UNIVERSITY OF CAMBRIDGE

Multi-particle theory of superconductivity

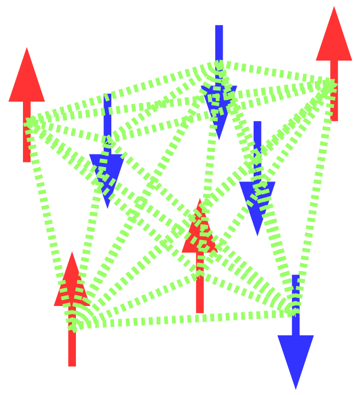
Thomas Whitehead and Gareth Conduit

Theory of Condensed Matter Group

Perturb in the number of particles

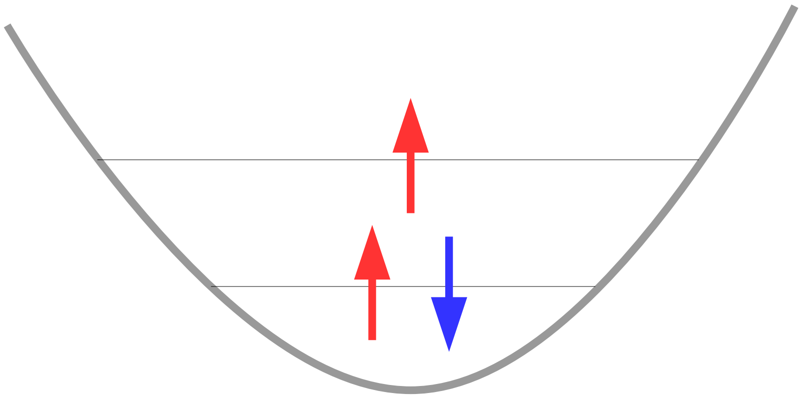
Good understanding of
few-particle system

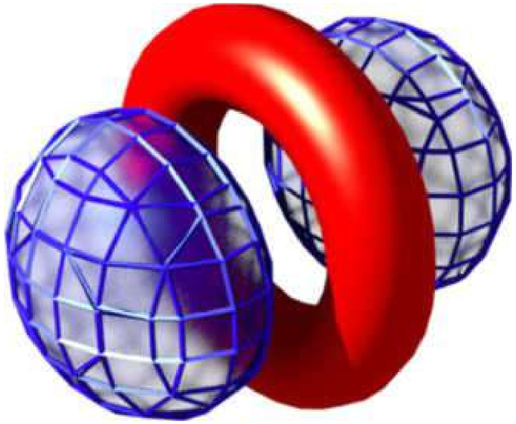
Perturb in the number of particles



Good understanding of
few-particle system

Building block for
many-body state

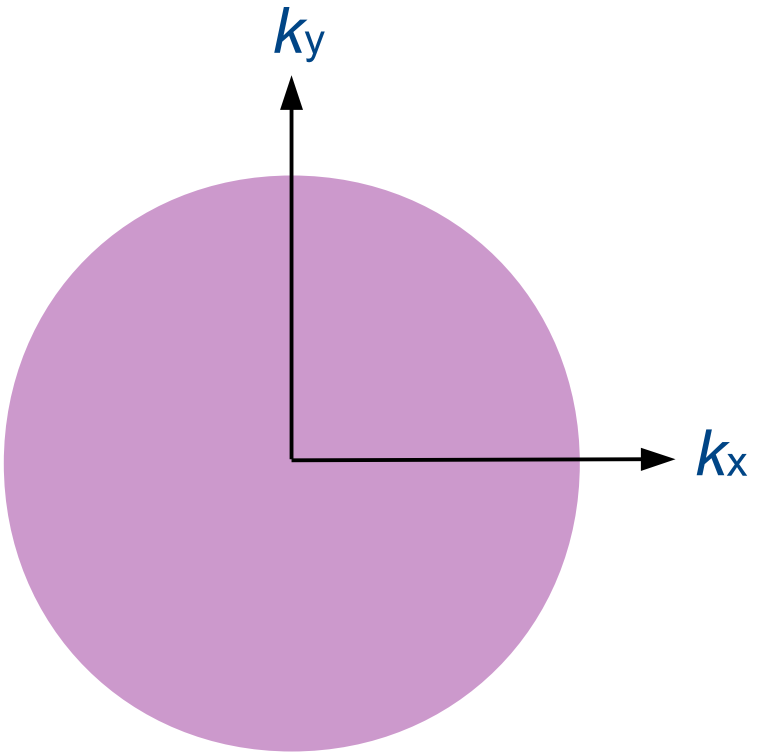




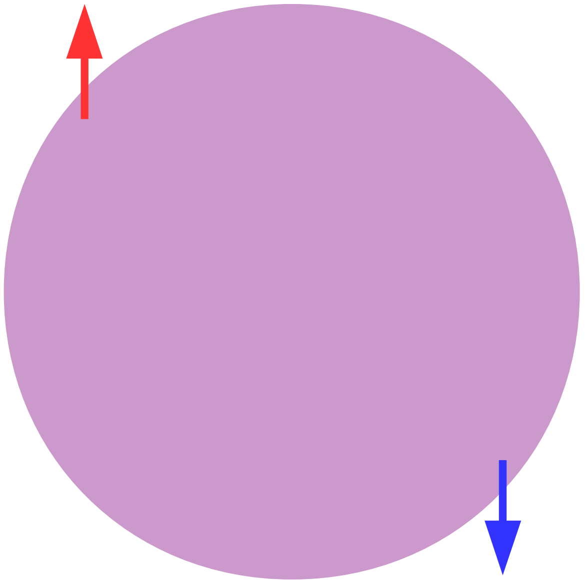
Five atoms gave Jochim the few-many particle crossover

Acknowledgement: Tom Whitehead 2016-

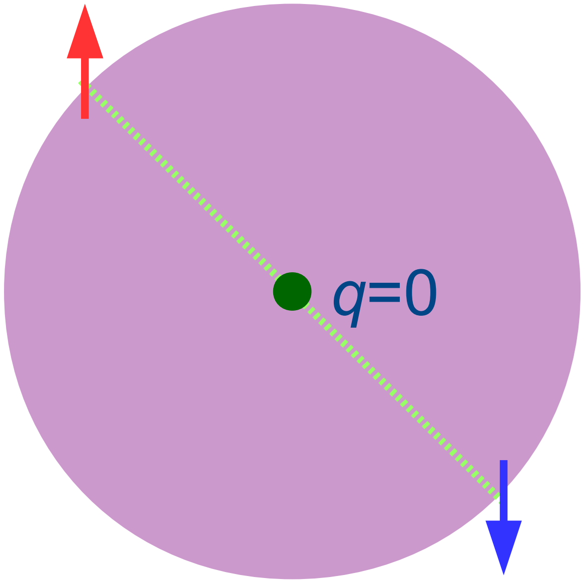
Cooper pair



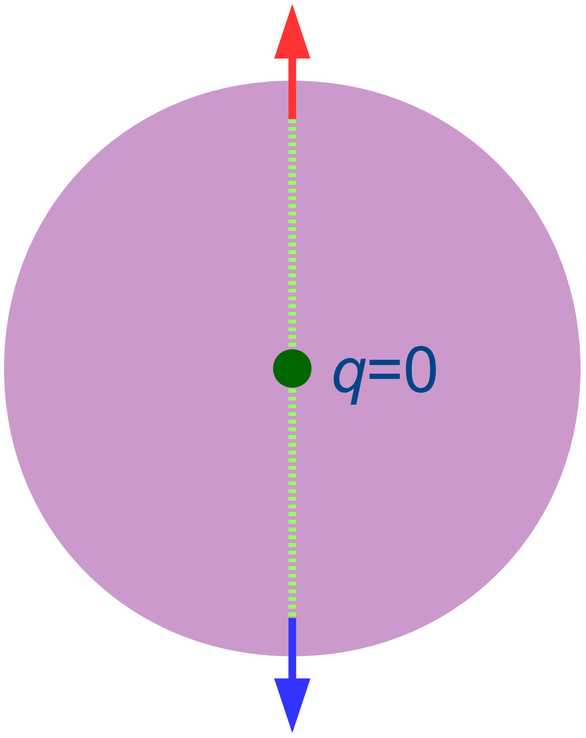
Cooper pair



Cooper pair

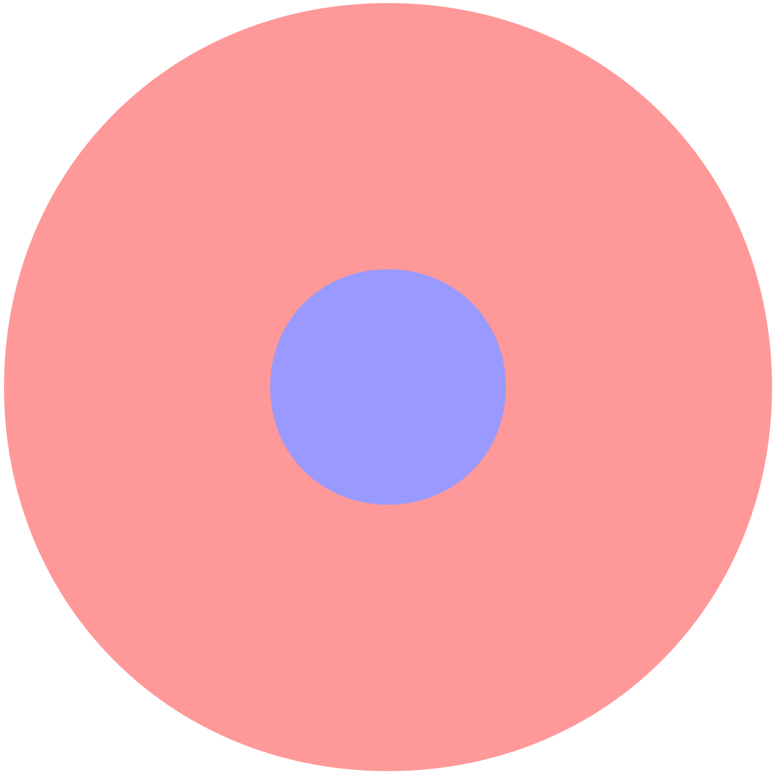


Cooper pair

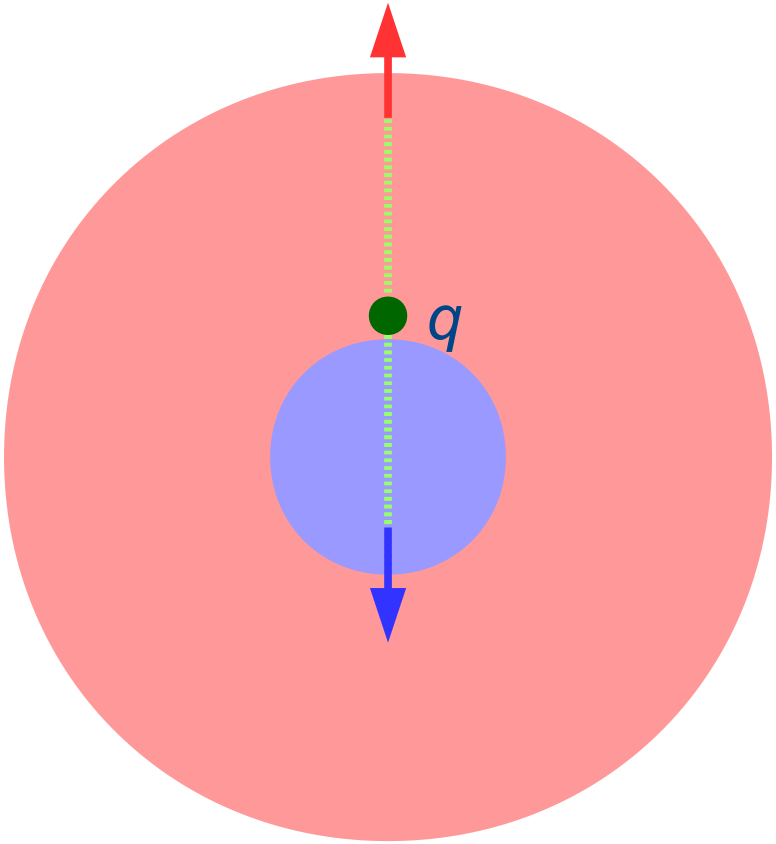


Binding energy of a Cooper pair $E = 2\omega_D \exp\left(-\frac{2}{g\nu}\right)$

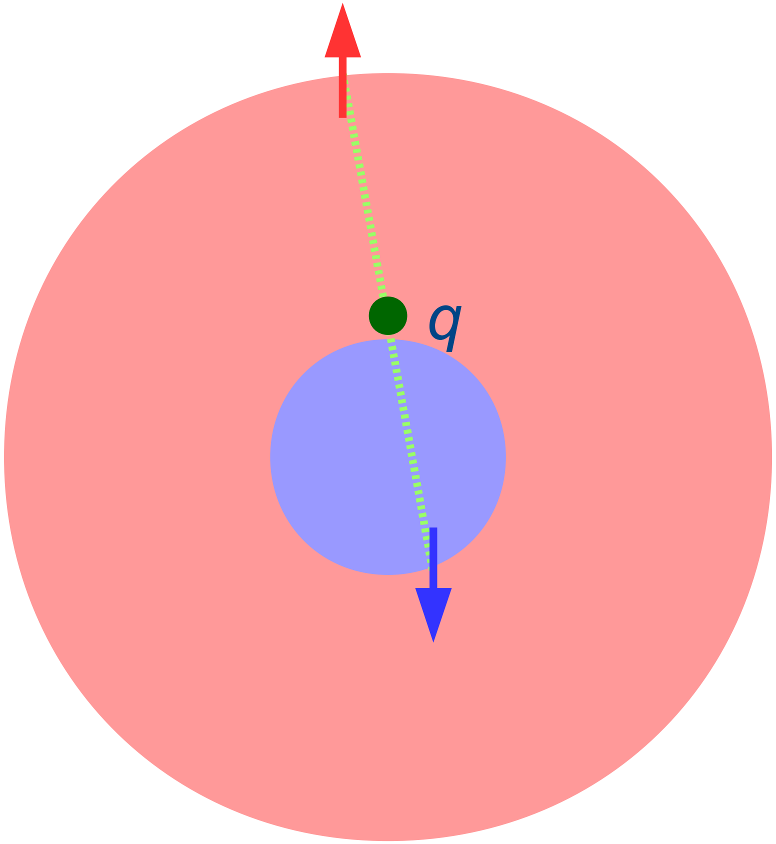
Cooper pair in a spin-imbalanced Fermi sea



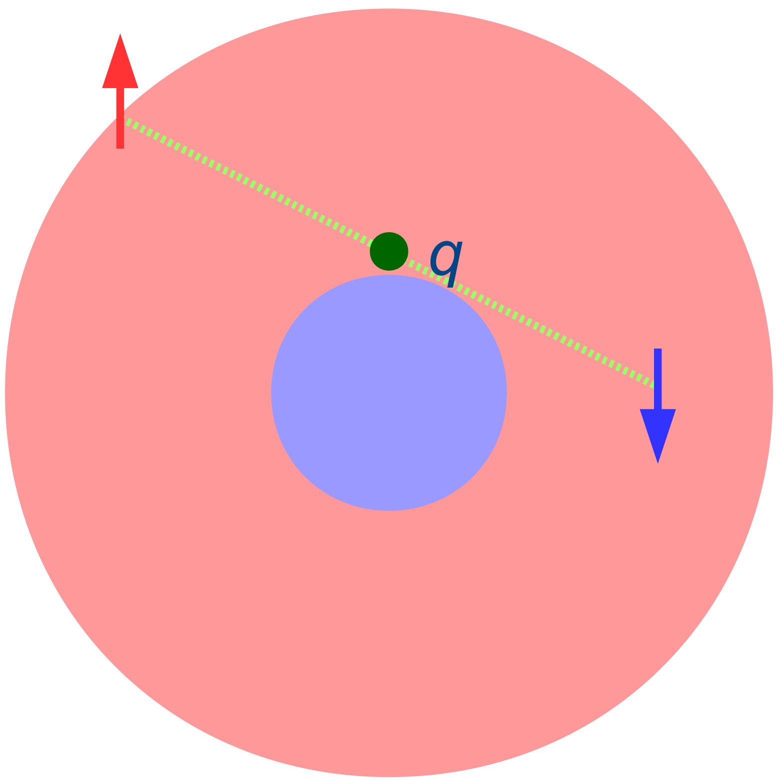
Cooper pair in a spin-imbalanced Fermi sea



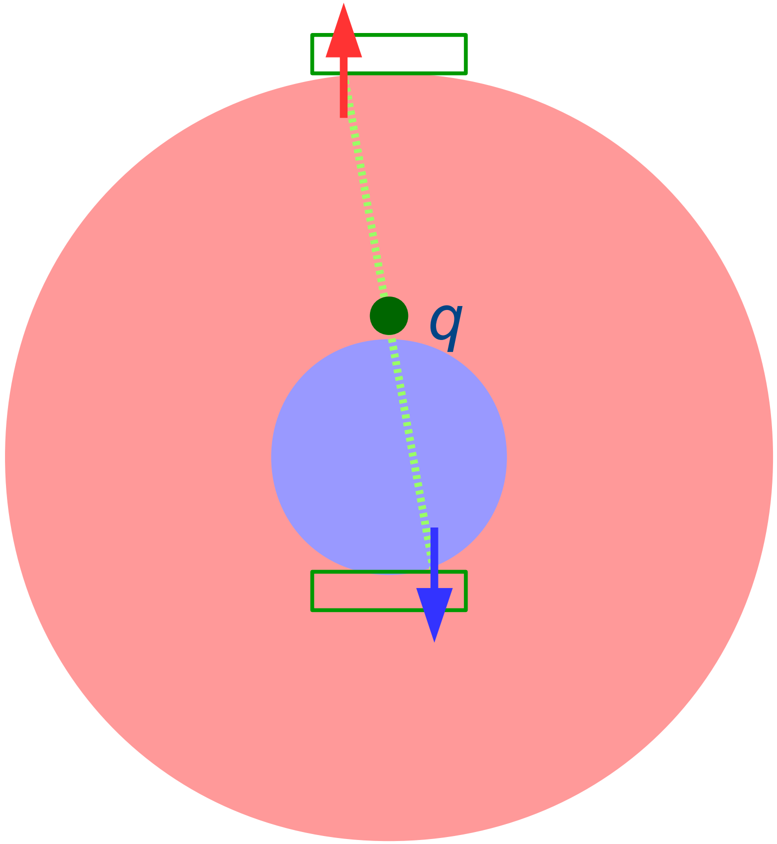
Cooper pair in a spin-imbalanced Fermi sea



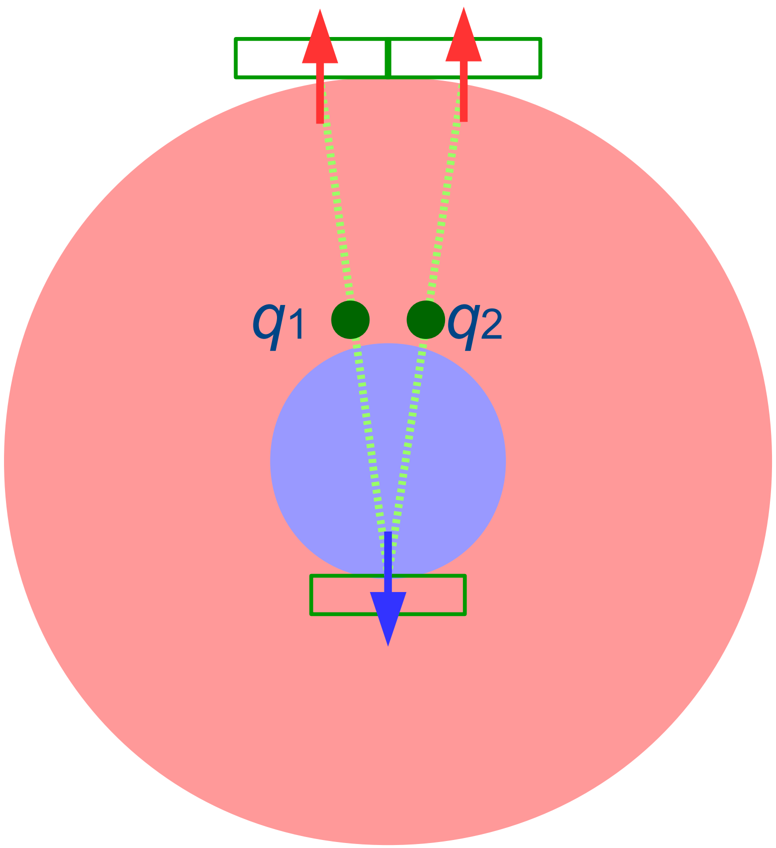
Cooper pair in a spin-imbalanced Fermi sea



States included in the wave function



Multiple majority spins in the instability



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

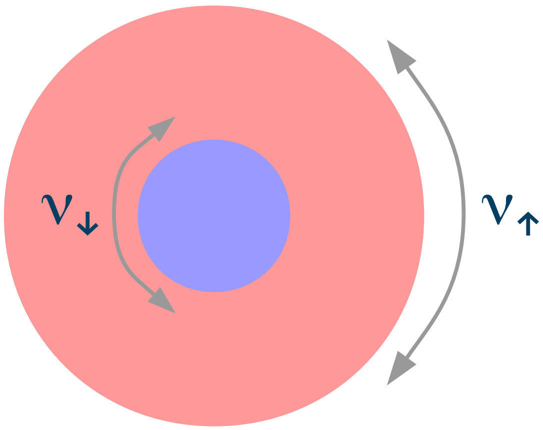
Binding energy of a Cooper particle

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

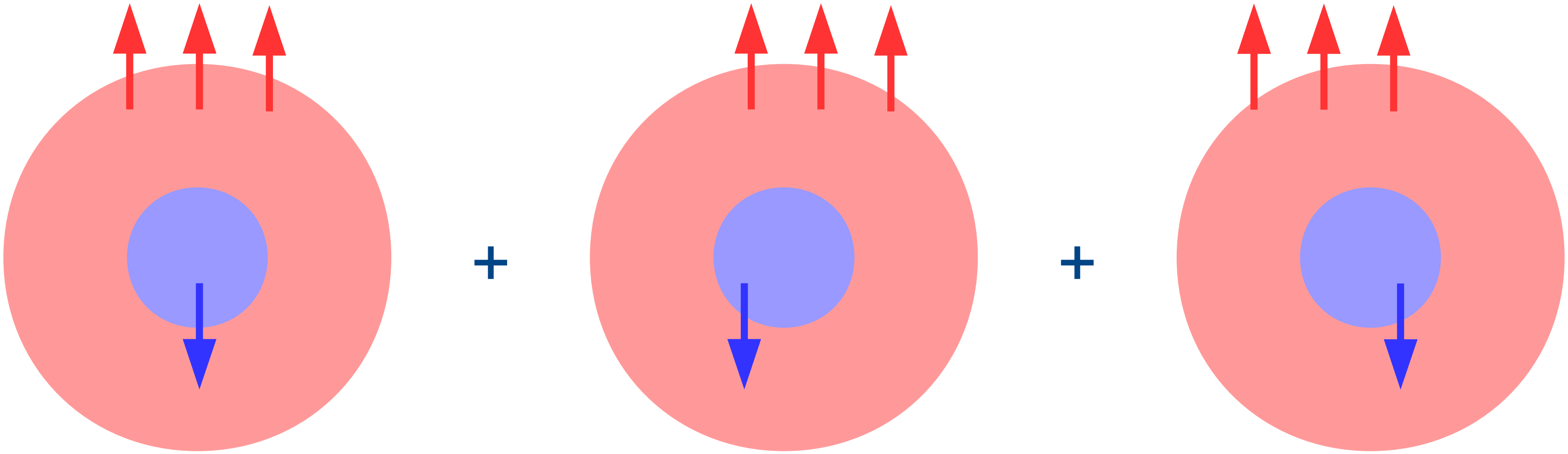
$$E=2\omega_D \exp\left(-\frac{2\xi'}{g\nu}\right)$$

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

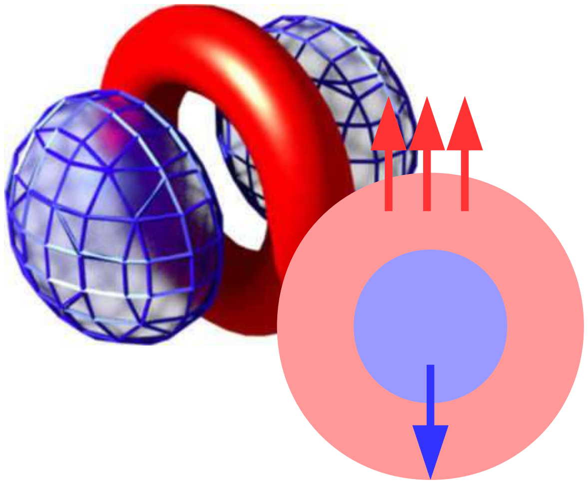
Superconducting state based on multi-particle instability in a spin-imbalanced system

Analytical, exact diagonalization, and Diffusion Monte Carlo evidence

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

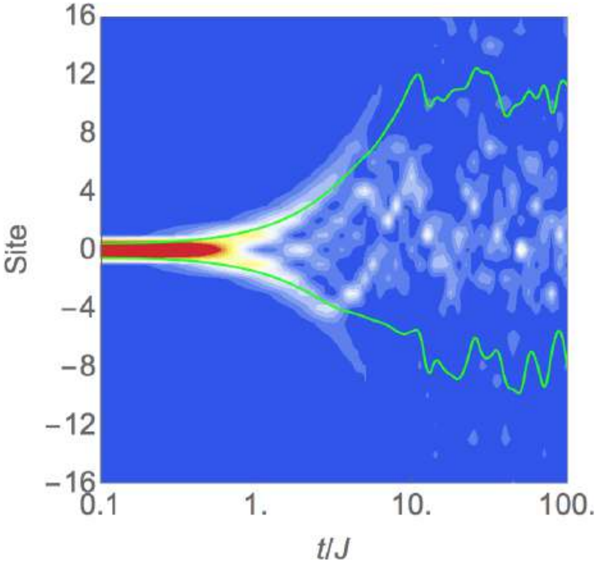
Future plans in few-to-many particles

Multi-particle superconductivity



Observables of the superconducting state
Spin-orbit coupling
Number fluctuations in BCS superconductor

Non-equilibrium physics



Extract eigenvectors with greatest overlap
Time evolution of a disordered system