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Clock model interpolation and symmetry breaking in O(2) models

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The q-state clock model is a classical spin model that corresponds to the Ising model (when $q = 2$) and the XY model (when $q \to \infty$). The integer-q clock model has been studied extensively and has been shown to have a single phase transition when $q = 2, 3, 4$ and two phase transitions when $q > 4$.We define an extended-q clock model that reduces to the ordinary q-state clock model when q is an integer and otherwise is a continuous interpolation of the clock model to non-integer q. We investigate this class of clock models in 2D using Monte Carlo (MC) and tensor renormalization group (TRG) methods, and we find that the model with non-integer q has a crossover and a second-order phase transition. We also define an extended-O(2) model (with a parameter γ) that reduces to the XY model when $\gamma = 0$ and to the extended-q clock model when $\gamma \to \infty$, and we begin to outline the phase diagram of this model. These models with non-integer q serve as a testbed to study symmetry breaking with tensor methods where experimental parameters can be tuned continuously.

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