Exciton condensation in strongly correlated electron bilayers
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Our idea: combine bilayer excitons and strongly correlated electron systems

A bilayer exciton is an exciton where the hole and electron are spatially separated in two different layers. An insulating layer in between prevents annihilation of the excitons. Because of their long life-time, bilayer excitons are ideal candidates for realizing a Bose condensate of excitons. [1]

What is a bilayer exciton in a strongly correlated background?

In strongly correlated electron systems the electrons are localized, and standard electronic band theory does not apply.

The high-temperature superconducting cuprates are an example of layered strongly correlated electron systems. Because of their quasi-2D nature, strongly correlated electron systems are ideal candidates for bilayer excitons.

What happens at any finite exciton density?

When there is a finite density of excitons, there is strong competition between three different phases:
- the antiferromagnet (AF) in the absence of excitons;
- the exciton condensate (EC). For large exciton hopping, excitons will form a Bose condensate. The wavefunction of the condensate is given by a superposition on each run of a spin singlet with an exciton:

\[
\prod_i (u_i + \sqrt{2}E_i^x) |0\rangle
\]

- the checkerboard phase (CB) at half-filling, where the strong exciton-exciton repulsion leads to an exciton Wigner crystal.

However, for most parts of the phase diagram the competition leads to macroscopic phase separation between these three phases. (See the ground state phase diagram on the right.)

Our model predicts that the exciton condensate is incoherent at half filling, and becomes coherent as it moves away from fillings. The spectral function of exciton in undoped YBaCuO is shown.

The collective modes (see left pictures, for \( t = 2 \text{ eV} \)) of the exciton condensate consist of triplet excitations (middle row) and the exciton superfluid phase mode (bottom row).

The surprise that the triplet modes are characterized by a dispersion with a bandwidth determined by the superfluid density of the exciton condensate.

Therefore the superfluid density can be measured in spin fluctuation spectra (neutron scattering). [3]

References