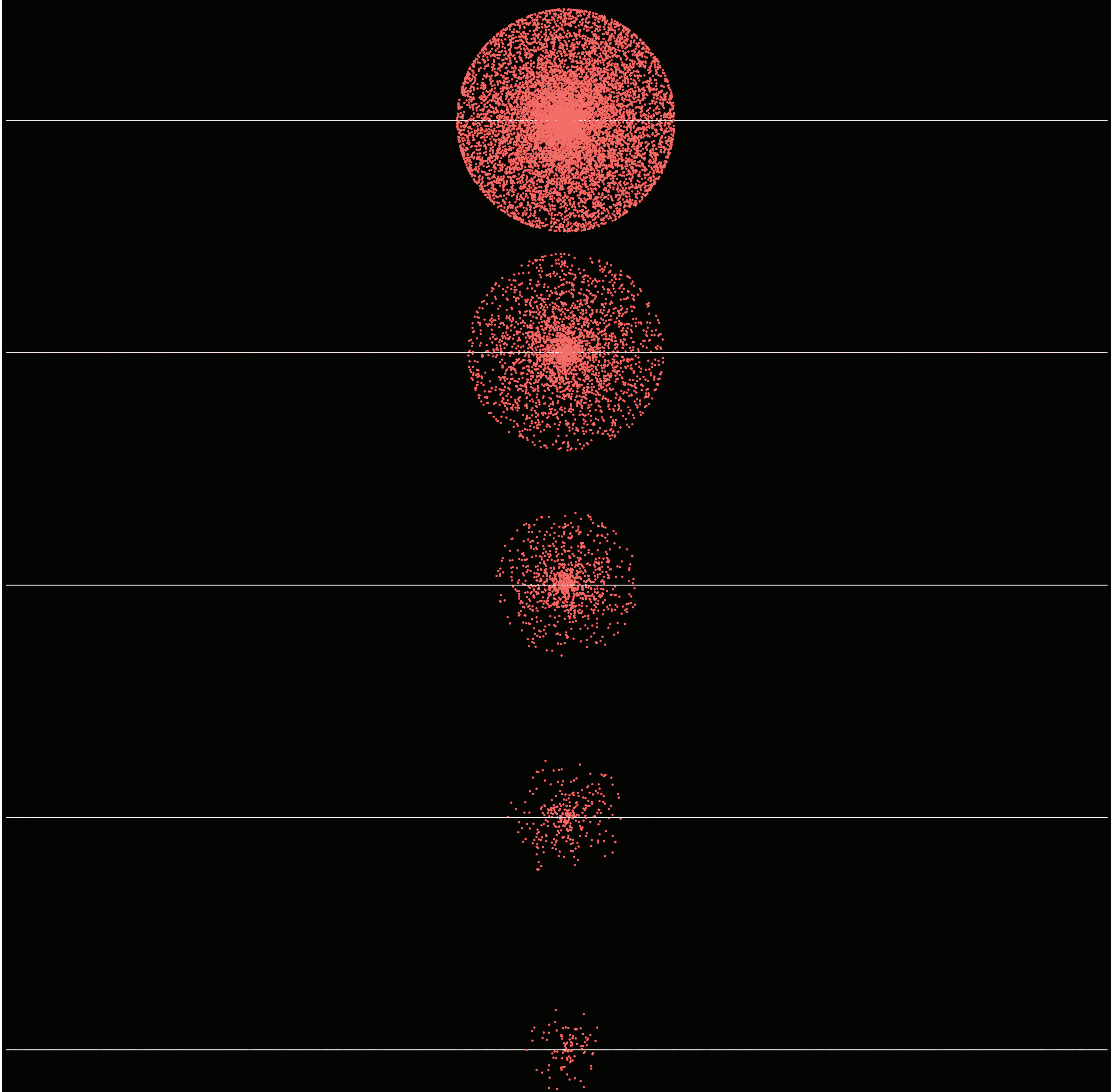
Quantum

de·co·ded

Five properties that will amaze you

These posters were created by the "Physics Reimagined" team / physics : Julien Bobroff / design : da fox

1 Quantization



Discontinuous Behavior

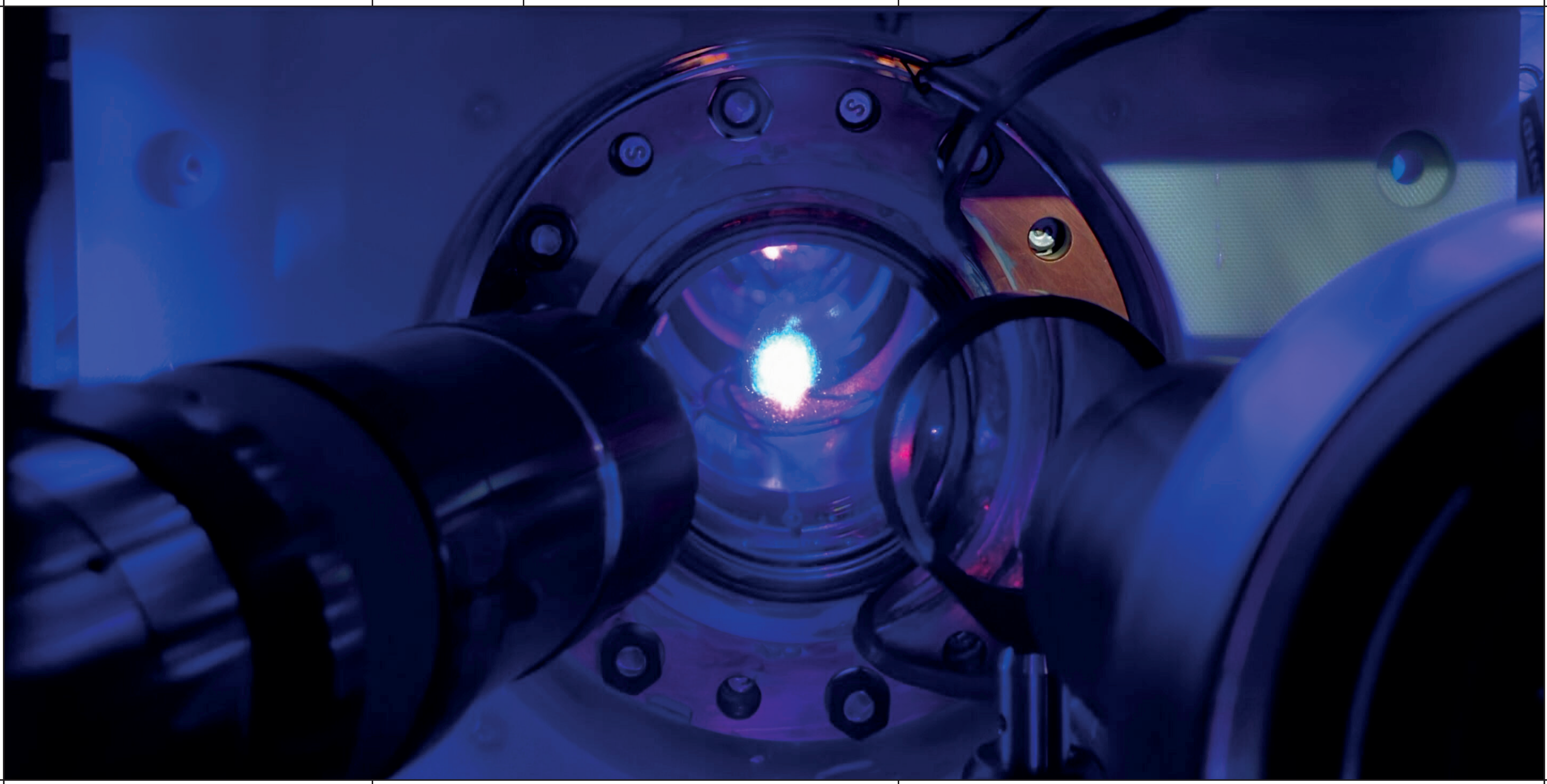
A quantum object, such as an electron in an atom, exhibits “quantized,” discontinuous behaviors.

For example, it occupies an energy level, like a rung on a ladder.

The electron can suddenly jump to another level, but it will never be found between two levels.

1

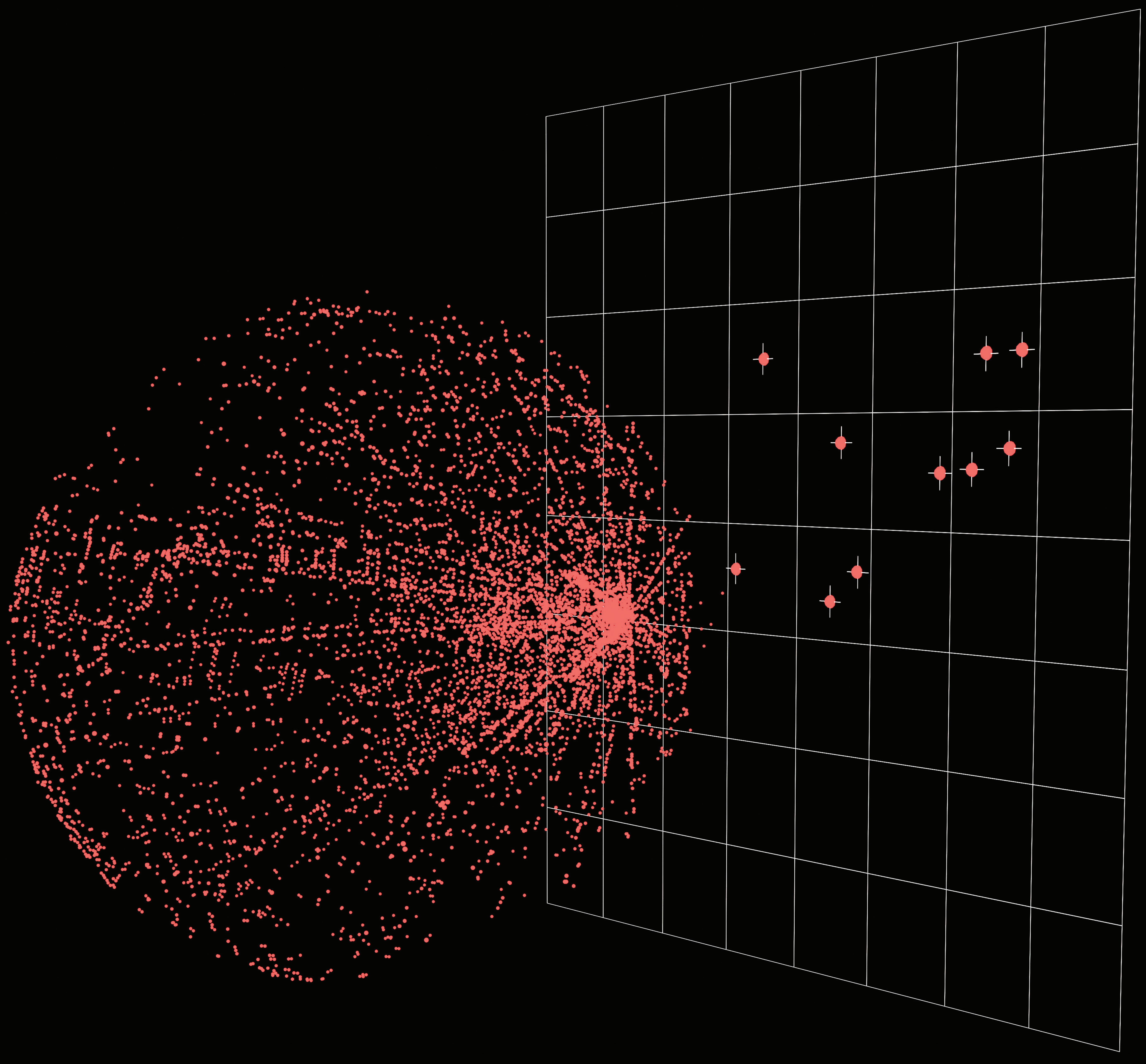
The world's most precise clock is quantum



By shining an ultra-precise laser on strontium atoms, researchers have created the world's most accurate atomic clock. The laser's frequency is fine-tuned to make an electron in the strontium atom jump between its energy levels, and the clock is synchronized to this frequency. It then measures time to within a billionth of a billionth of a second.

« Clock with 8× 10^{-19} systematic uncertainty. »
A. Aeppli et al., Phys. Rev. Lett. (2024)
Jun Ye team, NIST and the University of Colorado Boulder (USA) @ Kyungtae Kim, JILA

2 Duality

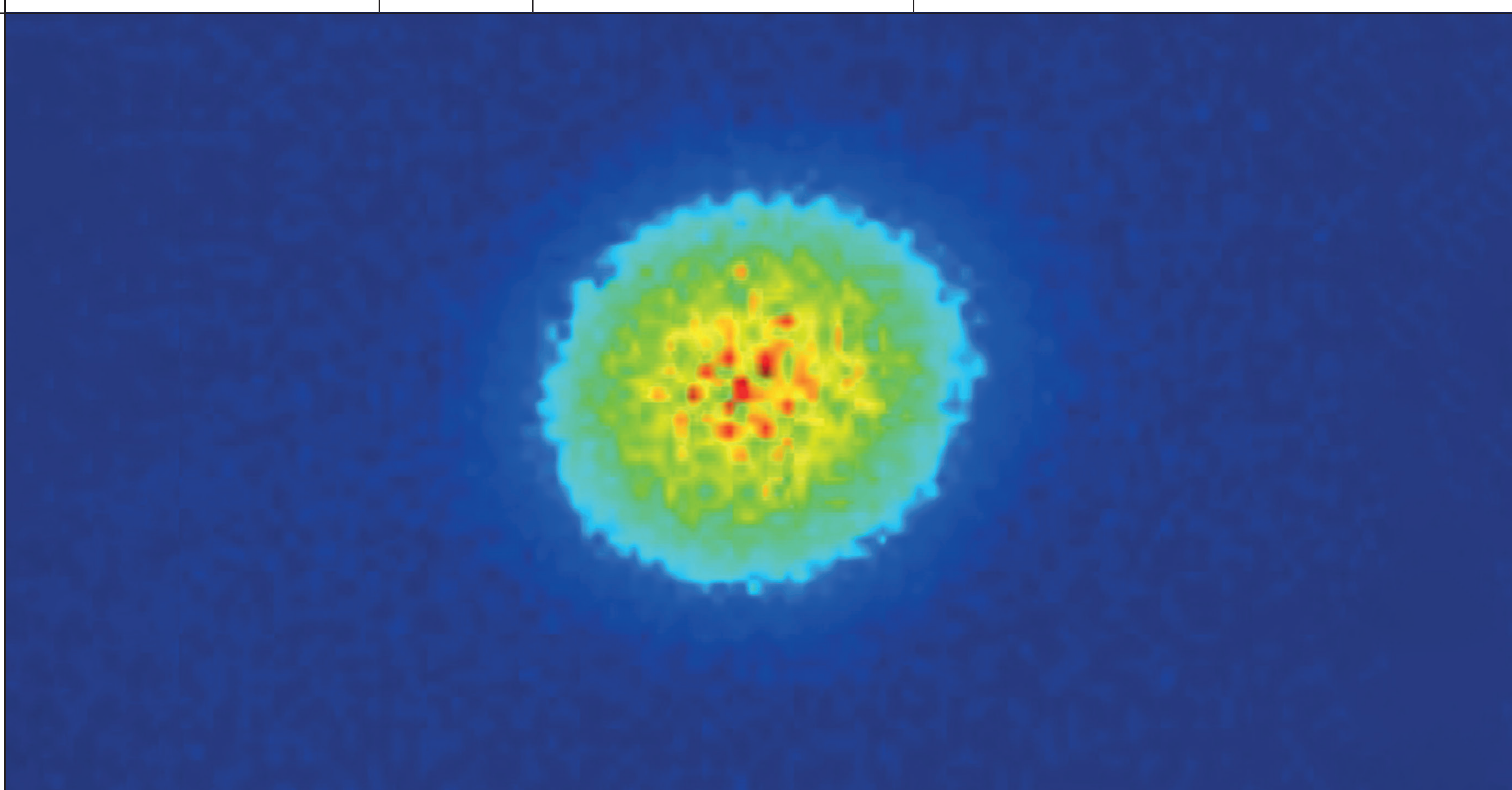


Wave or Particle?

A quantum object occupies an entire region of space, somewhat like a cloud or a wave. When attempting to measure its location, it suddenly localizes at a precise spot, as if randomly selected from within that cloud!

But beforehand, it is impossible to determine exactly where it is located—we can only calculate its probability…

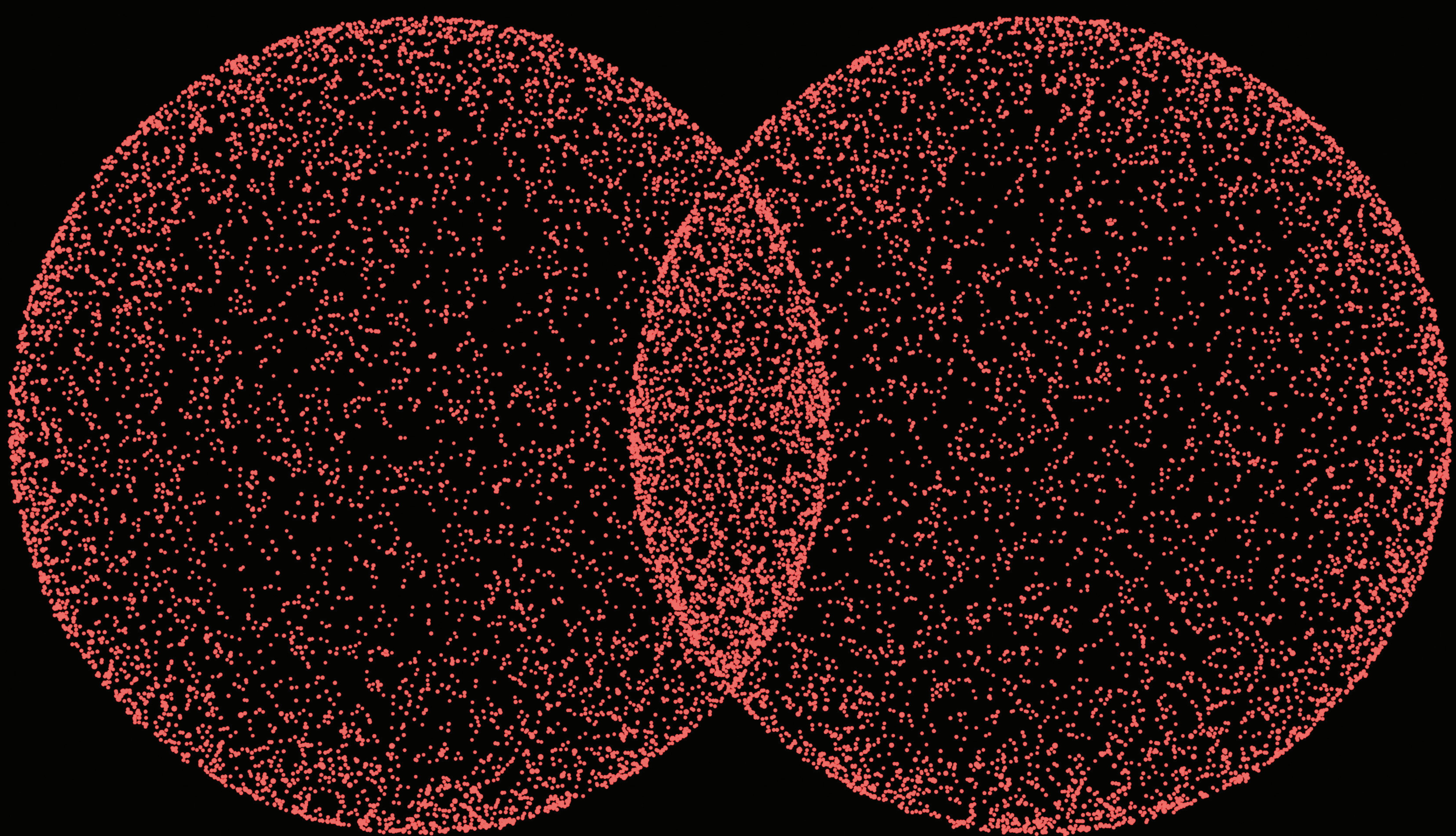
2 Here's what an electron in a hydrogen atom looks like



While we can't directly observe an electron's shape within an atom, scientists have indirectly mapped its presence in a hydrogen atom.
The electron occupies a cloud-like region around the nucleus, defined by its quantum wave function.
The height of the image is less than one nanometer.

« Hydrogen Atoms under Magnification: Direct Observation of the Nodal Structure of Stark States» A. S. Stodolna et al, Phys. Rev. Lett. (2013) Marc Vrakking team, Max Planck Institute Berlin (Germany)

3 Superposition of States



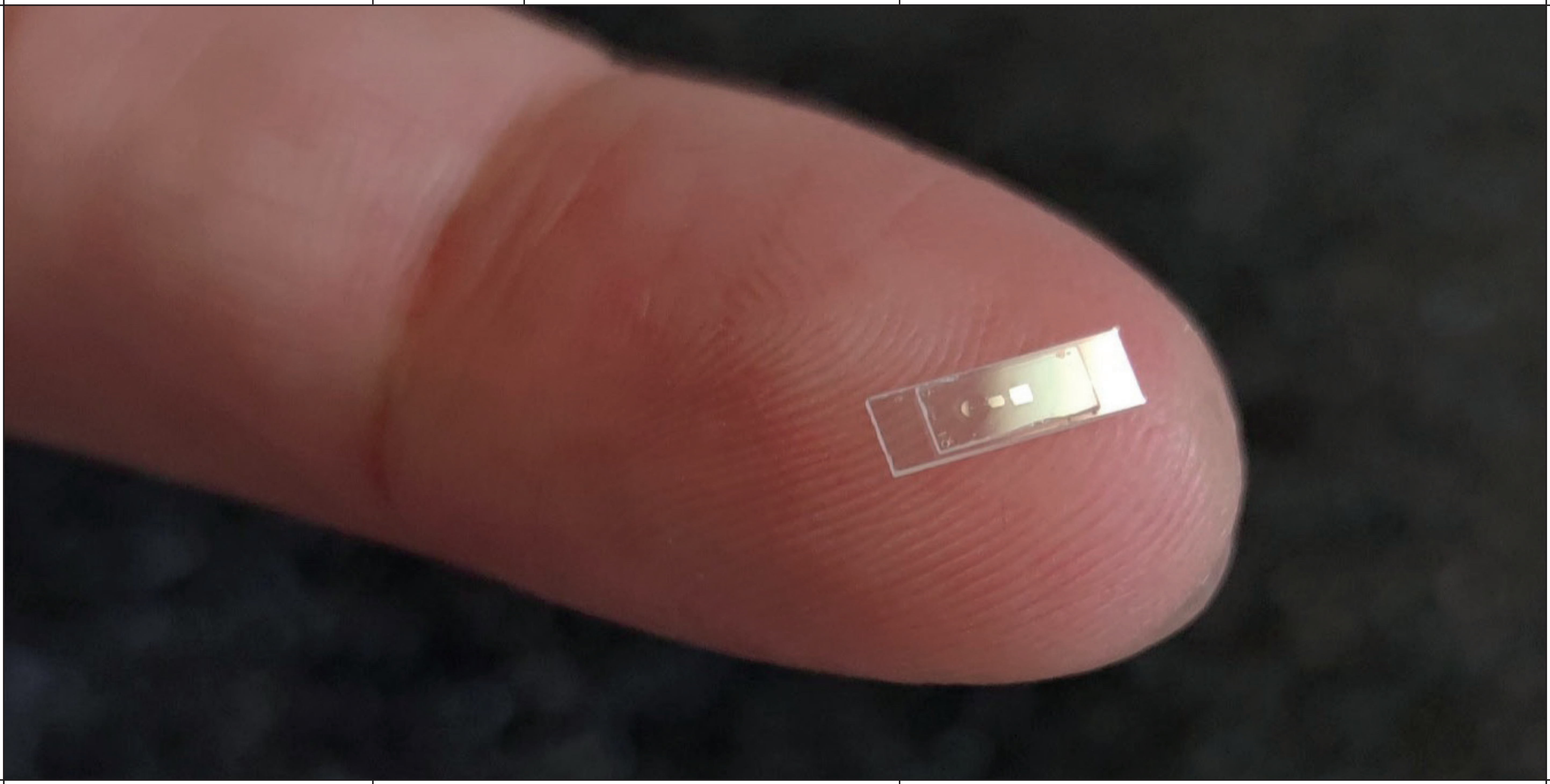
Quantum Ubiquity

A quantum object can exist in multiple states simultaneously!

For example, an electron can be both excited and in its ground state. Even more strikingly, an atom can appear to be in two places at once.

It is only when attempting to determine its location that the atom “chooses” one of the two positions.

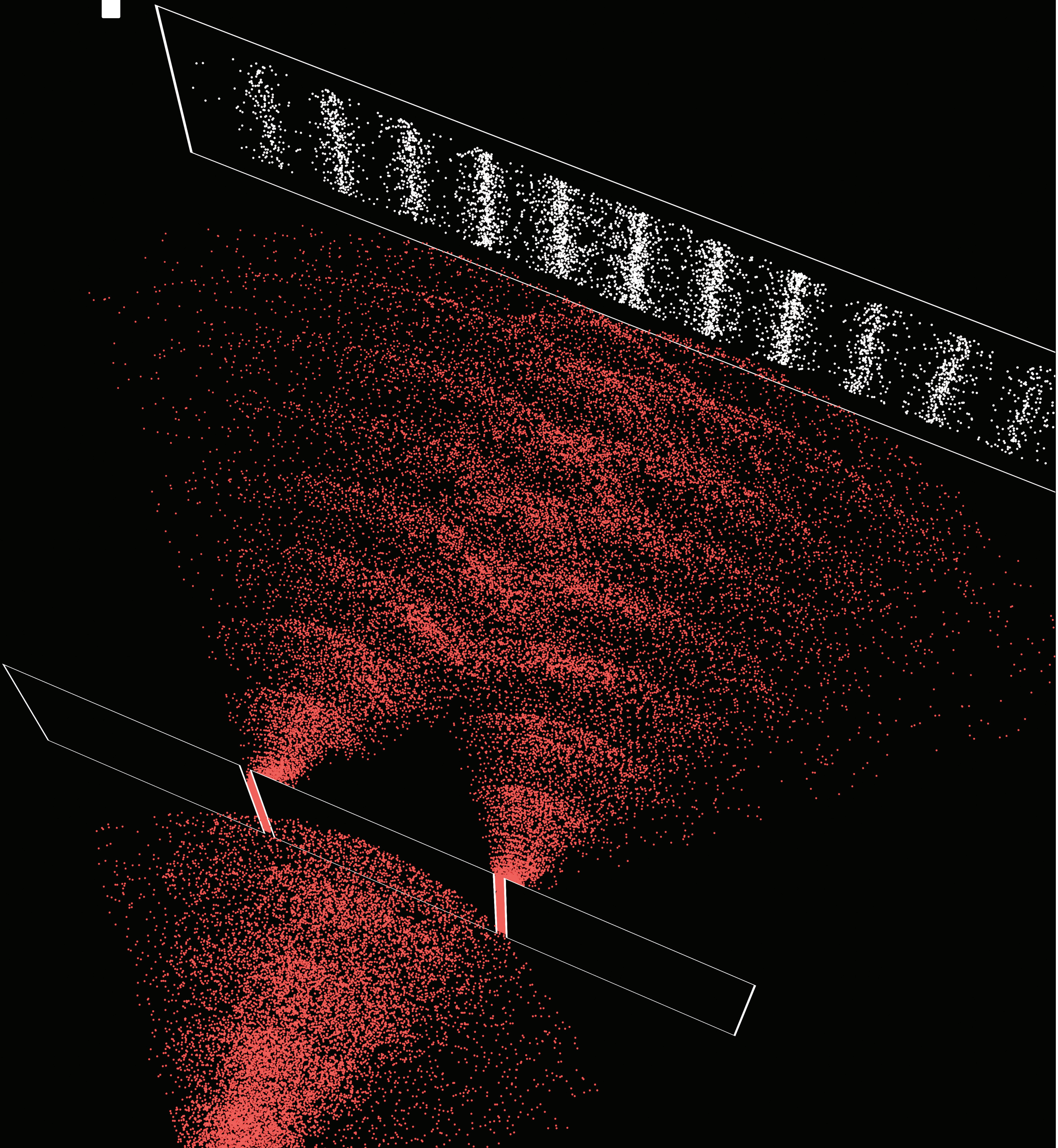
3 The largest Schrödinger's cat is a spring



This electronic component weighs 16 micrograms—just enough to be visible to the naked eye. By cooling it, a team successfully placed it in two states simultaneously: a spring both stretched and compressed, mirroring Schrödinger's cat being both dead and alive.

« Schrödinger cat states of a 16-microgram mechanical oscillator», M. Bild et al, Science (2023)
Yiwen Chu team, ETH Zurich (Switzerland)
@Matteo Fadel, ETH Zürich

4 Young's double-slit



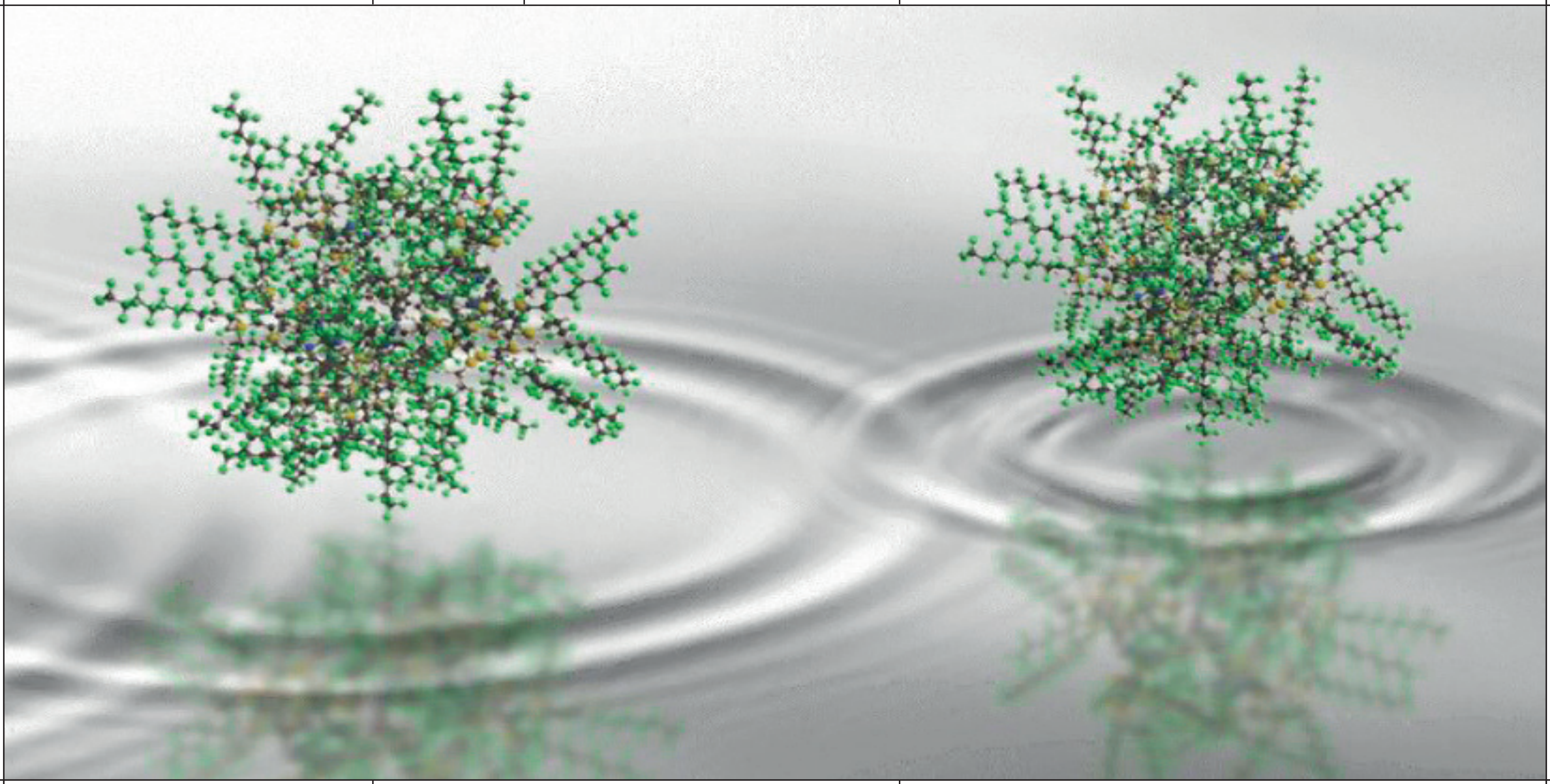
The Key Experiment

In this experiment, a particle such as an electron is sent through a plate with two slits. When detected on a screen behind the plate, it appears at a precise point.

However, the accumulation of these points reveals alternating dark and bright fringes. These fringes can only be explained if each particle passed through both slits simultaneously, interfering with itself!

It only collapsed into a single point at the moment of detection.

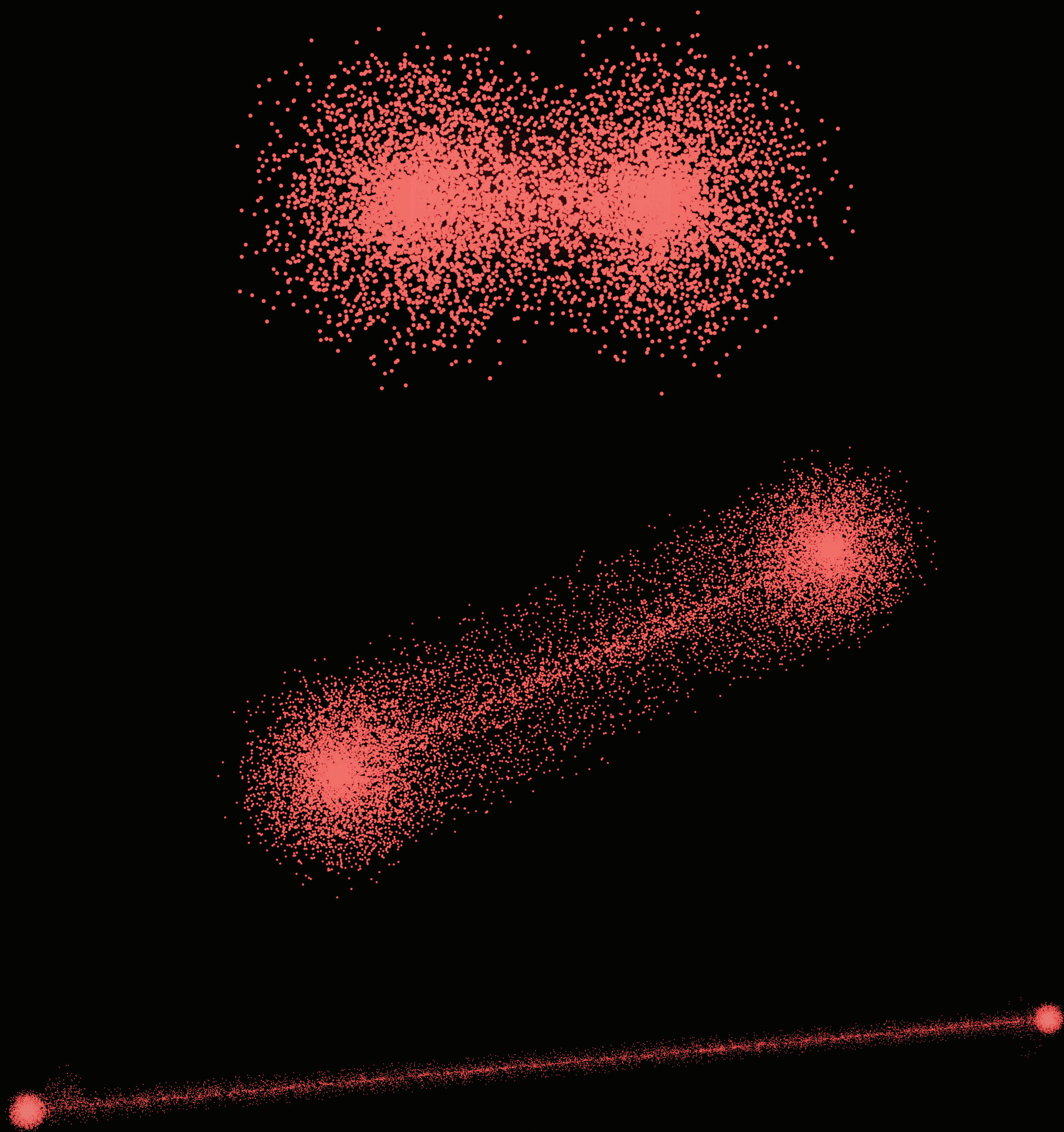
4 A massive molecule passes through two slits at once



This 2000-atom molecule is the largest quantum object ever measured in Young's double-slit experiment. Scientists successfully made it pass through both slits simultaneously and observed it interfering with itself like a wave.

« Quantum superposition of molecules beyond 25 kDa »
Y. Fein et al, Nature Physics (2019)
Markus Arndt Team, University of Vienna (Austria)
@Yaakov Fein, University of Vienna

5 Entanglement

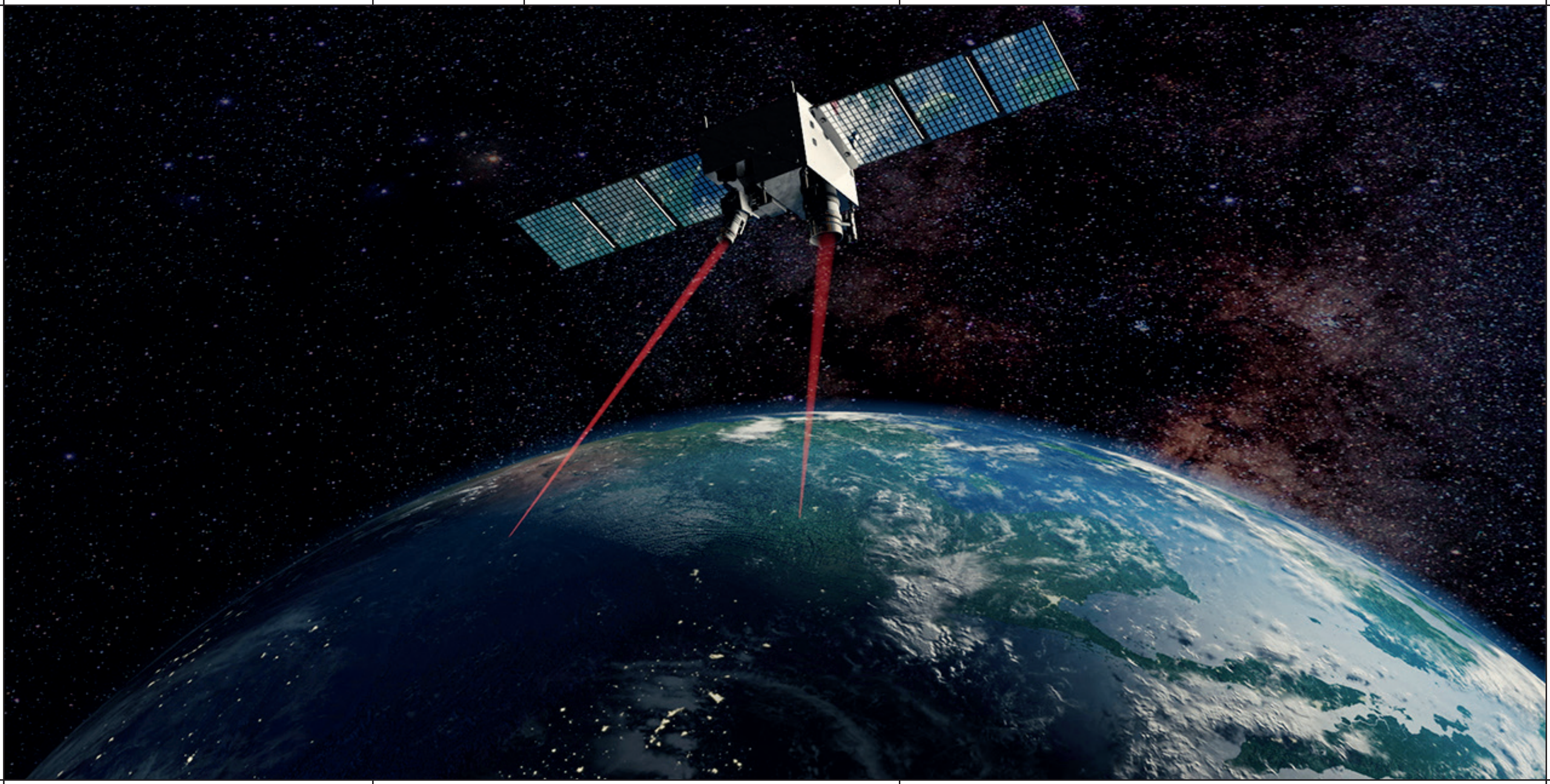


Influence at a Distance

When two particles are entangled, they remain connected through surprising “quantum” correlations, regardless of the distance separating them.

Measuring one particle causes the other to react instantaneously, without any communication between them! This phenomenon defies intuition and illustrates the non-locality of the quantum world.

5 Entangled particles over 1,000 km apart



A satellite successfully sent entangled photons to opposite ends of China.
The photons remained quantum-linked across distances exceeding 1,000 km, enabling secure cryptographic key sharing for quantum-encrypted communication.

« Entanglement-based secure quantum cryptography over 1,120 kilometer », Y. Juan et al., Nature (2020).
Jian-Wei Pan Team, University of Science and Technology of China, Hefei (China) / @ C. Bickel - Science