QUBIT.ZONE

QUANTUM COMPUTERS

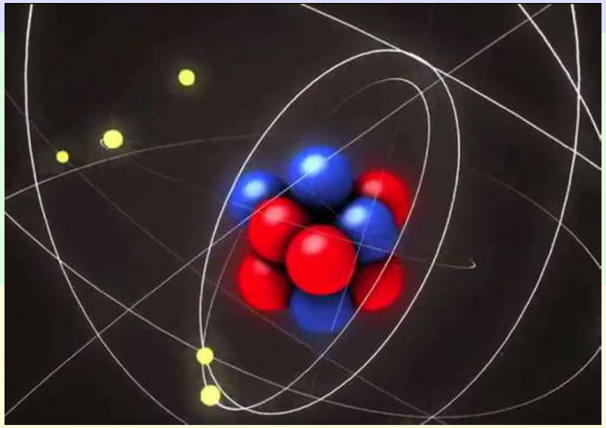
Scientists around the world are racing to build the first *quantum computer*.

These will give our civilization incredible new abilities to:

- design drugs
- analyze data
- break encryption
- build intelligent robots

But what *are* quantum computers?

THE QUANTUM WORLD



Atoms and electrons are some of the smallest things that exist.

They obey the laws of *quantum theory*—mysterious, counterintuitive and surprising.

Quantum objects can do lots of amazing things:

- *Superposition*—be in two places at once.
- *Entanglement*—different objects that behave identically.
- *Super Coding*—transfer twice as much information as usual.

Quantum computers will exploit these to perform their amazing tasks.

QUBITS

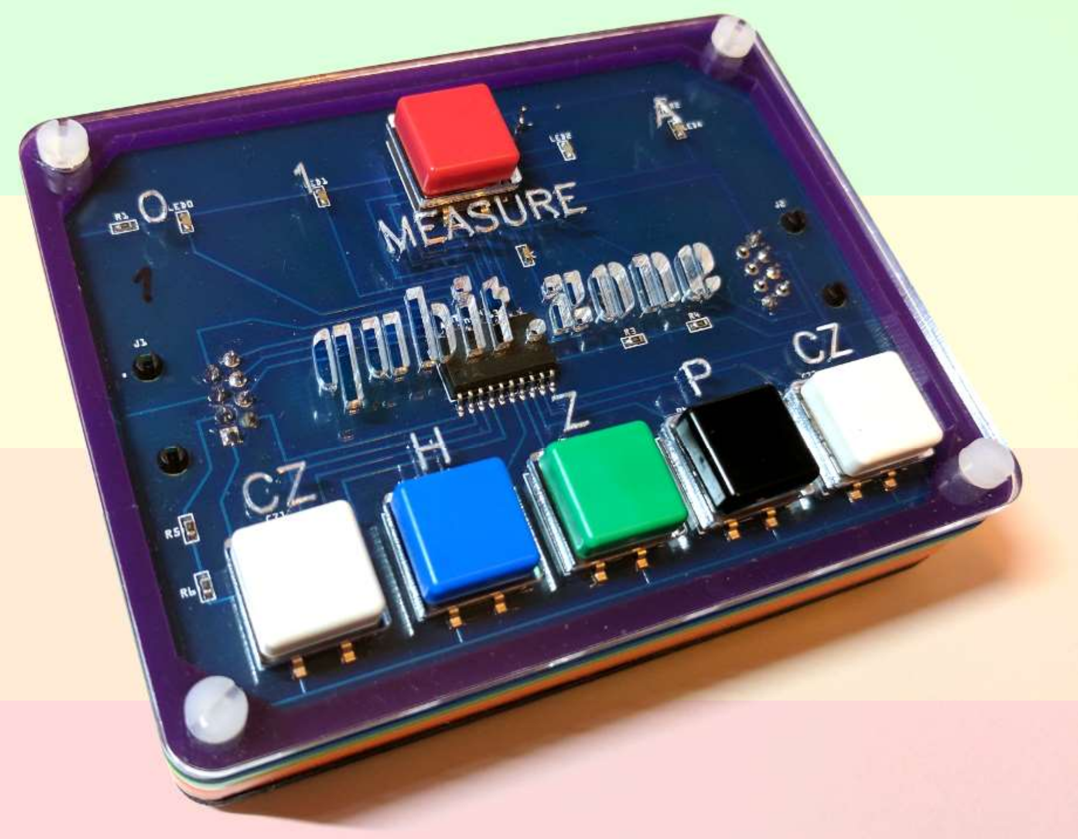
Ordinary computers are built from *bits*, which can equal 0 or 1.

Quantum computers will be built from *qubits*. You've got one in front of you.*

It has got lots of mysterious buttons. Give them a try!

We will use these qubits to investigate the properties of quantum computers.

* Just a *simulated* qubit unfortunately :(.



QUBITS

Let's try it!

① Press H, Z or P

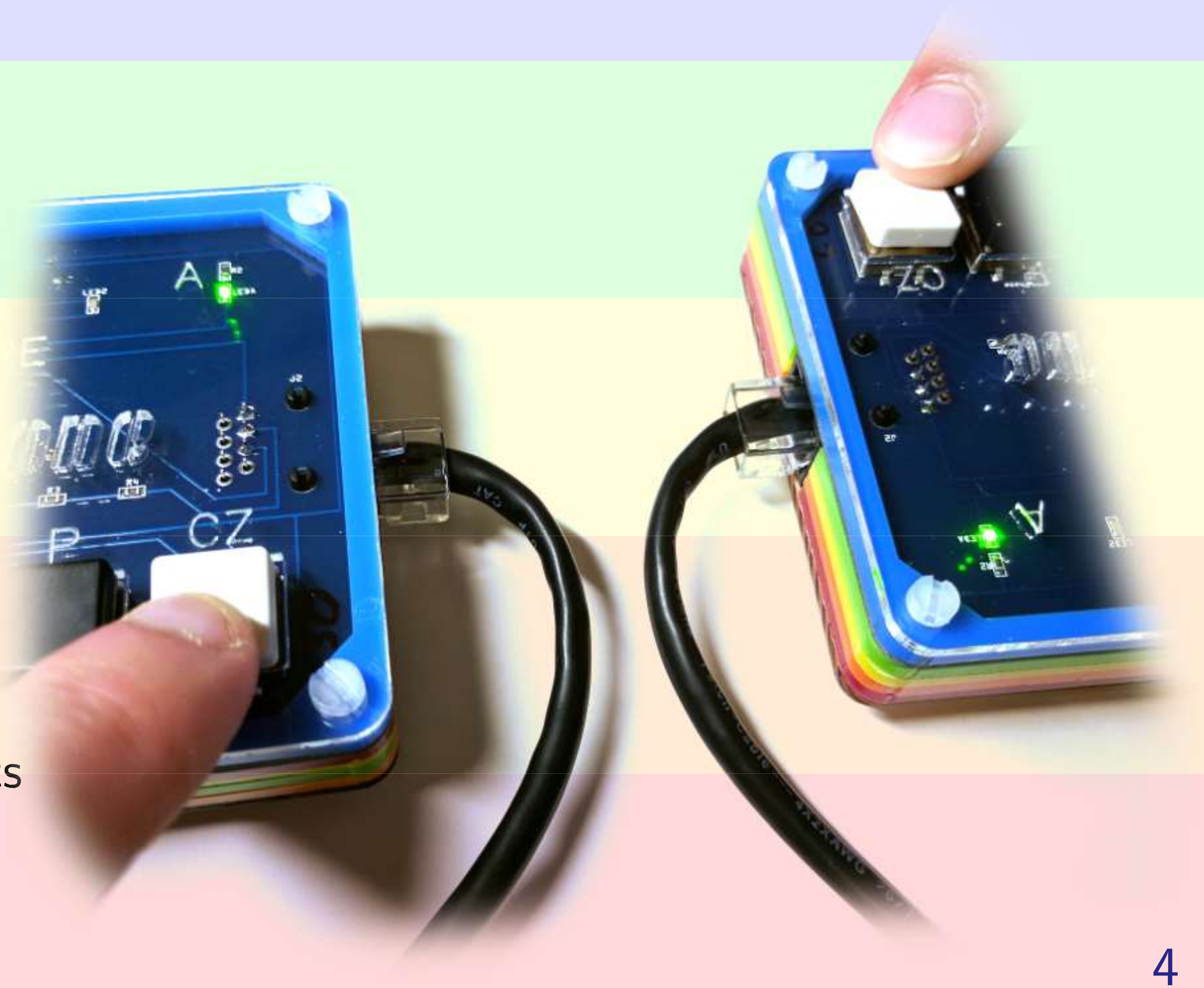
A green LED lights up in the corner.
This shows something is happening.

② Press M

A red LED light up as well,
showing 0 or 1.

③ Connect a cable between 2 qubits

On each qubit, press CZ buttons
by the cable at the same time.



SUPERPOSITION

Ordinary objects obey common-sense rules.

For example, they can't be in two places at once.

Quantum objects violate this rule! This is *superposition*.

A famous example is *Schrödinger's Cat*, both dead *and* alive.

But when we look in the box, it's dead *or* alive.

Scientists call this measurement. It *destroys* superposition.

SUPERPOSITION

Let's try it!

① Press M to measure at your qubit. It's storing 0 or 1

② Press H to put your qubit into superposition. Now it's storing 0 *and* 1

③ Press M to measure at your qubit. The superposition has been destroyed!

Sometimes we will need to *force* a qubit to store 0.

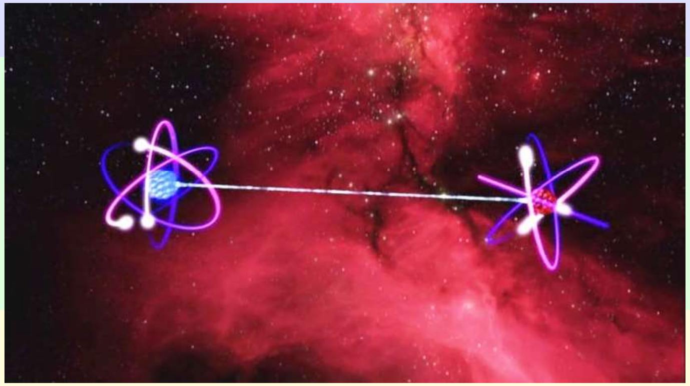
Do this by pressing H then M repeatedly, until you get 0.

ENTANGLEMENT

Two quantum systems can sometimes become strongly connected, even if they are far apart.

This is called *entanglement*.

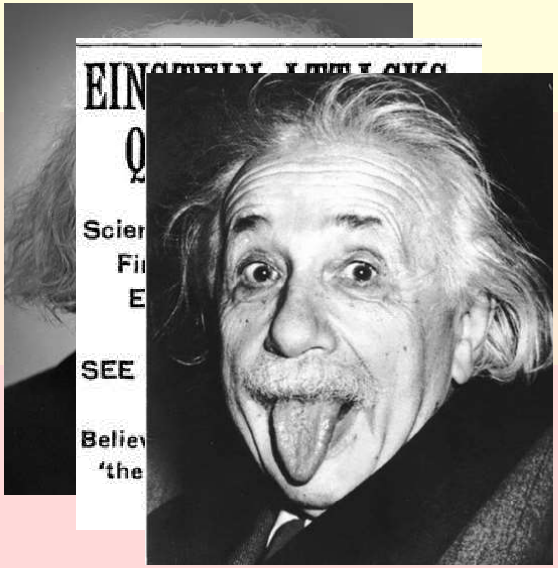
Although individually each system is unpredictable, they will match each other exactly.



Einstein hated quantum entanglement.

He thought it was "spooky", and showed that quantum mechanics wasn't a *complete* theory.

He was wrong! Silly Einstein.



ENTANGLEMENT

Let's try it! Get into pairs called Alice and Bob.

① Both store 0 in your qubits

② Both press H

③ Connect a cable and both press CZ

④ Remove the cable

⑤ Alice press H

The qubits are now entangled.

④ Alice and Bob, both press M

You should get the same result!

SUPER CODING

How many bits can you send using a qubit?

You can definitely send *one* bit:

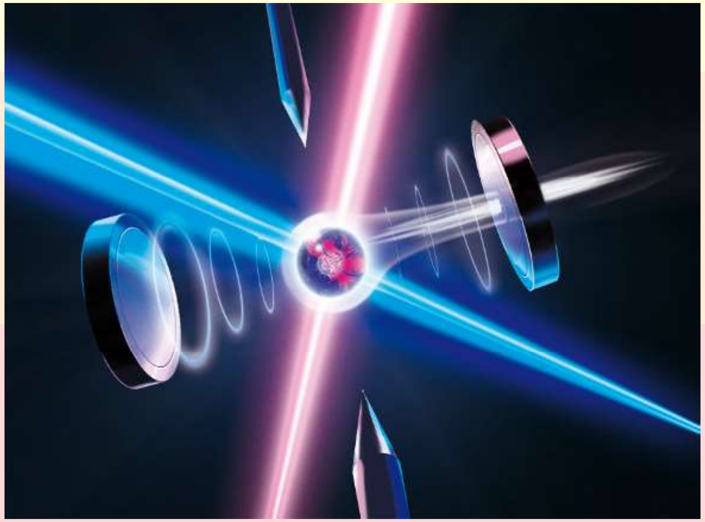
1. Press H then M until you get what you want
2. Send the qubit to your friend
3. Your friend presses M to receive the bit

In fact, you can use a qubit to send *two* bits!

This uses *entanglement* in a critical way.

This will allow quantum networks to transmit information with super efficiency.

There's a catch: the entanglement is *destroyed*.



SUPER CODING

Let's try it! Get into pairs called Alice and Bob.

1 Entangle your qubits

Alice's program:

2 Secretly choose a *first number* and *second number*, each either 0 or 1

3 If your first number is 1 press Z

4 Press H

5 If your second number is 1 press Z

6 Give your qubit to Bob

Bob's program:

7 Connect a cable and do CZ on both qubits

8 Press H separately on both qubits

9 Measure your original qubit.
This gives Alice's *first number*

10 Measure the qubit Alice gave you.
This gives Alice's *second number*

We've encoded two bits in a single qubit!

SUPER CODING

It seems like sending a qubit should transmit a *single number*.

But using entanglement, it can transmit *two numbers*.

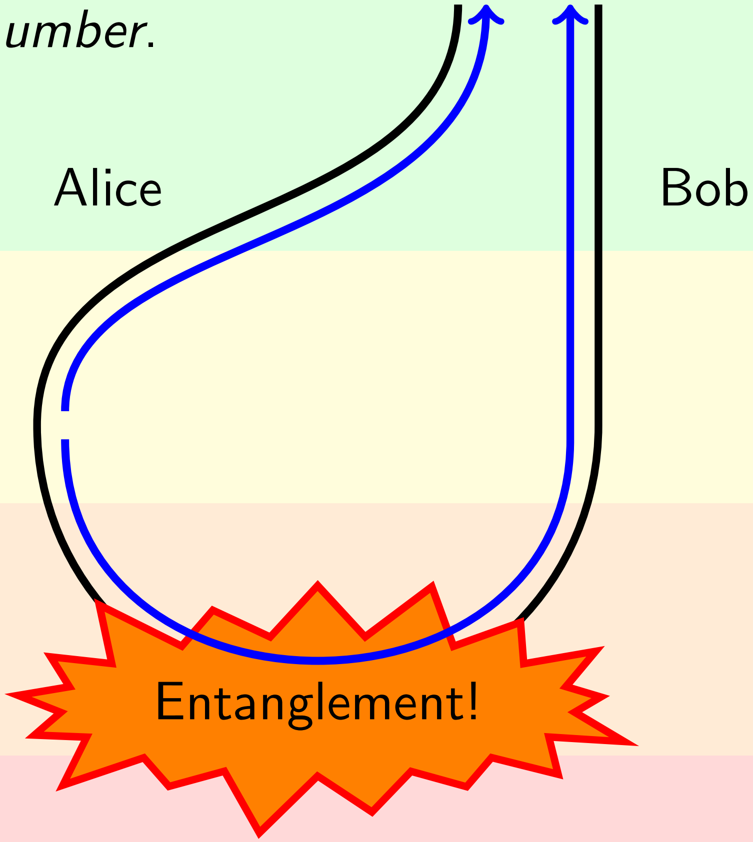
How can this be possible?

This picture represents our quantum program.

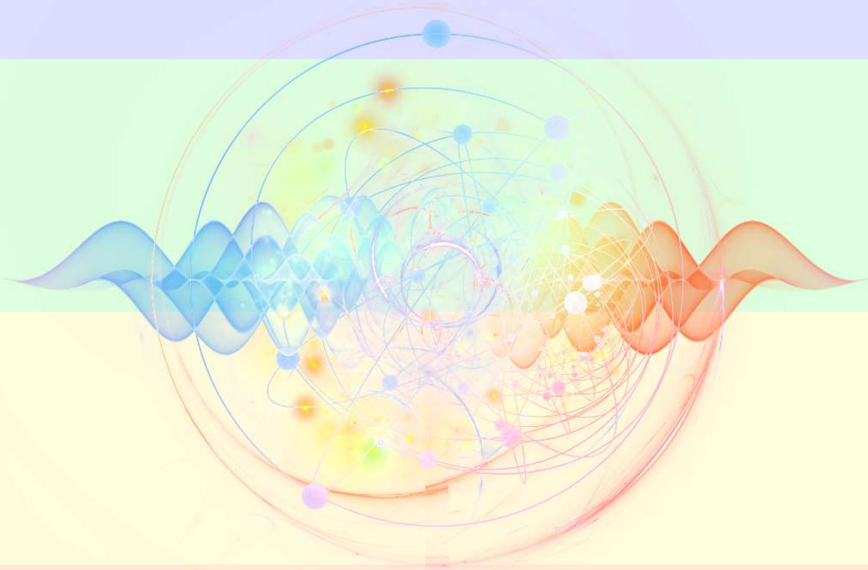
One number gets transmitted when Alice passes her qubit to Bob.

Some scientists have suggested the other number travels *back in time*, through the entangled state.

Probably not true. But it shows the difficulty scientists have understanding quantum computing.



THE END



We've explored some incredible quantum phenomena:

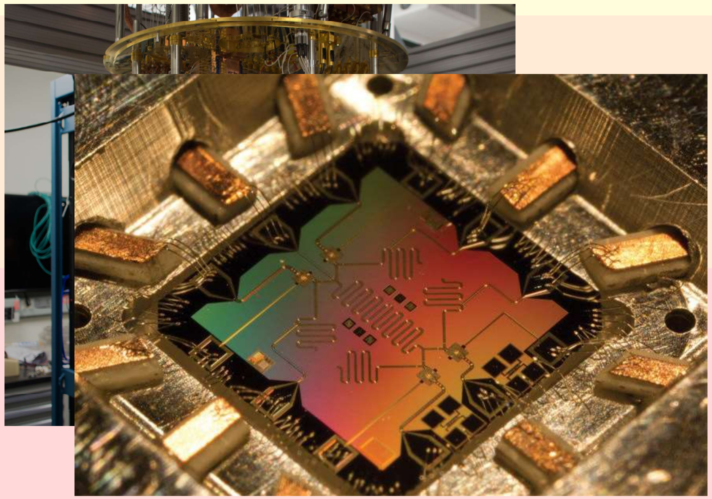
- Superposition
- Entanglement
- Super coding

But *when* will quantum computers arrive?

Just last month, IBM launched a 16-qubit quantum computer you can use over the internet.

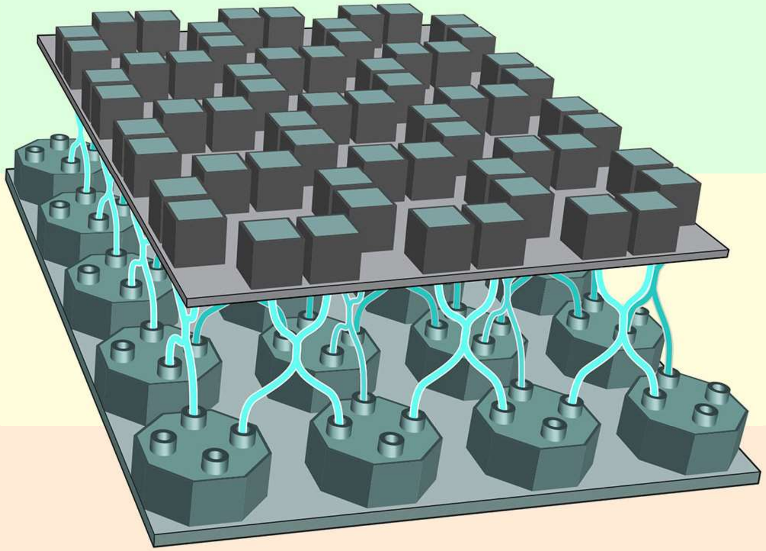
Google will release a 49-qubit machine this year.

The quantum revolution is about to begin!



REAL QUANTUM COMPUTERS

Real quantum computers don't exist yet. Here's a plan for one we're building in Oxford:



Each little octagon will hold 20 qubits, giving the whole computer 400 qubits.

We want to create entanglement and superposition across the *whole computer*.

It's hard because *errors* can easily accumulate.

REAL QUANTUM COMPUTERS

Let's try it!

1. Arrange your qubits in a single line, connected by cables
2. Everybody, store 0 in your qubit
3. Everybody, press H
4. First and second qubits press CZ, then the second qubit press H
5. Second and third qubits press CZ, then the third qubit press H

⋮

Last Step. Last two qubits press CZ, then last qubit press H

All the qubits are entangled! Or have errors destroyed the quantum effects?

Everybody, press M to measure your qubit!