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Cooper pair density-wave and dual Hofstadter butterfly in underdoped cuprates[1]

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An XY-type model of quantum phase fluctuations in a correlated 2D lattice d-wave superconductor is introduced and studied[2]. The model is based on the QED_3 effective theory of high temperature superconductors and is geared toward describing not only the long distance but also the *intermediate* lengthscale physics of underdoped cuprates. In particular, I elucidate the dynamical origin and investigate specific features of the Cooper pair density-wave, which I propose as the state behind the periodic modulation in the local tunneling density of states (DOS) discovered in recent STM experiments. I illustrate how Mott-Hubbard correlations near half-filling suppress superfluid density and favor an incompressible state which breaks translational symmetry of the underlying atomic lattice. The formation of the Cooper pair density-wave in such a quantum-fluctuating superconductor can be recast as an Abrikosov-Hofstadter problem in a type-II *dual* superconductor, with the role of dual magnetic flux per plaquette, f, played by the electron density: $f = (1-x)/2$, where x is the doping. The Abrikosov-Hofstadter problem generates the sequence of doping "magic fractions" at which f exhibits high degree of commensurability with the CuO_2 lattice. The resulting Abrikosov-Hofstadter lattice of dual vortices translates into the periodic modulation of the gap function and the electron density. The energetics of various dual vortex arrays and their signatures in the single-particle local tunneling DOS are studied in detail. A 4×4 checkerboard modulation pattern naturally arises as an energetically favored ground state at and near $x = 1/8$ and produces local DOS in good agreement with experiments.
[2]Z. Tešanović, Phys. Rev. Lett. **93**, 217004 (2004); A. Melikyan and Z. Tešanović, cond-mat/0408344.

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