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Intertwined Charge and Pairing Fluctuations in the Emergence of Stripe-Aligned d-Wave Superconductivity

Stripe order is a defining feature of the high-temperature cuprate phase diagram and has been numerically shown to be the ground state of the two-dimensional Fermi-Hubbard and t-J models in specific regimes. Upon heating, stripe and superconducting orders give way to the strange metal and pseudogap phases, whose microscopic origins remain elusive. Using advanced tensor network techniques, we uncover critical aspects of this transition. Infinite projected entangled pair state (iPEPS) simulations reveal a pronounced maximum in the uniform charge susceptibility above the stripe phase, near hole doping p = 0.9 which intensifies upon cooling. Finite-width cylinder METTS simulations trace this maximum to the formation of fluctuating charge clusters, reminiscent of phase separation into hole-rich and hole-poor regions. However true phase separation is ultimately forestalled by the emergence of stripe order at low temperatures. Investigating the doped Mott regime within the t-t'-J model, we observe that fluctuating domain walls of doped holes serve as precursors to superconductivity. At low temperatures, transient mergers of hole-rich regions form larger clusters, within which distinct areas host fragmented superconducting channels. As the temperature decreases, these fragmented condensates gradually phase-lock into a globally coherent, stripe-aligned d-wave superconductor. Our findings suggest a unified framework where local charge and pairing fluctuations coalesce into stripe order and superconductivity, offering new insights into the intertwined nature of these phenomena in strongly correlated systems.

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