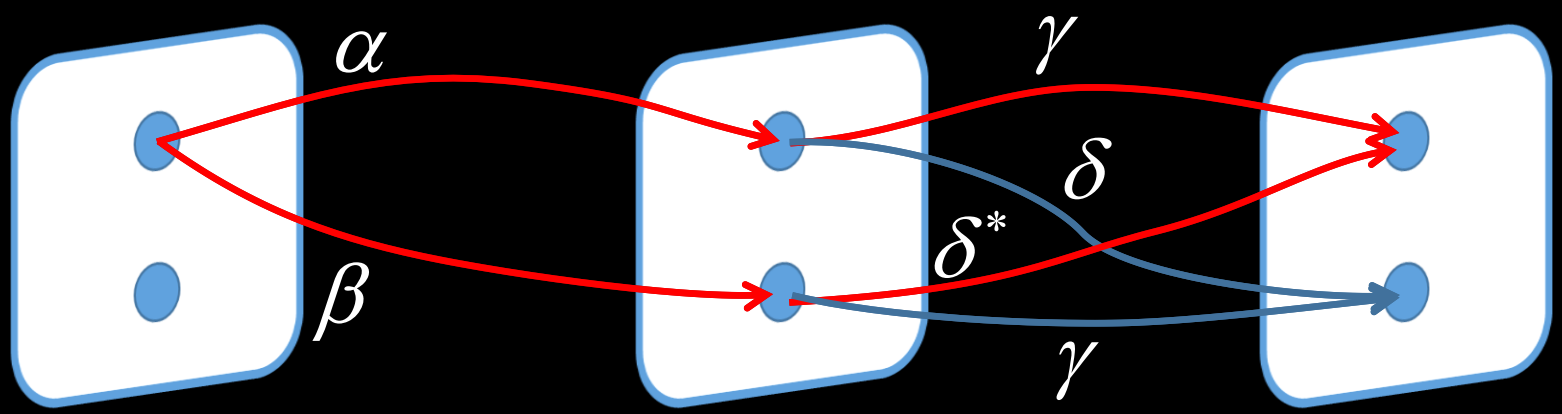
# Sum of paths

$$\begin{pmatrix}1\\0\end{pmatrix} \xrightarrow{\begin{pmatrix}\alpha & \beta^*\\ \beta & \alpha\end{pmatrix}\begin{pmatrix}1\\0\end{pmatrix}} \begin{pmatrix}\alpha\\ \beta\end{pmatrix} \xrightarrow{\begin{pmatrix}\gamma & \delta^*\\ \delta & \gamma\end{pmatrix}\begin{pmatrix}\alpha\\ \beta\end{pmatrix}} \begin{pmatrix}\gamma\alpha+\delta^*\beta\\ \delta\alpha+\gamma\beta\end{pmatrix}$$



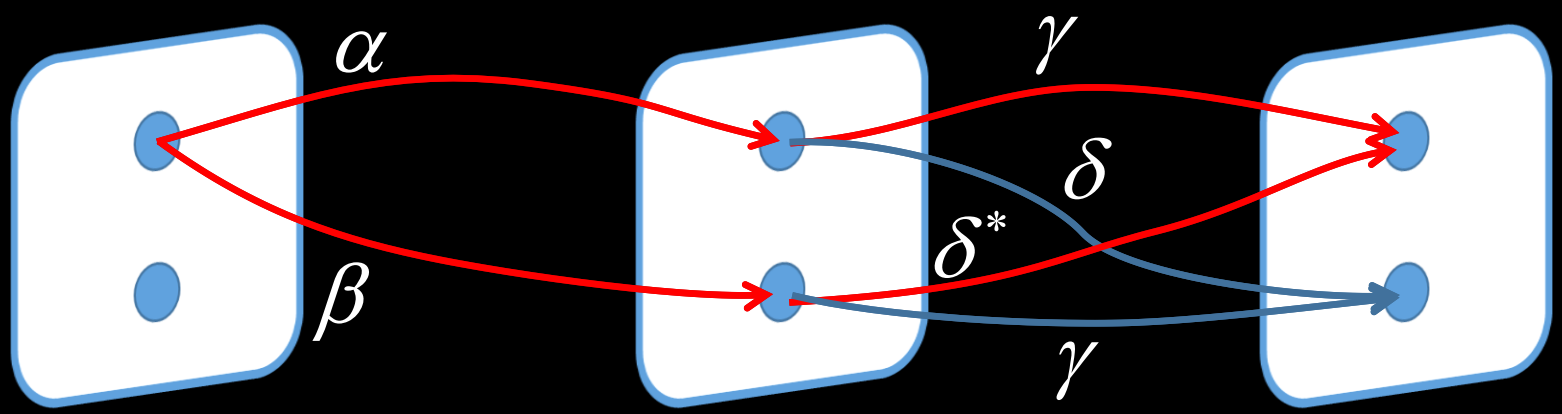
# Sum of paths

$$\begin{pmatrix}1\\0\end{pmatrix} \xrightarrow{\begin{pmatrix}\alpha & \beta^*\\ \beta & \alpha\end{pmatrix}\begin{pmatrix}1\\0\end{pmatrix}} \begin{pmatrix}\alpha\\ \beta\end{pmatrix} \xrightarrow{\begin{pmatrix}\gamma & \delta^*\\ \delta & \gamma\end{pmatrix}\begin{pmatrix}\alpha\\ \beta\end{pmatrix}} \begin{pmatrix}\gamma\alpha+\delta^*\beta\\ \delta\alpha+\gamma\beta\end{pmatrix}$$



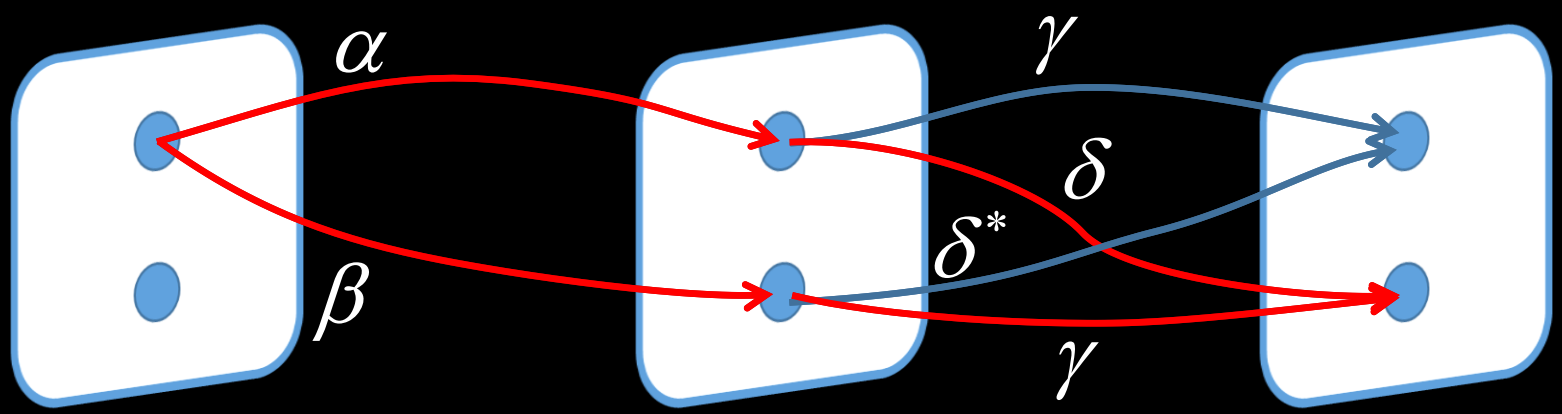
# Sum of paths

$$\begin{pmatrix}1\\0\end{pmatrix} \xrightarrow{\begin{pmatrix}\alpha & \beta^*\\ \beta & \alpha\end{pmatrix}\begin{pmatrix}1\\0\end{pmatrix}} \begin{pmatrix}\alpha\\ \beta\end{pmatrix} \xrightarrow{\begin{pmatrix}\gamma & \delta^*\\ \delta & \gamma\end{pmatrix}\begin{pmatrix}\alpha\\ \beta\end{pmatrix}} \begin{pmatrix}0\\ \delta\alpha+\gamma\beta\end{pmatrix}$$



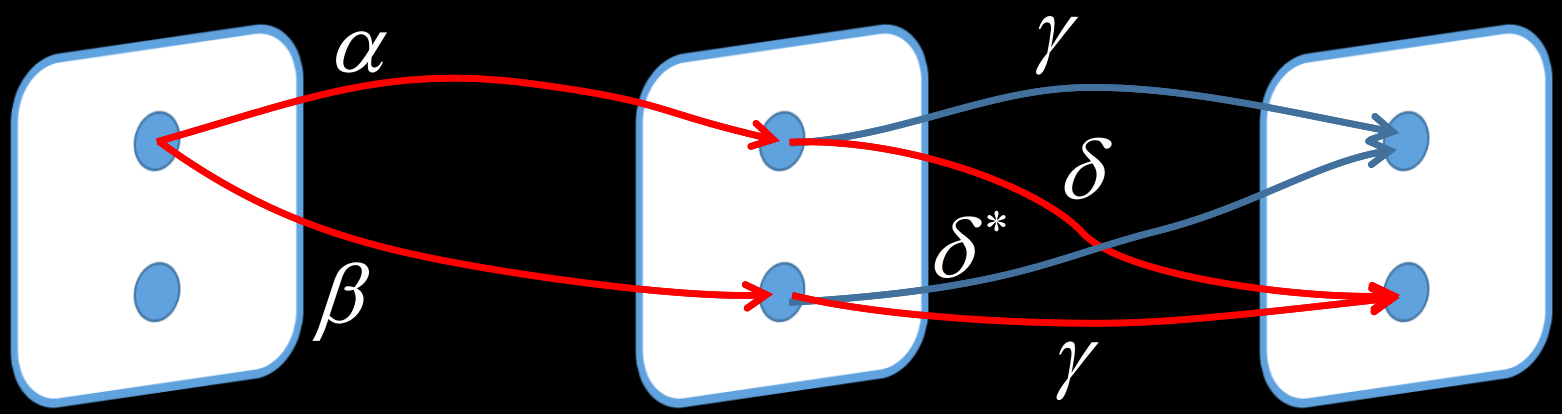
# Sum of paths

$$\begin{pmatrix}1\\0\end{pmatrix} \xrightarrow{\begin{pmatrix}\alpha & \beta^*\\ \beta & \alpha\end{pmatrix}\begin{pmatrix}1\\0\end{pmatrix}} \begin{pmatrix}\alpha\\ \beta\end{pmatrix} \xrightarrow{\begin{pmatrix}\gamma & \delta^*\\ \delta & \gamma\end{pmatrix}\begin{pmatrix}\alpha\\ \beta\end{pmatrix}} \begin{pmatrix}0\\ \delta\alpha+\gamma\beta\end{pmatrix}$$

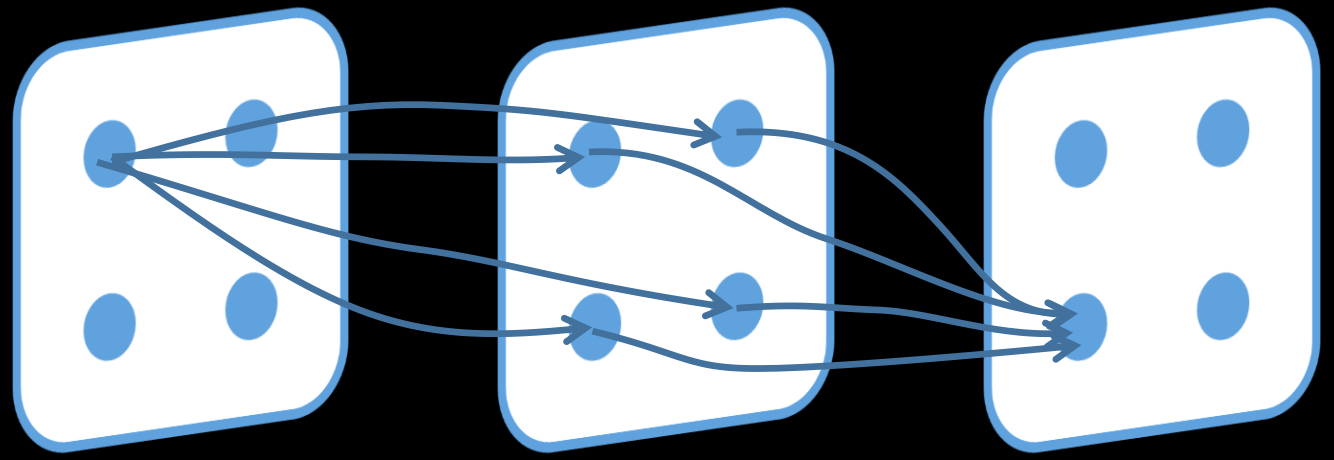


# Sum of paths

$$\begin{pmatrix}1\\0\end{pmatrix} \xrightarrow{\begin{pmatrix}\alpha & \beta^*\\ \beta & \alpha\end{pmatrix}\begin{pmatrix}1\\0\end{pmatrix}} \begin{pmatrix}\alpha\\ \beta\end{pmatrix} \xrightarrow{\begin{pmatrix}\gamma & \delta^*\\ \delta & \gamma\end{pmatrix}\begin{pmatrix}\alpha\\ \beta\end{pmatrix}} \begin{pmatrix}0\\1\end{pmatrix}$$

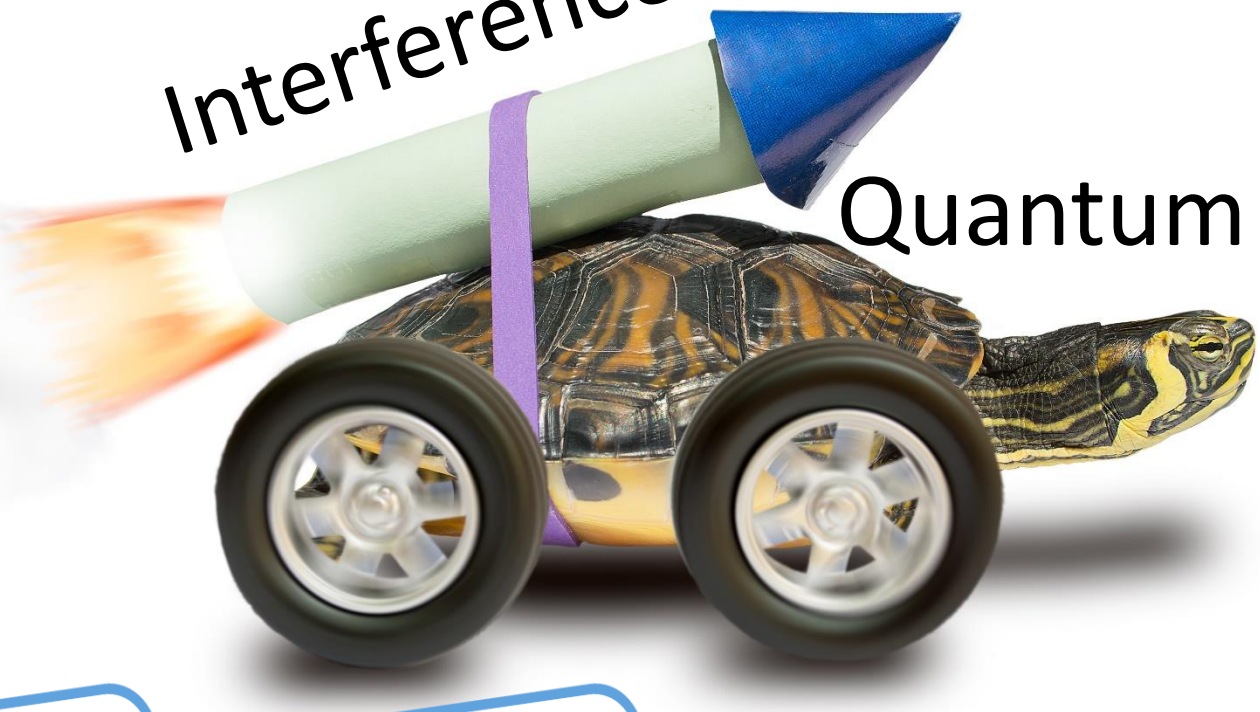


Interference is our tool to make parallel quantum paths work **together**

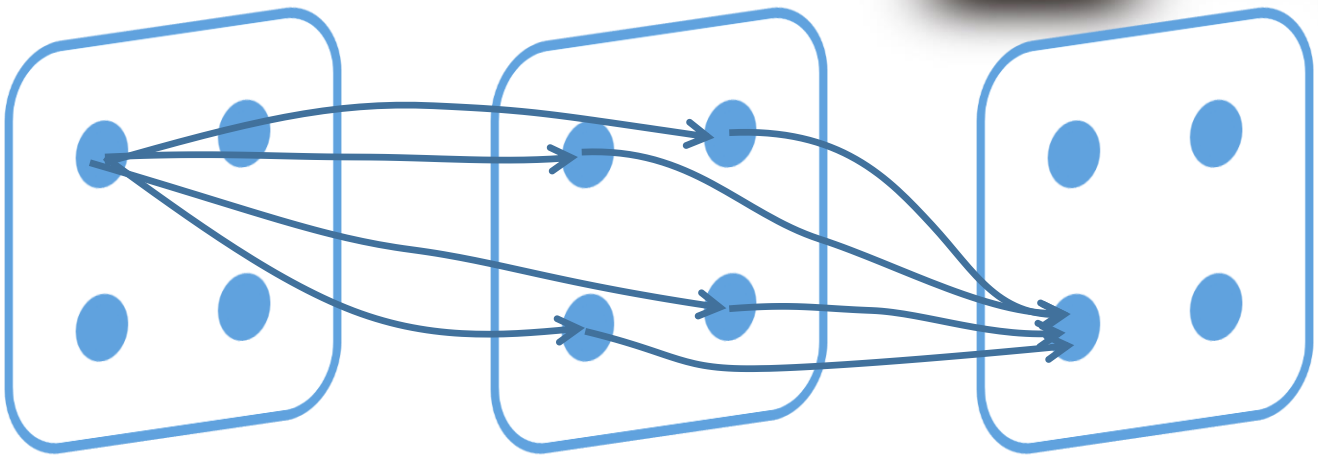


Classical

Interference



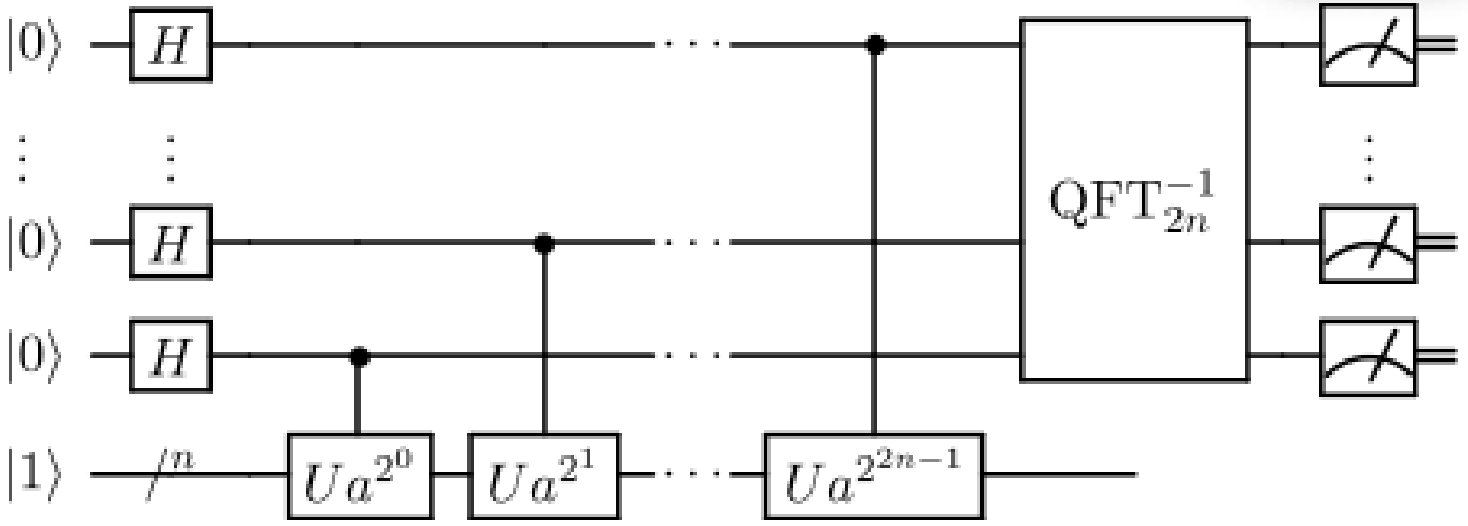
Quantum



Classical

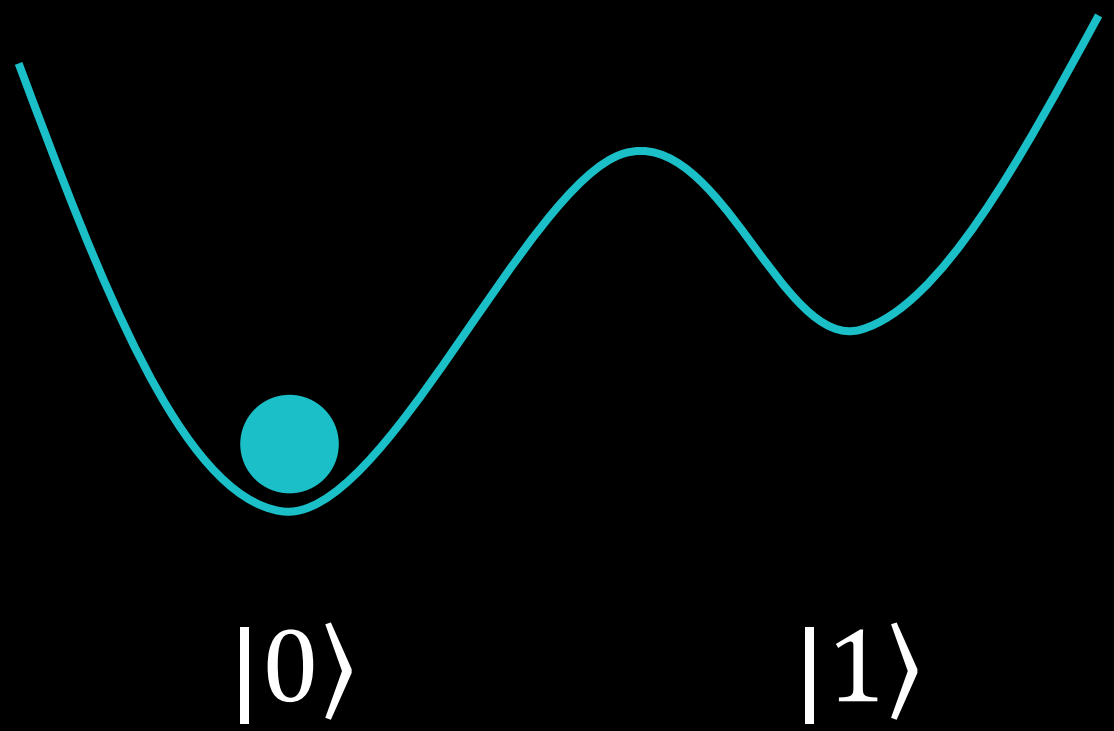
Interference

Quantum

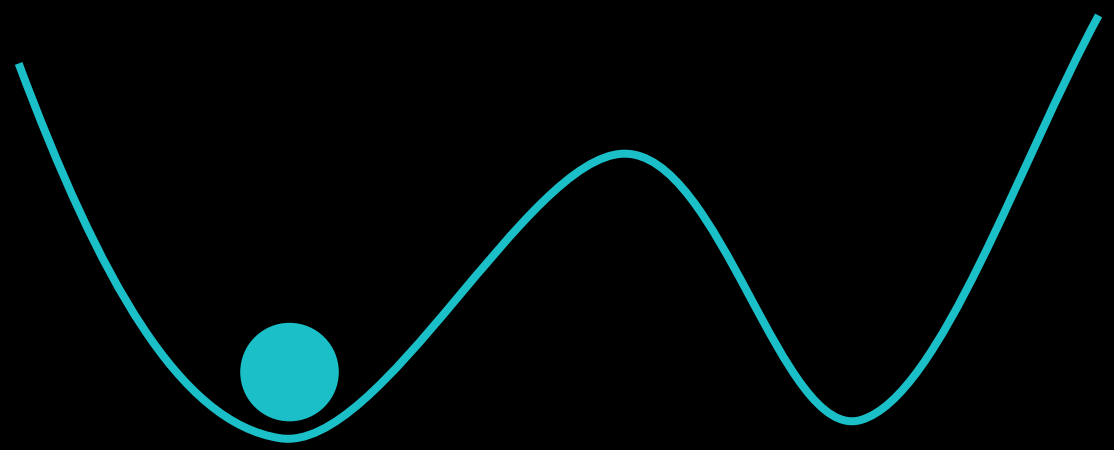


# Adiabatic Quantum Computing

# Classically

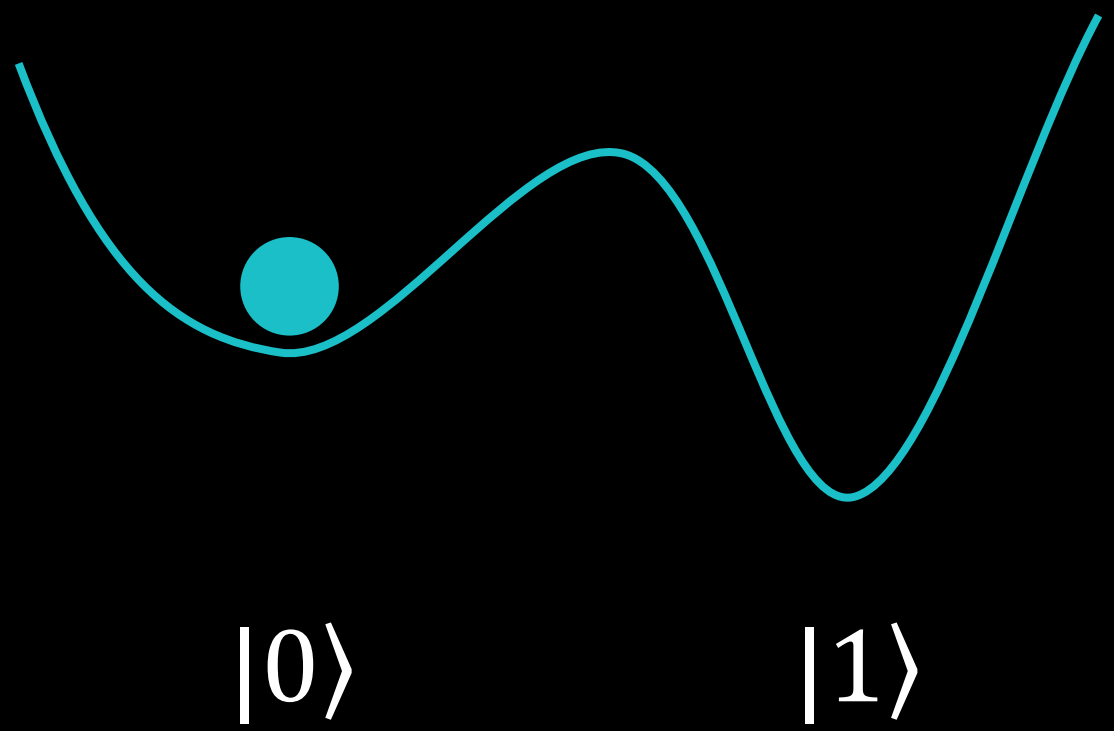


# Classically

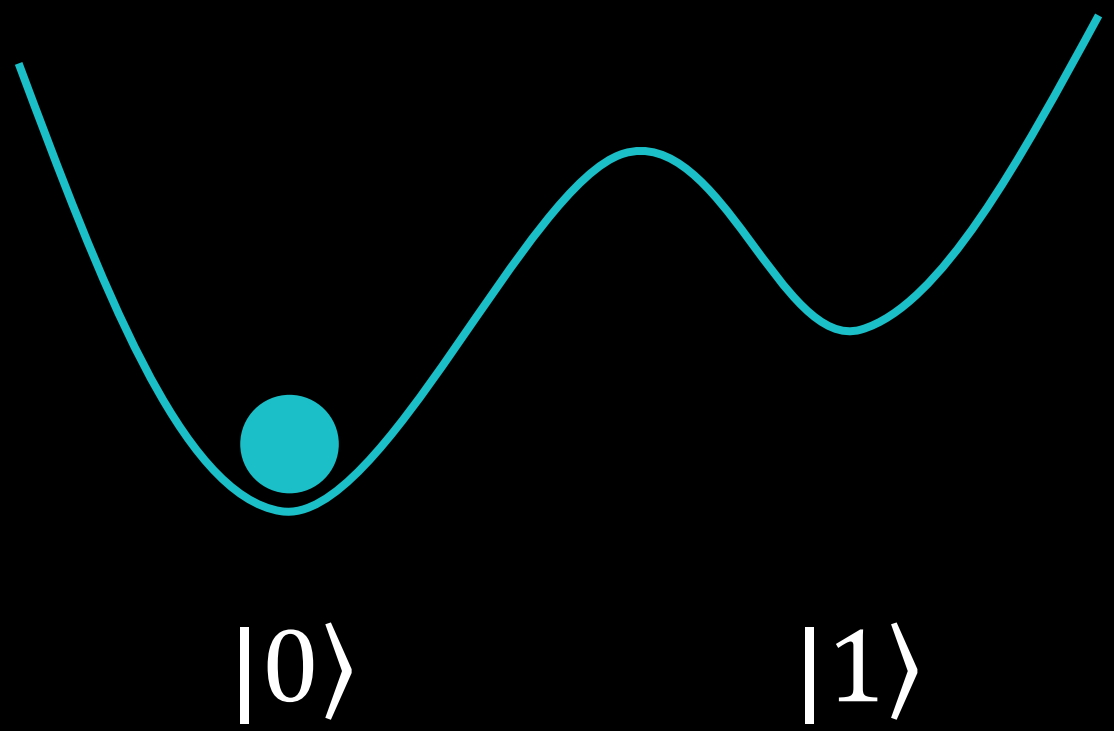


$|0\rangle$ $|1\rangle$

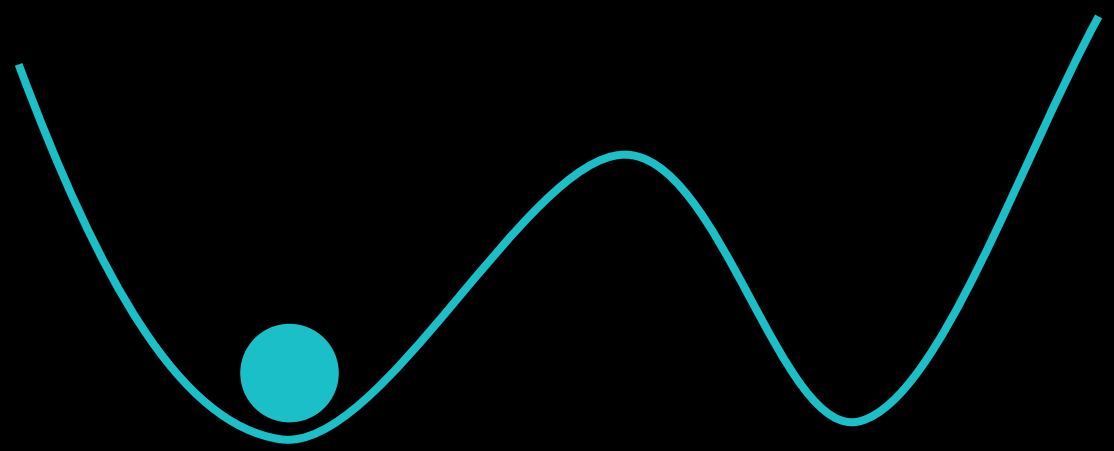
# Classically



# Quantumly

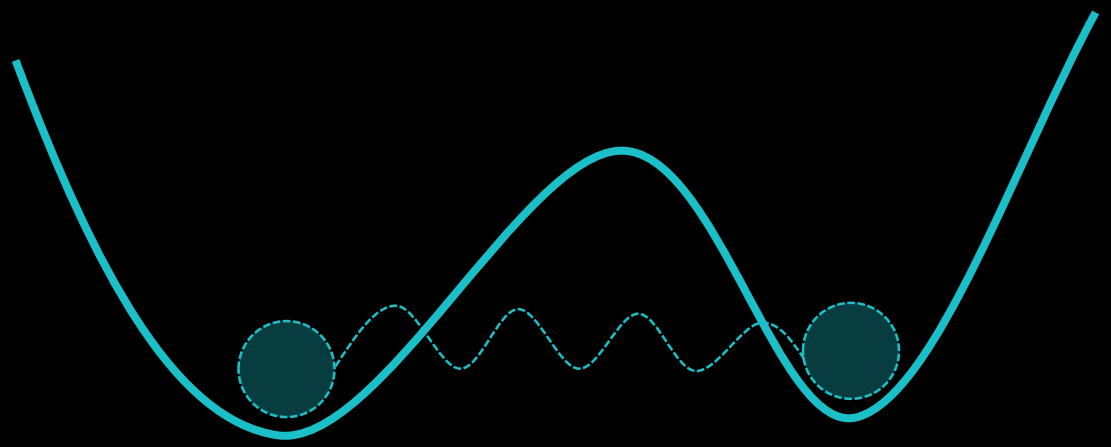


# Quantumly



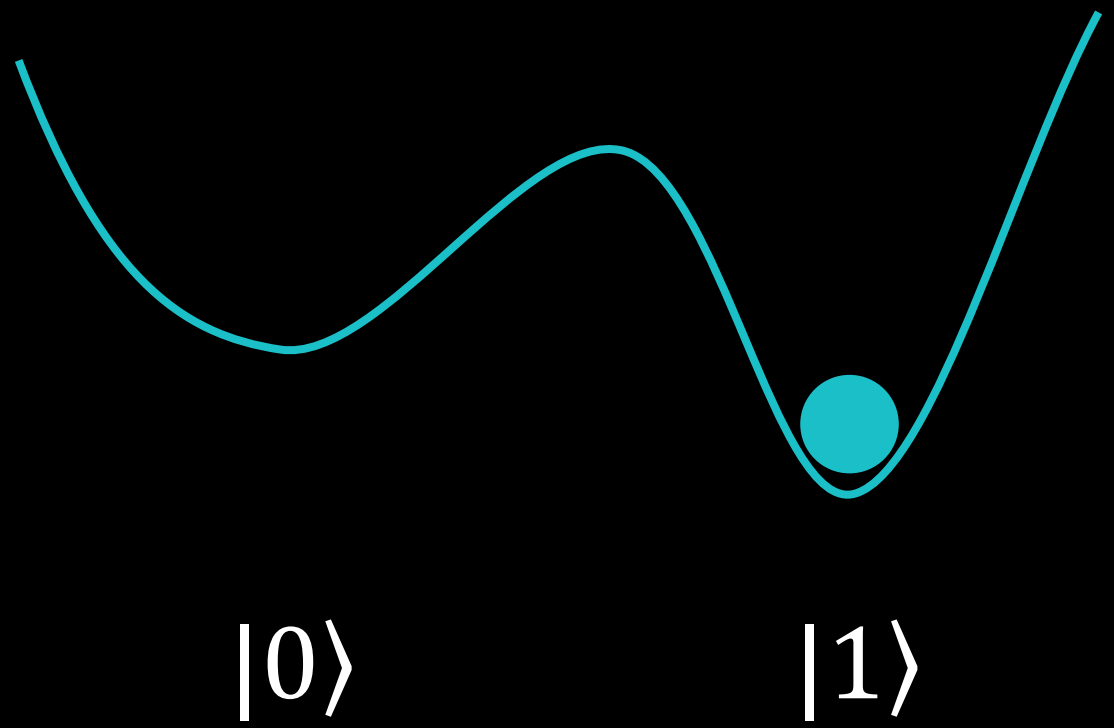
$|0\rangle$ $|1\rangle$

# Quantumly

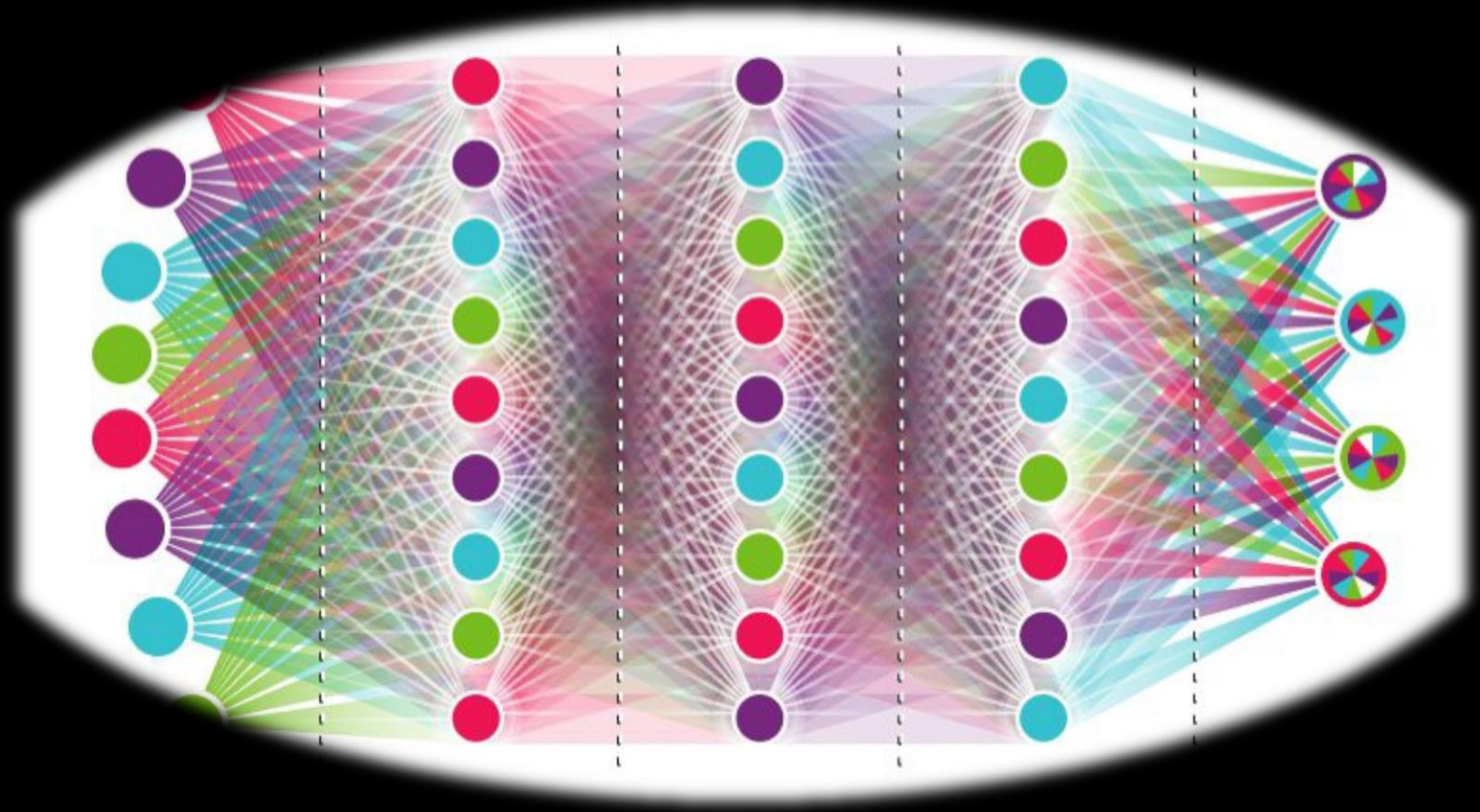


$$\frac{1}{\sqrt{2}}(|0\rangle - |1\rangle)$$

# Quantumly



# Quantum Neural Networks

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