Effective theory and emergent $SU(2)$ symmetry in the flat bands of attractive Hubbard models

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We study fermions interacting via attractive Hubbard interaction on a lattice with a flat Bloch band separated from the other bands by a finite energy gap. First, we project the Hamiltonian into the flat band Wannier functions. Then, we do a further approximation which leads to an effective ferromagnetic spin chain with an emergent $SU(2)$ symmetry. As a specific example, we consider a one-dimensional ladder with two perfectly flat Bloch bands. We show that as a manifestation of the emergent $SU(2)$ symmetry the Bardeen-Cooper-Schrieffer (BCS) wavefunction is the exact ground state of the projected Hamiltonian, and that the compressibility is diverging. We extend the projected model by using the Schrieffer-Wolf transformation and show that the $SU(2)$ symmetry is broken by second order interband transitions also resulting in a finite compressibility, which we calculate analytically and compare to the result obtained via quasi-exact DMRG simulations. Our predictions can be tested via transport measurements in cold atom experiments.