How Decoherence Killed Schrodinger's Cat

The inventors of quantum mechanics in the early twentieth century had no illusions about its weirdness. In 1935 the German physicist Erwin Schrodinger illustrated this by reference to a cat held at the mercy of a device that could kill it. If the device was operated by a quantum event, this implied that the cat could be simultaneously dead and alive. Now US physicists have experimentally demonstrated the process by which, for better or worse, the cat escapes this curious fate.

Quantum mechanics dictates the behavior of matter at very small scales, around the size of single atoms-a world utterly at odds with our intuition. Whereas we are used to the idea that an object can be in only one state at a time-either on the table **or** on the floor-a quantum object can be in two (or more) states at once. It is then said to exist in a 'superposition of states'.

To show how quantum superpositions contradict common sense, Schrodinger posited his cat-threatening device, in which the outcome of an atomic-scale quantum event would trigger, say, a gun to fire. If, said Schrodinger, the quantum system was in a superposition of the states that triggered and failed to trigger the gun, then the gun would simultaneously fire and not fire. The cat would be both killed and spared.

Fortunately, there is a way out of this illogical outcome. Every real system, whether quantum or classical(such as a life-sized cat), is in contact with an external environment - a messy, noisy collection of atoms whose state can never be perfectly known. This coupling between a quantum system in a superposition and the environment in which it is embedded leads the system to 'collapse' or decay over time into one state or another. This process is known as decoherence.

The rate of decoherence depends on the size of the quantum system. Physicists can now create and maintain quantum particles such as atoms or single photons of light in superpositions for significant periods of time, if the coupling to the environment is weak. For a system as big as a cat, however, comprised of billions upon billions of atoms, decoherence happens almost instantaneously, so that the cat can never be both alive and dead for any measurable instant. It is rather like a juggler trying to keep billions of balls in the air

Yet physicists would dearly like to know just how that process of decoherence takes place for many-atom systems. David Wineland and colleagues at the National Institute of Standards and Technology(NIST) in Colorado, USA, suspected that this might be possible to follow at intermediate scales - for superposition states of only moderate size. Now, they report that they have been able to watch decoherence happen and see how it speeds up as the system gets larger.

They set up superpositions of quantum states in single ions (charged atoms) of the element beryllium cooled to very low temperatures using laser beams and held within a trap created by an electromagnetic field. In this trap, laser light can then be used to prepare the ion in a variety of superpositions of its possible quantum states.

Wineland and colleagues tailored the coupling between the ion and its environment, which induces decoherence. In particular, they showed that the amount of **coherence** - crudely put, the amount of superposition still surviving - declined over time in the manner predicted by quantum theory. They also verified that the rate of decoherence increases as the **size** of the superposition increases. Furthermore, by using a special trick to control the coupling of the trapped ion to its environment, they simulated the effect of **shrinking** the environment to the point that they could observe slowing and even reversals of decoherence.

This information about how quantum superpositions decay is not only of theoretical interest. Proposals to exploit quantum physics in computers with many times the power of today's supercomputers depend on the ability to maintain many quantum **switches** in coherent superpositions. These results suggest that, at least in principle, this can be achieved by controlling the coupling to the surroundings in some way.