Wrestling with the finite temperature two dimensional Fermi-Hubbard Model: A Tensor Network Approach

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The Fermi Hubbard Model is a simple model of interacting electrons on a lattice. However, solving it in two dimensions has been a long-standing challenge. Recent advancements in numerical tools like tensor network methods, specifically infinite projected entangled pair states (iPEPS), have enabled a better understanding of the ground states of the model [1] in the thermodynamic limit (infinite size). Finding solutions at finite temperature, however, has seen limited success, and even then only for small lattices. In our work, we leverage the newly developed Neighborhood Tensor Update (NTU) [2] and imaginary time evolution with iPEPS to reach temperatures as low as 0.17 times the hopping rate working in the thermodynamic limit. Our findings [3] reveal disruption in the antiferromagnetic background with mobile holes in a slightly doped Hubbard model, as well as the presence of hole-doublon pairs and signatures of hole-hole repulsion. Currently, we are developing algorithms to reach lower temperatures by repurposing NTU to work with pure states on finite PEPS and computing the thermal observables. During my presentation, I will give highlights of the numerical challenges that we have faced and outline our efforts to overcome these challenges through the construction of new tensor network algorithms. The application of these algorithms not only provides valuable insights into the physics of the under-doped Hubbard model, but can also be applied to the study of other bosonic and fermionic models. Our findings serve as reliable benchmarks for both theoretical work and experiments with ultracold atoms.

References:

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