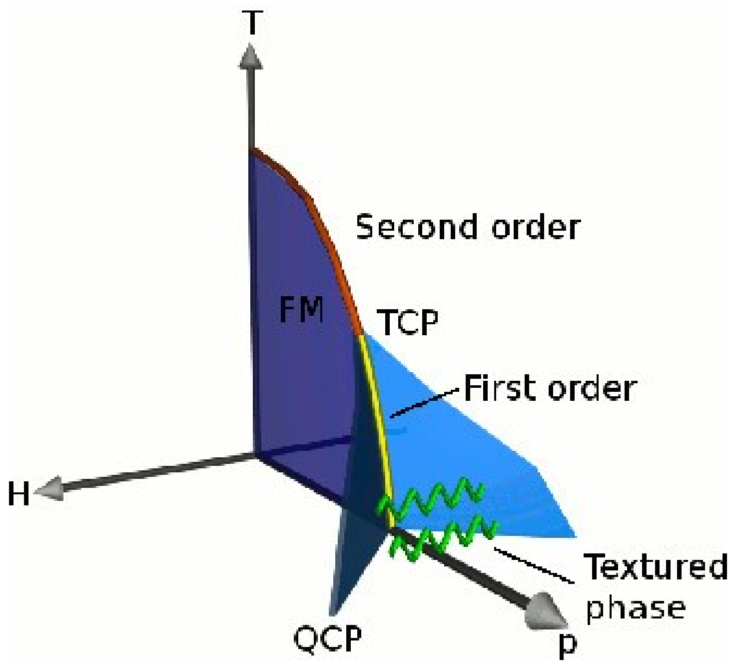
UNIVERSITY OF CAMBRIDGE

A multi-particle Cooper pair?

Gareth Conduit

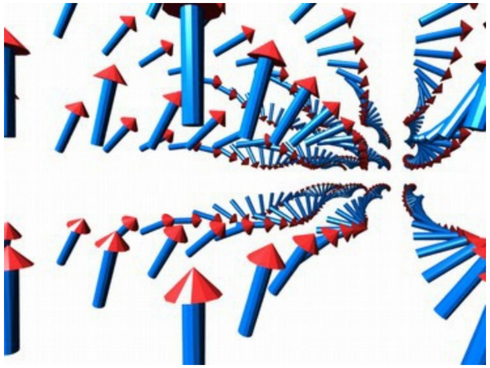
TCM Group, Department of Physics

Itinerant ferromagnet 2009

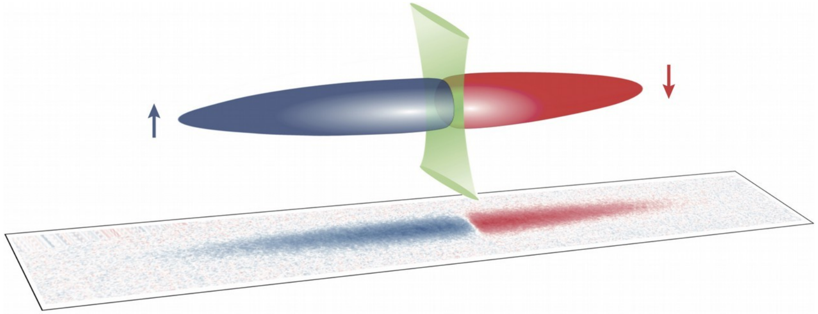


Fluctuation corrections drive exotic quantum phases

CeFePO (2012)

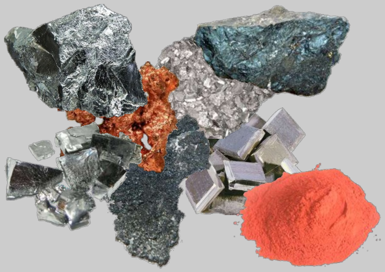


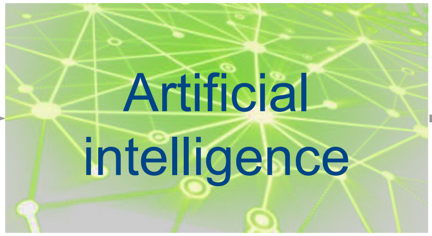
Cold atom gas (2016)



Neural networks for materials design 2013-

Composition





Properties

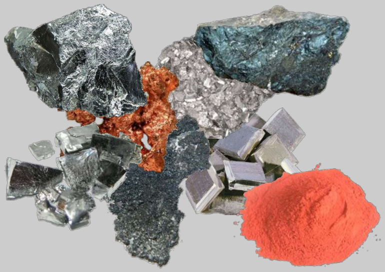
Yield stress

Cost

Fatigue life

Neural networks for materials design 2013-

Composition



Properties

Yield stress

Cost

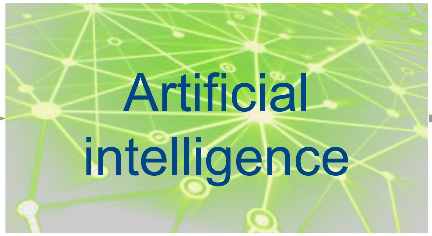
Fatigue life

Simulations

Density Functional

Molecular dynamics

Finite element



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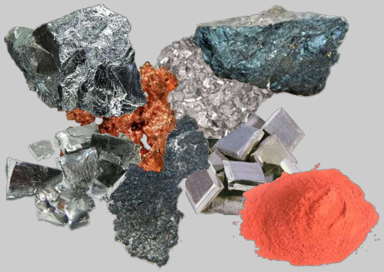

Properties

Yield stress

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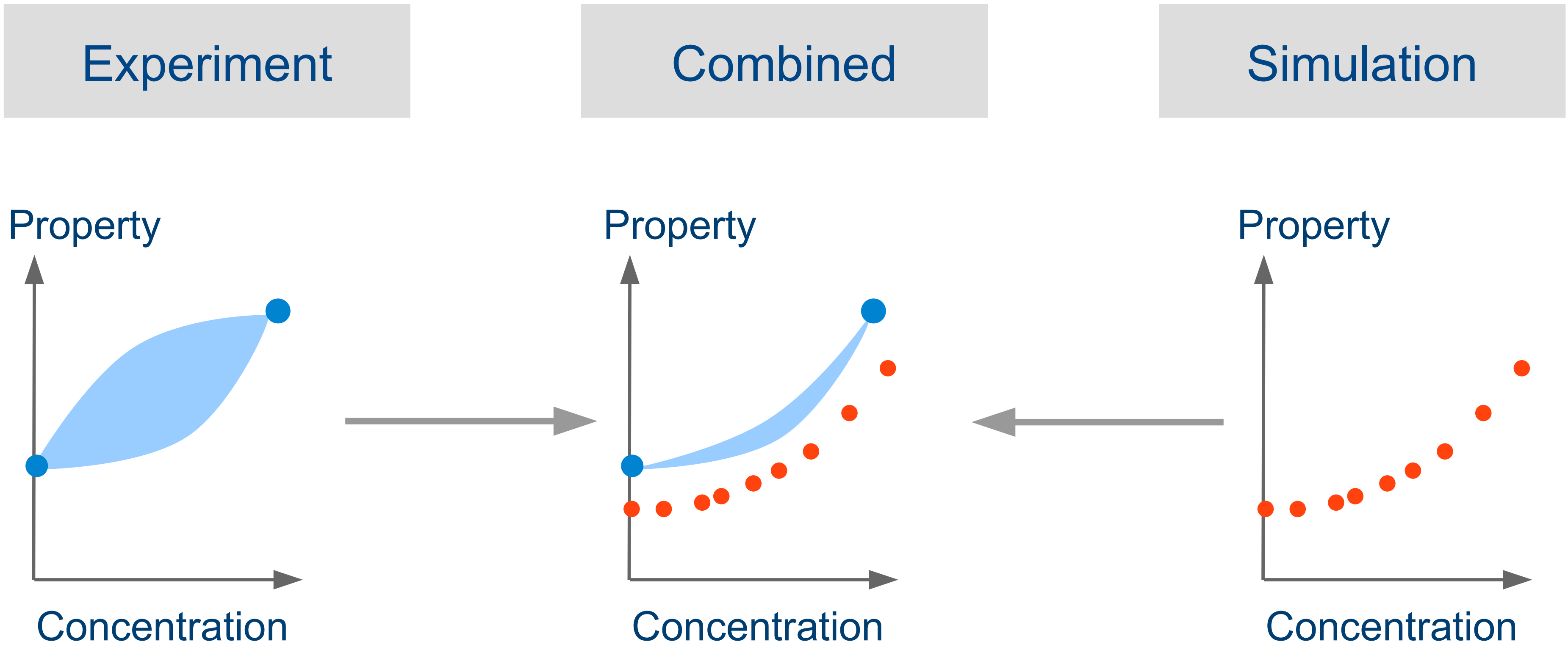
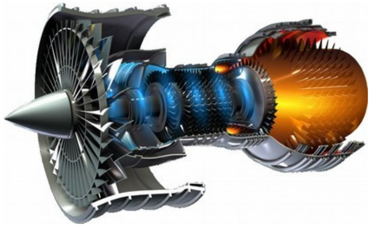
Combine databases with neural networks 2013-



Materials design

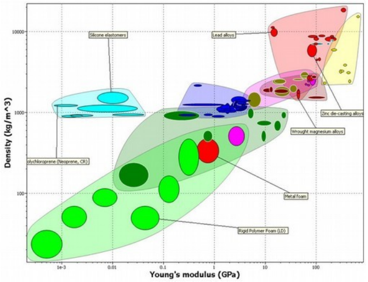
2013-

Experimental
Alloys for turbine blades



ROLLS
ROYCE

Experimental
Materials databases



GRANTA
MATERIAL INSPIRATION

Structural and experimental
Drug discovery

e-Therapeutics plc
systems biology drug discovery

Materials design 2013-

DFT and experimental
Battery design

SAMSUNG

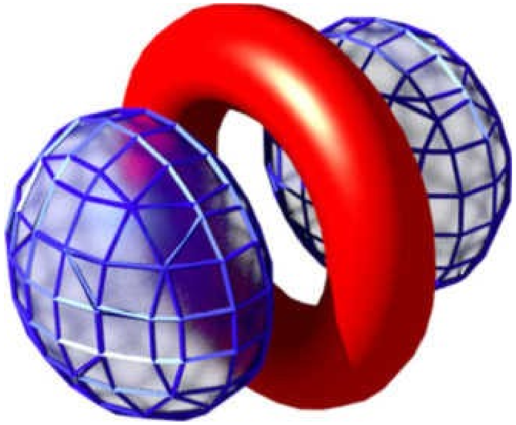
DFT and experimental
Lubricants

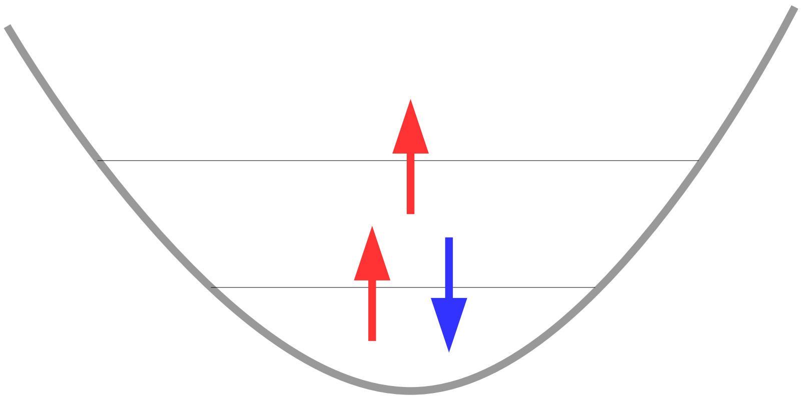
bp

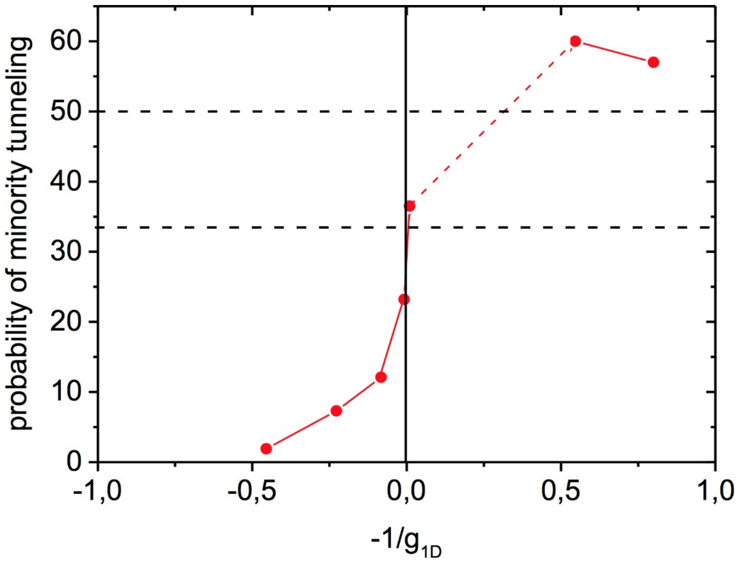
Quantum mechanics and experimental
Thermometer

Lake Shore
CRYOTRONICS

Few-particle quantum physics 2013

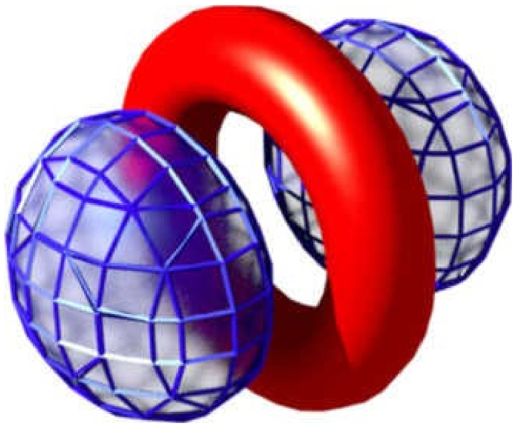


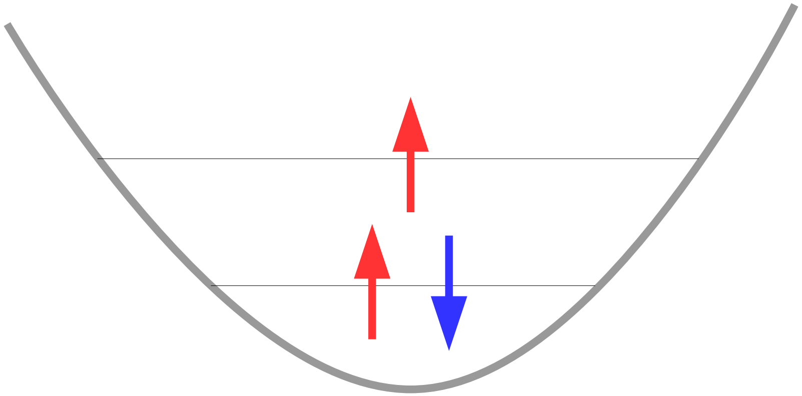


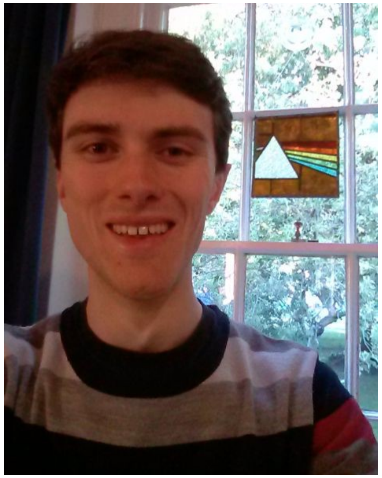


Characterization of the few-many particle crossover and ferromagnetism

Motivation from few-body physics 2016-







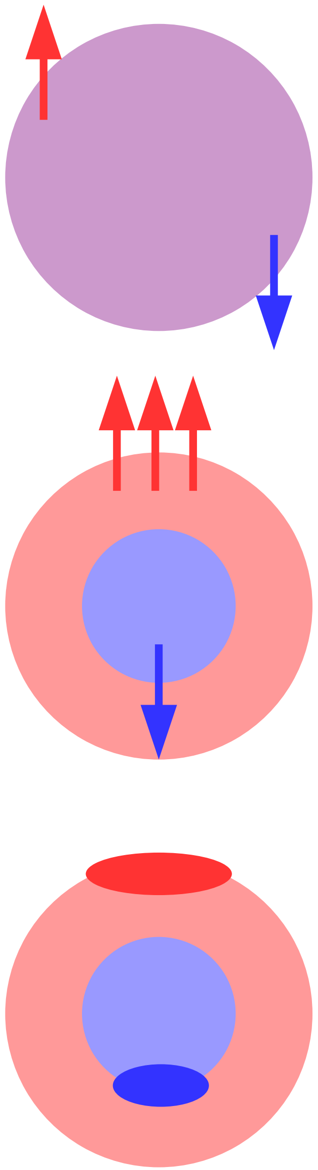
Thomas Whitehead

Multi-body Cooper particles 2016-

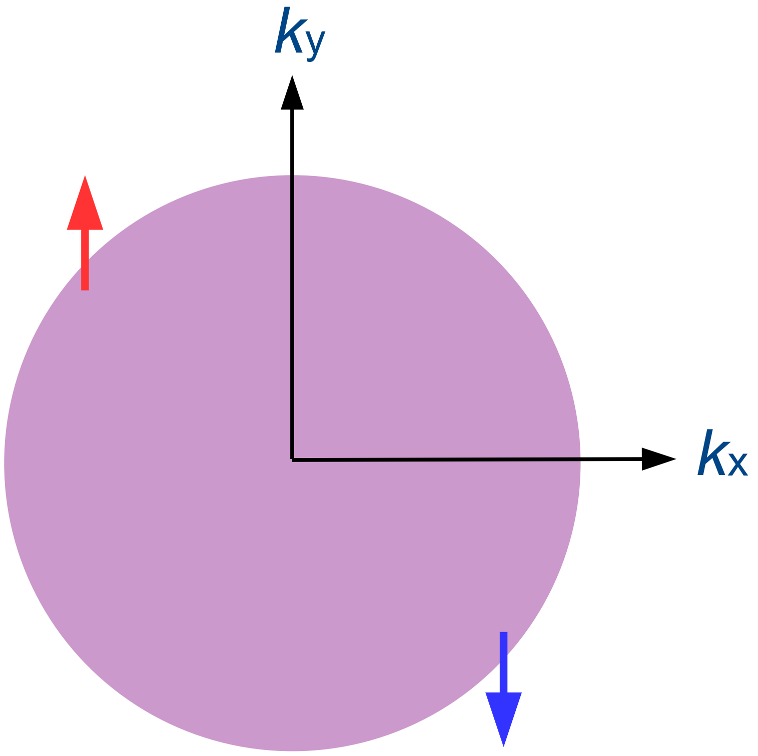
Standard superconductor

Few-body instability
  Analytical
  Numerical

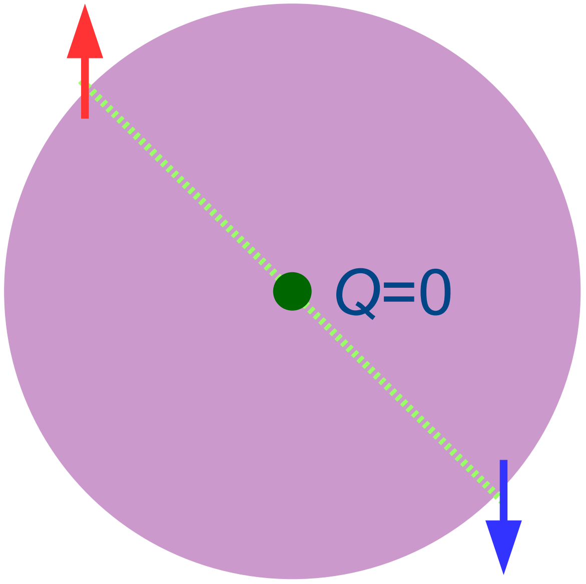
Many-body problem
  Analytical
  Numerical



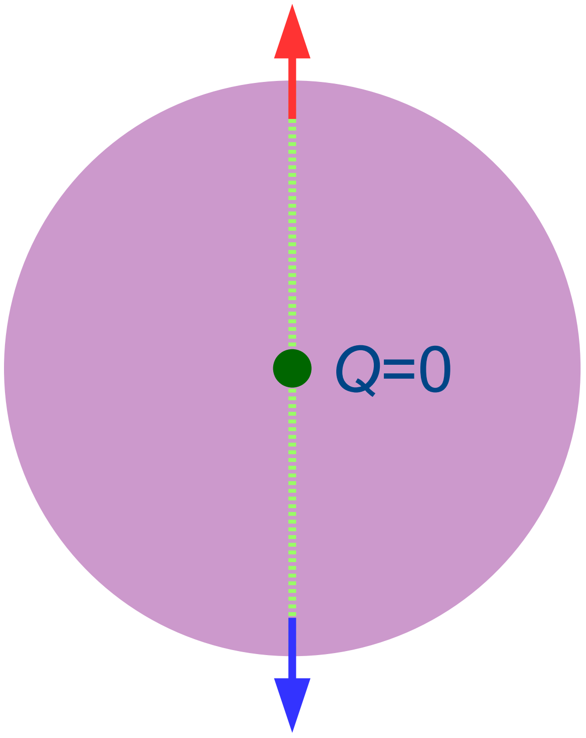
Cooper pair



Cooper pair

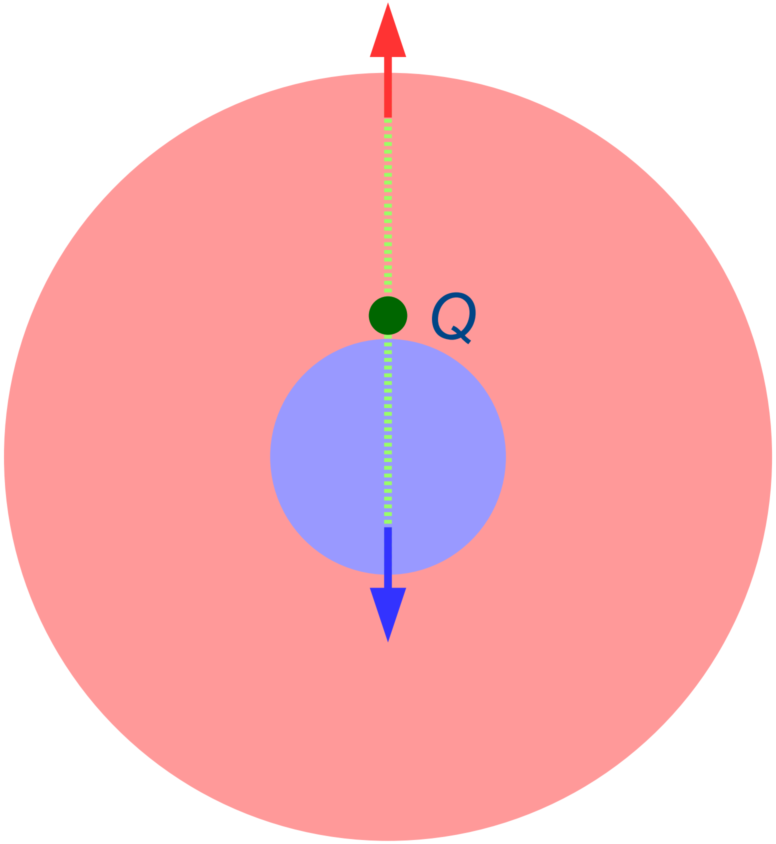


Cooper pair

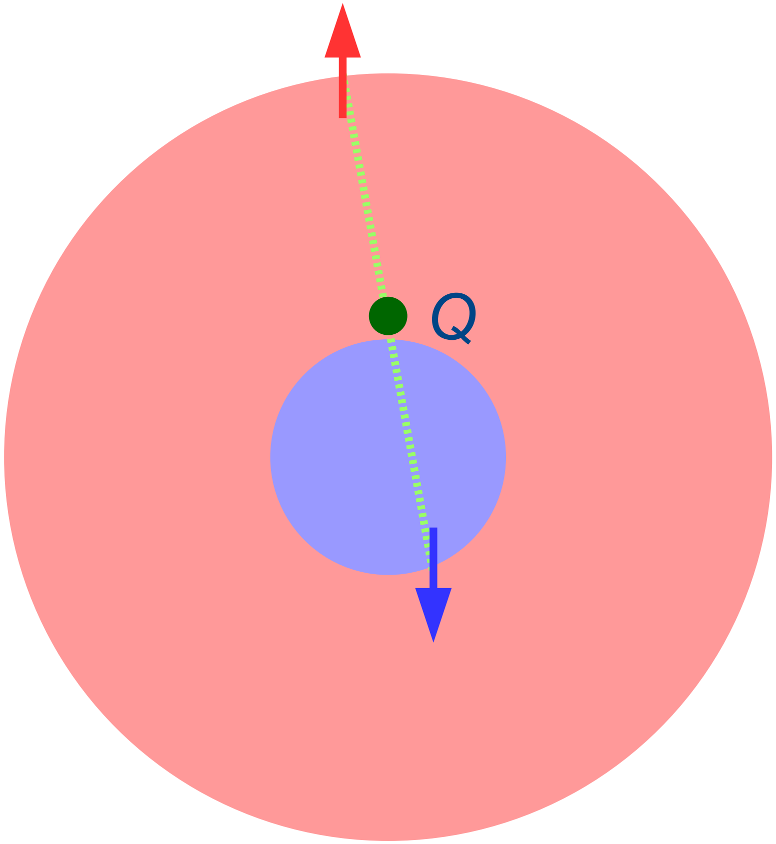


Binding energy of a Cooper pair $E = 2\,\omega_D \exp\left(-\frac{2}{g\,\nu}\right)$

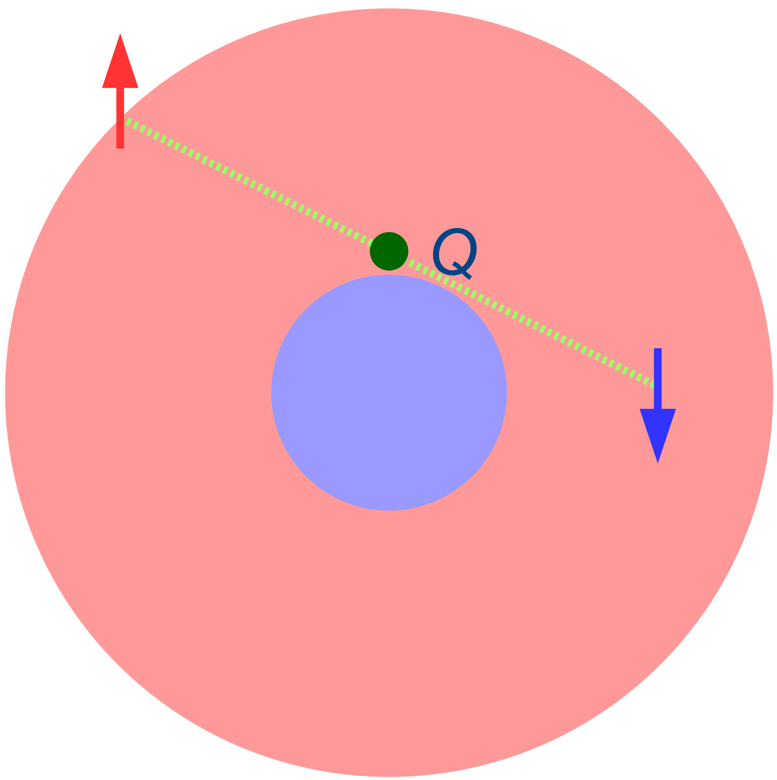
Cooper pair in imbalanced Fermi sea



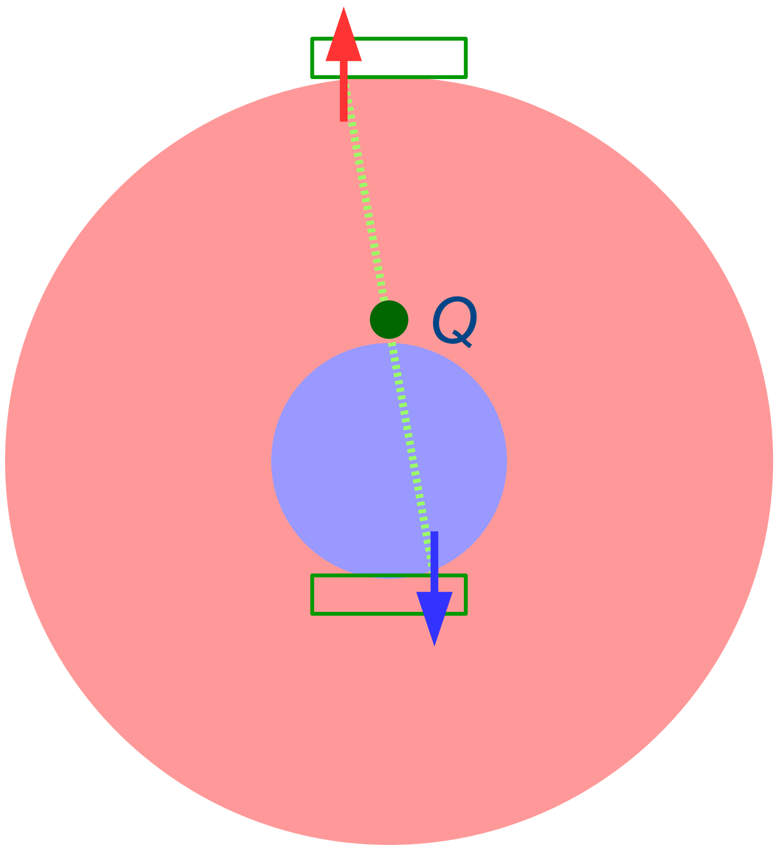
Cooper pair in imbalanced Fermi sea



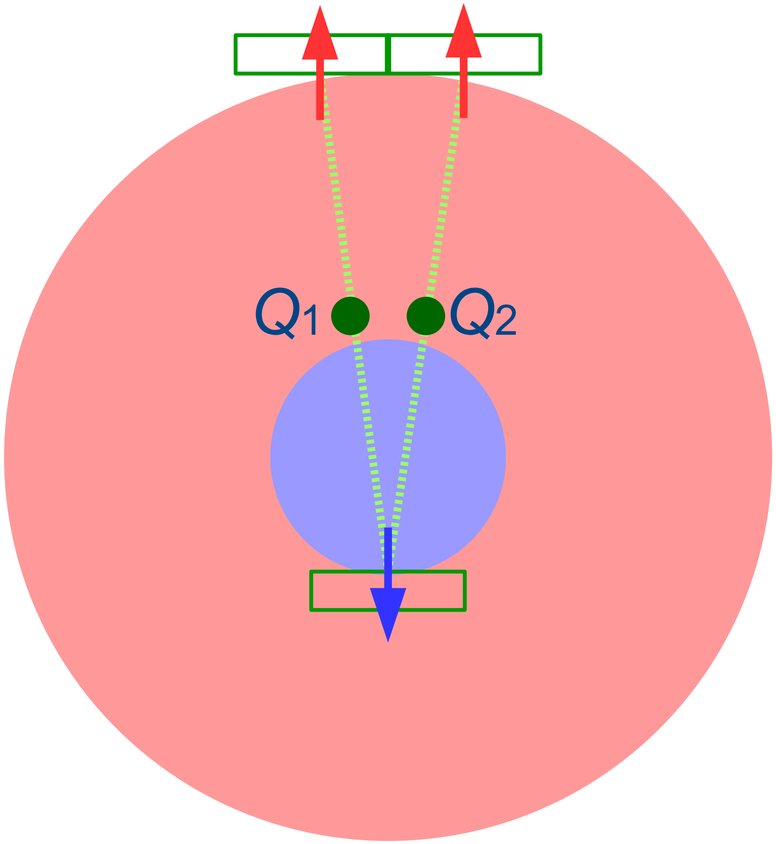
Cooper pair in imbalanced Fermi sea



Region of correlation



Multiple majority spins in the Cooper particle



Energy

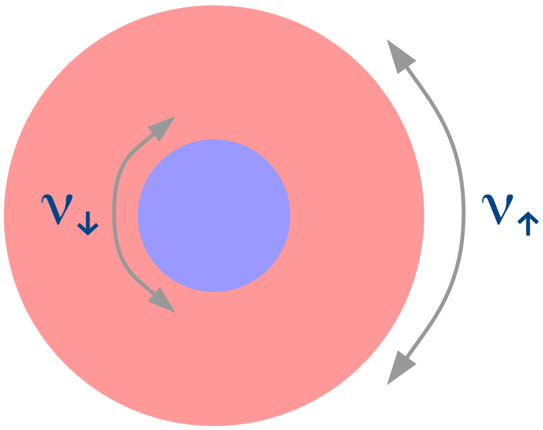
Binding energy of a Cooper particle

$$E = (N_{\uparrow} + N_{\downarrow})\,\omega_{\mathrm{D}} \exp\left(-\frac{(N_{\uparrow}+N_{\downarrow})\xi'}{g N_{\uparrow} N_{\downarrow}} \frac{N_{\mathrm{c}}}{\nu_{\mathrm{c}}}\right)$$

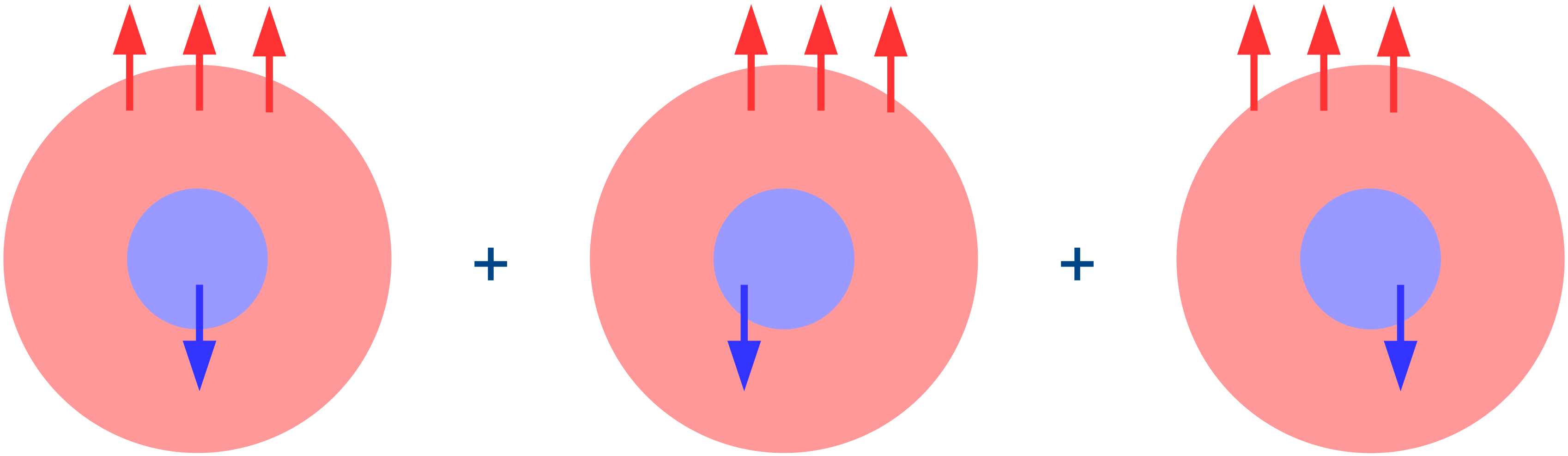
$$E = 2\,\omega_{\mathrm{D}} \exp\left(-\frac{2\xi'}{g\nu}\right)$$

Optimal number of up and down spin electrons in a Cooper particle is

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



Many-body superconductor



Superconducting transition temperature (even $N_\uparrow + N_\downarrow$)

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

Peak transition temperature is at the number ratio

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

Summary of many-particle Cooper instability

Optimal number of up and down spin electrons in a superconducting state is the ratio of the density of states

Future consequences

- Competition with the FFLO state
- Experimental observation
- Spin orbit and mass imbalanced systems
- Number fluctuations in balanced superconductor