Quantum correlations -- without entanglement

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(PhysOrg.com) -- Few people doubt the "quantumness" of entanglement. Quantifying the quantum correlation of entanglement is something that is relatively regular right now. However, things change a bit when it comes to quantum correlations other than entanglement. However, there is a growing interest in the use of non-entanglement quantum correlations in a number of possible future applications.

“A few years ago, scientists proposed quantum discord as a quantum correlation measure that goes beyond the entanglement paradigm,” Roberto Serra tells *PhysOrg.com*. “Quantum discord may be present, even in separate, non-entangled states. However, some doubt was being shed on the quantum qualities of non-entangled states because of the difficulty in quantifying the correlations.”

In order to remedy the difficulty in “seeing” the correlations in a laboratory setting, Serra, a scientist at the Federal University of ABC in São Paulo, Brazil, worked with a group to create a technique that makes it possible to recognize nonclassical correlations in quantum discord. Serra worked with a team from different Brazilian institutions of higher learning, including the Brazilian Agricultural Research Corporation's and the Brazilian Center for Physics Research both in Rio de Janeiro, and the Physics Institute of São Carlos, in São Paulo State. The results of the work can be seen in Physical Review Letters: Experimentally Witnessing the Quantumness of Correlations.”

“Nuclear Magnetic Resonance systems at room temperature were used to test principles of quantum computation with a good level of success," Serra explains. "The quantum nature of these demonstrations was questioned because there is no entanglement in such a system. In our experiment we reveled directly the quantum nature of this system at room temperature. We used a sample of chloroform molecules, since it's the simplest two-qubit system. We folded a qubit in the carbon nucleus and another one in the hydrogen nucleus."

Next the Brazilian scientists were able to manipulate the system. Even though they used hot quantum bits, the system actually works as a quantum mechanical one. "We displaced the system from the thermal equilibrium by a very tiny deviation, and the phase coherence present there could encode quantum correlations as the measured by the quantum discord," Serra says.

"Our methods can be applied to another system, such as an optical system. This can enable us to say if a given system is purely classical in nature, or if it has truly quantum correlations," he continues. Serra thinks that using this test, which is relatively simple to perform in a laboratory setting, could help lay to rest the debate over whether or not these other types of correlations are truly quantum.

"We test the quantumness of discord at room temperature, and this very robust quantumness can be used to get an advantage in quantum protocols," Serra insists. He believes that this method can already be used for metrology. "We are involved now in a test of principles in quantum metrology using this type of system, and exploiting this very tiny nonclassical correlation. We are testing those right now, to see about advantages over classical protocols, and we hope to have new results in the next few months."

"We hope to develop future applications, and advance our comprehension about the rule played by this kind of quantumness in tasks as, for example, quantum communications," Serra continues. "We are building collaborations between theoretical and experimental researchers, and we hope that we can do more to show the usefulness of other quantum correlations beyond entanglement."

More information: R. Auccaise, J. Maziero, L.C. Céleri, D.O. Soares-Pinto, E.R. deAzevedo, T.J. Bonagamba, R.S. Sarthour, I.S. Oliviera, and R.M. Serra, "Experimentally Witnessing the Quantumness of Correlations," *Physical Review Letters* (2011). Available online: link.aps.org/doi/10.1103/PhysRevLett.107.070501/