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Quantifying entanglement in a 68-billion-dimensional quantum state space

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Entanglement is the powerful and enigmatic resource central to quantum information processing, which promises capabilities in computing, simulation, secure communication, and meteorology beyond what is possible for classical devices. Exactly quantifying the entanglement of an unknown system requires completely determining its quantum state, a task which demands an intractable number of measurements even for modestly-sized systems. Here we demonstrate a method for rigorously quantifying high-dimensional entanglement from extremely limited data. We improve an entropic, quantitative entanglement witness to operate directly on compressed experimental data acquired via an adaptive, multilevel sampling procedure. Only 6,456 measurements are needed to certify an entanglement-of-formation of 7.11 ± .04 ebits shared by two spatially-entangled photons. With a Hilbert space exceeding 68 billion dimensions, we need 20-million-times fewer measurements than the uncompressed approach and 10^{18}-times fewer measurements than tomography. Our tech-nique offers a universal method for quantifying entanglement in any large quantum system shared by two parties.

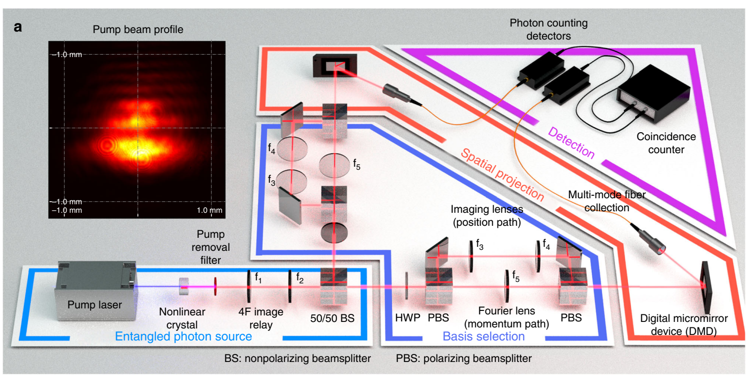
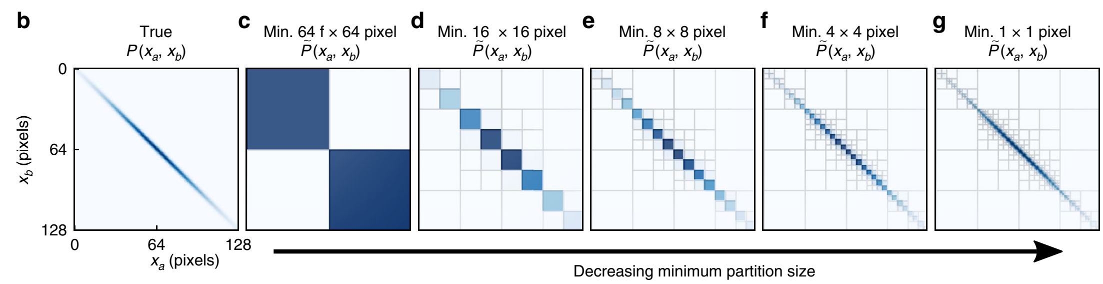


Fig. 2 Measured joint probability distributions at 512 × 512 pixel resolution. a–d show the four estimated joint probability distributions with their single-party marginal distributions overlaid, showing tight correlations. e shows an enlarged version of ~PðXa; XbÞ overlaid with the adaptive partitioning, with f showing a small central region to see fine detail. The histogram g shows the number of partitions as a function of their area. Only 6456 measurements are needed instead of 2 × 5124



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