Not all quantum properties are lost through interaction with the environment

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(PhysOrg.com) -- One of the most well-known "rules" of quantum physics is that all quantum properties are lost due to environmental interaction. This rule, though, may not hold true in all situations. "We have discovered the first counter to this common rule," Sabrina Maniscalco tells *PhysOrg.com*. Maniscalco is a researcher at the Turku Centre for Quantum Physics, University of Turku in Finland. Along with fellow researcher (and husband) Jyrki Piilo, and Ph.D. student Laura Mazzola, Maniscalco has identified evidence that some quantum correlations can remain intact.

The results of their work are published in Physical Review Letters: “Sudden Transition between Classical and Quantum Decoherence.”

“Laura really did most of the work,” Maniscalco says. “She was studying different interactions between quantum properties and the environment, and looking for different correlations in noisy quantum systems. No one expected her to find strange behavior. When she first called Jyrki and me with the result, we thought it must be a mistake.”

Maniscalco and Piilo went over the data and realized that it wasn’t a mistake. “We checked the calculations again, and found that the time evolution of quantum correlations in this case remains constant for a long time. It represented a transition between classical and quantum decoherence, and the quantum property was not lost.”

This particular correlation can be found, for example, in quantum systems comprising of two qubits. “These qubits, each with different properties, such as different polarizations, have to interact with a type of noise that doesn’t change the energy of the qubits,” Maniscalco explains. “Instead of changing the energy, the noise just changes the phase, such as flipping polarizations. The type of noise that we have considered is one that contains all frequencies in a way that is very similar to white noise.”

While this discovery is theoretical, Maniscalco says that it has an experimental basis as well. “A very recent experiment has confirmed a type of quantum correlation that is not affected by the environment. And this is not a weird type of environment; it’s a natural environment that we could work in right now.” (For more on this experiment, see Jin-Shi Xu, et. al., “Experimental investigation of classical and quantum correlations under decoherence,” *Nature Communications* (April 2010). Doi:10.1038/ncomms1005.)

In the last 20 years, Maniscalco points out, technology has advanced to the point where it is possible to use single atoms or photons to build quantum logic gates for future quantum computers, or perform communication, measurement and cryptography tasks. “We’ve learned that it is possible to exploit the quantumness of the microscopic state, but in order for us to succeed, the quantum properties have to remain intact for a long time. That is a challenge, since once the properties are lost through interaction with the environment, a device can’t exploit quantumness.”

This discovery that certain quantum correlations are not lost in presence of the environment could lead an increased ability to exploit the quantum world for use in technological devices. Maniscalco points out that the idea that all quantum properties need not be lost through interaction with the environment presents more than interesting fundamental implications. “While this work has a surprising fundamental aspect,” she says, “it opens up a whole range of possibilities with applications in quantum technology, including computing, communications, metrology and cryptography.”

Next, Maniscalco says that her group, and Piilo’s group, at the University of Turku will need to study this effect. “We need to learn the most general conditions for this behavior, and see if it holds for other environments. We are also working toward deigning a quantum protocol that uses this state, so that we can demonstrate an application of this effect in practice.”

For more information, you can visit the Open Quantum Systems and Entanglement group and the Non-Markovian Processes and Complex Systems group web pages.

More information: Laura Mazzola, Jyrki Piilo, and Sabrina Maniscalco, “Sudden Transition between Classical and Quantum Decoherence, Physical Review Letters (May 2010). Available online: link.aps.org/doi/10.1103/PhysRevLett.104.200401