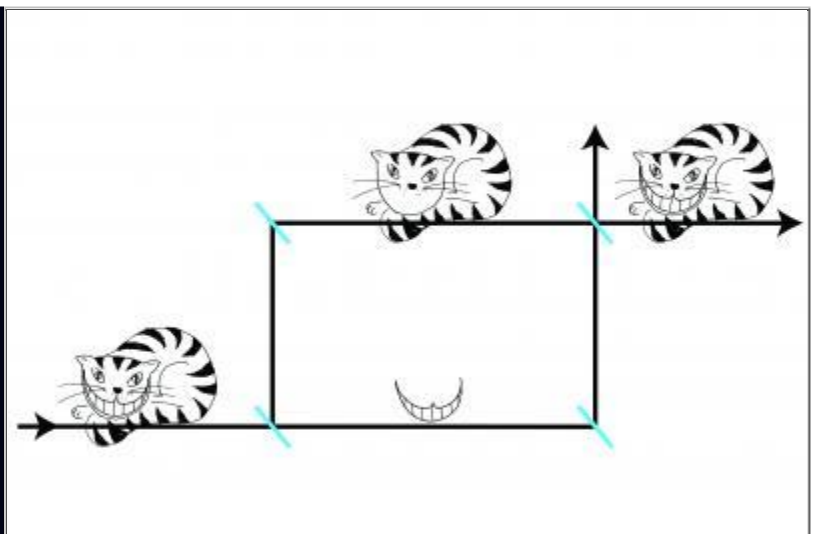
Particles can be physically separated from own properties, scientists say

July 31, 2014
Courtesy of Vienna University of Technology,
Chapman University
and World Science staff

"'Well! I've often seen a cat without a grin,' thought Alice, 'but a grin without a cat! It's the most curious thing I ever saw in my life!'" So goes the story of the Cheshire cat in the Lewis Carroll novel Alice in Wonderland, a smiling feline that disappears leaving its own grin behind.

Alice's surprise stems from her experience that an object and its property can't exist independently. It seems to be impossible to find a grin without someone grinning.



The diagram shows an object can be separated from one if its properties in an interferometer -- like a cat, moving on a different path than its own grin. (Credit: TU Vienna / Leon Filter)

Yet the strange laws of quantum mechanics, the theory which governs the microscopic world of atoms and their parts, suggest it's possible to separate a particle from its properties—a phenomenon strikingly analogous to the Cheshire cat story.

According to quantum mechanics, particles can be in different physical states at the same time.

If, for example, a beam of neutrons, subatomic particles, is divided into two beams, it can be shown that the individual neutrons don't have to decide which of the two possible paths they choose. Instead, a particle can travel along both paths at the same time, a situation called quantum superposition.

In a new study, physicist Yuji Hasegawa from the Vienna University of Technology brought together a team of scientists to study whether a particle can also separated from its properties.

Neutrons aren't electrically charged, but they have a magnetic direction, called neutron spin. This also means they have a property called magnetic moment, the twisting force they undergo in a magnetic field.

In the new type of experiment, a neutron beam is split into two parts in an instrument called an interferometer. Then the spins of the two beams are shifted into different directions: the upper neutron beam has a spin parallel to the neutrons' trajectory, the spin of the lower beam points in the opposite direction. After the two beams have been recombined, only those neutrons are chosen, which have a spin parallel to their direction of motion. All the others are ignored.

The idea is that these neutrons, which are found to have a spin parallel to their direction of motion, must have traveled along the upper path.

Things get tricky when the system is used to measure where the spin is located. The spin can be slightly changed using a magnetic field. When the two beams are recombined appropriately, they can amplify or cancel each other. This is exactly what can be seen in the measurement if the magnetic field is applied at the lower beam – but that is the path which the neutrons considered in the experiment are actually never supposed to take. A magnetic field applied to the upper beam, on the other hand, has no effect.

The results "suggest that the system behaves as if the neutrons go through one beam path," the upper, "while their magnetic moment travels along the other," the researchers wrote, reporting their findings July 29 in the journal *Nature Communications*.

The experiment achieves "a situation in which both the possible paths in the interferometer are important for the experiment, but in very different ways," said collaborator Tobias Denkmayr of the university. "Along one of the paths, the particles themselves couple to our measurement device," or interact with it, "but only the other path is sensitive to magnetic spin coupling," the change in spin.

* * *