QUANTUM MECHANICS

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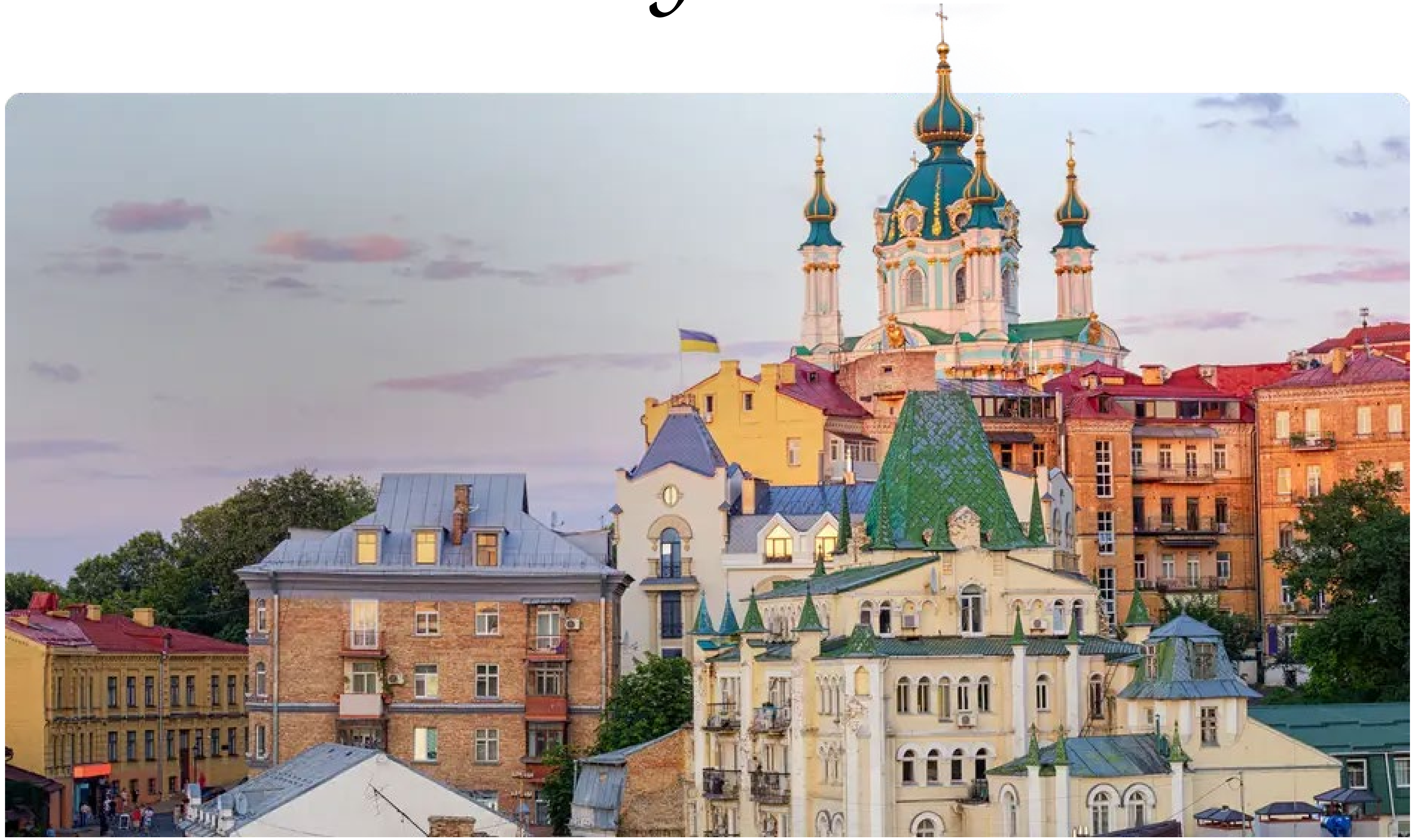
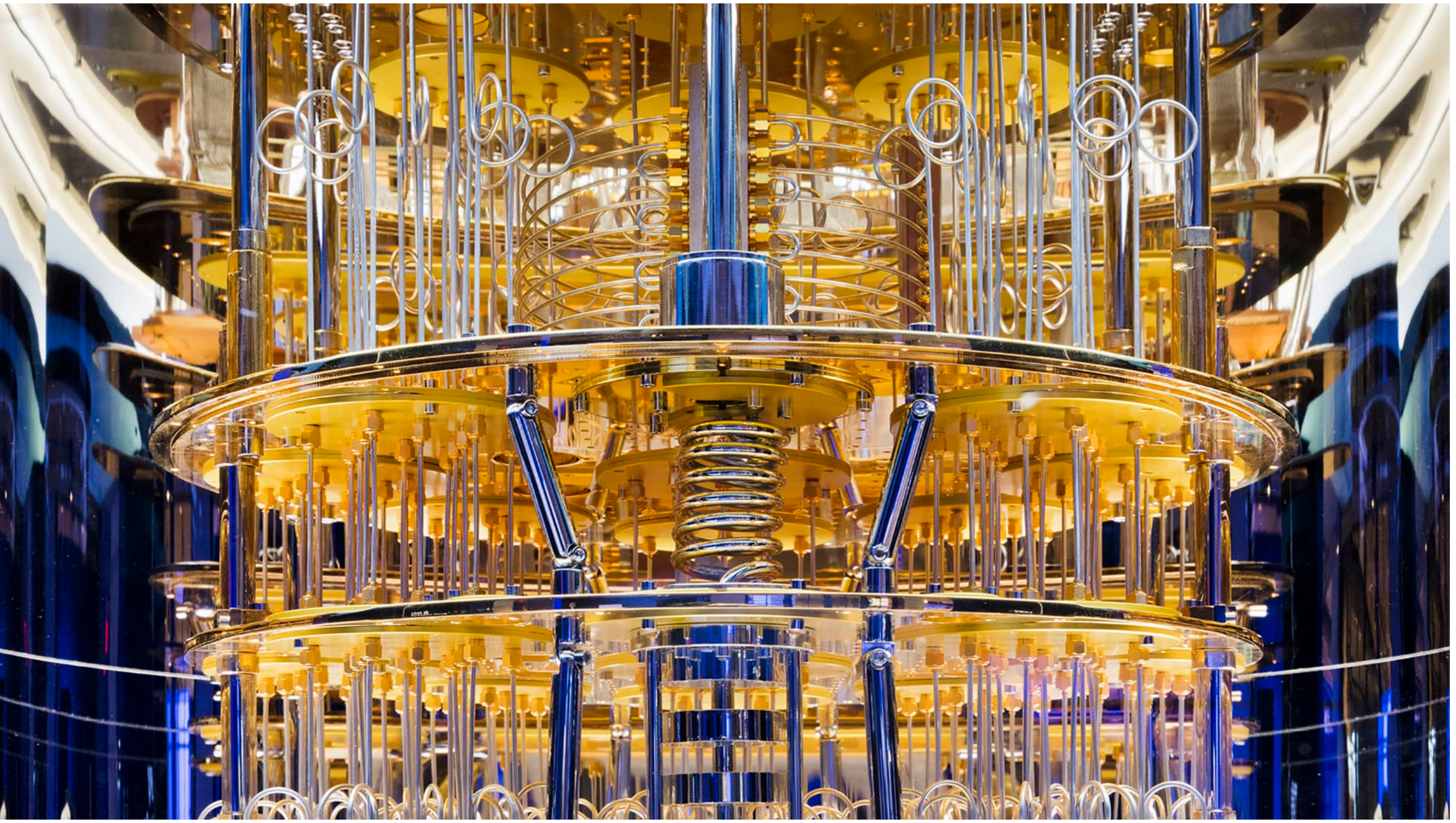
Please join in a moment of silence in solidarity with the citizens of Ukraine



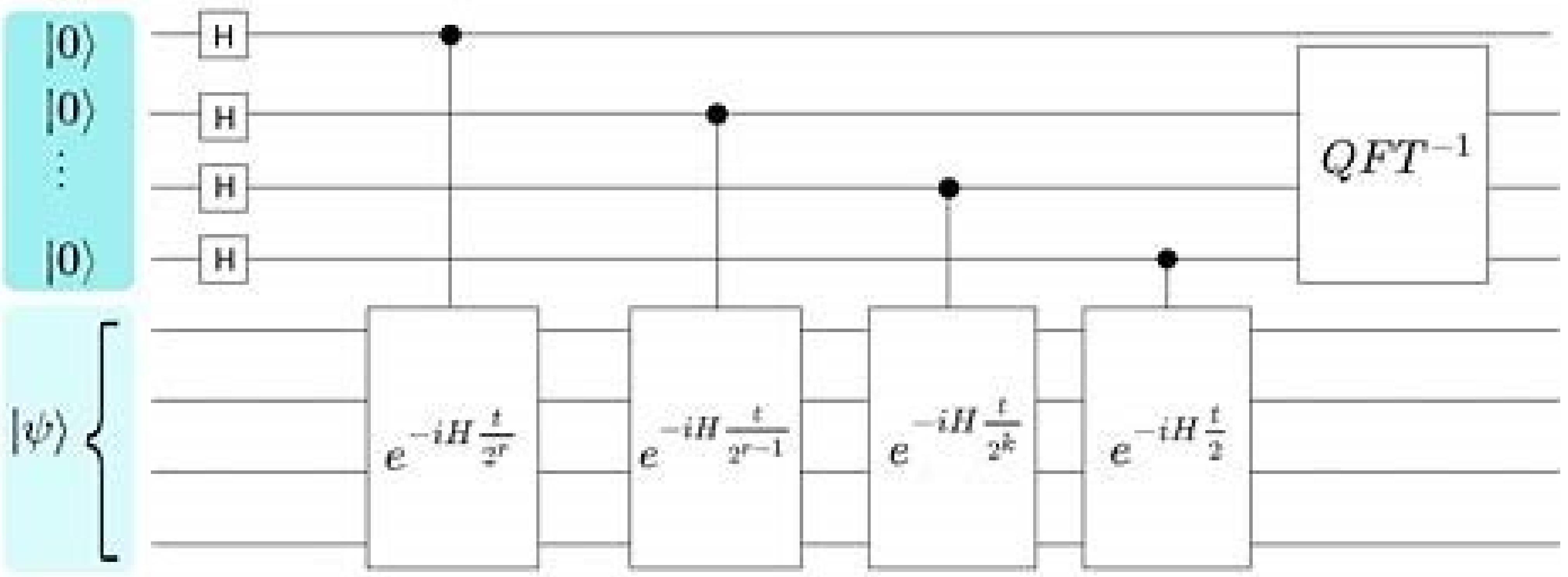
Quantum information science

Quantum information science has three pillars

Quantum computing

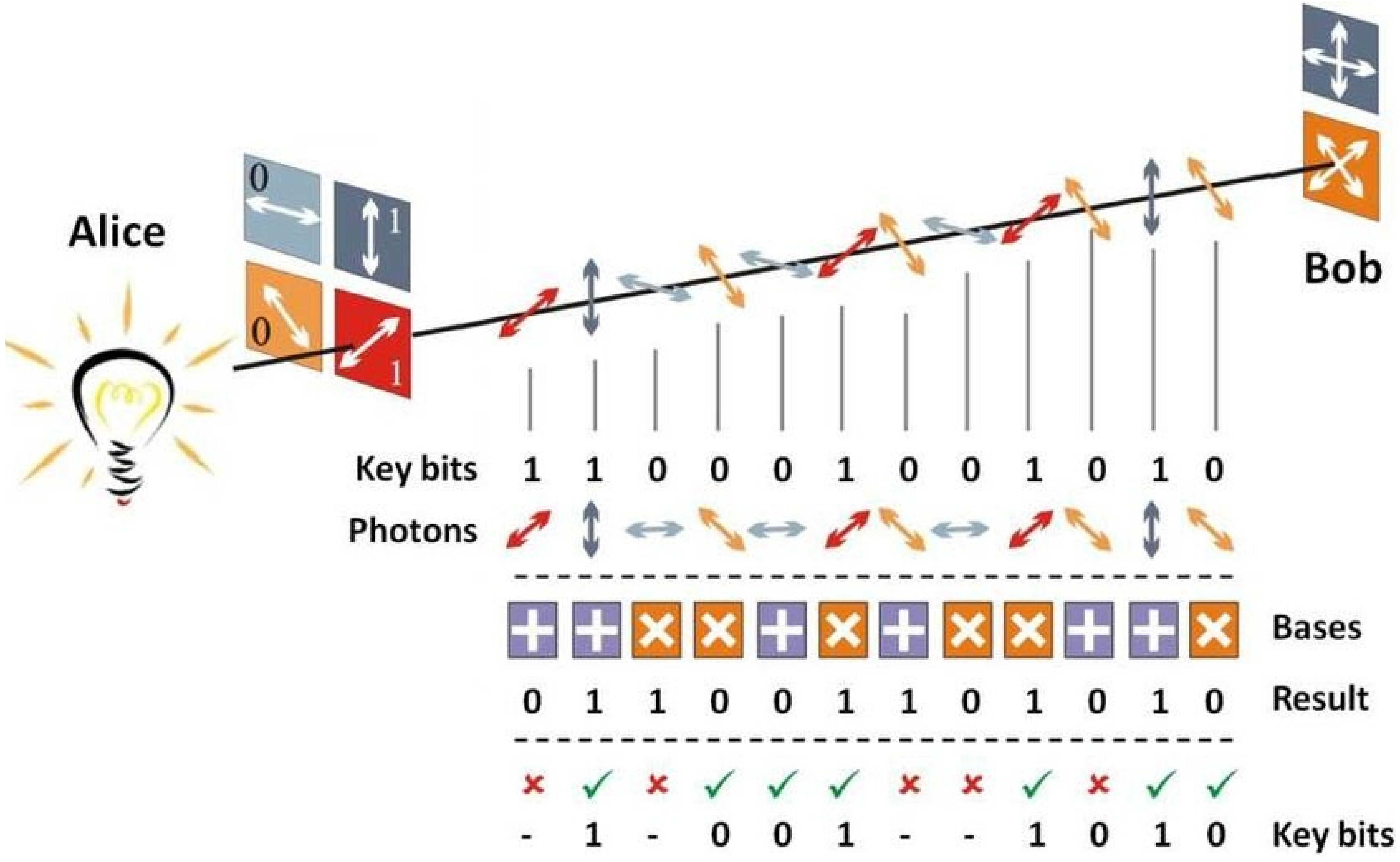


IBM quantum computer



Quantum Phase estimation algorithm

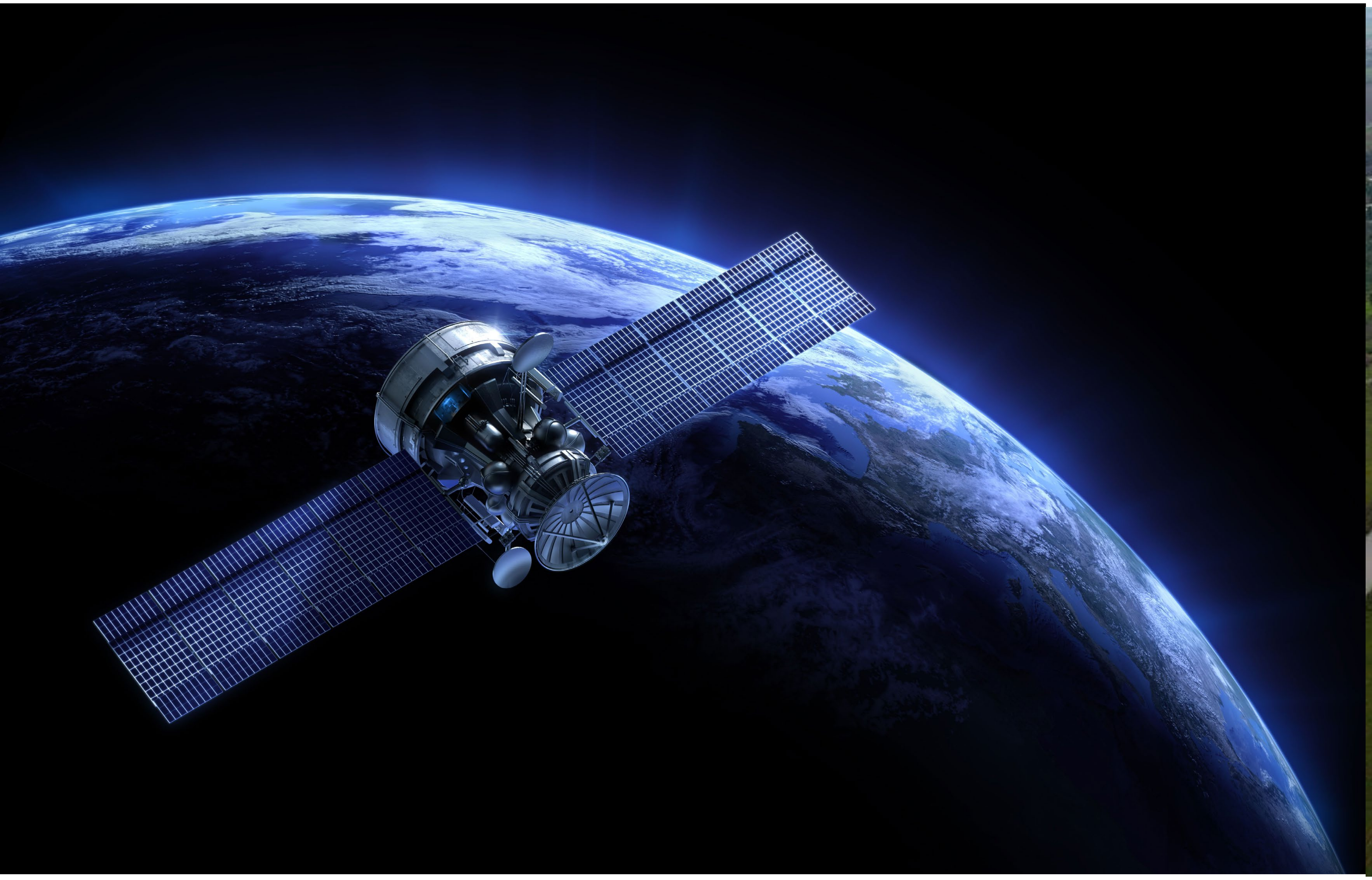
Quantum communication



IDQ quantum key distribution system

BB84 communication protocol

Quantum sensing



Global positioning system

Laser interferometry gravitational wave observatory

Physicists have the strongest overlap with the quantum sensing pillar

Let's supercharge your quantum mechanics course for quantum sensing

Asher Peres tells us to focus on the real world

Quantum phenomena do not occur in a Hilbert space. They occur in a laboratory.

So, be sure to teach quantum science, not quantum science fiction

The science fiction of quantum measurement

To measure a quantum observable:

(i) Prepare the quantum state to be measured

(ii) Entangle the state uniquely with the apparatus, so pointer states of the apparatus are correlated with the eigenstates of the measured operator

(iii) Apply collapse at measurement (or use decoherence to fix the pointer position)

John von Neumann

The science fiction of quantum measurement

But

John von Neumann

The science fiction of quantum measurement

I do not know of a single quantum experiment that operates in this way.

John von Neumann

The science fiction of quantum measurement

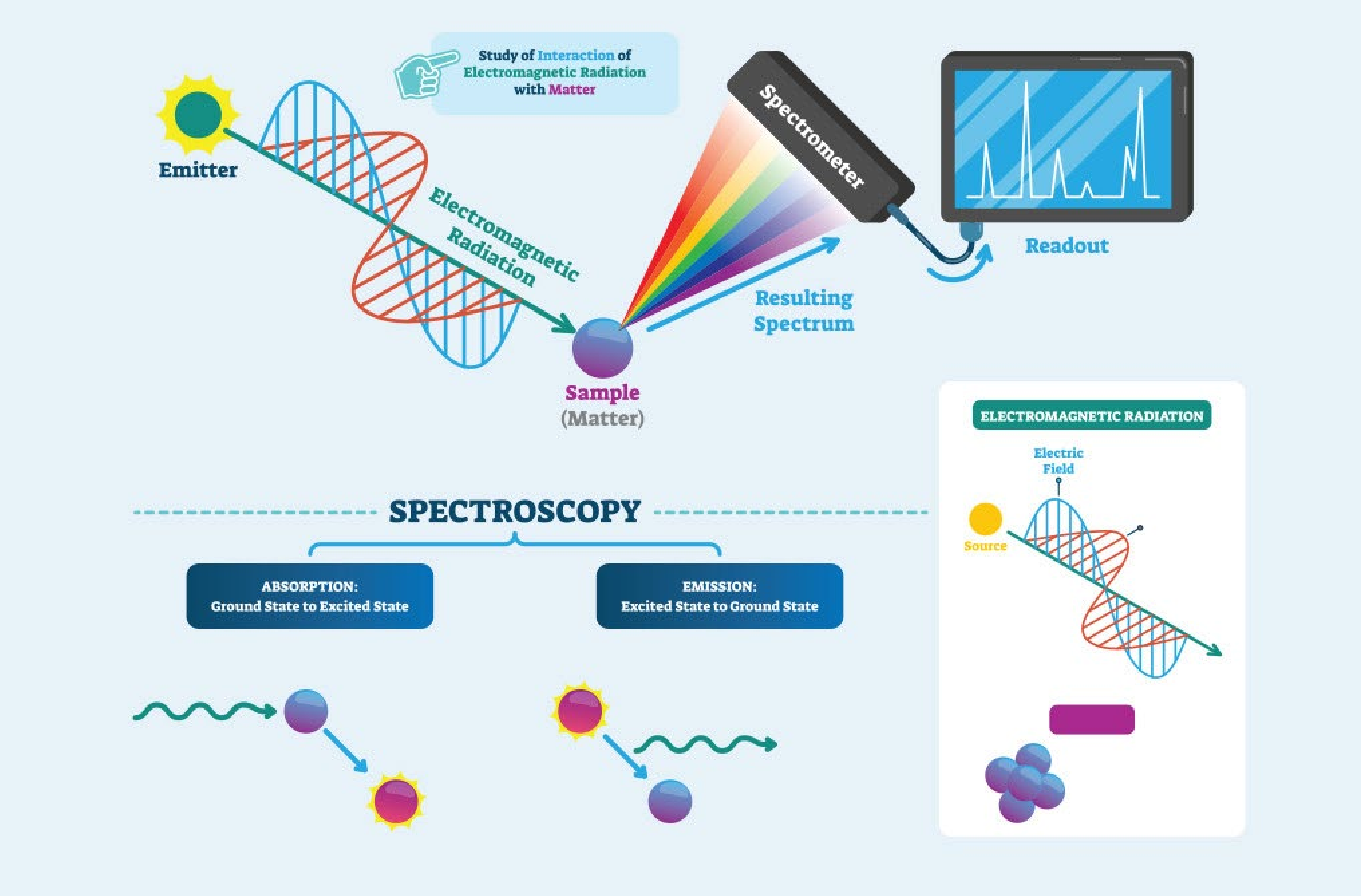
Why do we propose a measurement theory that has no basis in reality??

John von Neumann

How do we actually measure quantum objects?

In many cases we *infer* properties by clever experimental set ups.

Spectroscopy

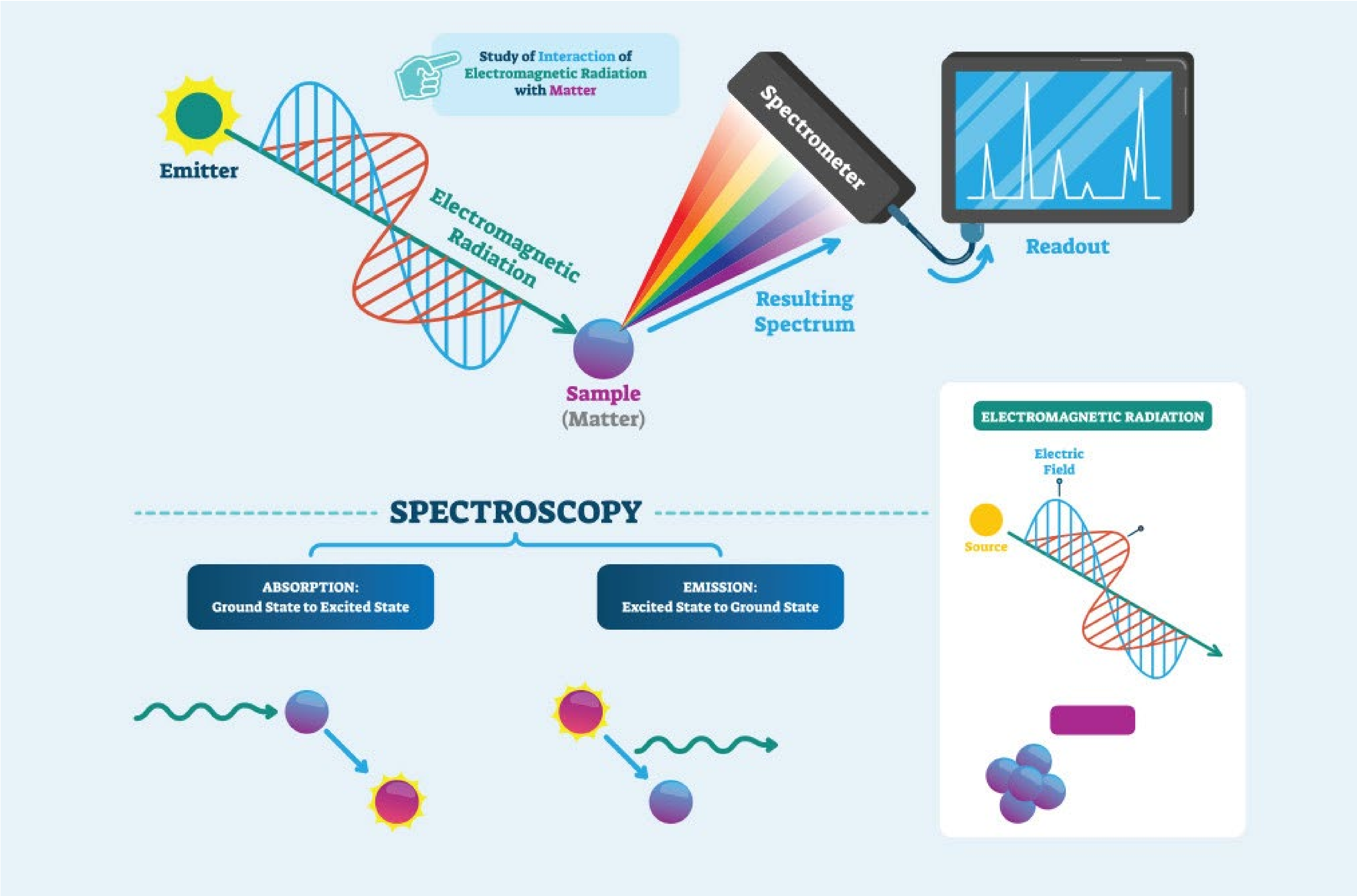


Shine light in, diffract off a grating, measure an angle, determine an energy

Where is the entanglement?

What is the pointer?

Where is the wavefunction collapse?



Spectroscopy falls into the wide class of quantum measurements that involve counting quantum particles

Such experiments do not obey the projective measurement paradigm and often are not discussed in textbooks

How would you respond to this question?

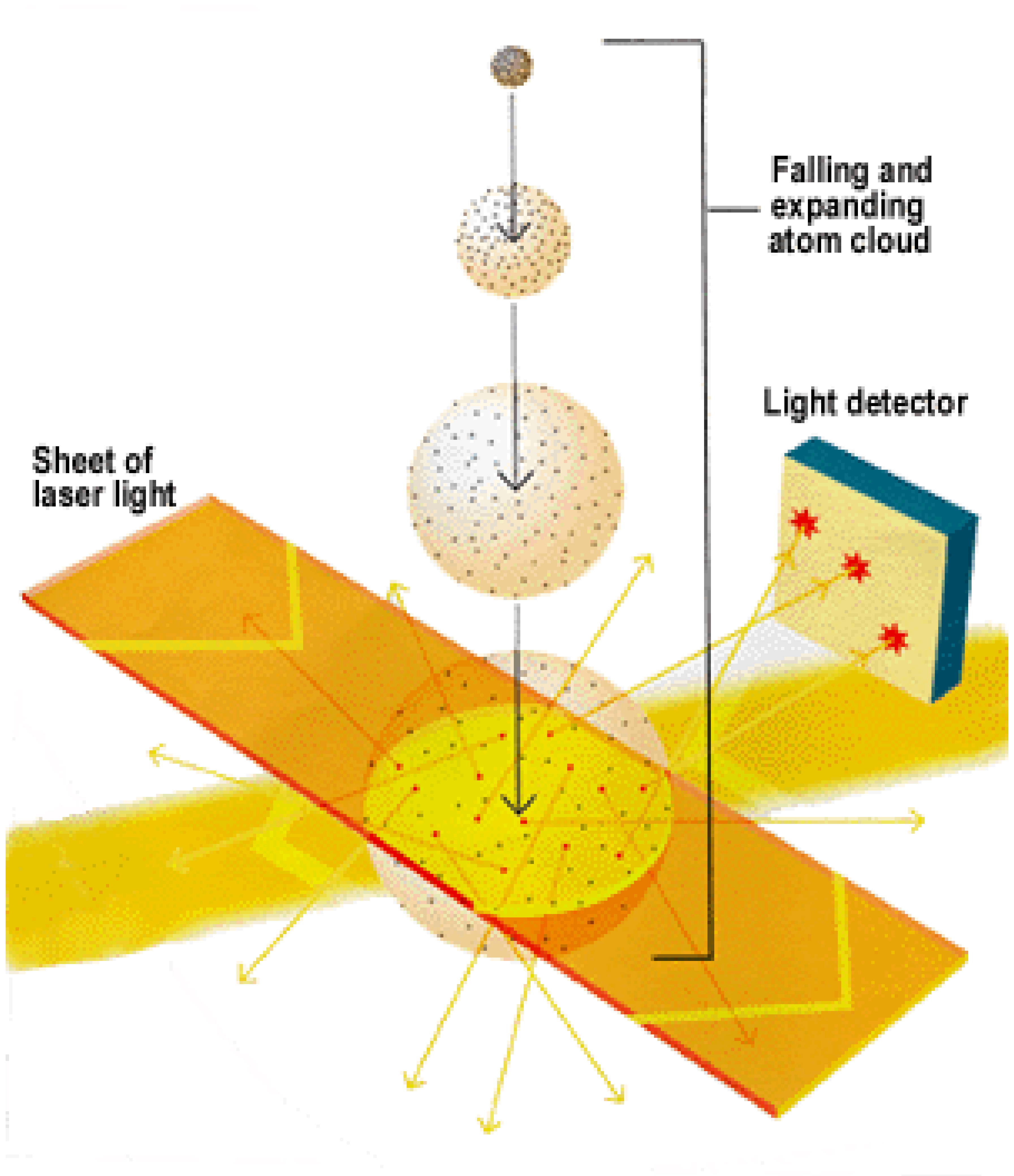
What variables can be measured in physics? Is it only the position of a particle that is always measured and the rest of the variables inferred from it?

One common answer:

- Dynamic variables include position, momentum, phase, spin orientation, and polarization can be measured independently. But noncommuting operators cannot be measured at the same time.
- Also known as: *if it is a Hermitian operator, it can be measured, but it must respect uncertainty*.
- But, isn't the detector located at some position? Isn't it always *de facto* measuring position along with whatever else it measures?

Time of flight

1. An event starts a clock
2. The particle travels through free space to the detector where it is detected
3. We divide the distance travelled by the time to compute the speed
4. From the speed we get the momentum
5. At the instant of measurement, we know the position and the momentum of the particle at the same time.



It is simply not true that one cannot measure position and momentum at the same time! Please don't tell your students this.

Quantum measurement is difficult and subtle. We should always describe precisely how it is done and never say it can "just be done."

Interaction-free experiment

We all know a simple interaction-free experiment

It is in every quantum textbook

The Millikan oil-drop experiment

Harvey Fletcher soon after his wedding in September 1908. (Photograph provided by Stephen Fletcher.)

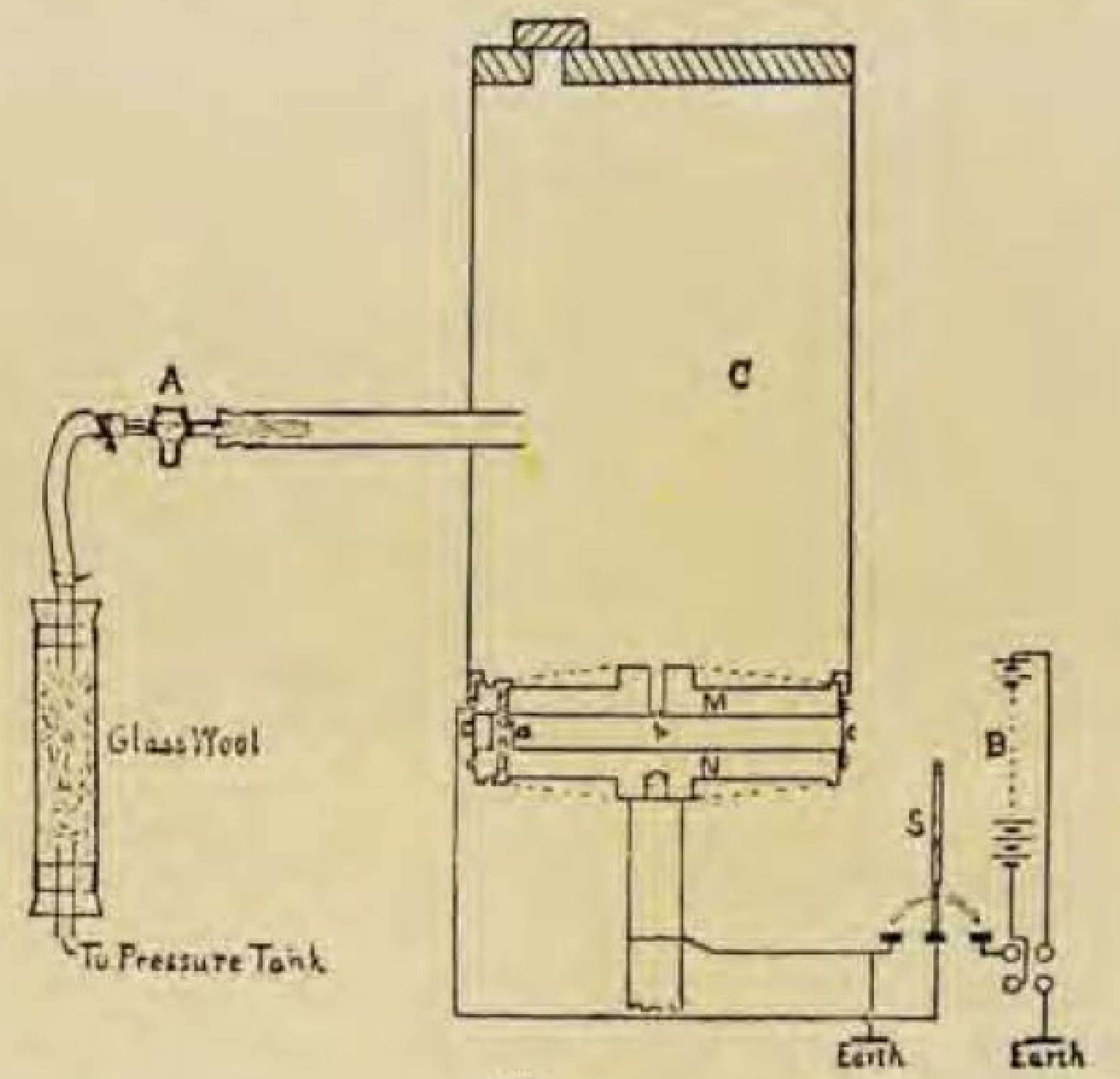


Fig. 3

Fletcher
The ~~Millikan~~ oil-drop experiment

Harvey Fletcher soon after his wedding in September 1908. (Photograph provided by Stephen Fletcher.)

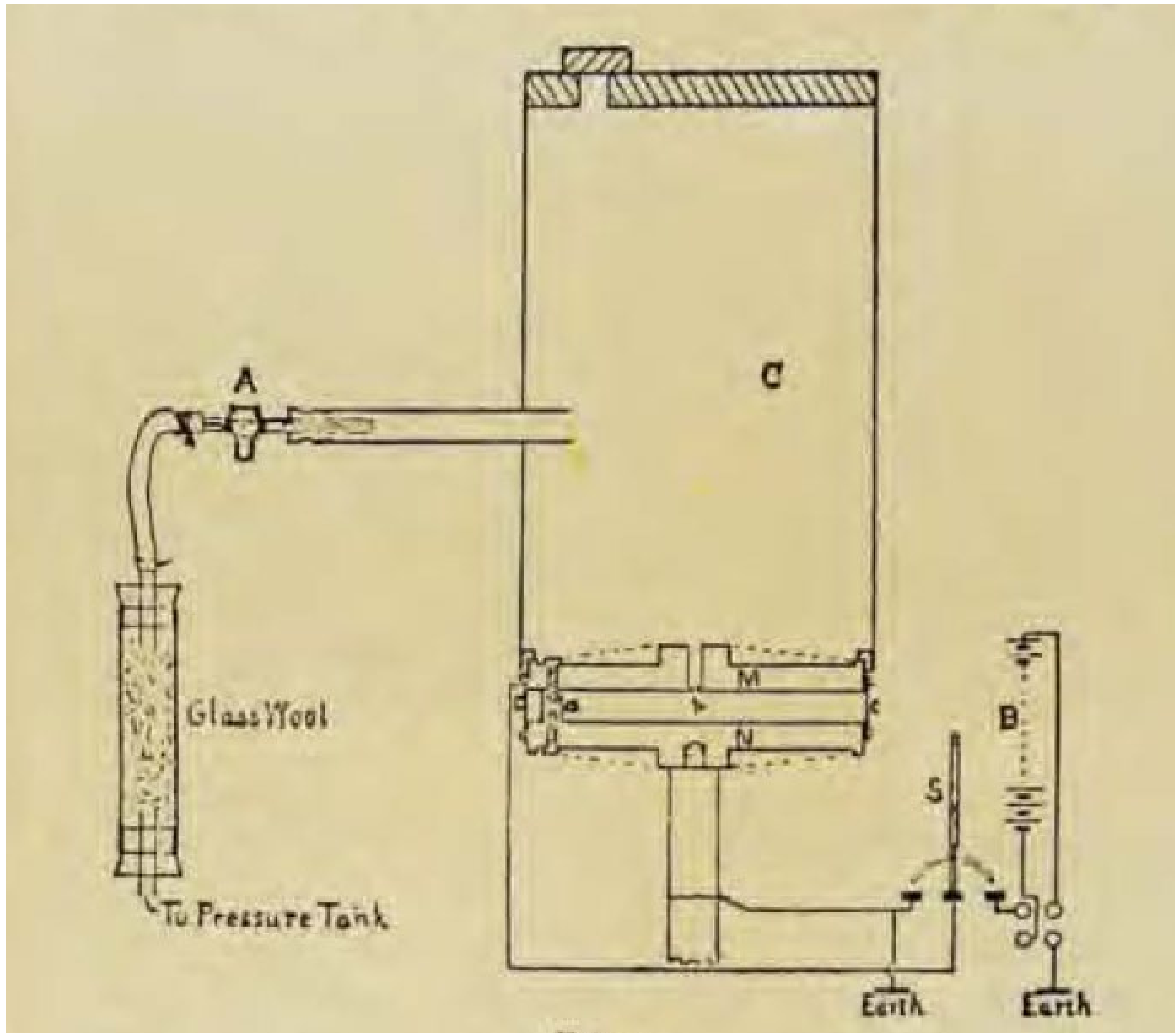


FIG. 3

We have a great opportunity to improve quantum-mechanics instruction.
Come and join with us.

Thanks to

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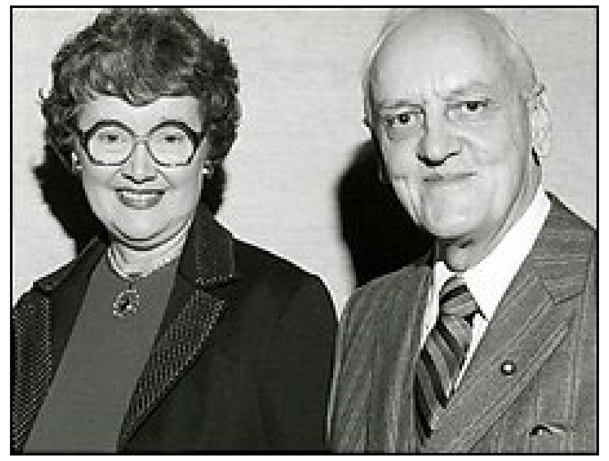
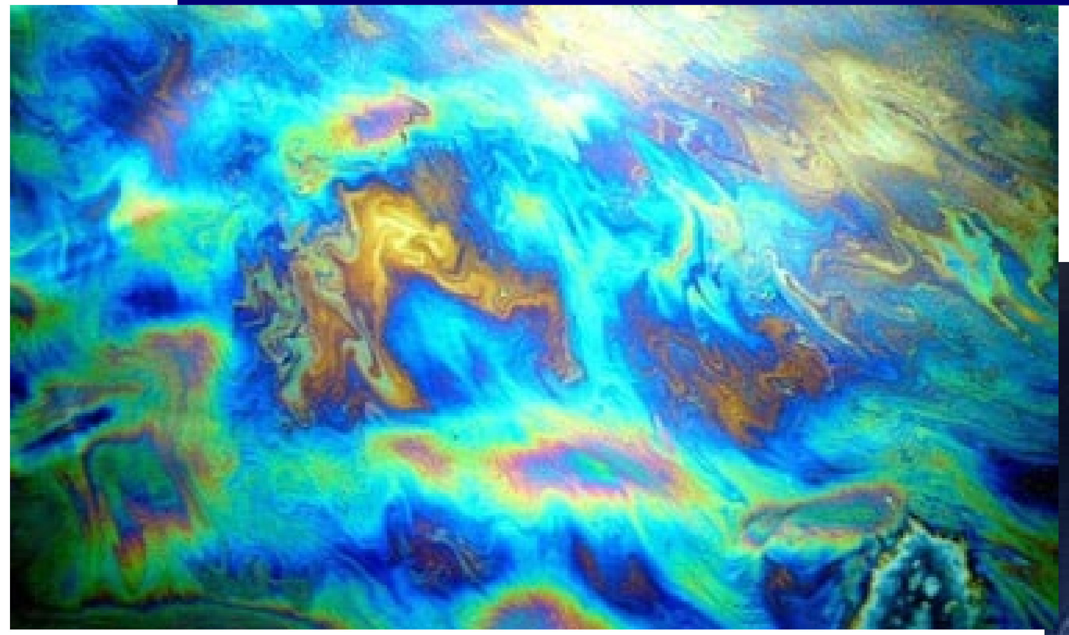


Resources

$\langle q | \hat{O} | m \rangle$

Quantum operator mechanics

https://quantum.georgetown.domains



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