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Entanglement at quantum critical points in two dimensions

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In two or more spatial dimensions, leading-order contributions to the scaling of entanglement entropy typically follow the "area" or boundary law. Although this leading-order scaling is non-universal, at a quantum critical point (QCP), the sub-leading behavior does contain universal physics. Different universal functions can be access through entangling regions of different geometries. For example, for polygonal shaped regions, quantum field theories have demonstrated that the subleading scaling is logarithmic, with a universal coefficient dependent on the number of vertices in the polygon. Although such universal quantities are routinely studied in non-interacting field theories, it often requires numerical simulation to access them in interacting theories. In this talk, I discuss quantum Monte Carlo (QMC) and numerical Linked-Cluster Expansion (NLCE) calculations of the Renyi entropies at the transverse-field Ising model QCP on the $2D$ square lattice. We calculate the universal coefficient of the vertex-induced logarithmic scaling term, and compare to non-interacting field theory calculations. Also, we examine the shape dependence of the Renyi entropy for finite-size toroidal lattices with smooth boundaries. Such geometries provide a sensitive probe of the gapless wave function in the thermodynamic limit, and give new universal quantities that could be examined by future field-theoretical studies in $2 + 1D$.