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Stripe Order vs. Superconductivity: Revisiting the doped t-J model with iPEPS and AD

The t-J model is one of the simplest theoretical models believed to capture key aspects of high-temperature superconductivity in cuprate materials. Despite extensive study, the nature of its ground state at finite doping remains unsettled. Stripe order, characterized by intertwined charge and spin density waves, appears to compete closely with d-wave superconductivity. Previous DMRG studies using up to six-leg cylinders pointed towards a stripe-ordered ground state without coexisting superconductivity [1, 2], while iPEPS simulations suggested competition between uniform and striped d-wave superconducting states [3]. More recently, DMRG on eight-leg cylinders indicated a d-wave superconducting ground state that may coexist with weak pair-density wave and stripe orders [4]. With the inclusion of negative nearest-neighbour hopping t', uniform superconductivity was favoured, contrasting with iPEPS predictions for the corresponding t-t' Hubbard model, which favour period-4 stripes, either with suppressed superconductivity near 1/8 doping or with coexisting superconductivity at higher doping [5].

In view of these contrasting results, we revisit the problem using iPEPS simulations combined with gradient-based optimization using automatic differentiation. We investigate the ground-state phase diagrams of both the plain t-J and t-t'-J models at finite hole doping, focusing on the competition between uniform and striped superconducting phases. To reliably compare these competing states, we employ energy extrapolation techniques, including extrapolations based on a new developed method for computing the energy variance of iPEPS.

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