Study narrows the scope of research on quantum computing

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According to many scientists, quantum computers will have great importance in the future but, despite all efforts, research in this field is still in its infancy. One of the difficulties is understanding what criteria a quantum system should meet to be able to solve problems that are impossible for conventional computers. An international research team headed by SISSA has just published a study that establishes a basic characteristic that universal quantum simulators should possess.

"A quantum computer may be thought of as a 'simulator of overall nature," explains Fabio Franchini, a researcher at the International School for Advanced Studies (SISSA) of Trieste. "In other words, it's a machine capable of simulating nature as a quantum system, something that classical computers cannot do." Quantum computers are machines that carry out operations by exploiting the phenomena of quantum mechanics, and they are capable of performing different functions from those of current computers. This science is still very young and the systems produced to date are still very limited. Franchini is the first author of a study just published in *Physical Review X* which establishes a basic characteristic that this type of machine should possess and in doing so guides the direction of future research in this field.

The study used analytical and numerical methods. "What we found," explains Franchini, "is that a system that does not exhibit 'Majorana fermions' cannot be a universal quantum simulator." Majorana fermions were hypothesized by Ettore Majorana in a paper published 1937, and they display peculiar characteristics: a Majorana fermion is also its own antiparticle. "That means that if Majorana fermions meet they annihilate among themselves," continues Franchini. "In recent years it has been suggested that these fermions could be found in states of matter useful for quantum computing, and our study confirms that they must be present, with a certain probability related to entanglement, in the material used to build the machine."

Entanglement, or "action at a distance," is a property of quantum systems whereby an action done on one part of the system has an effect on another part of the same system, even if the latter has been split into two parts that are located very far apart. "Entanglement is a fundamental phenomenon for quantum computers," explains Franchini.

"Our study helps to understand what types of devices research should be focusing on to construct this universal simulator. Until now, given the lack of criteria, research has proceeded somewhat randomly, with a huge consumption of time and resources."

The study was conducted with the participation of many other international research institutes in addition to SISSA, including the Massachusetts Institute of Technology (MIT) in Boston, the University of Oxford and many others.

"Having a quantum computer would open up new worlds. For example, if we had one today we would be able to break into any bank account," jokes Franchini. "But don't worry, we're nowhere near that goal."

At the present time, several attempts at quantum machines exist that rely on the properties of specific materials. Depending on the technology used, these computers have sizes varying from a small box to a whole room, but so far they are only able to process a limited number of information bits, an amount infinitely smaller than that processed by classical computers.

However, it's not correct to say that quantum computers are, or will be, more powerful than traditional ones, points out Franchini. "There are several things that these devices are worse at. But, by exploiting quantum mechanics, they can perform operations that would be impossible for classical computers."

More information: "Local Convertibility and the Quantum Simulation of Edge States in Many-Body Systems." *Phys. Rev. X* 4, 041028 – Published 13 November 2014 DOI: dx.doi.org/10.1103/PhysRevX.4.041028

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