Conclusion

High-temperature cuprate superconductors exhibit interesting coexisting phases originating from doping the strongly correlated Mott insulating parent compounds. We address how these competing orders contribute to the apparent non-universal phenomena among the electron- and hole-doped cuprates via the scanning tunneling spectroscopic studies of two representative cuprate families, the hole-doped YBCO and the electron-doped SLCO. We focus on the detailed analyses of the spectral evidence for the pairing symmetry and pseudogap phenomena of the two systems. The quasiparticle spectral features and the impurity scattering effects in the optimally doped and underdoped YBCO are consistent with a predominantly $d_{x^2-y^2}$($> 95\%$)-wave pairing, whereas those of the overdoped Ca-YBCO exhibit $d_{x^2-y^2}$ pairing with a significant s-component mixing ($> 30\%$), indicative of a change of ground state properties. While the satellite features in the tunneling spectra of YBCO above the spectral gap imply the existence of a competing order comparable in strength to superconductivity, the low-energy quasiparticle spectral characteristics are well-captured by the mean-field generalized BTK theory, indicating that quantum fluctuations are less significant in describing the low-energy physics of YBCO.

On the contrary, quasiparticle tunneling spectra of the n-type infinite-layer pure and impurity-doped SLCO support an isotropic s-wave pairing potential, and the spectral characteristics demonstrate the complete absence of satellite features in the superconducting state and the absence of pseudogap in the normal state. The emergence of the current-induced pseudogap suggest that, in SLCO, superconductivity coexists with a small competing order, which manifests itself only upon the suppression of superconductivity by external perturbations. The small amplitude of the competing order is consistent with the invisible pseudogap phenomena and satellite features in zero field.

The excess low-energy excitations revealed by tunneling spectroscopy deviate significantly from the mean-field prediction, which indicates the presence of strong quantum fluctuations as corroborated by the high-field vortex dynamic measurements.

To understand the distinctly different physical properties between the two types of cuprate, we consider a simple model of density waves as competing orders coexisting with superconductivity. By taking into account the varying proximity to quantum criticality and the varying degree of quantum fluctuations, numerical results of the theoretical proposal reproduce the excess subgap low-energy excitations of SLCO below T_c. Furthermore, we show that, by tuning the relative strength of competing orders and superconductivity, the proposal reconciles the occurrence of pseudogap phenomena above T_c or H_{c2} in the hole-doped cuprates with their absence in the electron-doped cuprates and thus provides a unified explanation for the seemingly non-universal behavior among the cuprate superconductors.