New principle sets maximum limit on quantum information communication

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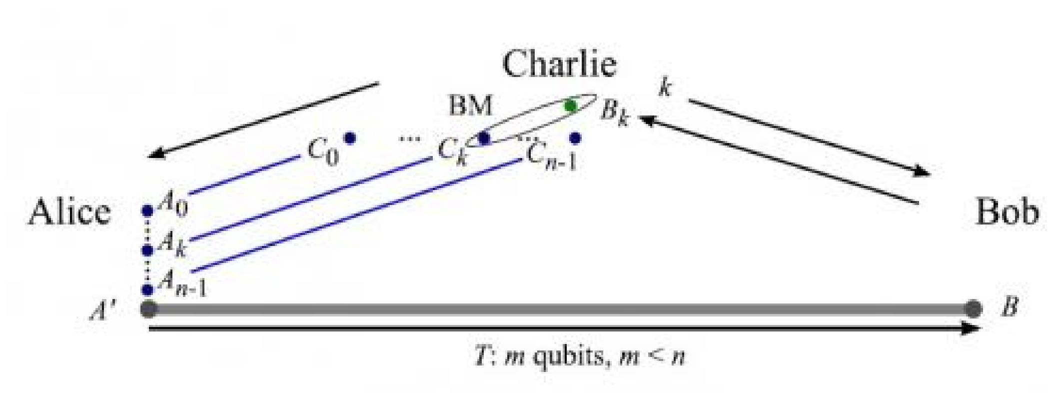

Schematic of the quantum information causality game, in which the amount of quantum information communicated among the parties is limited by the principle of quantum information causality. Credit: Pitalúa-García. ©2013 American Physical Society

(Phys.org) —When two parties use a quantum system to share information, the amount of quantum information that can be communicated is fundamentally limited by quantum properties. Now in a new paper, Damián Pitalúa-García, a scientist in the University of Cambridge's Centre for Quantum Information and Foundations in the Department of Applied Mathematics and Theoretical Physics, has proposed a principle that can determine the maximum amount of quantum information that a quantum system can communicate. According to this principle, the maximum amount of information is limited only by the quantum system's dimension, and does not depend on any physical resources previously shared by the communicating parties.

Pitalúa-García's paper, called "Quantum Information Causality," is published in a recent issue of *Physical Review Letters*.

Specifically, Pitalúa-García's principle of quantum information causality says that, after a quantum system of m qubits is transmitted from one party to another, the quantum information shared between the two parties cannot increase by more than $2m$. As Pitalúa-García explains, this limit is the maximum amount of information that a quantum system can fundamentally communicate, regardless of how technologically advanced it may be and how much quantum entanglement the communicating parties share.

"The principle of information causality states that m classical bits can transmit m's worth of information," Pitalúa-García told *Phys.org*. "On the other hand, quantum information causality states that m qubits can transmit $2m$'s worth of information. In this sense, a qubit can communicate twice the amount of information that a classical bit can communicate. This might seem strange because, after being measured, a qubit reduces to a classical bit. However, a qubit can be entangled with another qubit, while a classical bit cannot. It is entanglement that allows a qubit to communicate more information than a classical bit."

In his paper, he showed that quantum information causality follows from three mathematical properties satisfied by quantum information. While the maximum amount of information is independent of any previously shared quantum physical resources, it does depend on the quantum system's dimension.

"The dimension of a quantum system can be understood as the number of different possible outcomes that are obtained when the system is subject to a measurement," Pitalúa-García said. "For example, a qubit has dimension two, because it gives one of two possible measurement results. Similarly, a system of m qubits has dimension 2^m. It is thus natural to expect that a system with bigger dimension can communicate more quantum information. This is proved mathematically by quantum information causality."

In order to illustrate the limit imposed by quantum information causality and come as close as possible to reaching this limit, Pitalúa-García presented a new quantum game. He found that an optimal strategy in this game is a quantum teleportation strategy.

Although this method is not the first for determining the maximum of quantum information that can be communicated by a quantum system, it is different because it does not involve any classical components.

"Other methods can determine the maximum amount of information that can be transmitted by a quantum system, but in different scenarios," Pitalúa-García said. "For example, [in some scenarios,] the communicated information is classical, as stated in a theorem by Holevo in 1973, or the transmitted system is classical, as published in 2009 in the principle of information causality. Our approach considers the scenario in which the transmitted and the communicated information are both quantum and the communicating parties share any quantum physical resources. This scenario is more general because, fundamentally, every system is quantum, and a classical system is a special class of quantum system."

Overall, the principle of quantum information causality may have implications for the broad field of quantum information, which deals with how information can be fundamentally encoded, processed, and communicated using quantum systems.

More information: Damián Pitalúa-García. "Quantum Information

Causality." *PRL* 110, 210402 (2013). DOI: 10.1103/PhysRevLett.110.210402