Parts determine the whole in a generic pure quantum state

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One of the most important open question in quantum information theory is to understand what fundamentally different types of quantum entanglement are possible. However, despite the considerable effort worldwide, this has proved remarkably difficult. We know, for example, that for any number of particles, N, there are states which have irreducible N-particle correlation (i.e. correlations that cannot be ascribed to the correlations amongst groups of fewer than N particles). However we do not know how many different types of irreducible N-particle correlation there are; indeed there may be infinitely many for any N. Most recent work seems to suggest ever increasing complexity and subtlety as the number of particles grows and the number of degrees of freedom increases. I will describe some recent work with William Wootters [Phys Rev Lett, 89, 277906 (2002)], building on our earlier work with Sandu Popescu [Phys Rev Lett 89, 207901 (2002)], which sheds a very unexpected light on this body of research. For while, as described above, one can find special states with irreducible correlations at all orders, for almost all states of N quantum particles, the situation is much less complicated. Specifically, for generic pure quantum states of N particles the correlations amongst at most about two-thirds of the particles contain all the information in the state. Expressed differently, the lower order correlations uniquely specify the higher order ones. Thus for almost all pure quantum states, the whole is not greater than the sum of two-thirds of the parts.