Emerging Exotic Phases in Unconventional Superconductors with Long-range Interactions

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Continuum limits are a powerful tool in the study of many-body systems, yet their validity is often unclear when long-range interactions are present. In this work, we rigorously address this issue and put forth an exact representation of long-range interacting lattices that separates the model into a term describing its continuous analog, the integral contribution, and a term that fully resolves the microstructure, the lattice contribution [1].
For any system dimension, any lattice, any power-law interaction, and for linear, nonlinear, and multi-atomic lattices, we show that the lattice contribution can be described by a differential operator based on the multidimensional generalization of the Riemann zeta function, namely the Epstein zeta function.
We employ our representation in Fourier space to solve the important problem of unconventional superconductors with density-density long-range interactions. We derive a generalized Bardeen–Cooper–Schrieffer gap equation and find emerging exotic phases in two-dimensional superconductors with topological phase transitions. Finally, we utilize non-equilibrium Higgs spectroscopy [2] to analyze the impact of long-range interactions on the collective excitations of the condensate.
We show that the interactions can be used to fine-tune the Higgs mode's stability, ranging from exponential decay of the oscillation amplitude up to complete stabilization.

References

[1] A. A. Buchheit, T. Keßler, P. K. Schuhmacher, B. Fauseweh, arXiv:2201.11101, (2022)
[2] L. Schwarz, B. Fauseweh, et al., Nat. Comm., **11**, 287, (2020)

Figures

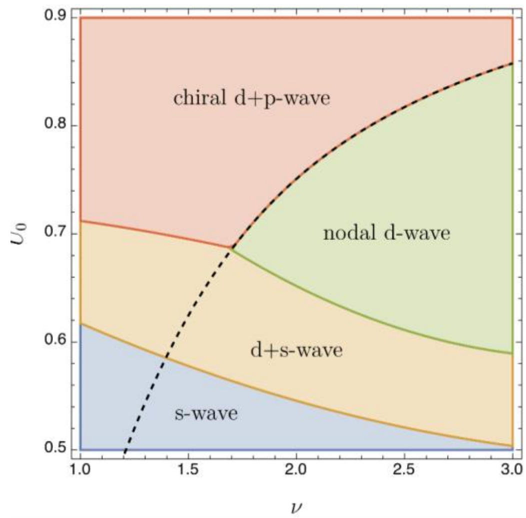

Figure 1: Zero temperature phase diagram for a 2D superconductor depending interaction exponent ν and interaction strength U_0.

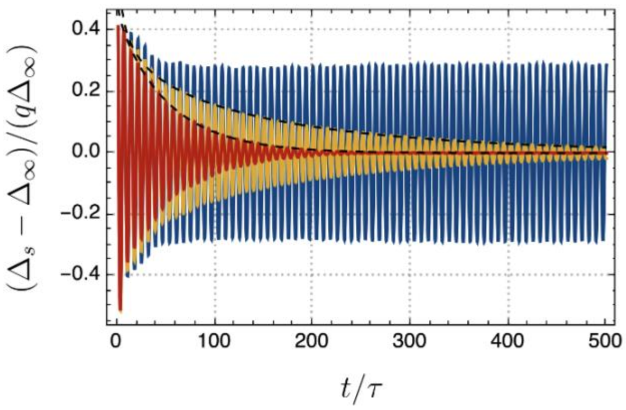

Figure 2: Higgs oscillation of a 2D superconductor demonstrating Higgs mode stabilization depending on the interaction exponent ν.