Charge response and Magnetism in 1D Wigner crystals

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Doped edge-sharing Cu-O chains are ideal realizations of 1D *generalized* Wigner lattices (WL). Such chains are found in the recently synthesized $Na_3Cu_2O_4$ and $Na_8Cu_5O_{10}$ systems [1], and are also structural elements in the widely studied composite compounds $Sr_{14-x}Ca_xCu_{24}O_{41}$. As a result of the geometrical structure (90 degree Cu-O-Cu coordination) the kinetic energy is small compared to the Coulomb interaction $V_l \sim V/l$ as required for WL formation. Nearest and next-nearest neighbor hopping matrix elements t_1 and t_2 are small but of comparable size and are both relevant for the description of magnetic properties.

The optical conductivity $\sigma(\omega)$ [2], the charge dynamics $N(k,\omega)$ [3] and the single particle spectral function $A(k,\omega)$ [3] are studied by exact diagonalization and to some extent also analytically, i.e., starting from a generalized Hubbard model including long-range Coulomb interaction $V_l \sim V/l$. At quarter-filling these spectra show clear signatures of charge fractionalization into pairs of domain walls. The long-range Coulomb interaction leads to a pronounced antibound state in $A(k,\omega)$ in striking contrast to the bound exciton state in the density response $N(k,\omega)$. In the case of the antibound state, we find clear evidence of spin-charge separation.

Results for the magnetic phase diagram of the WL at quarter-filling are presented, that were obtained both by density matrix renormalization group (DMRG) calculations and by analytical considerations [4]. In the $t_1 - t_2$ plane we find an asymmetric phase diagram with respect to the parameter t_2 . While most of the phase diagram is controlled by antiferromagnetic superexchange $\propto 1/U$, there is a regime at negative t_2 with fully saturated ferromagnetic ground states. This peculiar behavior is due to kinetic exchange processes in the 1D WL which are $\propto t_1^2 t_2/\Delta^2$, where Δ is the charge gap of the WL ($\Delta \ll U$). As unexpected as the appearance of ferromagnetism in the 1D Wigner lattice, is the surprisingly strong influence of magnetism on charge correlations.

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[3] M. Daghofer and P. Horsch, PRB **75**, 125116 (2007)
[4] M. Daghofer, R.M.Noack and P. Horsch, Phys. Rev. B 78, 205115 (2008).