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Energy minimization of paired composite fermion wave functions

The physics of electrons in half-filled Landau-levels is intimately related to that of free electrons via the composite fermion transformation. In particular, the half filled second Landau-level is thought to harbour a pairing instability, leading to a superconductor of composite fermions.

However, details of this superconducting state are contested, and recent controversy has revolved around the nature of the pairing state.
One strong contender is pairing in the p-wave channel, supporting non-Abelian Majorana fermion excitations. However, recent experiments have drawn some doubt on this picture, failing to match predictions for edge currents associated with this phase. Instead, these experiments are compatible with a particle-hole symmetry preserving pairing state baptised the P-H Pfaffian.

Here, we approach this question by means of the variational pairing states introduced in [1], and examine whether an energetically competitive pairing state can be found within this general class of paired states in the particle-hole symmetric s-wave channel [2].

We find that this class of variational states does not yield a strong contender for a new s-wave pairing state, but the variational freedom in the p-wave channel yields energies that are significantly below the energies obtained for the Moore-Read Pfaffian state [2]. We also undertake this analysis in the pairing sector corresponding to the anti-pfaffian, the particle-hole conjugate of the Moore-Read state, where we find that the variational optimisation yields a lesser advantage, but still delivers the most competitive trial state. We find that the optimal wave functions are well described by a weak-pairing BCS ansatz in the p-wave sectors, but in the s-wave sector show no sign of emergent CF pairing.

[1] G. Möller, S.H. Simon, Phys. Rev. B 77, 075319 (2008).
[2] Greg J. Henderson, Gunnar Möller, Steven H. Simon, arxiv:2309.17003.