Multi-particle theory of superconductivity

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Theory of Condensed Matter Group
In a spin-imbalanced electron gas the number of up to down spin electrons in few-particle instability is the ratio of the density of states.

Superconducting state based on multi-particle instability in a spin-imbalanced system.
Spin-balanced Fermi surface
Two electrons on the Fermi surface
Constructing the Cooper pair

$q = 0$
Binding energy of a Cooper pair

\[ E = 2 \omega_D \exp\left( -\frac{2}{g\nu} \right) \]
Cooper pair in a spin-imbalanced Fermi sea
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Cooper pair in a spin-imbalanced Fermi sea
States included in the wave function
Multiple majority spins in the instability

$q_1$, $q_2$
Energy of the \((N_{\uparrow}, N_{\downarrow})\)-spin instability

Binding energy of a multi-particle instability

\[
E = (N_{\uparrow} + N_{\downarrow}) \omega_D \exp \left( -\frac{(N_{\uparrow} + N_{\downarrow}) \xi' N_c}{g N_{\uparrow} N_{\downarrow}} \right)
\]

Optimal number of up and down spin electrons in the instability is

\[
\frac{N_{\uparrow}}{N_{\downarrow}} = \frac{\nu_{\uparrow}}{\nu_{\downarrow}}
\]
Multi-particle superconductor

Superconducting transition temperature

\[ T_c = \omega_D \exp \left(-\frac{(N_{\uparrow} + N_{\downarrow}) \xi'}{2 g N_{\uparrow} N_{\downarrow}} \frac{N_c}{\nu_c} \right) \]

Peak transition temperature is at the number ratio

\[ \frac{N_{\uparrow}}{N_{\downarrow}} = \frac{\nu_{\uparrow}}{\nu_{\downarrow}} \]
Number of **up to down** spin electrons is the ratio of the density of states.

Superconducting state based on multi-particle instability in a **spin-imbalanced** system.

**Analytical**, exact diagonalization, and Diffusion Monte Carlo evidence.

Applications in spin-orbit coupled systems and **number fluctuations** in the BCS superconductor.