FORESTALLED PHASE SEPARATION AS A PRECURSOR TO STRIPE AND SUPERCONDUCTING ORDER

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Stripe order and superconductivity are key features in the phase diagram of high-temperature cuprate superconductors, extensively studied within the two-dimensional Fermi-Hubbard model (FHM). Numerically, stripe order has been confirmed as the ground state of the two-dimensional FHM without nearest-neighbor (NN) coupling, while superconductivity emerges upon introducing NN couplings in specific parameter regimes. As temperature increases, both stripe and superconducting states transition into the enigmatic strange metal and pseudogap regimes, whose precise nature remains a long-standing puzzle. Using modern tensor network techniques, we discover a crucial aspect of these regimes. Infinite projected entangled pair state (iPEPS) simulations in the fully two-dimensional limit reveal a maximum in the charge susceptibility at temperatures above the stripe phase. This maximum is located around hole-doping $p = 1/8$ and intensifies upon cooling. Using minimally entangled typical thermal states (METTS) simulations on finite cylinders, we attribute the enhanced charge susceptibility to the formation of charge clusters, reminiscent of phase separation where the system is partitioned into hole-rich and hole-depleted regions. In contrast to genuine phase separation, the charge cluster sizes fluctuate statistically without a divergent charge susceptibility. Hence, while this precursor state features clustering of charge carriers, true phase separation is ultimately forestalled at lower temperatures by the onset of stripe order [1]. This charge clustering maybe linked to the pseudogap phenomenon, where antiferromagnetic (AFM) domains create an electronic gap while adjacent metallic regions partially fill it, characteristic of the pseudogap phase. Intuitively, antiferromagnetic correlations can be maximized whenever exactly two electrons reside on nearest-neighbor sites, and hence, strong antiferromagnetic correlations favor half-filled regions. Thus, an attraction between electrons mediated by antiferromagnetic correlations depletes other regions of the system, which constitute the hole-rich clusters. Additionally, in the t-J model with nearest- neighbor coupling t', we show that phase separation gives way to superconducting d-wave order, highlighting the interplay between AFM correlations, charge susceptibility, and superconductivity.

[1] Forestalled Phase Separation as the Precursor to Stripe Order, arXiv:2411.15158.