UNIVERSITY OF CAMBRIDGE

Multi-particle theory of superconductivity

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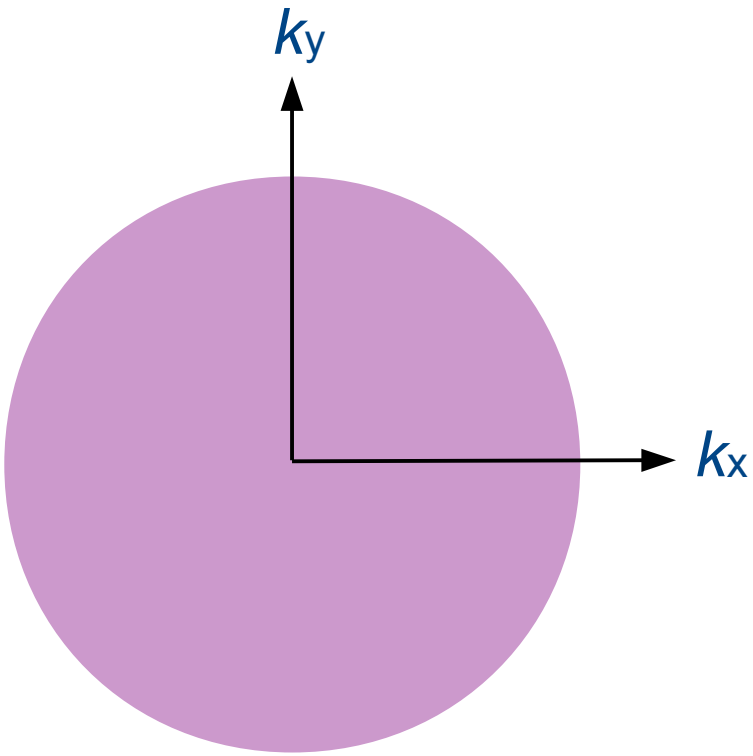
Theory of Condensed Matter Group

Multi-particle superconductor

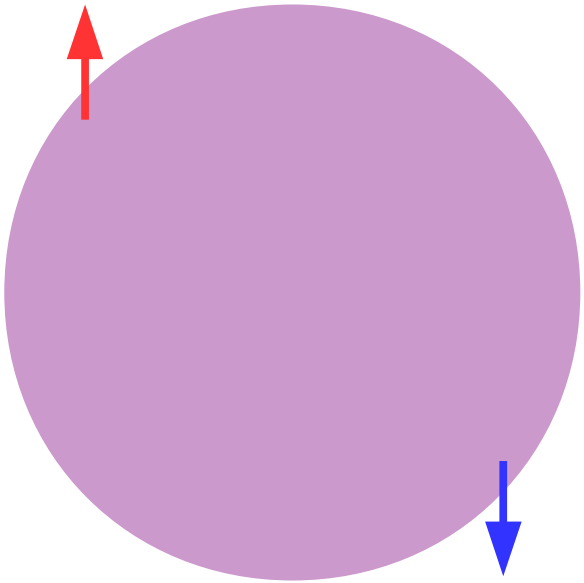
In a spin-imbalanced electron gas the number of up to down spin electrons in few-particle instability is the ratio of the density of states

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

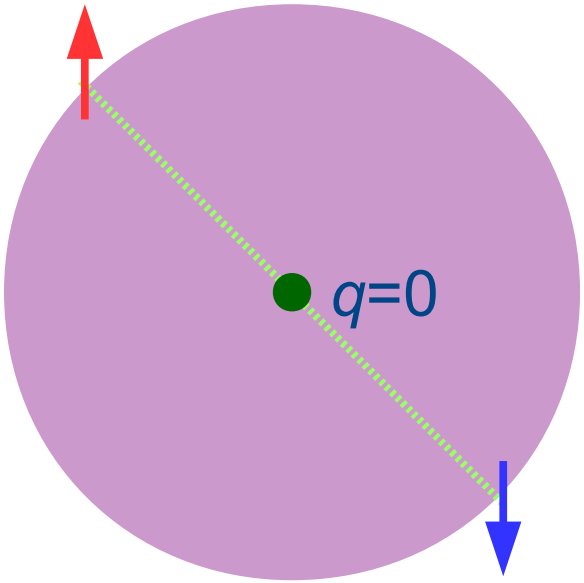
Spin-balanced Fermi surface



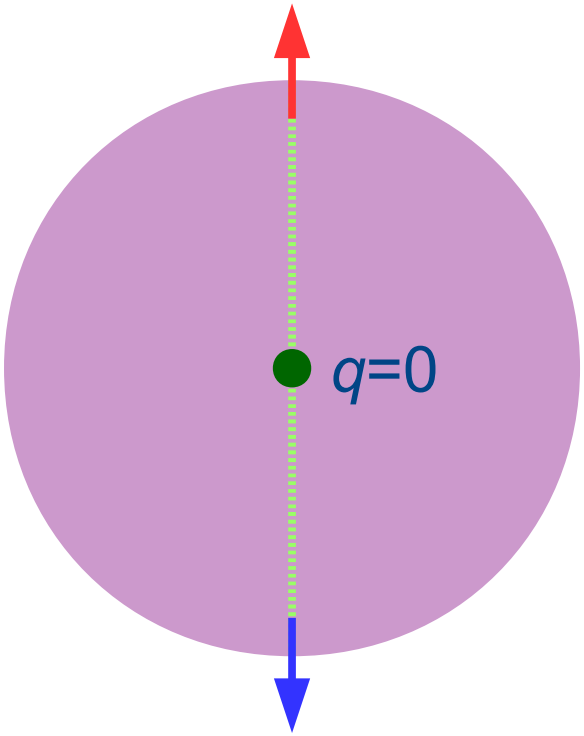
Two electrons on the Fermi surface



Constructing the Cooper pair

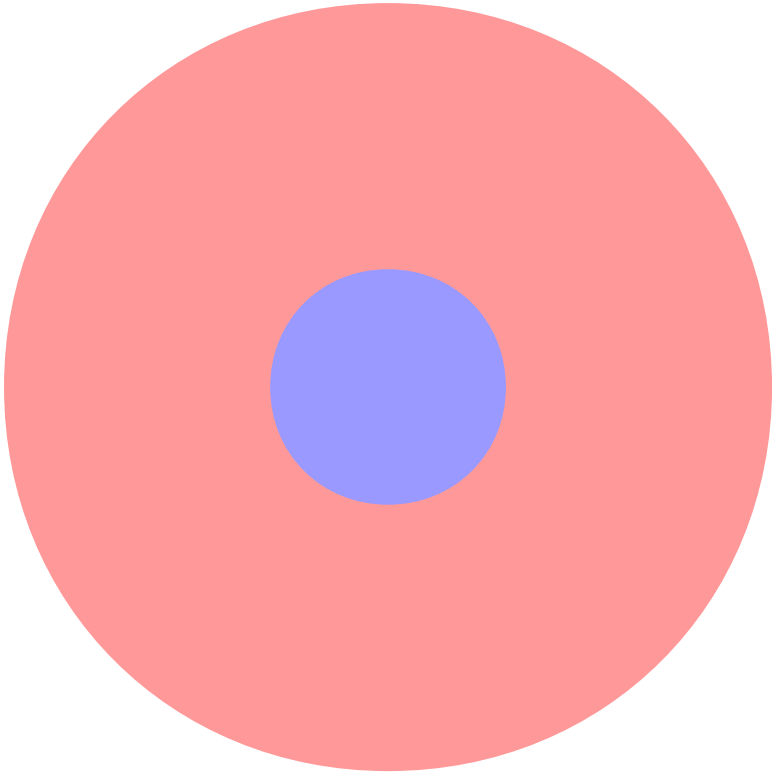


Cooper pair binding energy

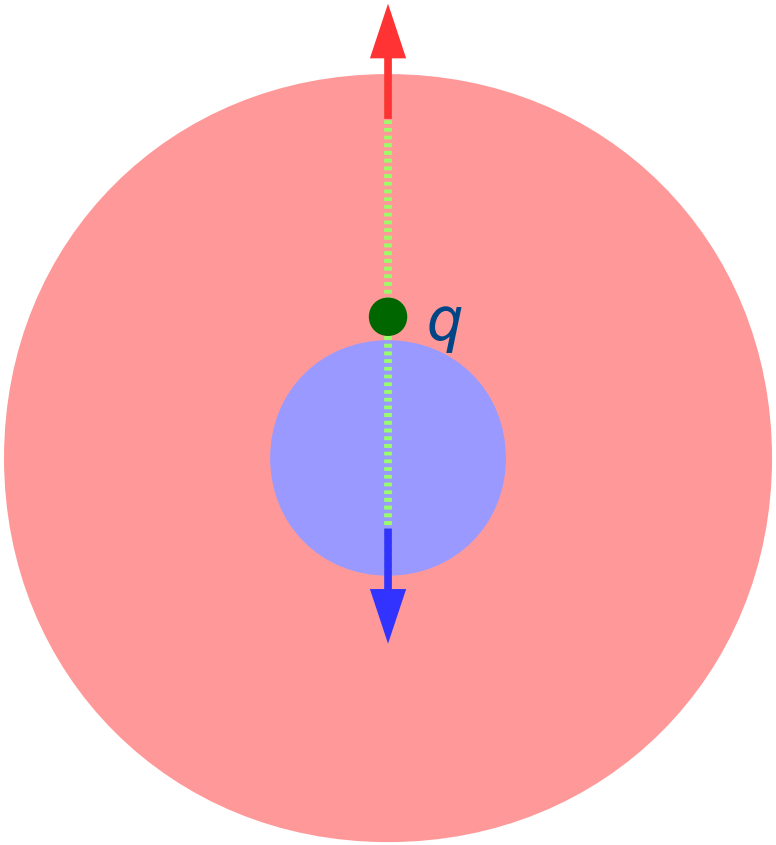


Binding energy of a Cooper pair $E = 2\omega_D \exp\left(-\frac{2}{g\nu}\right)$

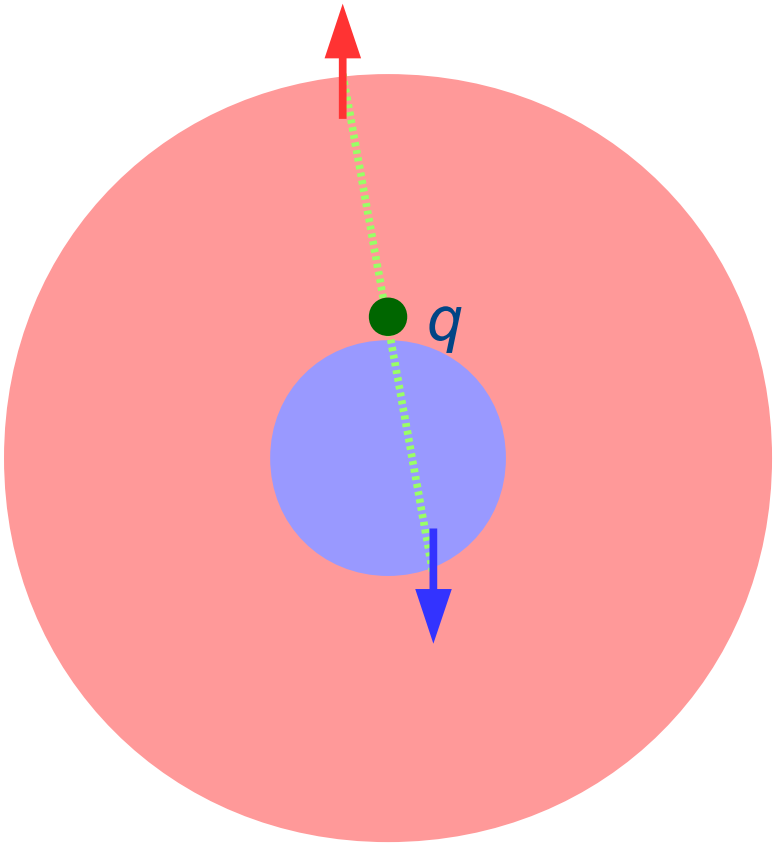
Cooper pair in a spin-imbalanced Fermi sea



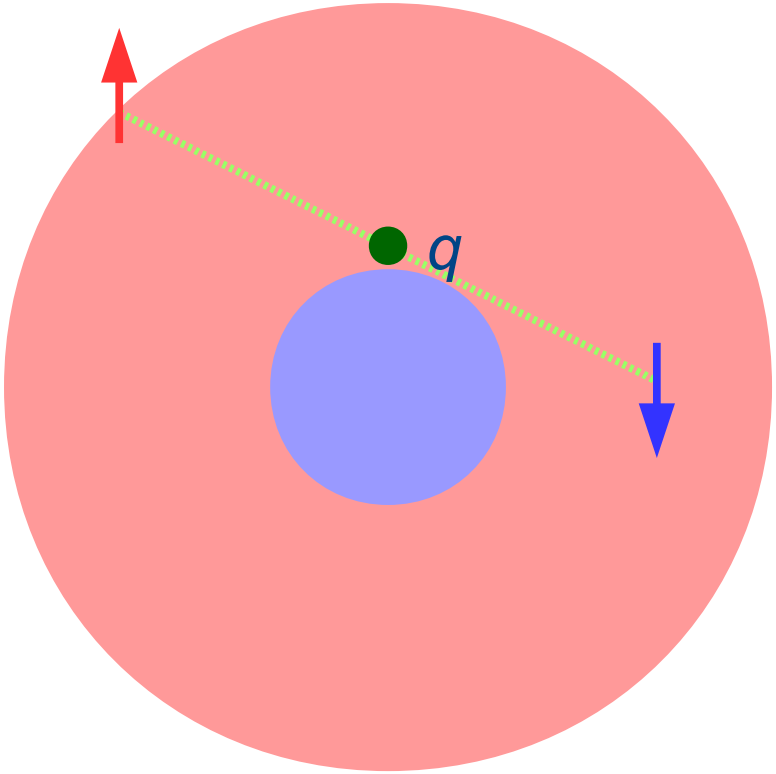
Cooper pair in a spin-imbalanced Fermi sea



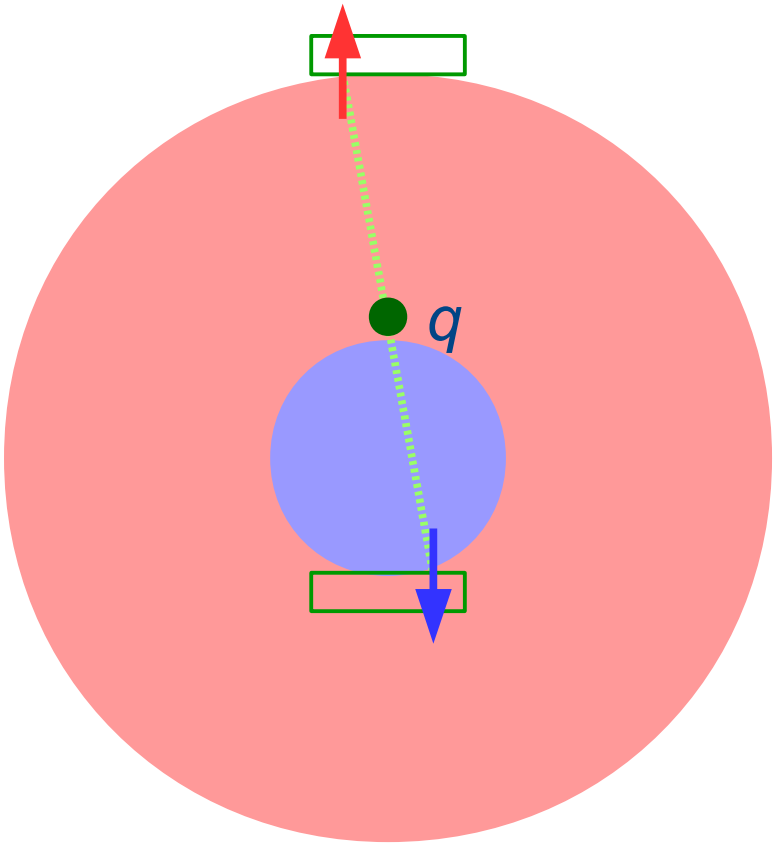
Cooper pair in a spin-imbalanced Fermi sea



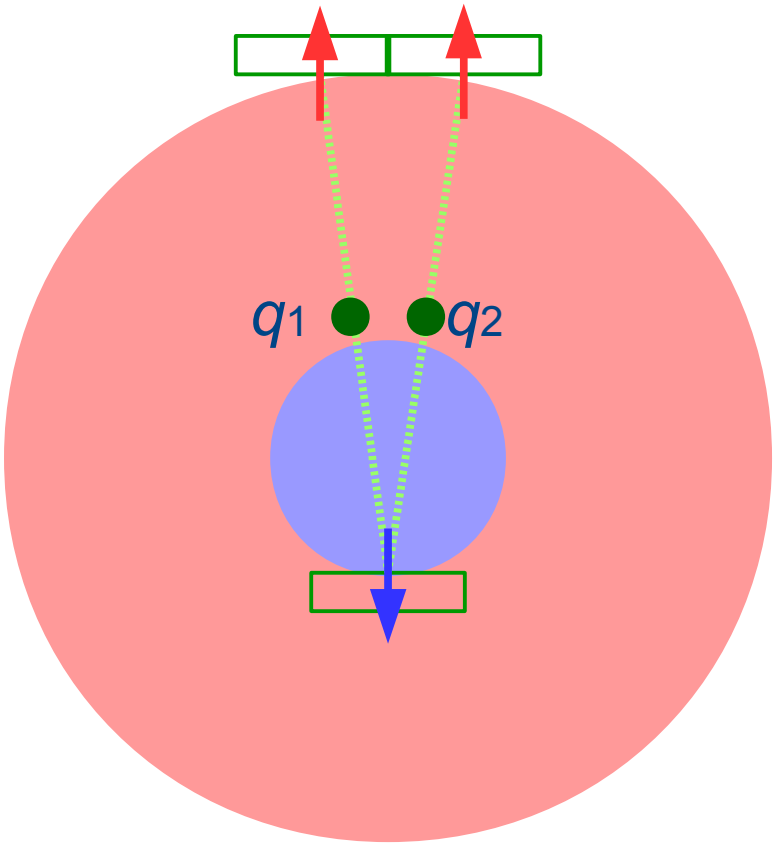
Cooper pair in a spin-imbalanced Fermi sea



States included in the wave function



Multiple majority spins in the instability



Energy of the ($N_\uparrow$,$N_\downarrow$)-spin instability

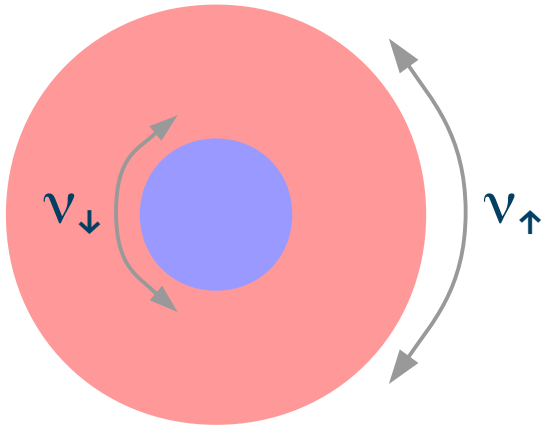
Binding energy of a multi-particle instability

$$E=\left(N_\uparrow+N_\downarrow\right)\omega_D \exp\left(-\frac{\left(N_\uparrow+N_\downarrow\right)\xi'}{gN_\uparrow N_\downarrow}\frac{N_c}{\nu_c}\right)$$

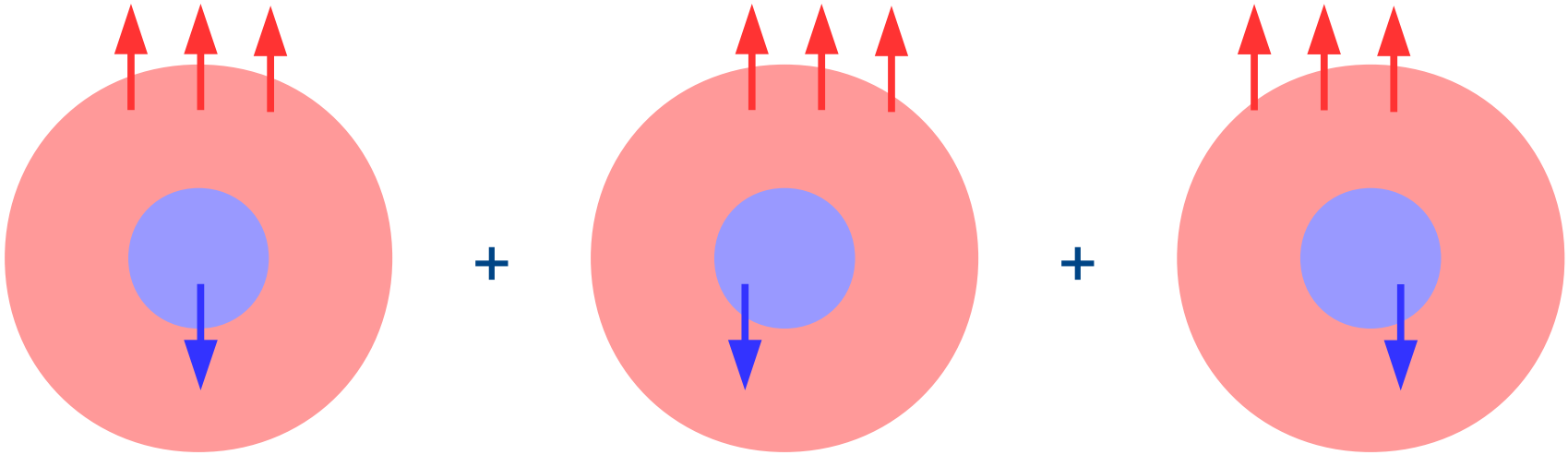
$$E=2\omega_D \exp\left(-\frac{2\xi'}{g\nu}\right)$$

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

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

Peak transition temperature is at the number ratio

$$\frac{N_\uparrow}{N_\downarrow} = \frac{\nu_\uparrow}{\nu_\downarrow}$$

Summary of multi-particle superconductor

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