Half-filled metal and molecular-orbital-mediated pairing in cuprate

Yayu WANG

Department of Physics, Tsinghua University

Email: yayuwang@tsinghua.edu.cn

In this talk, we present STM studies of underdoped cuprates, which reveal that doped holes form localized electronic molecules consisting of $4a_0 \times 4a_0$ plaquettes. Each plaquette contains approximately two holes, so the effective local doping level is around $p \sim 1/8$. Such high doped hole density is sufficient to destroy the underlying antiferromagnetic order and more importantly, recovers the half-filled metallic state of the original CuO_2 plane. The restored Fermi surface, hosting one hole per unit cell, is consistent with ARPES measurements and satisfies the Luttinger theorem. We then construct the momentum-space structure of the half-filled metal by taking into account the real-space configuration of electronic molecules. We show that the electronic potential with $4a_0$ periodicity imposed by the plaquettes and the quantum size effect of electronic molecules obliterate the nested antinodal Fermi surface sheets of the half-filled metal, leaving behind short arcs with coherent quasiparticles around the node. This picture thus gives a natural explanation for the mysterious pseudogap in underdoped cuprates. Based on these observations, we propose that the Cooper pairs in cuprates are formed between itinerant holes on the half-filled Fermi surface mediated by localized molecular orbitals. This two-component picture resolves several core issues concerning the mechanism of superconductivity in cuprates.