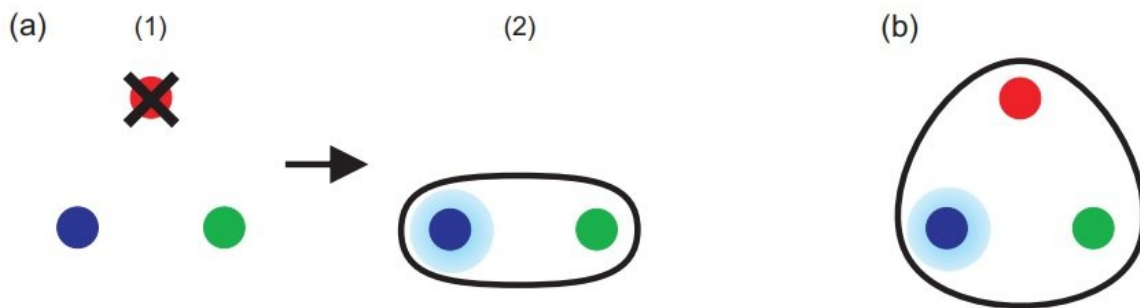


# Stronger-than-binary correlations experimentally demonstrated for the first time

May 21 2018, by Lisa Zyga



Two possible explanations for the quantum measurement process: (a) A binary measurement that generates the final outcome in two steps (first ruling out one of the three outcomes, then selecting between the two remaining outcomes), or (b) a ternary measurement that selects among all three outcomes at once. Credit: Hu et al. ©2018 American Physical Society

For the first time, physicists have experimentally demonstrated ternary—rather than binary—quantum correlations between entangled

objects. The results show that the quantum measurement process cannot be described as a binary process (having two possible outcomes), but rather stronger-than-binary ternary measurements (which have three possible outcomes) should be considered in order to fully understand how the quantum measurement process works.

The physicists, Xiao-Min Hu and coauthors from China, Germany, Spain, and Hungary, have published a paper on the stronger-than-binary correlations in a recent issue of *Physical Review Letters*.

"We discovered and experimentally verified the existence of genuine ternary measurements," coauthor Matthias Kleinmann at the University of Siegen in Siegen, Germany, and the University of the Basque Country in Bilbao, Spain, told *Phys.org*. "The experimental conclusions are independent of any underlying theory (here: [quantum theory](#)) and establish that ternary measurements are a generic feature of nature."

Before now, stronger-than-binary correlations have been theoretically predicted to exist, but this is the first time that they have been experimentally observed. In their experiments, the researchers entangled two photonic qutrits, each of which has three possible states (0, 1, and 2), instead of just two (0 and 1) as for qubits. They then sent the qutrits to different laboratories where they measured the state of each qutrit, enabling them to determine the strength of the correlations between the two qutrits.

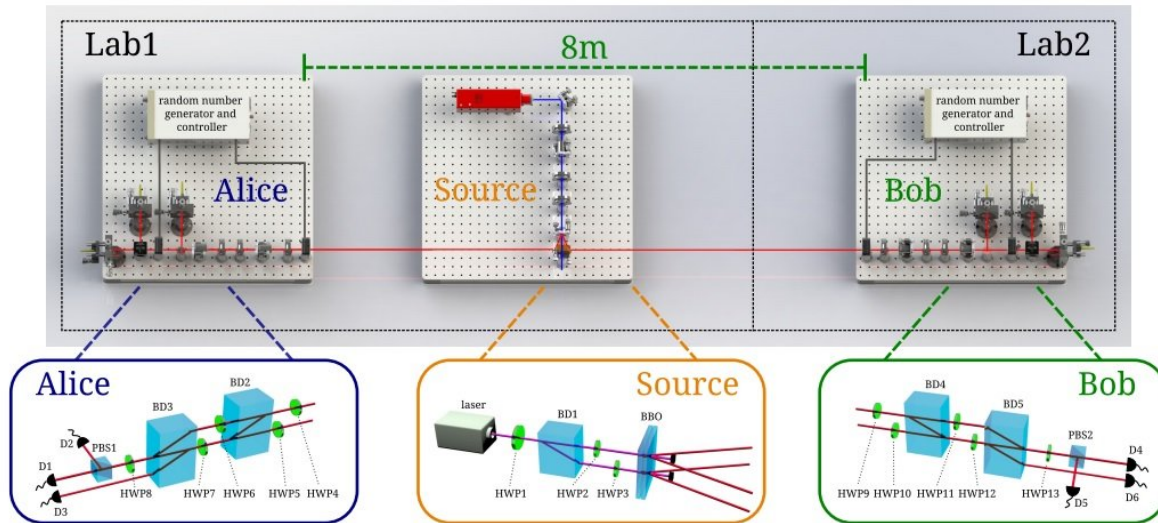


Illustration of the experimental setup for demonstrating ternary correlations.  
Credit: Hu et al. ©2018 American Physical Society

If the [quantum](#) measurement process were binary, then measurements could be described as a two-step process in which first one of the three possible measurement outcomes is ruled out by a classical mechanism, and then a quantum binary measurement selects between the two remaining outcomes. In this binary measurement process, the maximum [correlation](#) between two entangled objects cannot exceed a certain value.

In their experiments, the researchers demonstrated that the strength of the correlations between the entangled qutrits exceed this maximum value. To do this, they performed a Bell-type experiment in which they showed that the observed correlations violate the maximum inequality for nonsignalling binary correlations with a very high statistical significance, corresponding to 9.3 standard deviations. The results imply that the measurement process in quantum theory cannot be explained by the two-step process with binary measurements. Instead, the

measurement process here is genuinely ternary, where the quantum ternary measurement selects between all three of the possible states at once.

Overall, the researchers explain that the observations of stronger-than-binary correlations don't contradict previous experimental evidence of binary correlations, but add new possibilities for how the quantum measurement process works at the most fundamental level.

"Now that we have established the theoretical tools and the experimental methods to understand and create ternary correlations, we aim to proceed in two directions," Kleinmann said. "First, we hope for technological applications (for example, in randomness extraction) and second, we are now using our results as a new basis for a deeper understanding of quantum theory."

**More information:** More information: Xiao-Min Hu et al. "Observation of Stronger-than-Binary Correlations with Entangled Photonic Qutrits." Physical Review Letters. [DOI: 10.1103/PhysRevLett.120.180402](https://doi.org/10.1103/PhysRevLett.120.180402) , Also at arXiv:1712.06557 [quant-ph]

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