PHYSICS

# Schizophrenic Atom Doubles As Schrödinger's Cat—or Kitten

Schrödinger's cat has always been an elusive beast, but physicists may have finally trapped one in the laboratory. Sixty years ago, to illustrate the strangeness of the quantum world, the Austrian physicist Erwin Schrödinger described a cat shut up in what he called a "diabolical device": a closed box also containing a small amount of a radioactive substance. Over the course of an hour, the radioactive substance has a 50–50 chance of decaying. If it does, the decay is detected by a counter, which shatters a flask of deadly acid, killing the cat. If it doesn't, the cat lives. The indeterminacy of the atomic world, which governs radioactive decay, has now been transformed into macroscopic indeterminacy. Until an observer looks into the box, the quantum state of the radioactive substance is half decayed, half undecayed. And so the cat must also be in a superposition of states, neither dead nor alive, but half of each.

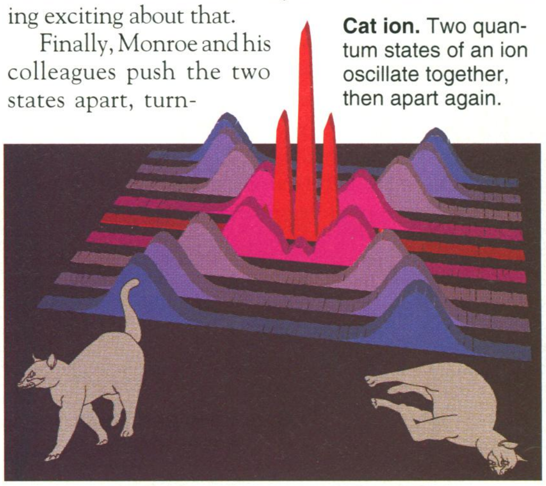
Since Schrödinger put forth his feline thought experiment, theorists have wondered whether the weirdness of the quantum world would inevitably evaporate when magnified to classical dimensions. Now, physicists at the National Institute of Standards and Technology (NIST) in Boulder, Colorado, may have succeeded in turning Schrödinger's cat—or at least a small version of it—into physical reality. As they report on page 1132, the NIST physicists, led by Chris Monroe and David Wineland, trap a single beryllium ion in an electromagnetic cage, excite it into a superposition of internal electronic quantum states, then ease those two states apart so that the atom appears to be in two distinct physical locations simultaneously. The result can be considered the anti-vivisectionist version of the dead-and-alive superposition of cat states.

While the interpretation of the NIST experiment as a bona fide Schrödinger's cat is open to debate, physicist Wojciech Zurek of the Los Alamos National Laboratory says the experiment itself is "marvelous" and a major step forward in "exploring in an experimental way the boundary between quantum and classical systems." It may also be ideal for studying a quantum effect known as decoherence, a phenomenon that would drain information from the quantum computers of which theorists now dream.

Monroe and his colleagues snare their cat—the beryllium ion—by letting it drift into an electromagnetic trap as a neutral atom, then stripping off one of its electrons. The resulting ion suddenly feels the electromagnetic cage around it and is trapped inside. The next step, says Monroe, is to cool the ion using lasers until it settles virtually motionless at the center of the trap.

Now that the ion can't squirm away, the physicists use a pair of laser beams of slightly different colors to coax it into a superposition of internal quantum states—in this case, states known as spin-up and spin-down hyperfine states—that correspond to the quantum indeterminacy of Schrödinger's radioactive atom. At any one time, the ion has a 50–50 chance of being in one of the two states. "This is well-known stuff," says Monroe, "nothing exciting about that."

Finally, Monroe and his colleagues push the two states apart, turning the quantum indeterminacy into a physical indeterminacy like that of the fabled cat. They do so by applying another pair of laser beams ("force" beams) that interfere to create a wave that jostles the ion at a frequency matching its natural oscillation frequency in the trap. The resulting force gets the ion moving much like the periodic force you might exert to get a child moving on a swing. "The lasers are tuned so they only affect one of the hyperfine states and not the other," says Monroe. By changing the tuning of the lasers, the NIST group first sets one hyperfine state in motion, then the other, out of phase with the first.



**Cat ion.** Two quantum states of an ion oscillate together, then apart again.

C. MONROE

"We basically have a spin-down state sloshing to and fro," says Monroe, "and a spin-up state sloshing fro and to. ... If you freeze time, you have an atom at position one with its internal state in spin up and [the same] atom at position two with its internal state in spin down." To measure the distance between the two states, the NIST physicists, in effect, first push them back together until they overlap and interfere with each other. How much the phase of the force lasers has to be changed before the states overlap tells the physicists how far apart the states were to begin with. This distance turns out to be some 80 nanometers, a gap that is bigger than the wave packets themselves, and much bigger than the actual ion.

This physical separation of a single ion's quantum states is what qualifies as Schrödinger's cat, say the NIST physicists. "Although it's on a very small scale," says Wineland, "we're realizing this condition where we have two parts of this quantum mechanical system that are separated by a mesoscopic distance. So this somewhat paradoxical situation seems in fact to exist, at least on a small scale."

Other physicists are not so sanguine about the NIST experiment. Anthony Leggett of the University of Illinois is one. "The two states superimposed should have properties that are demonstratively macroscopically distinct like the living and dead states of the Schrödinger's cat, not just being physically 80 nanometers apart," he says. Zurek, on the other hand, says that even if the NIST group hasn't created a fully macroscopic Schrödinger cat, they have created a "Schrödinger's kitten" that will be perfect for studying the effects seen where the quantum world gives way to the classical world. In particular, it should open the way to studying decoherence, in which a quantum system coupled to the environment at large tends to lose its ability to exist simultaneously in a quantum superposition of states.

Decoherence is not only fatal to Schrödinger's cat; it's also one of the problems standing in the way of the creation of quantum computers, which would exploit the superposition of quantum states to perform large numbers of calculations simultaneously. "You want your computer to stay nicely in a superposition forever," says Zurek, "or at least for the time needed to do a quantum calculation. So you want to check out the susceptibility of these sorts of states to the environment."

Monroe, Wineland, and their collaborators have already begun doing exactly that: increasing the physical separation between their ion wave packets to see how it affects what Wineland calls "the survival rates of these cats." So far, says Monroe, as the separation gets macroscopic, the lifetime seems to go "infinitely short." If so, physicists may never meet a full-grown Schrödinger's cat. But that's the beauty of the experiment, says Monroe: taking such questions out of the realm of theory and into the laboratory. "This issue of decoherence," he says, "is a very fishy one," and treating it experimentally rather than philosophically is "a pretty healthy attitude to take."

–Gary Taubes