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Taming the sign problem using tensor renormalization

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We consider the sign problem for classical spin models at complex beta =1/g^2 on square lattices. We show that the tensor renormalization group method allows reliable calculations for larger Im beta than the reweighting Monte Carlo method. For the Ising model with complex beta we compare our results with the exact Onsager-Kaufman solution at finite volume. We show that the Fisher zeros can be determined precisely with the TRG method. We check the convergence of the TRG method for the O(2) model when the number of states increases. We show that the finite size scaling of the calculated Fisher zeros agrees very well with the Kosterlitz-Thouless transition assumption and predicts the locations for larger volume.
We present new applications of the TRG method for the O(2) model with a chemical potential. It provides robust estimations of the eigenvalues of the transfer matrix. The results are in good agreement with results obtained with the worm algorithm developed by Banerjee and Chandrasekharan.
We discuss the phase diagram in the beta-mu plane. We discuss the possibility of using this framework to describe real time evolution.

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