



Suggestions for discussions in Tutorial 2:

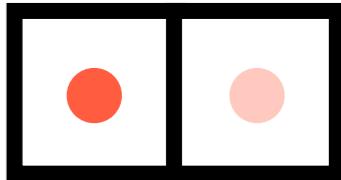
Let's talk quantum!

These slides are made exclusively for internal use
in the course CCST9077.

OUTLINE OF DISCUSSION TOPICS

The goal of today's tutorial is to help you digest the new ideas presented in Lecture 2 (quantum bits and their properties)

In that lecture, I introduced qubits with a “tale” about a magic box containing a ball that can be either on the left or on the right



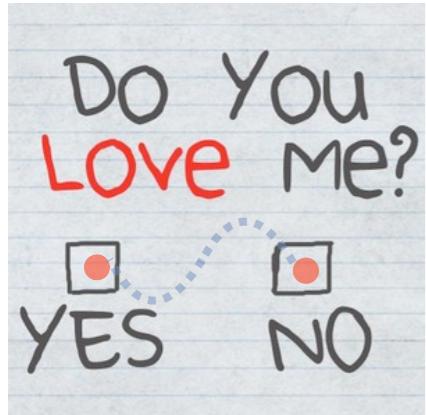
(1) Let's start with a game:

each of you constructs another “tale,” replacing the ball in the box with some other metaphor: for example, a box containing a cat, which can be either alive or dead.



Contest: let's see who can find the most interesting/ amusing tale!

Here are a few examples:



whether a person
loves you or not



whether a stock
will go up or down



whether an image
represents a duck
or a rabbit

What is your example?

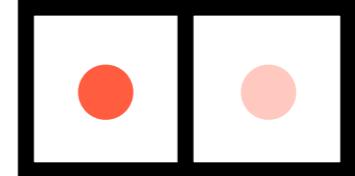
(2) Elaborate more on your tale:

in my example of the ball in the box,
there were two operations one could do on the box:
opening it, and shaking it.

What is the analogue of “opening the box” in your example?

What is the analogue of “shaking the box”?

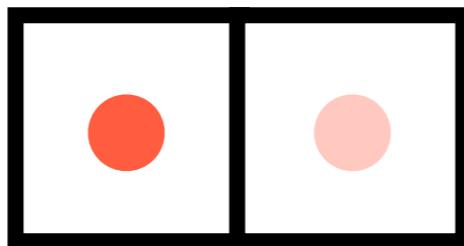
In my tale, I showed you an “experiment”
that could distinguish between a “superposition state”
and the situation where we just don’t know
whether the ball is on the left or on the right



*What kind of “experiment”
can you do in your tale?*

(3) What is real?

When a quantum particle is in a superposition of being in one place and another



we cannot say what its position is.

The position is not defined, it is not a “real property” of the particle.

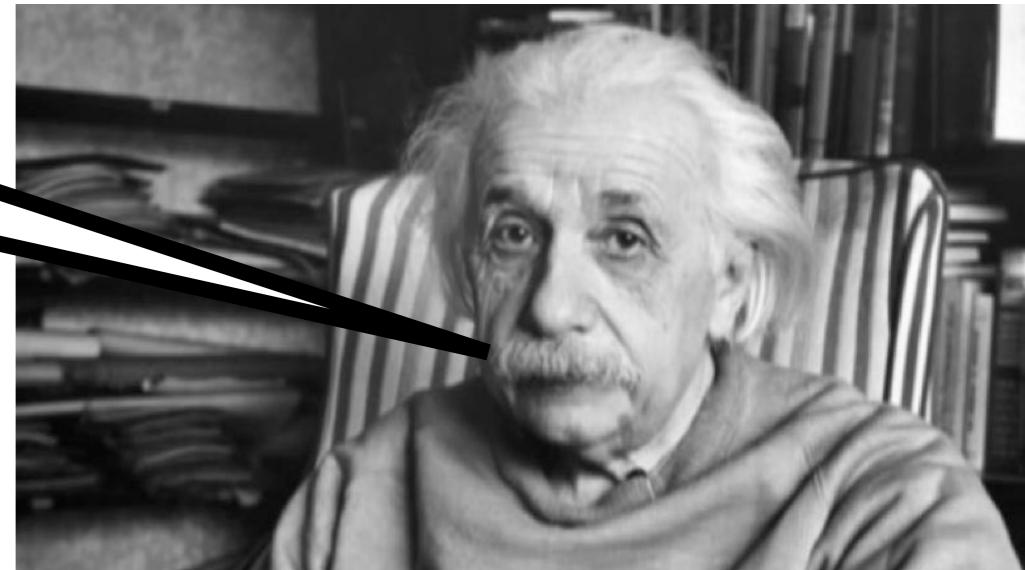
What is the thing that is “not real” in your tale?

And what things are still “real”?

(for example, in my tale the thing that is still real is that there is a ball in the box)

(4) Where is the border between the quantum world and the classical world of our everyday life?

I like to think that
the Moon is there
even if I am not looking
at it.



In everyday life, we don't see quantum superpositions.
We don't see cats in a superposition of being alive or dead.

Why is that?
Is it because everyday objects are “big”
and quantum physics applies to “small” things?

But how big should an object be, to behave in the way we are used to?
And aren't big objects made of small quantum particles?

Where is the border between the quantum world and the classical world?

THE BORDER TERRITORY

QUANTUM DOMAIN

PHOTONS
ELECTRONS
ATOMS
...
...

GRAVITY WAVE DETECTOR

QUANTUM BILL OF RIGHTS
INTERFERE IF YOU CAN!!!
SCHRODINGER'S EQUATION*

CLASSICAL DOMAIN

SUN
PLANETS
...
...
US
...
...

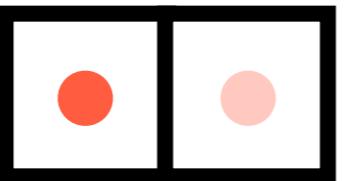
QUANTUM FLUIDS

CLASSICAL LAW AND ORDER
DO NOT INTERFERE!!!
NEWTON'S EQUATIONS
SECOND LAW OF THERMODYNAMICS

Cartoon by Wojciech H. Zurek

(5) But if there is no border, then what is real?

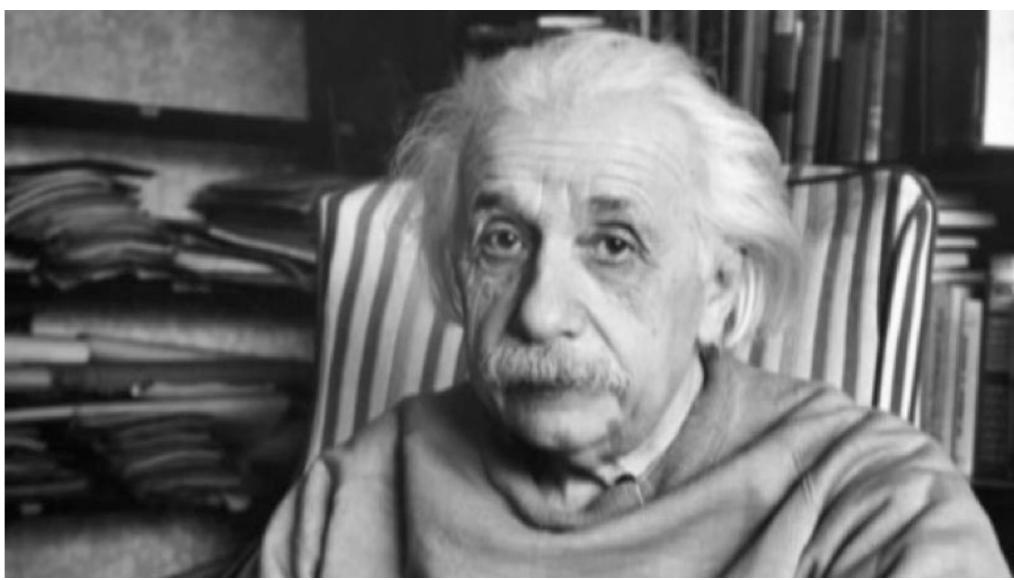
For the superposition state



the position of the ball is not real,
but at least there is one real thing: that the ball is in the box.

But we could think of another example where the ball is in a superposition of existing and not existing. In this example, the *existence* of the ball is not real.

Perhaps this is the issue that worried Einstein?



SOME INSPIRATIONS



Redwolf T-shirt



A meme that circulates on the web.
*This does not seem a good example...
...why?*



The disintegration of the persistence of memory, by Salvador Dalí

Painter Salvador Dalí was said to have been inspired by quantum mechanics for this painting. Note the “melting of reality” and how the familiar world is broken down into “bricks” (atoms? cells of a computer memory?)



Still from “Antman and the wasp” by Peyton Reed

“When I was brought in for the first movie to discuss some aspects of quantum physics that might be relevant to the plot, one of the things that really resonated with the writers and Paul [Rudd] was this idea that, as you go deeper and deeper into the Quantum Realm, the things that we take for granted – the idea that there are laws of physics, that there is a dimension of time and we're moving through it in one direction – all of these things potentially dissolve. *Reality itself is melting away and new possibilities appear.*”

Spiridon Michalakis, Caltech consultant for the movie Antman and the wasp.

GETTING STARTED

To kick off the discussion, let us start by making our own examples of “qubits”

After everyone has given their example,
we will vote for the most interesting/most amusing one.