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PLAYING DICE WITH THE UNIVERSE

To the casual observer, it was just another arcane scientific experiment. Physicists Alain Aspect, Jean Dalibard, and Gérard Roger energized some calcium atoms with a laser beam, waited for each atom to emit a pair of photons, and then carefully measured how these bits of light flew off in opposite directions.

But this enigmatic exercise was more than pure physics. The three researchers, working from the Institute of Theoretical and Applied Optics, in Orsay, France, were actually on a philosophical quest, seeking the rules by which the universe plays. Is it a game of chance, they were asking, or does nature perform like a well-oiled machine, steady and predictable?

In the closing years of the nineteenth century, smug Victorian scientists would have opted for the latter assertion, believing that all processes in the universe were precisely calculable. Sir Isaac Newton himself ushered in this Age of Determinism two centuries earlier, when he successfully calculated the motions of the far-flung planets with his law of gravitation.

But something went amiss when man attempted to apply these classical laws to the workings of the atom, an entity 1 billion times smaller than a golf ball. In fashioning the laws of this submicroscopic world (laws later dubbed quantum mechanics), scientists came to see that atomic particles behaved with less predictability than such ordinary objects as pencils or desks. Light, for one, could behave like either a particle or a wave, depending on the experiment. And one could never know both the position and the velocity of an atomic particle at the same time. The reason: The measuring instrument was so large and the particle so small, the physicists said, that the very act of measuring one parameter was bound to change the other.

Physicists as notable as Einstein railed against this uncertainty. They conjectured that quantum mechanics was merely an approximation and that if science delved a little further, it would find other variables—variables now hidden to us—that would enable man to describe atomic processes exactly.

To make his point, Einstein even posed a thought experiment. He proposed a situation in which two closely connected particles were suddenly flung miles apart. Physical law says that two such particles should possess equal but opposite properties. Yet according to quantum mechanics, the properties will remain unspecified until one of the particles is measured.

As far as Einstein was concerned, this presented a problem. If the two particles were always equal but opposite, and neither had any properties until one was measured, then the mere act of measuring one would bestow specific characteristics on the other, even if the two were separated by thousands of miles. This, said Einstein, would violate the principle of local causality, which holds that events cannot be instantaneously or directly influenced by distant objects. Taken to the extreme, this might mean that a fire in Los Angeles could instantaneously affect a schoolhouse in Peking. Incredibly, communication would be faster than the speed of light.

The philosophical debate over Einstein's thought experiment raged for years. Then, in 1965, physicist John Bell suggested that certain laboratory experiments could decide which scheme, chaos or order, governed the universe. For more than ten years now, scientists around the globe have avidly conducted such tests; the French experiment is the latest.

Motivated by their desire to see how nature operates, Aspect and his colleagues measured the polarization (the angle of vibration) of pairs of photons racing away from the calcium source in different directions. The experiment would work, they reasoned, because the correlation between photon pairs would be statistically higher if the theory behind quantum mechanics were correct. The earlier tests all seemed to support the mathematical predictions of quantum mechanics, but they had a gaping loophole. What if the first photon being measured could "send a message" back to the calcium source, telling all subsequent photons what properties they were being tested for? The French avoided this pitfall by switching the settings on their instruments every ten billionths of a second, too little time for the photon to report back to the source.

The result: As in past experiments, quantum mechanics was the overwhelming winner. The implication was that Einstein's hope for a comprehensible universe might never be fulfilled. But although Aspect accepts the experimental evidence for quantum mechanics, he still has his doubts. "Quantum mechanics is a good set of recipes for making predictions," he says, "but I still don't think it provides an adequate picture of how nature works."—*MARCIA BARTUSIAK*