Physicists demonstrate new way to violate local causality

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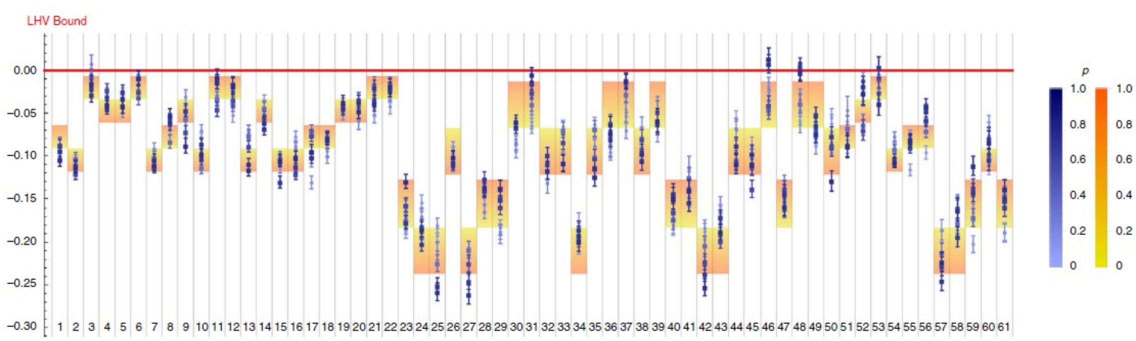

Diagram of 61 Bell inequality violation values. Credit: Carvacho et al. *Nature Communications*

(Phys.org)—For the first time, physicists have experimentally demonstrated the violation of "bilocal causality"—a concept that is related to the more standard local causality, except that it accounts for the precise way in which physical systems are initially generated. The results show that it's possible to violate local causality in an entirely new and more general way, which could lead to a potential new resource for quantum technologies.

The physicists, Gonzalo Carvacho et al., from institutions in Italy, Brazil, and Germany, have published a paper on the demonstration of the violation of bilocal causality in a recent issue of *Nature Communications*.

In general, the idea of local causality is usually taken for granted: objects can influence other objects only when they are physically close together, and any correlations between distant objects must have originated in the past when they were closer together. But in the quantum world, distant particles can be correlated in ways that are impossible for classical objects, unless these distant particles can somehow influence each other.

To determine whether local causality has been violated, physicists perform Bell tests, which attempt to violate Bell inequalities. If a Bell inequality is violated, then either locality or realism (or simply "local realism") has also been violated.

There are dozens of different versions of Bell inequalities, but currently they all make the same assumption: that the correlations between particles all originate from a single common source. In real experiments, however, particles and their correlations can come from many different sources.

To address this issue, the new paper considers a new type of Bell inequality that accounts for the fact that the two sources of states used in the experiment are independent, the so-called bilocality assumption. By violating this new type of Bell inequality, the researchers have for the first time violated bilocal causality, indicating the presence of non-bilocal correlations that are completely different than other types of quantum correlations.

The researchers also showed that, in certain situations, it's possible to violate bilocal causality but not any other type of local causality. This finding further suggests that this type of violation is truly different than any standard local causality violation.

"Our work is an experimental proof-of-principle for network generalizations of Bell's theorem," coauthor Fabio Sciarrino at the Sapienza University of Rome told *Phys.org*. "We experimentally demonstrated how bilocality can be considered a powerful resource enlarging our current capabilities to process information in a non-classical way."

Overall, the results contribute to the perspective that the standard Bell inequalities are just one particular type of more general phenomena. Further exploring this idea could guide the design of future experiments that may reveal greater insight into the violations of local causality and how they might be used in applications. The new non-bilocal correlations, for instance, could be used as a resource for establishing highly secure quantum communication channels in complex quantum networks.

In the future, the researchers plan to extend the experimental demonstration to larger quantum networks. They also noted that the current experiment is subject to loopholes, just like any other Bell test, other than the recent loophole-free Bell tests. The physicists hope that one day a loophole-free test may also be developed for bilocal causality violation.

"A natural next step is to experimentally realize larger quantum networks by adding more nodes and more entangled sources," Sciarrino said. "Our current research plans address the study of the bilocality in quantum networks under strict conditions of reference frames between the different parties in order to highlight another characteristic of this new resource."

More information: Gonzalo Carvacho et al. "Experimental violation of local causality in a quantum network." *Nature Communications*. DOI: 10.1038/ncomms14775