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Quasiparticle localization in a flat band superconductor

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Due to advances in ultracold gas experiments and the recent unexpected discovery of superconductivity in magic-angle twisted bilayer graphene and other moiré materials, much effort is currently being devoted to understand superconductors and superfluids in the strongly correlated regime characterized by electronic energy bands with very small, or even vanishing, bandwidth. According to mean-field theory, the superconducting critical temperature is sharply enhanced by the diverging density of states in this so-called flat band limit. However, noninteracting particles in a flat band have infinite effective mass and are localized, which means that charge transport is completely suppressed, in contrast to the very nature of the superconducting phase. This apparent paradox is resolved by noting that in a flat band two particles can form a bound state, that is a a Cooper pair, which is mobile and whose mass is finite and depends in a subtle way the properties of the flat band wave functions. On the other hand, an open question is what are the properties of the quasiparticles in a flat band superconductor, in particular it is interesting to ask whether they are localized or not. In this work, we present evidence, obtained with both analytical and numerical methods, that quasiparticle excitations have infinite effective mass and are thus localized as their noninteracting counterparts, and coexist with the highly mobile Cooper pairs 1. While the analytical results are rather general, in our numerical investigations using exact diagonalization, we focus on a specific lattice model with flat bands, the dice lattice, which could be implemented using optical lattices.

References:

1 K.Swaminathan, P. Tadros, S. Peotta, Signatures of many-body localization of quasiparticles in a flat band superconductor, arXiv:2302.06250.

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