Superconductivity on the Brink of Phase Separation

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Abstract

Doping a Mott antiferromagnet reshapes the medium that carriers traverse. In the regime where superconducting correlations are strongest, charge often becomes nonuniform, forming stripes and fluctuating mesoscale clusters. This forces a direct mechanism question: in an inhomogeneous charge landscape, where does the macroscopic pairing weight live? We study the square-lattice t-t'-J model on cylinders using minimally entangled typical thermal states. Superconductivity is diagnosed from the eigenstructure of a singlet-pair reduced density matrix, while charge organization is quantified via snapshot hole-cluster statistics. We uncover an extended intermediate-(T) regime of **forestalled phase separation [1]**, where doped charge forms fluctuating, mesoscopic hole-rich backbones without macroscopic segregation. Cluster-restricted spectra show distinct macroscopic pairing channels preferentially residing on different hole-rich clusters, with the hole-poor antiferromagnetic background contributing weakly. Upon further cooling, these channels lock together as stripe order develops, producing coherent d-wave superconductivity. Forestalled phase separation thus organizes finite-T superconductivity in a doped Mott insulator.

References

[1] Aritra Sinha, Alexander Wietek, Nature Communications 16, 10807 (2025)

Figures

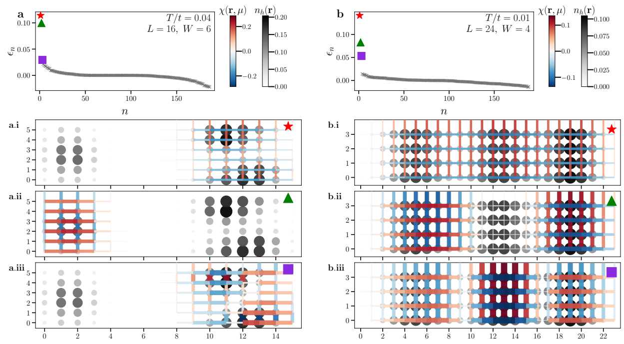

Figure 1: Real-space structure of leading superconducting pairing modes in single thermal snapshots. We show where pairing resides in an inhomogeneous charge landscape by visualizing the leading singlet pairing eigenmodes from individual minimally entangled typical thermal state (METTS) snapshots of the square-lattice t–t'–J model at fixed filling n = 0.9375 and next-nearest-neighbor hopping t'/t = 0.2. Panel (a) shows an L = 16, W = 6 cylinder at T/t = 0.04, and panel (b) an L = 24, W = 4 cylinder at T/t = 0.01. Top panels plot the snapshot pairing-eigenvalue spectrum, highlighting the three largest modes. Bottom panels (i–iii) display the corresponding bond-resolved pairing eigenmodes overlaid on the same snapshot's hole density: grey circles indicate local hole density (larger/darker means more hole-rich), while colored bonds indicate the signed pairing amplitude on each bond (common scale within each column).