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Electron-hole asymmetry and superconductivity

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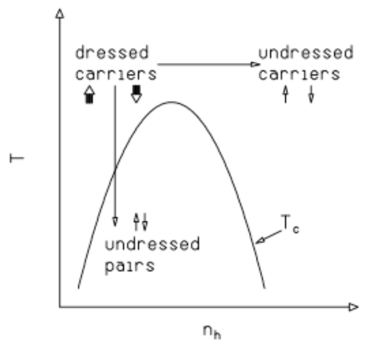
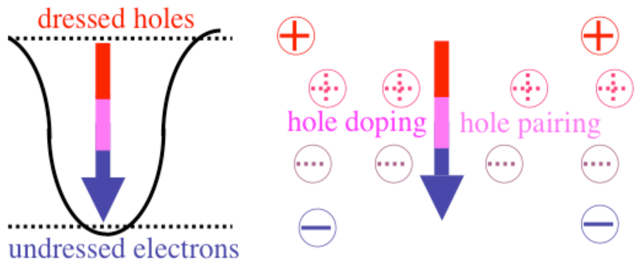
A rotating superconductor generates a magnetic field that is parallel, never antiparallel, to its angular velocity [1]. The tunneling current in a NIS junction is found to be larger for a negatively biased sample. The Hall coefficient goes from positive to negative when a normal metal becomes superconducting. Metals with negative Hall coefficient almost never become superconducting. These and other observations suggest that electron-hole asymmetry plays a key role in superconductivity, and in particular that carriers in the normal state are hole-like and in the superconducting state electron-like.

First principles atomic physics shows that 'holes' are more 'dressed' than electrons. Incorporating this physics in the many-electron problem leads to a new class of model Hamiltonians, 'dynamic Hubbard models', that are electron-hole asymmetric [2]. These Hamiltonians predict that dressed holes in the normal state will turn into undressed electrons upon pairing, and that this process is driven by lowering of kinetic energy. They also predict that hole doping in the normal state leads to gradual 'undressing' of carriers.





Experimental observations in cuprates show that the effective mass of carriers in the normal state decreases and the quasiparticle weight increases with hole doping, and that this 'undressing' also takes place in the transition from the normal to the superconducting state. The fact that both hole pairing and hole doping leads to 'undressing' was predicted by the above-mentioned theoretical framework many years before it was observed [2]. So was the electron-hole asymmetry in NIS tunneling [3].

The theory predicts that superconductivity is favored by hole conduction through negatively charged ions, and that when there is an electron-like band in addition to a hole-like band the electron-like band has a much smaller superconducting gap. Observations in MgB_2 [4] are consistent with these predictions.

Further development of the theory leads to the prediction that negative electric charge is expelled from the interior of superconductors towards the surface, that a 'spontaneous' electric field exists inside and around superconductors, and that the screening length for electric fields is the London penetration depth [5]. Superconductors are understood as 'giant atoms' and a new electrodynamics of superconductors emerges that is relativistically covariant, with the Meissner effect and the spontaneous electric field arising from the 'rigidity' of the Cooper pair wave function in Klein-Gordon theory. The London brothers briefly considered a related theory in their early work [6] but later discarded it because of the result of an experiment [6]. We suggest that that early experiment was flawed, and propose new experimental tests of the theory.

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3. F. Marsiglio and J.E. Hirsch, Physica C **159** (1989) 157.
4. P. Martinez-Samper et al, Physica C **385** (2003) 233.
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6. F. London and H. London, Physica **2** (1935) 341; H. London, Proc.Roy.Soc. A**155** (1036) 102.