Interplay between electron-phonon and Coulomb interactions

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Recommended with a Commentary by Claudio Castellani, Universita' di Roma

The electron-phonon interaction (EPI) in normal metals, specifically in the absence of electron-electron interaction, is a text-book subject and our understanding is quite satisfactory both at weak and strong coupling. There are no deep problems to be unraveled and no big surprises to be expected, even though our strong coupling analysis mainly concerns simple models like the Holstein model, where a Einstein phonon is locally coupled to the electron density. Our understanding of the EPI is instead much less (and honestly I would rather say that it is very poor) when electron-electron correlation is strong as in cuprates and standard methods to deal with EPI are quite unrealistic. The key question is whether EPI is enhanced or reduced by correlations, specifically in the context of cuprates

The paper "Interplay between electron-phonon and Coulomb interactions in cuprates" deals with exactly this problem and provides a rich overview on the present status of the research in the field. It can be quite useful for people who want to work or just think on this subject.

The paper has various assets. First, it provides an extensive list of the experimental evidences of EPI in cuprates. In my opinion, this makes clear that the strongest EPI effects on the single particle properties are in the extreme low doping limit where EPI interplay with antiferromagnetism. This is the region where the Mishchenko and Nagaosa analysis of the t-J model with phonons [1] is relevant to explain what looks like polaronic features in undoped Ca2CuO2Cl2 [2].

The second merit of the paper is that the authors review their and other people's theoretical work in a balanced way. They also make clear that the answer to the question "enhanced or reduced EPI" can depend (both experimentally and theoretically) on the specific property one is looking at. For instance phonon softening (specifically for half-breathing phonons) behaves

differently with doping (it is enhanced by doping) with respect to single particle properties. The phonon contribution to the effective mass is indeed predicted to decrease by doping the antiferromagnetic phase, in agreement with experiments.

From the review it is clear that the above key question still has not a clear-cut theoretical answer. The issue is the balance (or the unbalance) between the correlation induced quasi-particle reduction Z which depresses EPI and a possible (correlation induced) vertex correction enhancement. From this point of view it is clear that the kind (the "symmetry") of the electron phonon coupling is a relevant variable. In the Holstein-Hubbard model the phonons are locally coupled to density and are directly competing with U. This can be (and indeed is) different in different models [3]. Also, the q-dependence of the electron-phonon coupling [4] can be important, by itself or by the q- (and frequency-) dependence of the electron-phonon vertices in the presence of correlation.

With respect to the discussion in the review, I would have been more sceptical on the possibility to explain the famous kink in ARPES in terms of phonons (or in general in terms of standard boson modes). There, the most astonishing aspect is not the kink by itself but the constance with decreasing doping of the low energy slope while the kink feature is enhanced by the enhancement of the high energy slope. In the review there is not much about transport, mainly, I think, because there is not much work on that. Indeed the absence of phonon energy scales in the linear in T resistivity near optimal doping is, in my opinion, still the strongest evidence that at least there phonons play only a marginal role.

[1] A.S.Mishchenko and N.Nagaosa, Phys. Rev. Lett. **93** 036402 (2004)
[2] K.M.Shen et al., Phys. Rev. Lett. **93** 267002 (2004)
[3] M.Capone et al., Science **296** 2364 (2002); J.E.Han, O.Gunnarsson, and V.H.Crespi, Phys. Rev. Lett. **9** 167006 (2003)
[4] Z.B. Huang et al., Phys. Rev. B **68** 220507 (2003)