FFLO instability in 2D atomic gases

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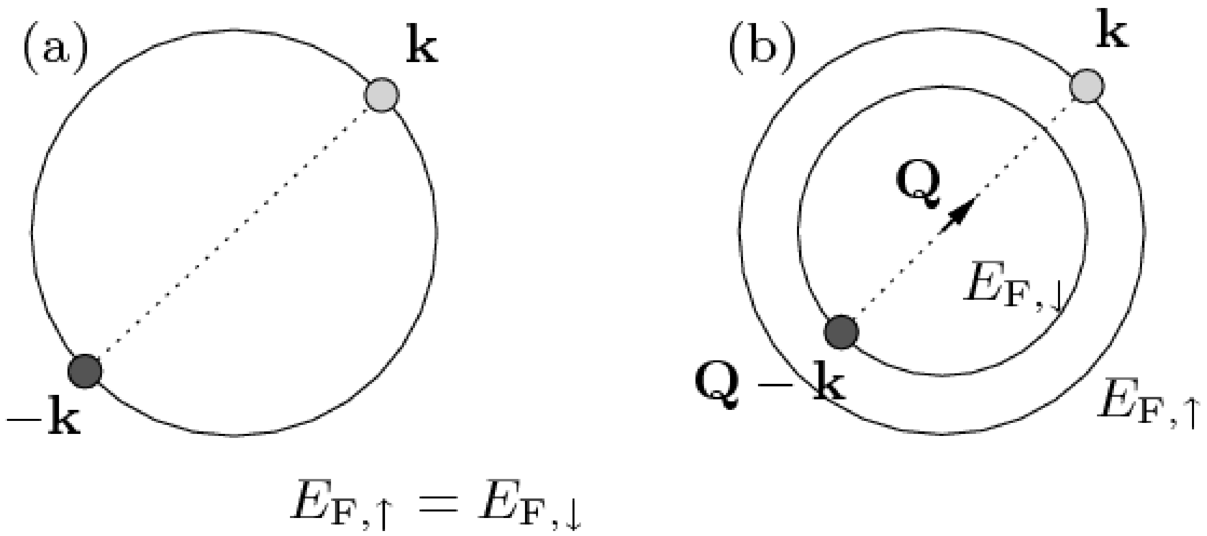
Funded by the EPSRC

“*Superfluidity at the BEC-BCS crossover in two-dimensional Fermi gases with population and mass imbalance*”, G.J. Conduit, P.H. Conlon & B.D. Simons, Phys. Rev. A**77**, 053617 (2008)

Motivation to study FFLO

- BCS Cooper pairs have no total momentum (a)
- A population imbalance (or a ratio of masses) means Cooper pairs have a non-zero total momentum (b)



- No disorder & can tune interaction strength so atomic gases provide an opportunity to search for FFLO phase
- Similarities to electron-hole bilayers, where electron/holes are the normal phase and excitons the superfluid

Analytical approach

Ginzburg-Landau approach

- FFLO phase transition is second order[1] so expand thermodynamic potential

$$\Phi = \sum_{\boldsymbol{q}} \alpha_{\boldsymbol{q}} |\Delta_{\boldsymbol{q}}|^2$$

- If coefficient $\alpha_{\boldsymbol{q}}$ is negative, it is favorable for $\Delta_{\boldsymbol{q}} \neq 0$ -- an FFLO instability
- Get analytical results but cannot pick up first order transitions

Single Fourier component approach

- Minimize exact thermodynamic potential with respect to a single wave vector **Q** and the order parameter $\Delta_{\boldsymbol{Q}}$

$$\Phi(\Delta_{\boldsymbol{Q}})$$

- Numerical results distinguish between first and second order transitions
- The **Q=0** state can be evaluated analytically

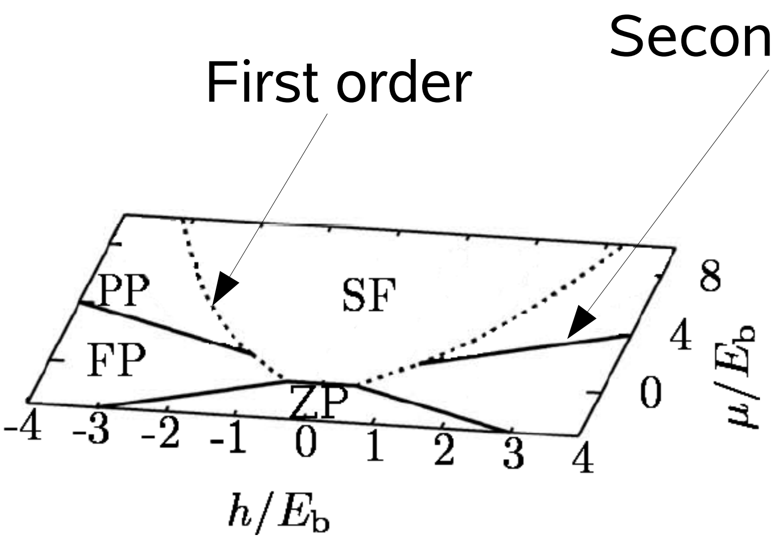
[1] Combescot & Mora, Eur. Phys. J B**44** 189 (2005)

Free system: Q=0

- Equal masses $m_\uparrow = m_\downarrow$, population imbalanced system with $\mu_\uparrow = \mu + h$ and $\mu_\downarrow = \mu - h$
- The superfluid (SF), partially polarized normal (PP), fully polarized normal (FP), phases and the system containing no particles (ZP) are shown

Notation:
$\mu_\uparrow = \mu + h$
$\mu_\downarrow = \mu - h$
E_b: Binding energy
SF: Superfluid
PP: Partially polarized
FP: Fully polarized
ZP: No particles

[2] Tempere, Wouters & Devreese, PRB **75**, 184526 (2007)

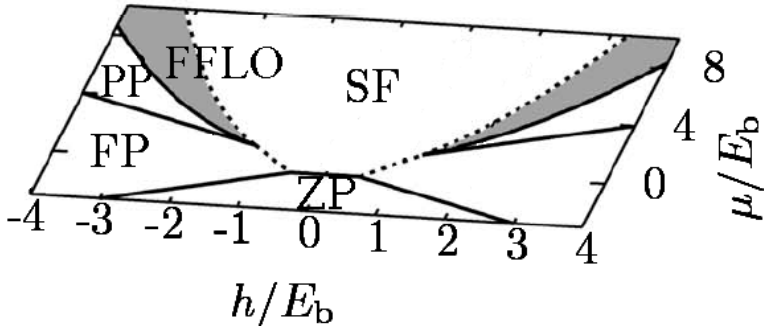


Free system: Q≠0

- The FFLO instability encroaches into the partially polarized normal state (PP) but not the superfluid
- Second order transition from partially polarized (PP) to FFLO instability
- No FFLO instability in fully polarized state (FP) as there are no minority spin particles
- FFLO phase more prominent in 2D than in 3D[3]

Notation:
$\mu_{\uparrow}=\mu+h$
$\mu_{\downarrow}=\mu-h$
E_b: Binding energy
SF: Superfluid
PP: Partially polarized
FP: Fully polarized
ZP: No particles

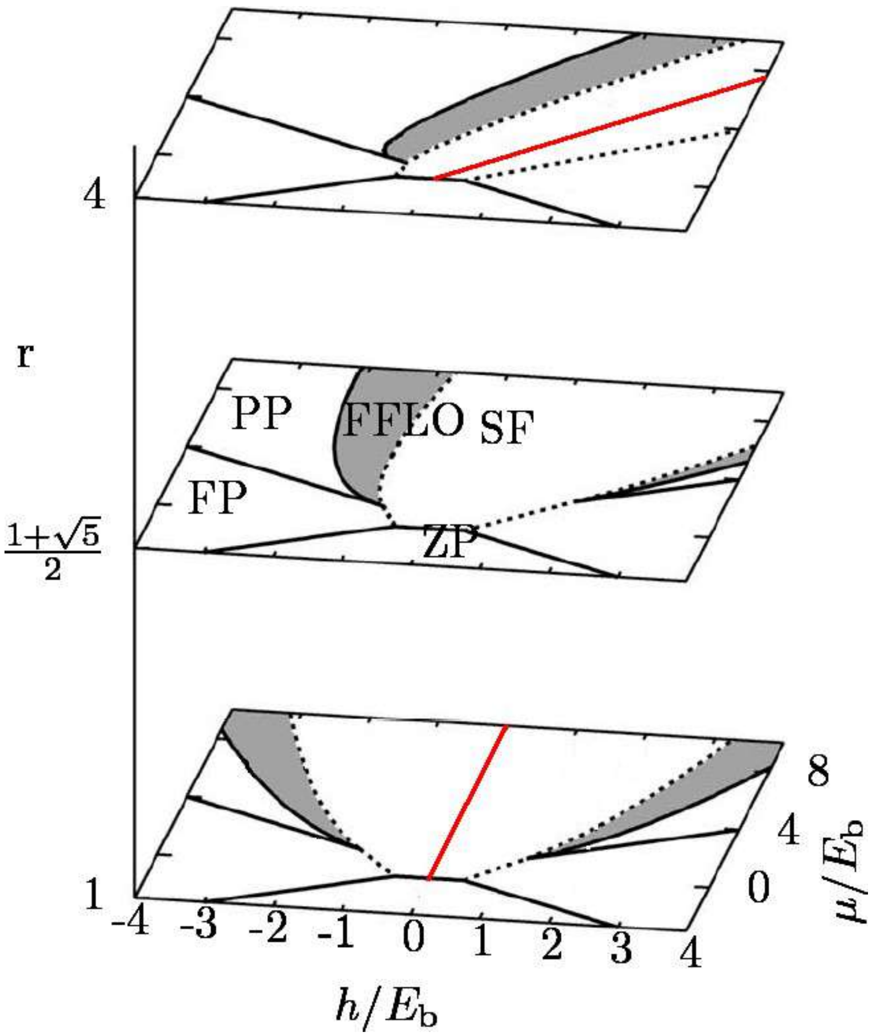
[3] Hu, Liu, Zhang & Duan



Free system: changing mass ratio r

- Generalize to allow different particle masses where $r = m_\downarrow / m_\uparrow$
- Superfluidity is favored if the light species is in excess

Notation:
$\mu_\uparrow = \mu + h$
$\mu_\downarrow = \mu - h$
$r = m_\downarrow / m_\uparrow$
E_b: Binding energy
SF: Superfluid
PP: Partially polarized
FP: Fully polarized
ZP: No particles



Conclusions

- Ginzburg-Landau and single Fourier component approaches were used to derive analytic expressions for phase boundaries in a 2D fermionic atomic gas
- The FFLO phase is more prominent in 2D than in 3D
- Superfluidity is favored if the light species is in excess
- Thanks to Peter Conlon, Benjamin Simons, and the EPSRC