The Death of Entanglement: Life Without Half-Life

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(PhysOrg.com) -- Quantum entanglement, a type of correlation peculiar to quantum objects, has been found to disregard completely the "half-life" rule that is obeyed by all natural processes, such a radioactive decay.

In the current issue of the journal *Science*, Joseph Eberly, professor of physics at the University of Rochester, with his colleague Ting Yu, reviews four years of investigation into what is now called "the sudden death of entanglement," which they first reported in 2004.

"Our original paper on this triggered an explosion of interest because it attacks an issue that is so fundamental, the natural dying away of physical order" says Eberly. "Entanglement is at the heart of quantum computing, cryptography, teleportation—all these weird effects that physicists are just starting to exploit in labs around the world. And now we have to face that for some reason entanglement doesn't follow the rules."

Eberly and Yu discovered that entanglement—a quantum mechanical phenomenon that exists only when shared—weakens and disappears completely in the face of any common environmental "noise" such as heat or random vibration. In contrast, other known processes under similar circumstances get weaker by half in each successive time interval without ever quite disappearing.

Environmental noise, says Eberly, is usually Markovian noise, characterized by fluctuations too small and brief to measure. For instance, the average temperature in a room may in reality fluctuate a thousandth of a degree many times per second, but we are unable to measure such fluctuations so we take a gross measurement with a thermometer. A cup of warm tea in this room, for instance, may cool to a temperature mid-way between its original temperature and the room temperature in the first hour, then halfway again in the next hour, etc., coming ever closer to the room's temperature without reaching it exactly.

Not so with entanglement, says Eberly. In the presence of Markovian noise entanglement has been found to "die" completely after a fixed time.

"This may present difficult problems for quantum computing because even when entanglement has degraded very far, it's possible to restore it back to full entanglement," says Eberly. "Among other things, engineers are relying on that fact. But dead is dead. If the entanglement disappears completely, there's no way to resurrect it, and that adds an unexpected obstacle in the way of the goals desired for computing and cryptography."

Eberly says that their discovery opens a new front for quantum exploration. "The half-life rule is so ubiquitous that it's exciting to find something that doesn't fit it," he says. "It reveals a great gap in our understanding. Why does this exception exist? That's what we're looking to answer."

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