A perspective on collective excitations in high-temperature copper-oxide superconductors

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Strong local correlations are believed to be among key constituents of high-temperature superconductivity (high-T_c SC) in layered copper oxides. Yet, the same electrons which are involved in Cooper pairing participate also in collective charge (plasmon) and magnetic (paramagnon) excitations that persist across the high-T_c SC dome, from underdoped to overdoped regime. A linear scaling between the paramagnon energies and maximal SC transition temperatures, established experimentally for multiple cuprate families [1], points toward a plausible involvement of the collective excitations in SC pairing mechanism, in par with local correlations.

We address theoretically the relationship between local correlations and collective excitations in the cuprates, employing the Hubbard, t-J, and t-J-U models [2]. Collective-excitation spectra are obtained using a generalized variational scheme that goes beyond the renormalized mean-field theory. The results are shown to reproduce experimentally observed paramagnon robustness across the high-T_c phase diagram, as well as agree quantitatively with measured acoustic plasmon spectra. For representatives of the cuprate Bi-family with up to thee CuO_2 planes in the unit cell, we calculate paramagnon energies based on experimentally mapped fermiology and charge transfer energy, demonstrating agreement with experiment within 6% margin [3]. Finally, we comment on the correlation between the calculated quantities and measured SC transition temperatures.

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References

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