

## Detecting and identifying two-dimensional symmetry-protected topological, symmetry-breaking, and intrinsic topological phases with modular matrices via tensor-network methods

Symmetry-protected topological phases exhibit nontrivial order if symmetry is respected but are adiabatically connected to the trivial product phase if symmetry is not respected. However, unlike the symmetry breaking phase, there is no local order parameter for SPT phases. Here we employ a tensor-network method to compute the topological invariants characterized by the simulated modular S and T matrices proposed by Hung and Wen [PRB 89,075121 (2014)] to study a transition in a one-parameter family of wavefunctions which are  $Z_2$  symmetric. The studied wavefunctions are in some sense the SPT analog of  $Z_2$  topological states under a string tension. The numerically obtained S and T matrices are able to characterize the two different phases and identify the transition point.