The Transitions between the Normal, Superfluid, and FFLO states in a Fermi gas.

By Dean Norris
Wave Particle duality
Two types of Particles

Example of a Boson – Rubidium

Fermions

Spin = $\frac{1}{2}$

Spin = $\frac{3}{2}$, $\frac{5}{2}$, ...

Bosons

Spin = 1*

Spin = 0, 1, 2, ...

Fermion-Lithium 6
What is Bose-Einstein condensation (BEC)?

High Temperature $T$:
- thermal velocity $v$
- density $d^{-3}$
- "Billiard balls"

Low Temperature $T$:
- De Broglie wavelength $\lambda_{dB} = \frac{h}{mv} \propto T^{-1/2}$
- "Wave packets"

$T = T_{\text{crit}}$:
- Bose-Einstein Condensation
  $\lambda_{dB} \approx d$
- "Matter wave overlap"

$T = 0$:
- Pure Bose condensate
- "Giant matter wave"
Pauli exclusion principle

Low energy levels

Bosons

Fermions

$E_{\text{Fermi}}$
Cooper pairs

Correlated motion
Normal and Superfluid states

Cooper pairs only form when energy of system can be Decreased.
Equations

Energy of the Normal state

\[ E_n(\mu, h) = - \left( \frac{(2m)^{\frac{3}{2}}}{2\pi^2} \right)^{\frac{2}{15}} \left( (\mu + h)^{\frac{5}{2}} + (\mu - h)^{\frac{5}{2}} \right) \]

Energy of the Superfluid state

\[ E_s(\mu, h) = - \left( \frac{(2m)^{\frac{3}{2}}}{2\pi^2} \right)^{\frac{1}{15}} \frac{\mu^{\frac{5}{3}}}{15} \frac{1}{x_o I_6(x_o) + (4x_o^2 + 3) I_5(x_o)} \]
Another state FFLO

- Fulde Ferrell Larkin Ovchinnikov state
- Cooper Pairs with momentum
- Polarization spin up vs spin down
Thank you

• Dr. Veillette – advisor
• Berea College Physics Department
• Fellow students