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## Avalanche of entanglement and correlations at quantum phase transitions


We study the ground-state entanglement in the quantum Ising model with nearest neighbor ferromagnetic coupling J and find a sequential increase of entanglement depth d with growing J. This entanglement avalanche starts with two-point entanglement, as measured by the concurrence, and continues via the three-tangle and four-tangle, until finally, deep in the ferromagnetic phase for $J = \infty$, arriving at a pure L-partite (GHZ type) entanglement of all L spins. Comparison with the two, three, and four-point correlations reveals a similar sequence and shows strong ties to the above entanglement measures for small J. However, we also find a partial inversion of the hierarchy, where the four-point correlation exceeds the three- and two-point correlations, well before the critical point is reached. Qualitatively similar behavior is also found for the Bose-Hubbard model, suggesting that this is a general feature of a quantum phase transition. This should be taken into account in the approximations starting from a mean-field limit.