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Strong coupling picture of superconductivity in underdoped cuprates I: weak phase stiffness and mass divergence of d-wave superfluid
YUCEL YILDIRIM, WEI KU, Brookhaven National Lab. — Despite more than two decades of intensive investigations, the true nature of high temperature superconductivity observed in the cuprates remains elusive to the researchers. In particular, in the so-called "underdoped" region, the overall behavior of superconductivity deviates qualitatively from the standard BCS description. Recently, the importance of phase fluctuation of the superconducting order parameter, has gained significant support from various experiments. However, the microscopic mechanism responsible for the surprisingly soft phase remains one of the most important unsolved puzzles. Here, opposite to the standard BCS starting point, we propose a simple, solvable low-energy model in the strong coupling limit, which maps the superconductivity literally into a well-understood physics of superfluid in a special dilute bosonic system of local pairs. In the prototypical material $(La_{1-\delta}Sr_{\delta})_2CuO_4$, without the use of any free parameter, a d-wave superconductivity is obtained for doping above 5.2%, below which unexpected incoherent p-wave pairs dominate. Throughout the whole underdoped region, very soft phases are found to originate from enormous mass enhancement of the pairs. Furthermore, a striking mass divergence is predicted that dictates the occurrence of the observed quantum critical point. Finally, good theoretical agreement with experiments will be presented.

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