Non-uniform and anisotropic polarizability resulting in pronounced local repulsion minima in high-T_c superconductors

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Tremendous research effort, both on the experimental and theoretical sides, is being invested by the scientific community to understand the underlying physics of high-T_C superconductors in the hope of using that knowledge to design and produce them at ambient conditions. We demonstrate here the dramatic effect of non-uniform, discrete electric polarizability in high-T_C superconductors on the spatial fluctuations of the short to medium range Coulomb interactions through a real-space semiclassical model. Although this is a general property, we focus on the cuprates as parent compounds, in which the charge carriers are primarily concentrated on the O sublattice. The anisotropic effective Cu-O bond polarization caused by charge transfer energy modulation and the O^{2-} atomic polarizability together generate a non-monotonic screened hole-hole Coulomb interaction at short distances that displays a local minimum at the in-plane second nearest neighbor O-O distance solely along the Cu-O bond direction. This is in accordance with the pseudogap phase anisotropy [1] and the short coherence length [2] observed in many high-T_C superconductors.

References

[1] V. Aji, A. Shekhter, and C. M. Varma, Physical Review B 81 (2010) 064515
[2] J. Hwang, Scientific Reports 11 (2021) 11668

Figures

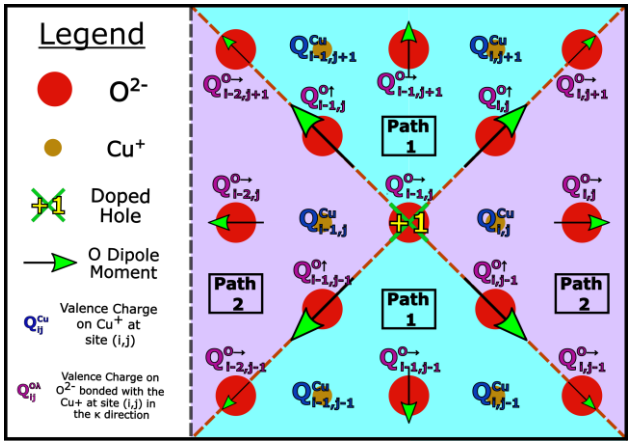

Figure 1: Diagram of the polarization effects induced by a doped hole on an O site of a CuO_2 cluster. The two regions in which placing a second hole results in distinct interaction behaviour are highlighted.

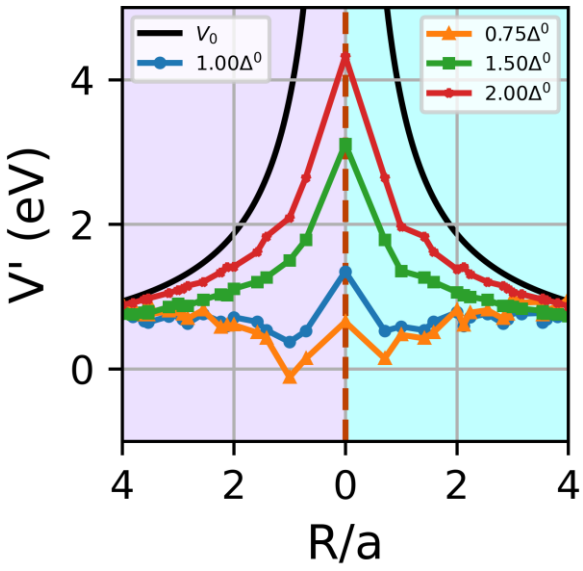

Figure 2: Screened Coulomb interaction V' between two holes hosted by oxygen ions in a cuprate plane for different Cu-O charge transfer energies (Δ^0 = 6.00 eV).