Quantum computing: Entanglement may not be necessary

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(PhysOrg.com) -- It is a truth universally acknowledged that quantum computing must have entanglement.

"Entanglement," Andrew White tells *PhysOrg.com,* "is normally considered a non-negotiable part of quantum information processing. In fact, if you told me a couple of years ago that you could do quantum computing without entanglement, I would have been pretty skeptical – to say the least!"

White says that he first heard the idea of non-entanglement quantum computing from Carl Caves. "I was intrigued when Professor Caves, on sabbatical here in Australia from New Mexico, mentioned that there were sober predictions that entanglement wasn't always necessary."

White leads a team of young experimental scientists at the University of Queensland in Brisbane, Australia. Ben Lanyon, Marco Barbieri, Marcelo Almeida and White have been studying deterministic quantum computing with only one pure qubit (DQC1). "Entanglement is not the final story on what makes quantum information processing powerful," White insists. The Australian team's results can be found in Physical Review Letters: "Experimental Quantum Computing without Entanglement."

"Normally, in order for quantum computing to work," White explains, "we need to encode the information into quantum bits—qubits—which are in a noise-free pure state. It's known that the entanglement between these is what makes standard quantum computing powerful." He continues, "With a DQC1 scheme, you only have to have one pure qubit, and the rest can be noisy or mixed." The idea behind quantum information processing using entanglement is that noiselessness has to be applied in order to provide a substantial advantage over classical computing. DQC1, though, could potentially offer a more efficient and less resource-intensive method of quantum computing, since entanglement would no longer be a necessity.

"For this demonstration," White says, "we used the smallest possible example: a circuit with just two qubits, one pure and one mixed. We ran a phase-estimation algorithm as a small example, and found in every setting there was zero entanglement, but that most of the states couldn't be described efficiently in a classical manner."

White points out that this is suggestive that there are other possibilities, beyond entanglement, that contribute to the power provided by quantum information processing. "We're still chewing through the implications," he says.

"This is not a universal panacea," White admits. "For some problems and algorithms you just need pure qubits and entanglement, problems such as Shor's algorithm. However, there are applications and problems where the DQC1 method will work quite well, and will be more efficient than trying to get qubits that are all pure."

With so many different architectures and schemes for quantum computing – all of them trying to create a system in which all the qubits are pure – it is rare to see a group looking to find applications for a quantum information system that makes allowances for impurity and the introduction of noise – insisting that entanglement is not necessary. "The fact is that certain classes of problems don't need entanglement, and they don't need all of the purity. In some cases, all that is needed is one pure qubit and the rest could be mixed. Really, with DQC1, you don't have to work as hard as you think you do."

We are starting to build more complicated algorithms to get an idea of where this could go. Regardless, the idea that entanglement may not be necessary for some types of quantum computing is big news."

More information: B. P. Lanyon, M. Barbieri, M. P. Almeida, and A. G. White. "Experimental Quantum Computing without Entanglement." *Physical Review Letters* (2008). Available online: link.aps.org/abstract/PRL/v101/e200501 .