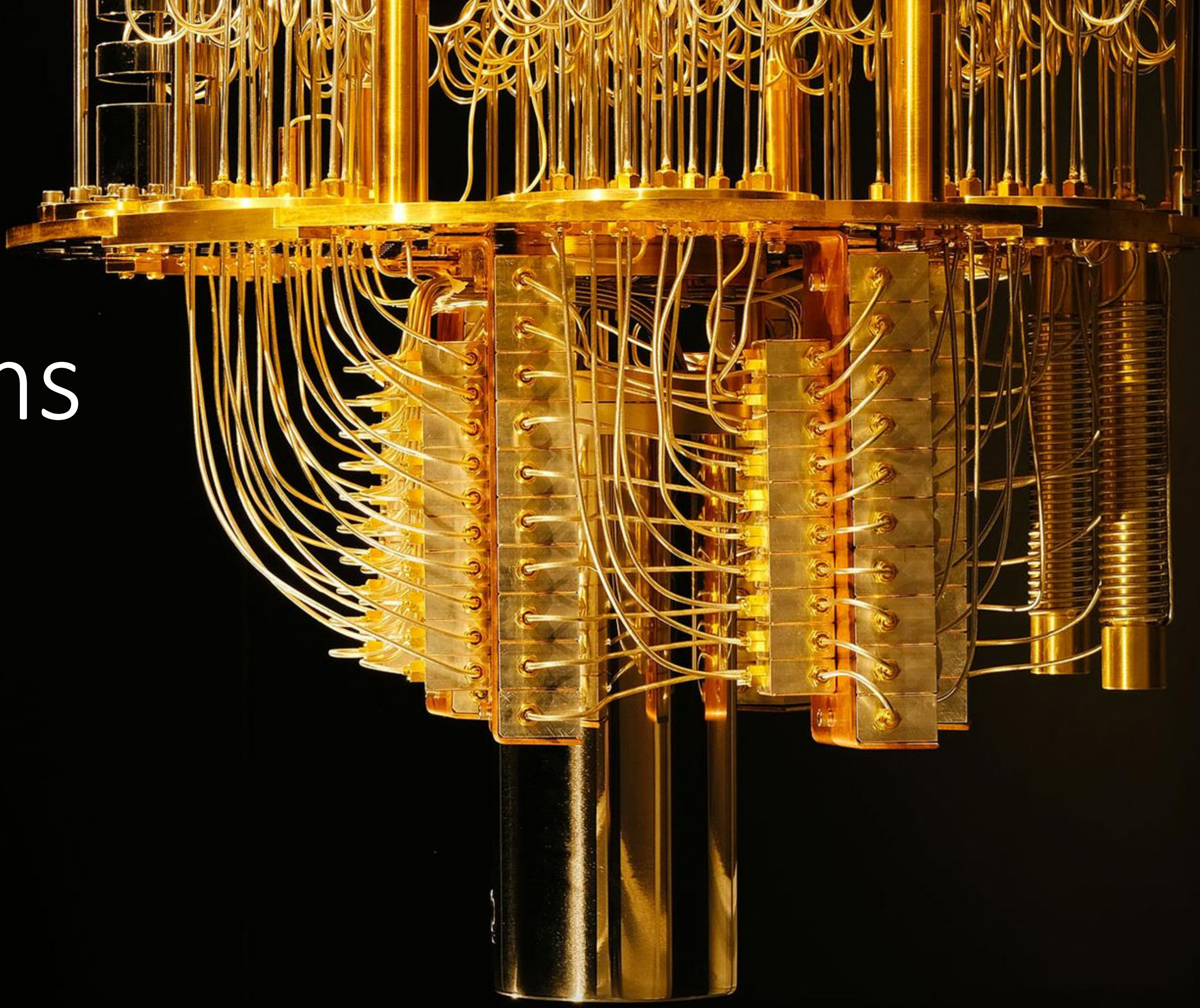
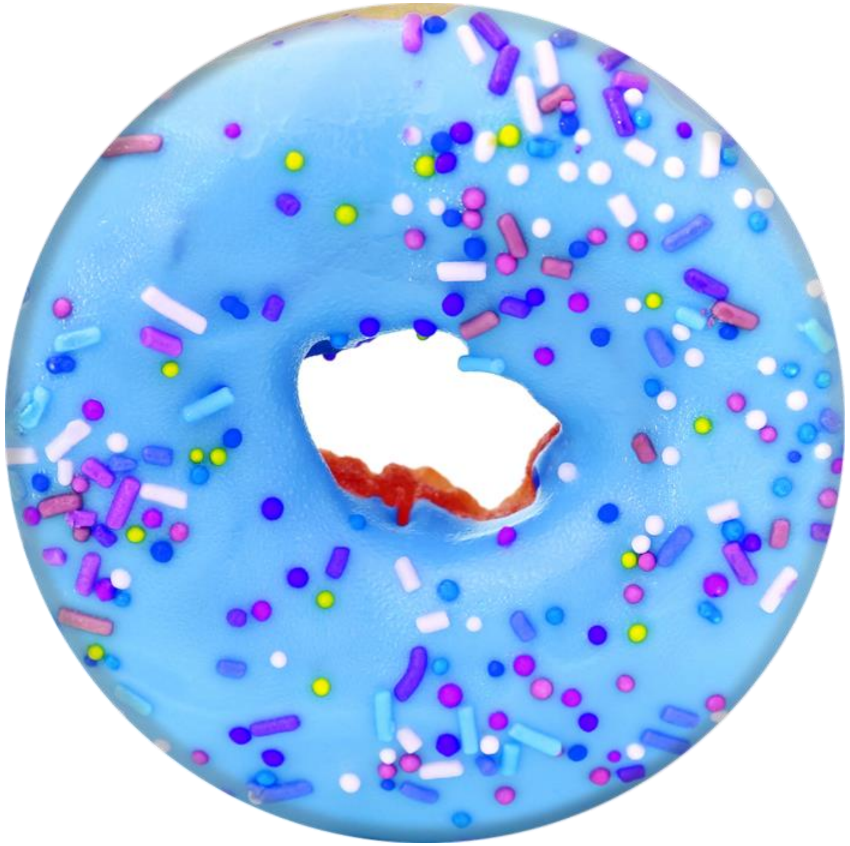
2 Qubit Systems and Entanglement



Priya Angara, Ulrike Stege

Two Qubit System

First Qubit



Second Qubit

Two qubit systems

When we have two quantum states in the same systems, the qubit can be in one to all of the following states

$|00\rangle$

$|01\rangle$

$|10\rangle$

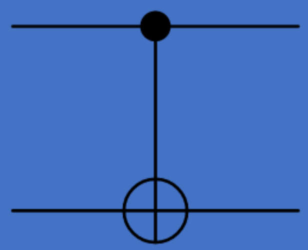
$|11\rangle$

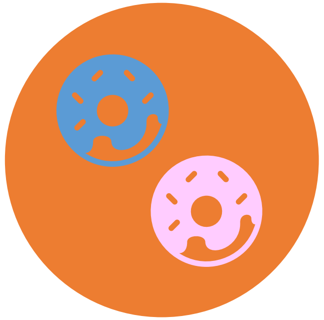
Psi for a two qubit system




$$|\psi > \quad = \alpha \, |00 > + \, \beta \, |01 > + \, \gamma \, |10 > + \, \delta \, |11 >$$

Controlled-NOT: A Two Qubit Gate

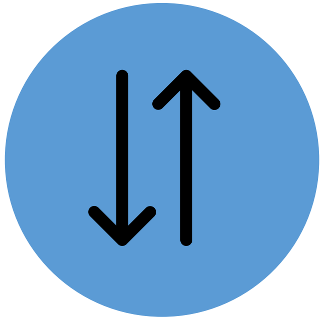




Controlled NOT gates make use of two qubits

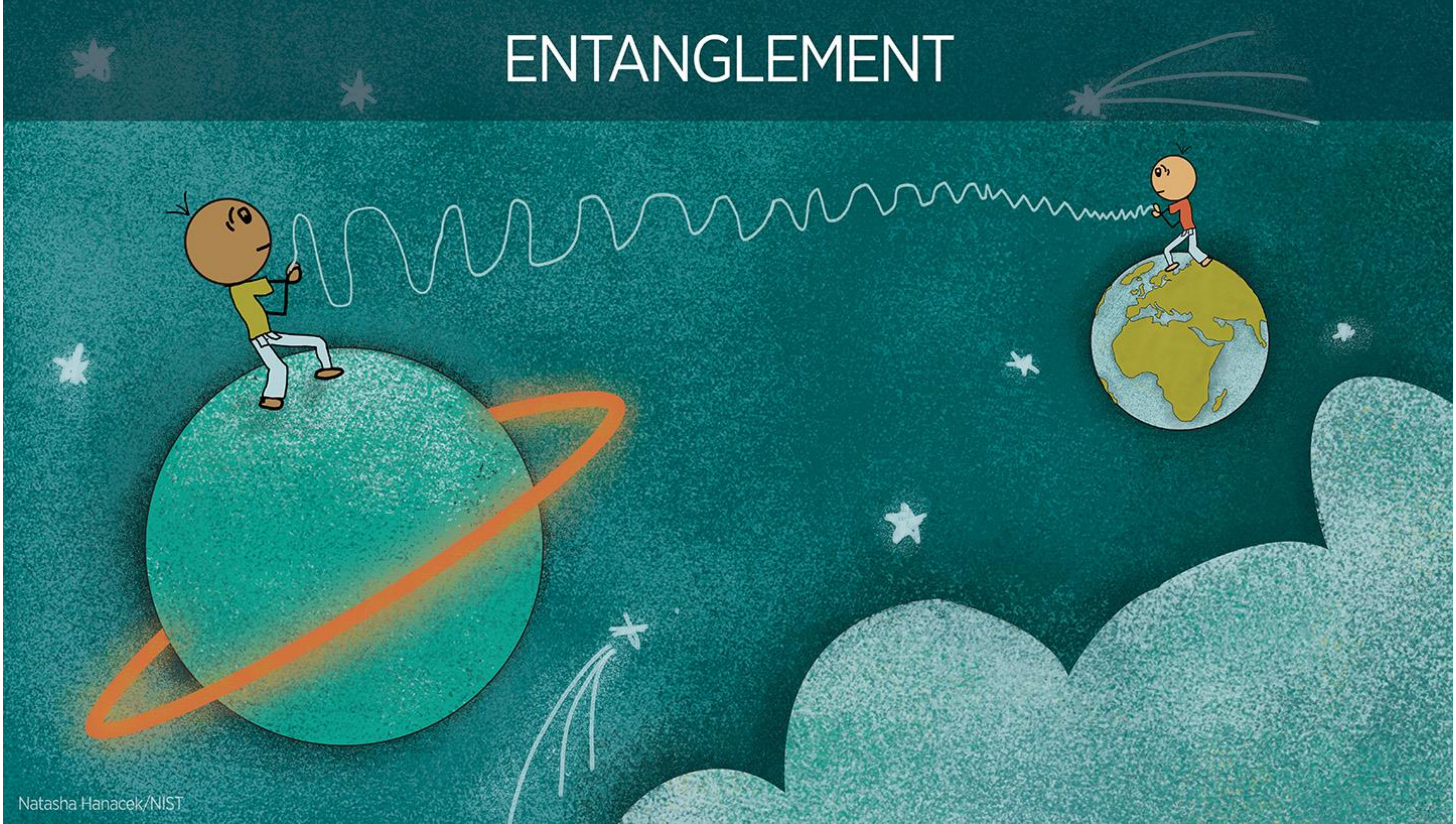
The first qubit decides the fate of the second qubit

If the first qubit is |0>, the second qubit remains unchanged



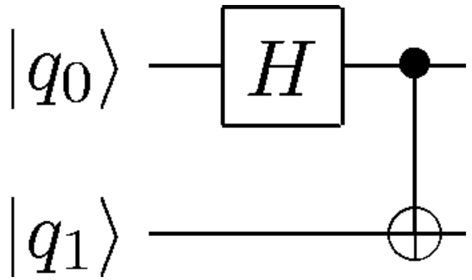
If the first qubit is |1>, the second qubit flips state

Let’s Qode!


ENTANGLEMENT
Natasha Hanacek/NIST

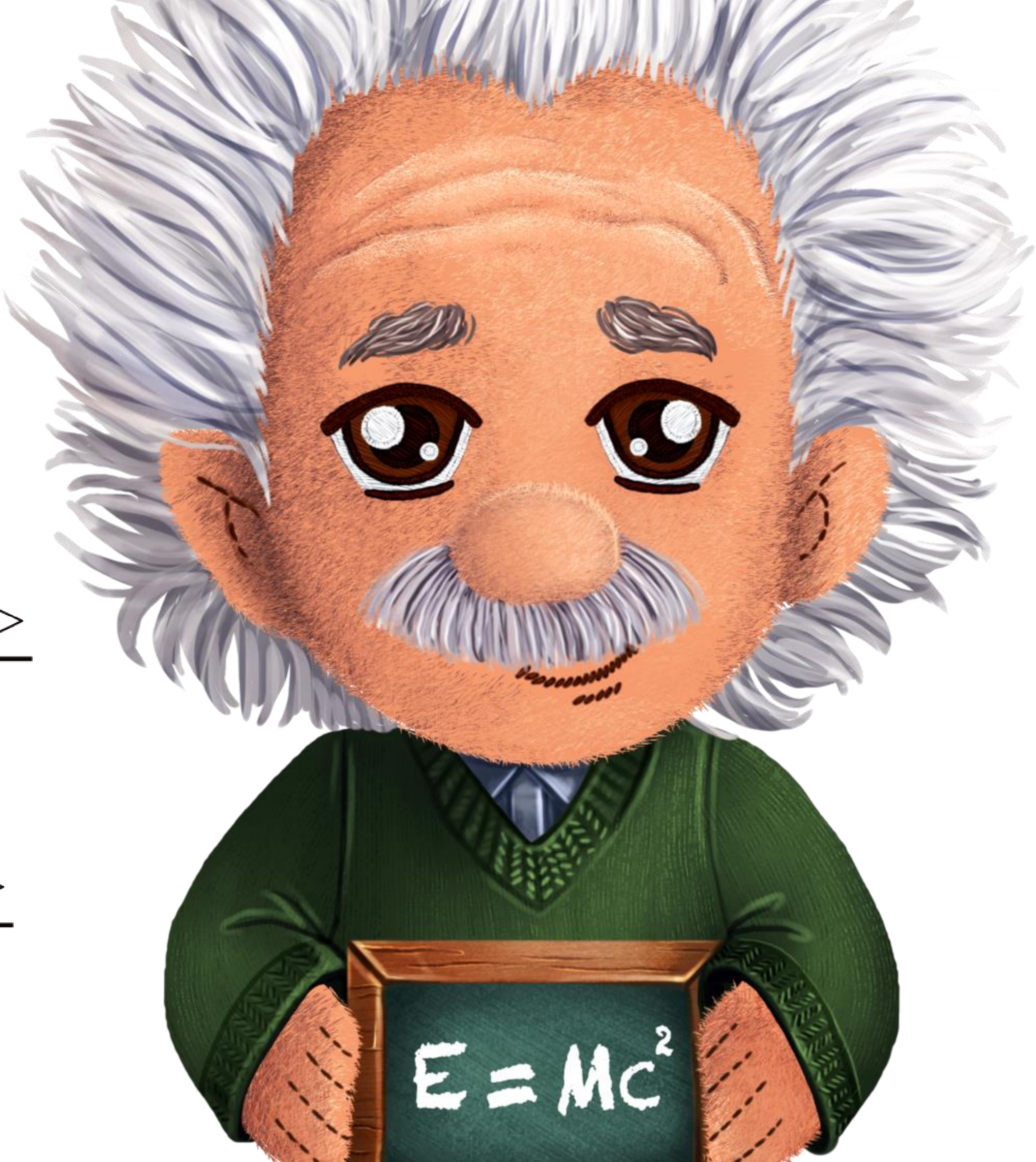
CNOT + Hadamard: Something Spooky

$|00>$

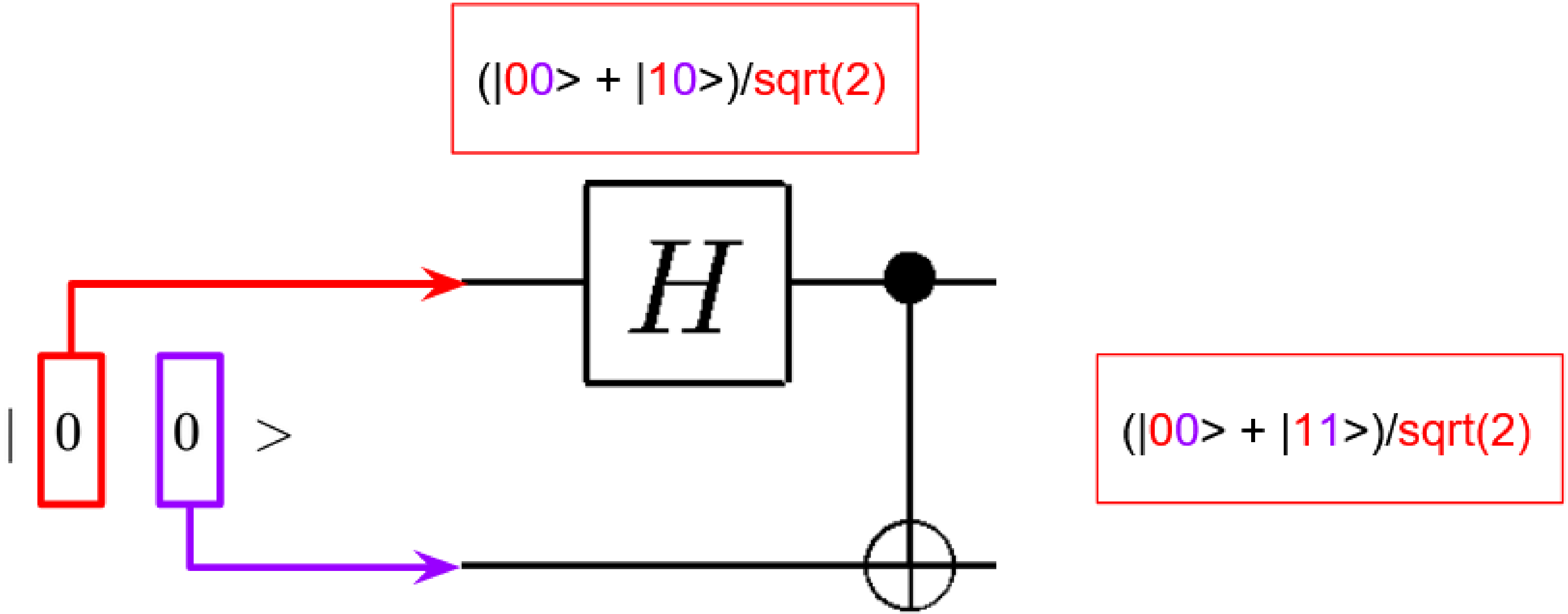


$\frac{|00>+|11>}{\sqrt{2}}$

$$|00> \xrightarrow{H} \frac{|00>+|10>}{\sqrt{2}} \xrightarrow{\text{C-NOT}} \frac{|00>+|11>}{\sqrt{2}}$$



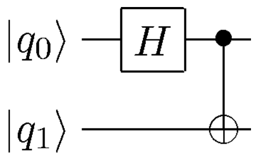
Which Qubit goes first?



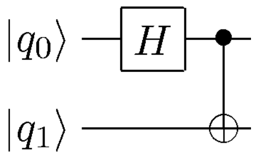
Let’s try this with some other states

Hadamard + CNOT on:

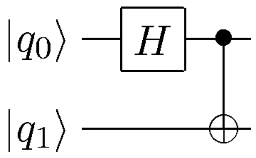
|01>



|10>



|11>



We’ll do this on our worksheet

Measurements

- We can measure both qubits at the end of our experiments like the single qubit systems.
- However, we can also do a partial measurement – This means we measure only one of the qubits.
- Maybe we can look at the measured qubit, and speculate about the unmeasured one?

We'll do this on our worksheet

Entanglement: Spooky Action at a distance

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

If we measure the first qubit, we know that it could be either 0 or 1.

But once we measure the first qubit, can we say something about the second qubit?

Bell States

$$|\Phi^+\rangle = \frac{1}{\sqrt{2}}(|00\rangle + |11\rangle)$$

$$|\Phi^-\rangle = \frac{1}{\sqrt{2}}(|00\rangle - |11\rangle)$$

$$|\Psi^+\rangle = \frac{1}{\sqrt{2}}(|01\rangle + |10\rangle)$$

$$|\Psi^-\rangle = \frac{1}{\sqrt{2}}(|01\rangle - |10\rangle)$$

Let’s Qode!