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Pseudogap and Superconductivity in Cuprate Superconductors Solved by Ab initio and Machine Learning Studies

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We first summarize how the *d*-wave superconducting and stripe states are severely competing in the simple Hubbard models, which is elucidated by using combined variational Monte Carlo, tensor network and Lanczos methods [1,2]. The result is not consistent with the experimental indications. On the other hand, *ab initio* Hamiltonian of carrier doped cuprates recently derived without any adjustable parameters [3,4] well reproduces the experimental phase diagram.

We next discuss renewed understanding of the superconducting mechanism. An experimental long-standing puzzle was the featureless structure in the spectral function indicated by the angle resolved photoemission spectroscopy (ARPES) spectra, in contrast to the case of conventional strong-coupling BCS superconductors in the history. We discuss how the puzzle has been solved with the help of quantum-cluster dynamical mean-field studies of the Hubbard model [5,6] and a completely independent machine learning studies purely based on the ARPES data [7]. An emergent dark fermion theory is discussed in detail [8].

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