Electron-electron versus electron-phonon interactions in exotic superconductors*

S. Mazumdar[1], H. Li[1], R. T. Clay[2]
[1]*University of Arizona, Tucson, Az, USA,* [2]*Missisisppi State University, Mississippi State, MS,USA*
Email: sumit@physics.arizona.edu

Two entirely different classes of theories have been proposed for the family of exotic superconductors including both high T_c cuprates and organic charge-transfer solids (CTS). These generally emphasize either electron-electron (e-e) or electron-phonon (e-p) interactions. Within theories emphasizing e-e interactions, the pairing interaction is driven usually by antiferromagnetic (AFM) spin fluctuations [1], and e-p interactions play either a weak or even a pair-breaking role. Convincing proof of pairing within such theories has remained elusive. Similarly, within theories emphasizing e-p interactions, the Coulomb repulsion between electrons plays a pair-breaking role and, and pair-binding can occur only for very strong e-p interactions leading to bipolarons [2]. Whether or not such bipolarons can only be on-site with very large effective mass, or can be inter-site mobile bipolarons remains a contentious issue.

Experiments on cuprates indicate that not only both e-e and e-p interactions are involved, but rather these interactions act co-operatively [3]. In the CTS the state proximate to superconductivity can be AFM [4] or charge-ordered [5], showing again the strong role of both interactions. We show that the difficulty in arriving at a theory where e-e and e-p interactions can act co-operatively arises from the assumptions of either an electron-gas or a band-filling of ½: configuration-space pairing in two dimensions is difficult to attain in these cases where each electron has a large number of neighbors. Next we discuss the ¼-filled band in one and two-dimensions, where we show that pairing and charge-ordering go hand in hand. Our theory has similarities with both RVB and bipolaron theories, while being distinct from both. We show that bipolarons within the ¼-filled band arise from a co-operative interaction between e-e and e-p interactions, are necessarily inter-site, and light. Our theory has immediate applications to the CTS and we believe it is quite general. We discuss ¼-filled band spinel oxides and chalcogenides such as $LiTi_2O_4$, $LiRh_2O_4$, and $CuRh_2S_4$, with metal-insulator or superconducting transitions similar to those in the CTS.

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