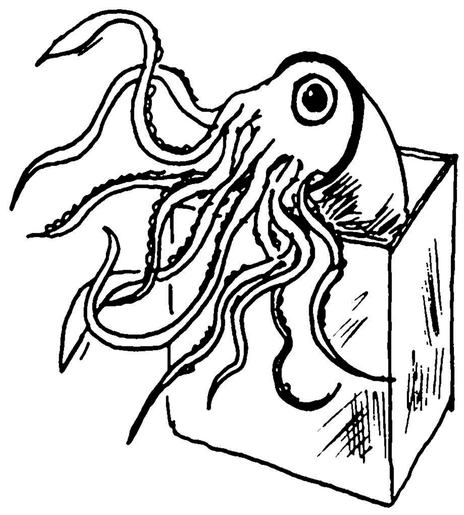
Quantum mechanics

Schrödinger's squid

ERWIN SCHRÖDINGER'S cat-in-a-box thought experiment is justly famous. Schrödinger tried, in 1935, to show just how ridiculous the implications of quantum physics could be. Quantum theory says that objects can exist in multiple states simultaneously. So according to quantum mechanics, he teased, an unfortunate cat in the hands of a miscreant scientist could be both dead and alive at the same time.

Physicists dug themselves out of this contradictory hole by arguing that such quantum effects manifest themselves only at the scale of the very tiny. Real cats are either dead or alive, never both. Now, however, a group of researchers has shown that quantum effects resembling Schrödinger's cat do happen at the "classical" level of objects that can be seen and touched. This could mean that the vision of creating a quantum computer that performs calculations beyond the dreams of Intel is within a whisker of becoming reality.



The creature in question is not a cat, but a SQUID—a Superconducting Quantum Interference Device. This is a thin loop of wire cooled almost to absolute zero. At such a low temperature, an electric current can whizz round the loop indefinitely.

A SQUID, which is a tenth of a millimetre across, is gigantic by physicists' standards, even if tiny by those of the rest of humanity (it is about the width of a hair). It is, however, just visible to the naked eye.

If a SQUID behaved in a classical way, the current in it should only ever flow in one direction—either clockwise or anticlockwise. This is because it comes up against an energy barrier whenever it tries to go into reverse. In the quantum world, however, there is a chance that instead of having to climb over the energy barrier, the current will "tunnel" through it and start flowing in the opposite direction. A SQUID can therefore act as a type of quantum switch.

This switching effect has been known for a while. What was unknown, until Jonathan Friedman, James Lukens and their colleagues from the State University of New York at Stony Brook began their investigation, was whether, having flipped once, the current could flip back again—and, indeed, keep on flipping. They found that it can, and have published their results in this week's *Nature*. These results matter because current-flipping in a SQUID is a form of the quantum effect known as "superposition"—the phenomenon that Schrödinger was describing when he suggested that a cat might be both dead and alive at the same time.

Superposed states have a bizarre property—there is never only one of them. In other words, Schrödinger's cat can be both dead and alive in two different ways. Similarly, there are two superpositions of clockwise and anticlockwise current flow in a SQUID. Theory predicts that these states should have different energies, but this has never before been measured.

Dr Friedman and Dr Lukens bathed their SQUID in a burst of microwaves, which hoisted the current nearer to the top of the energy barrier. This gave it a better chance of switching direction. By measuring the magnetic field around the SQUID after the transition had taken place, they could calculate the energy of the system during the flip. They found, as they had hoped, that the energy of the SQUID changes as the current flips back and forth between clockwise and anticlockwise states. In cat language, they showed that Schrödinger's beast really can be both dead and alive in two different ways.

The problem with Schrödinger's thought experiment is that the scientist doing it has to open up the box to see how the cat has fared. But the act of looking destroys the superposition. The quantum states "decohere" or collapse into one classical state or the other. In other words, whenever you actually look in the box, the cat is always either dead or alive.

What is remarkable about Dr Friedman's and Dr Lukens's experiment is that they have managed to measure the energy of superposed states without destroying them. This is like looking at the cat in a box with cloudy glass walls. You can observe the state of the dead-and-alive cat, but you cannot stroke it.

That also points to a way forward for quantum computing. Normal computers handle data as "bits"—strings of ones and zeros. These are represented physically by a switch in a circuit being either "on" or "off". But a quantum bit can exist in a superposed state, and so be both "on" and "off" at the same time. This means that a series of quantum switches connected in parallel could process information in a way that is impossible for normal computers.

There is, however, a catch. A quantum computer has to be prevented from interacting with its environment in order to allow the ghostly quantum states to store information. But it also has to be manipulated to allow calculations to be performed. It seems that Schrödinger's SQUID could square this circle by preventing most interaction so as to facilitate information storage, but allowing enough for data-manipulation to take place.

Whether that means a cat really could be dead and alive at the same time is still unclear. But if you had to cool it down to absolute zero to find out, it would probably be rather unwell. ■