Too much entanglement can render quantum computers useless

May 25 2009, By Miranda Marquit

(PhysOrg.com) -- "For certain tasks, quantum computers are more powerful than their classical counterparts. The task to be performed is the same for quantum or classical systems. However, the former ones can do it in a more efficient way," David Gross tells *PhysOrg.com*. "But we can't pinpoint the exact reason why a quantum computer is more powerful. Until now, it has been accepted that the reason is entanglement. But entanglement is the easy answer, and we have discovered that it is not so simple."

Gross, at the Institute for Mathematical Physics in Braunschweig, Germany, has been working with S.T. Flammia at the Perimeter Institute for Theoretical Physics in Waterloo, Ontario, Canada and with Jens Eisert at the University of Potsdam in Germany, studying entanglement and trying to understand the role it plays in quantum computing. One of the more interesting findings from the group is that there is such a thing as too much entanglement. The exploration of the concept of too much entanglement is presented in *Physical Review Letters*: "Most Quantum States Are Too Entangled To Be Useful As Computational Resources."

"The conventional wisdom on entanglement is that the more you have, the more powerful your quantum computing will be," says Eisert. "We've found that when it comes to quantum computing, there can be too much entanglement, rendering the quantum information processing attempt useless. It doesn't matter how smart you are, or how you run your computer model; once you reach a certain threshold of entanglement, you are done."

Entanglement, explains both Eisert and Gross, represents correlations in behavior. One system is related to another on a global scale, each affecting the other. In quantum computing, the way systems are entangled - correlated - can help scientists perform powerful computational tasks. However, entanglement is about more than just correlations. “Entanglement introduces a certain randomness into the system,” Gross says. “This randomness appears in the measurement outcomes. However, as the entanglement goes up, so does the randomness. When entanglement increases to a certain point, there is so much randomness that the system ends up being about as useful as coins tossed into the air. You don’t get any useful information.”

Gross and Eisert agree that the discovery that entanglement can be too strong could represent a change in currently accepted attitudes about quantum information processing. “Everyone knows that there needs to be a minimum amount of entanglement for quantum computing to work,” Gross points out, “but almost no one seems to be asking the converse question: Can too much entanglement hurt your efforts?”

“This puts the use of entanglement into proportion,” Eisert insists. “We know that we have to have some entanglement or quantum computing won’t work. But now we know that if we have too much, it won’t work either.”

Implications for quantum computing, then, change. While entanglement is obviously important to processing information in this way, it is not the only thing that makes quantum computing work. There are other forces at play. “Clearly, there is more to what makes quantum computing powerful than just entanglement,” Gross says. “The next step is to figure out what else contributes to the why of quantum computing. We plan to study more aspects of entanglement and quantum computing to try and find an answer to what else is involved.”

“In the end,” says Eisert, “we hope that our work inspires a second look at the role entanglement plays in quantum communication. Hopefully, by looking for and finding the edges, scientists can direct their research in the right regions - the regions where quantum computing actually works.”

More information: Gross, Flammia, Eisert, “Most Quantum States Are Too Entangled To Be Useful As Computational Resources.” Physical Review Letters (2009). Available online: link.aps.org/doi/10.1103/PhysRevLett.102.190501 .