Wave or particle? Heisenberg, take a hike!

The dual nature of light, electrons, and even atoms has long fascinated physicists. Quantum mechanical rules permit these elementary objects to act both as waves and particles, but scientists can witness only one of those states at a time. Why the curtain falls on half the show has been a matter of debate since the 1920s.

Physicists have long believed that Werner Heisenberg's famous uncertainty principle manages the stage (SN: 2/19/94, p. 118). The act of measuring the position or momentum of a quantum mechanical entity collapses the duality, they say, because the principle forbids both quantities to be simultaneously known with precision.

Now, German experimenters find that the mere existence of information about an entity's path causes its wave nature to disappear. In the Sept. 3 NATURE, they offer experimental evidence that something deeper than uncertainty yanks offstage the wave- or particle-half of the duet. That unseen hand is known as entanglement, or correlations.

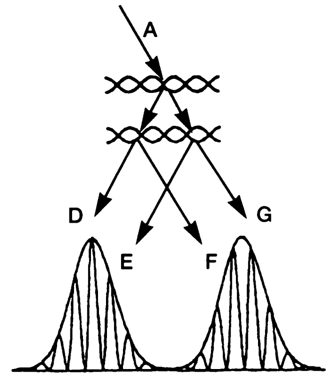
The University of Konstanz team passed ultracold rubidium atoms across a pattern of laser light that in essence splits each atom's path, enabling the atoms, wavelike, to simultaneously take divergent routes through an experimental apparatus. As long as no attempt was made to determine which way the atoms went, they emerged as a pattern of light and dark bands, or interference fringes.

That fringe pattern vanished, however, when the researchers turned on microwaves that would orient the spins of the atoms upward if they took one intermediate path and downward if they took the other. The researchers say this spin-flipping so little affected momentum that it shouldn't squelch the atom's wave, according to the uncertainty principle.

Entangling spin with which-way data tilts the wave-particle scales without invoking uncertainty, notes Gerhard Rempe, who led the team. "To explain the wave-particle duality, we need entanglement and correlation," he says. "The Heisenberg uncertainty relation has nothing to do with wave-particle duality."

The finding also deepens the quantum world's mystery, he says, since merely requiring the atoms to carry which-way data was enough to affect their behavior. "There is information stored, but we don't read the information," he says. "This is very strange indeed."

"I think this is an experiment that will be included in future textbooks," says Berthold-Georg Englert of the Max Planck Institute for Quantum Optics in Garching, Germany. It appears to confirm predictions made in 1991 by Englert, Marlan O. Scully of Texas A&M University in College Station, and other theorists.



Adapted from: Stephan Dürr *et al.*/NATURE

Laser light acts as gratings (horizontal squiggles), splitting atoms that arrive via path A for study of their wave-particle nature. Fringe patterns (bottom) appear when atoms, wavelike, travel multiple paths (D-G) simultaneously.

Critics of Englert's analysis acknowledge a subtle effect but disagree that the new experiment sends the uncertainty principle packing. "Correlations are observations about relationships between quantities and do not cause physical processes to occur," asserts Sze Tan of the University of Auckland in New Zealand.

If "we think of the uncertainty principle as more general than simply the inability to simultaneously measure position and momentum," it still applies, he argues. —*P. Weiss*

Following gravity's loops and knots

The force of gravity governs the motion of planets, asteroids, and other bodies in the solar system. Predicting their orbits requires solving equations representing the gravitational attraction between interacting masses.

Now, a mathematician has discovered a new set of approximate solutions of those equations. Each solution corresponds to a string of equally spaced masses—like the beads of a necklace—chasing each other around a closed loop at just the right speed.

Although the solar system is unlikely to harbor such behavior, it may occur among filaments and vortices in a plasma of huge numbers of charged particles, suggests Gregory R. Buck of Saint Anselm College in Manchester, N.H. He reports his findings in the Sept. 3 NATURE.

Newton's laws of movement provide a precise answer to the problem of determining the movement of two gravitationally interacting bodies. For example, if the solar system consisted of the sun and a single planet, the planet would follow an elliptical orbit.

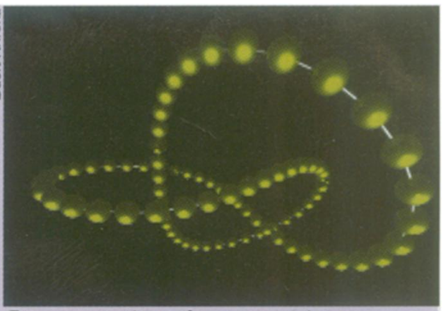
When the system consists of three or more bodies, however, solving the equations proves immensely difficult. The motion turns out to be chaotic and unpredictable (SN: 2/22/92, p. 120), except in a few special cases. For example, the sun is so much more massive than the planets that the solar system behaves roughly as if each planet were influenced only by the sun.

Another special case occurs for three bodies at the corners of an equilateral triangle. Such a configuration rotates as if the masses were fixed to a turntable. The sun, Jupiter, and the so-called Trojan asteroids, for instance, form such a triangle, which rotates about the system's center of mass.

"With such a configuration, appropriate initial conditions can be supplied so that the motion keeps the same configuration for all time," says Donald G. Saari of Northwestern University in Evanston, Ill.

Instead of considering specific geometric configurations, in which forces partially cancel out to produce a simple type of motion, Buck looked at what sorts of cancellations would occur among an enormous number of bodies.

He found that an infinite number of masses following a looped path satisfies Newton's equations. In effect, gravity pulls the bodies one after the other around each bend of the loop. Such loops can have any shape, no matter how tangled or knotted, as long as they don't intersect anywhere and there are no loose ends.



Buck/NATURE

Representation of an approximate solution of Newton's equations, in which evenly spaced masses follow each other along a knotted loop.

The equations may not be precisely satisfied, however, for a finite number of masses traveling in a loop, Saari notes. In that case, gravitational forces would tend to move masses away from a loop configuration. What isn't clear yet is how long a given loop configuration involving a finite number of masses would last, Buck says. —*I. Peterson*