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Random subspaces in quantum information theory

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The selection of random unitary transformations plays a role in quantum information theory analogous to the role of random hash functions in classical information theory. Recent applications have included protocols achieving the quantum channel capacity and methods for extending superdense coding from bits to qubits. In addition, the corresponding random subspaces have proved useful for studying the structure of bipartite and multipartite entanglement. In quantum information theory, we're fond of saying that Hilbert space is a big place, the implication being that there's room for the unexpected to occur. The goal of this talk is to further bolster this homespun wisdowm. I'm going to present a number of results in quantum information theory that stem from the initially counterintuitive geometry of high-dimensional vector spaces, where subspaces with highly extremal properties are the norm rather than the exception. Peter Shor has shown, for example, that randomly selected subspaces can be used to send quantum information through a noisy quantum channel at the highest possible rate, that is, the quantum channel capacity. More recently, Debbie Leung, Andreas Winter and I demonstrated that a randomly chosen subspace of a bipartite quantum system will likely contain nothing but nearly maximally entangled states, even if the subspace is nearly as large as the original system in qubit terms. This observation has implications for communication, especially superdense coding.