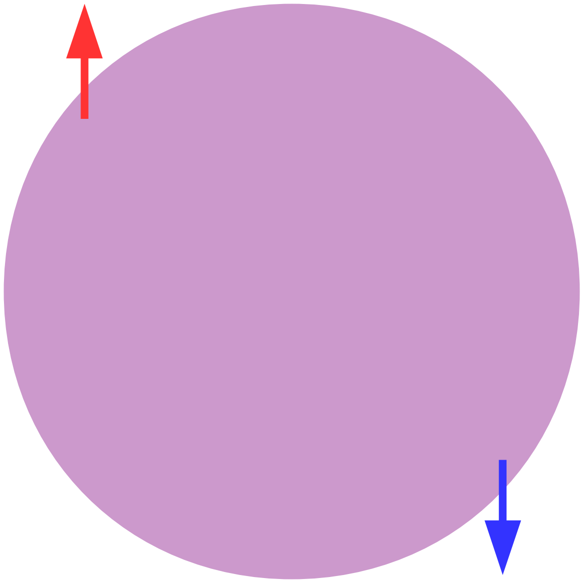
UNIVERSITY OF CAMBRIDGE

Multi-particle instability in an imbalanced electron gas

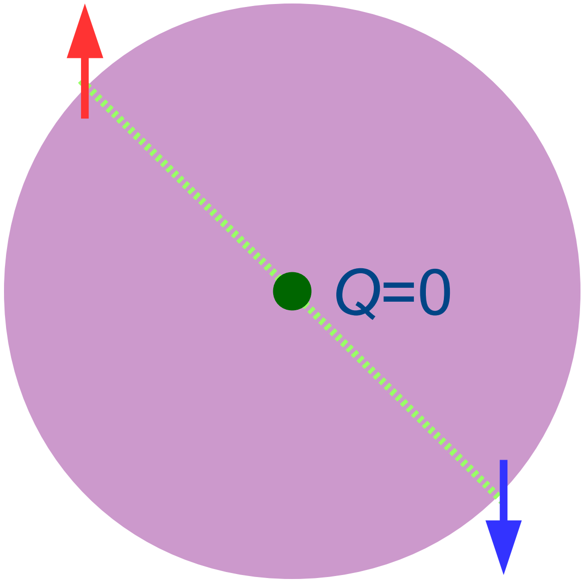
Thomas Whitehead
Gareth Conduit

TCM Group, Department of Physics

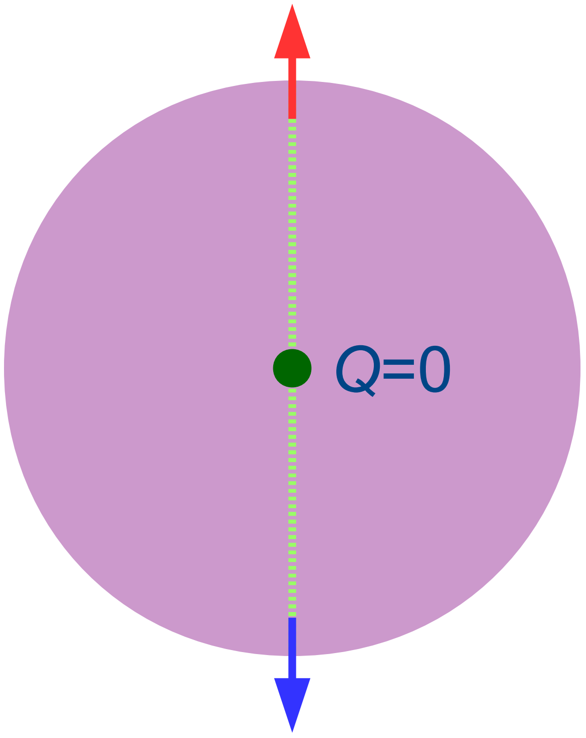
Cooper pair



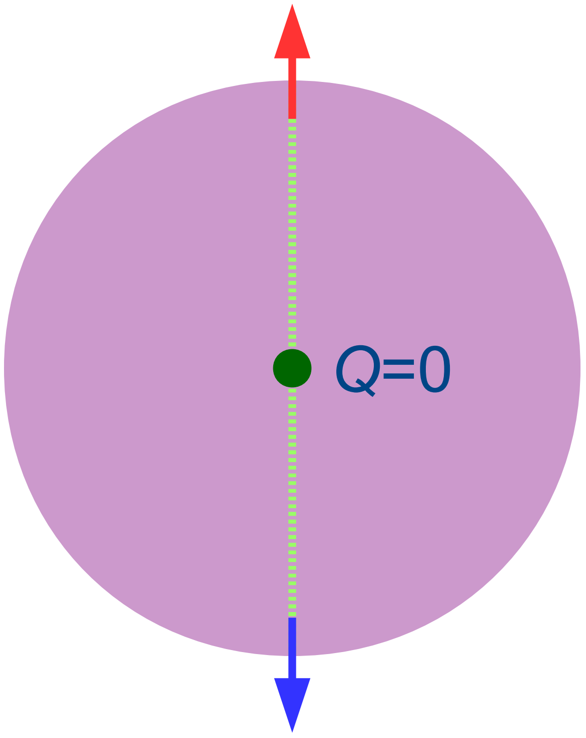
Cooper pair



Cooper pair

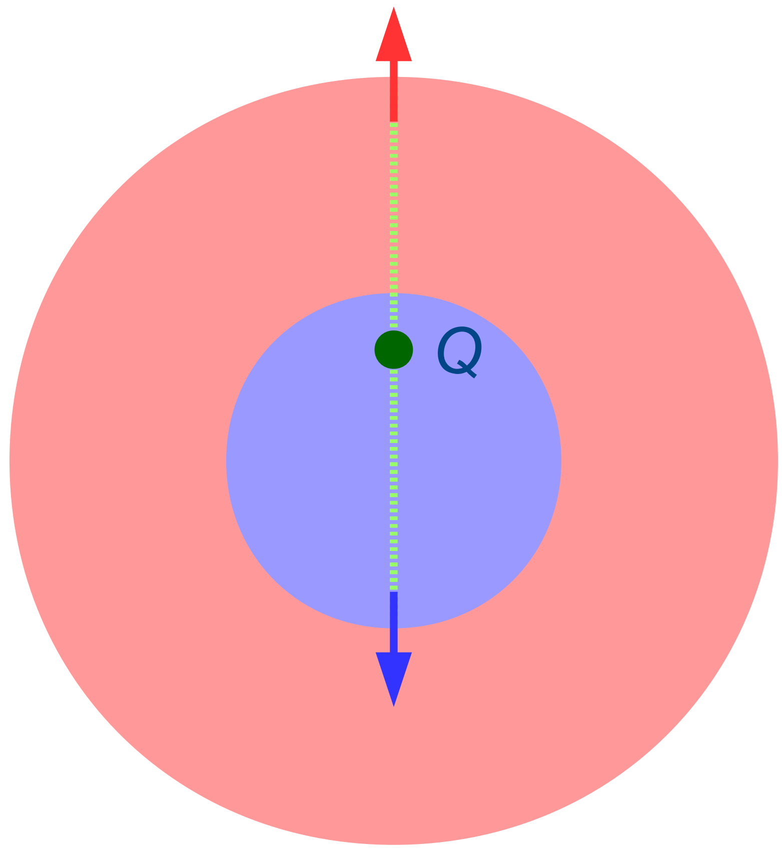


Cooper pair

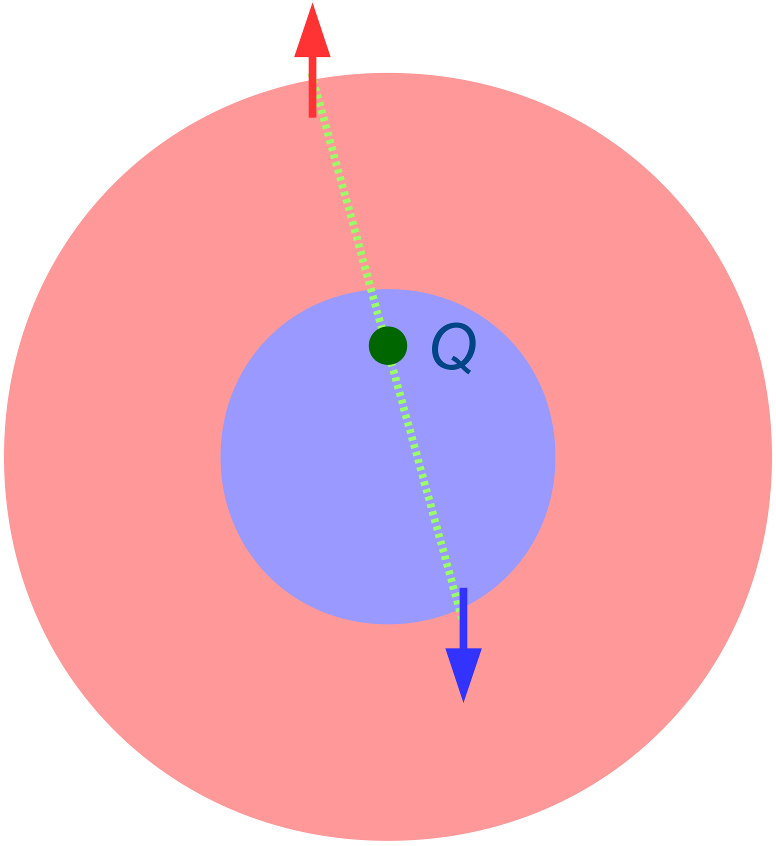


$$E = 2\,\omega_D \exp\left(-\frac{2\xi'}{g\nu_c}\right)$$

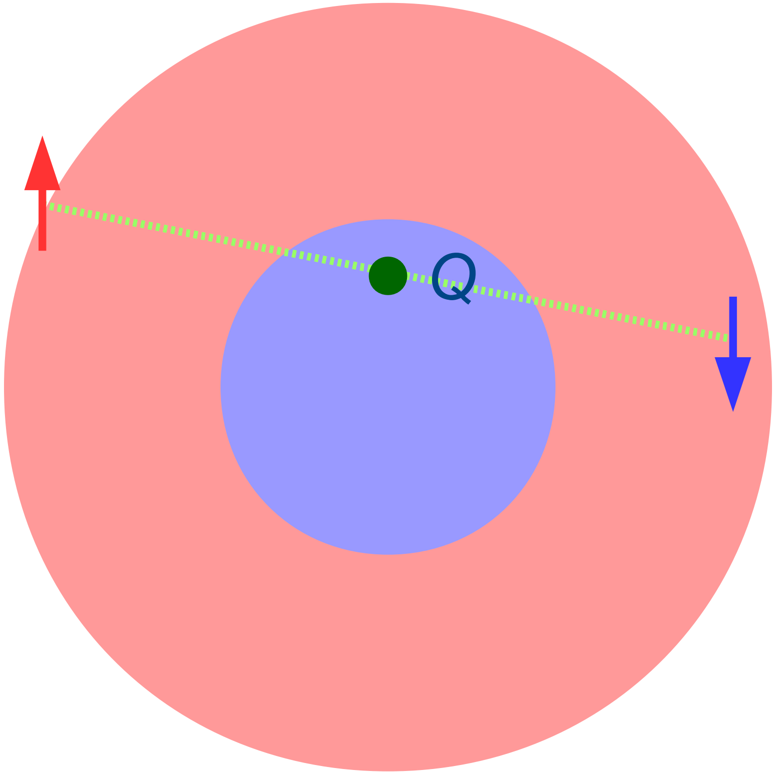
Cooper pair on imbalanced Fermi sea



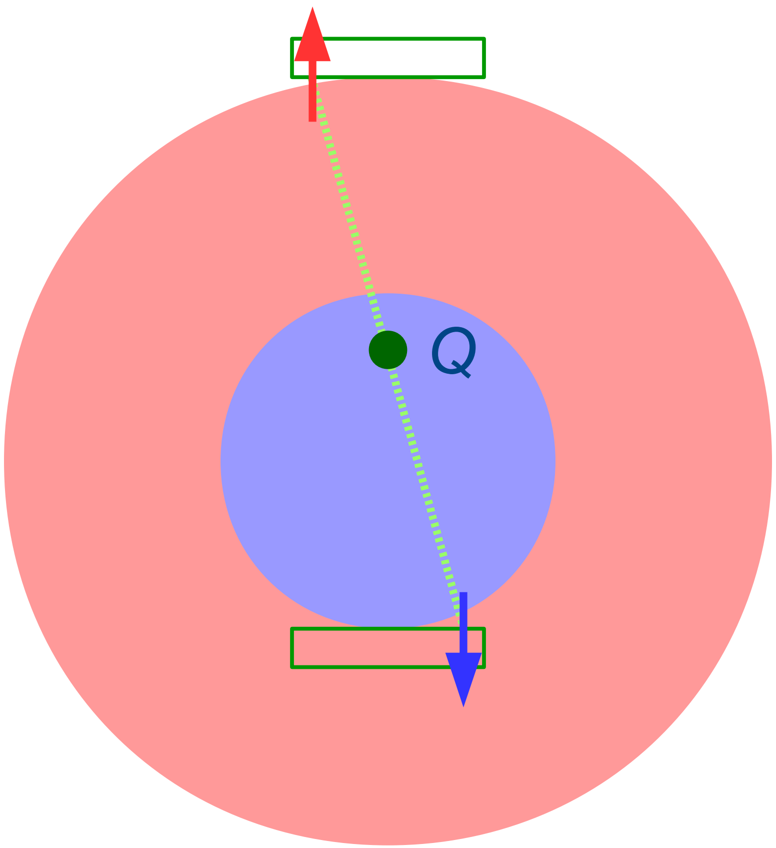
Cooper pair on imbalanced Fermi sea



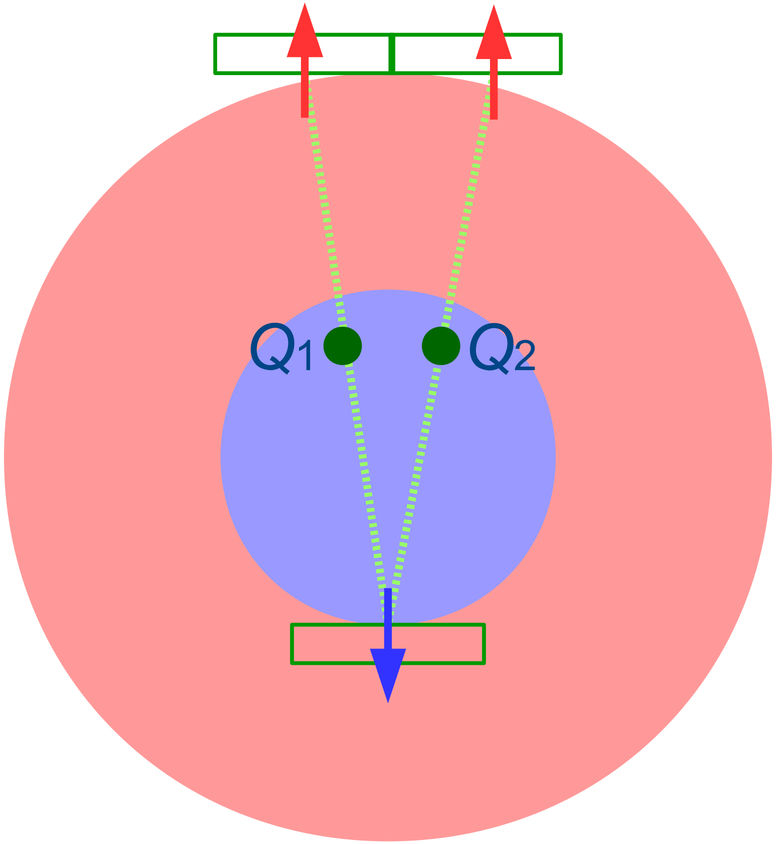
Cooper pair on imbalanced Fermi sea



Orbitals that can be correlated



Orbitals that can be correlated



Few-particle instability

Binding energy of a few-particle instability

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

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

Optimal number of up and down spin electrons in an instability

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

Many-body theory

Superconducting transition temperature

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

Optimal number of up and down spin electrons in an instability

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

Summary

Optimal number of up and down spin electrons in a Cooper particle is the ratio of the density of states

Cooper particle is the building block for superconducting state, verified by Diffusion Monte Carlo simulations

Energetically favorable to FFLO state

Possibility of number fluctuations in a superconductor

Recovering known results

Standard BCS result ($v_\uparrow = v_\downarrow$)

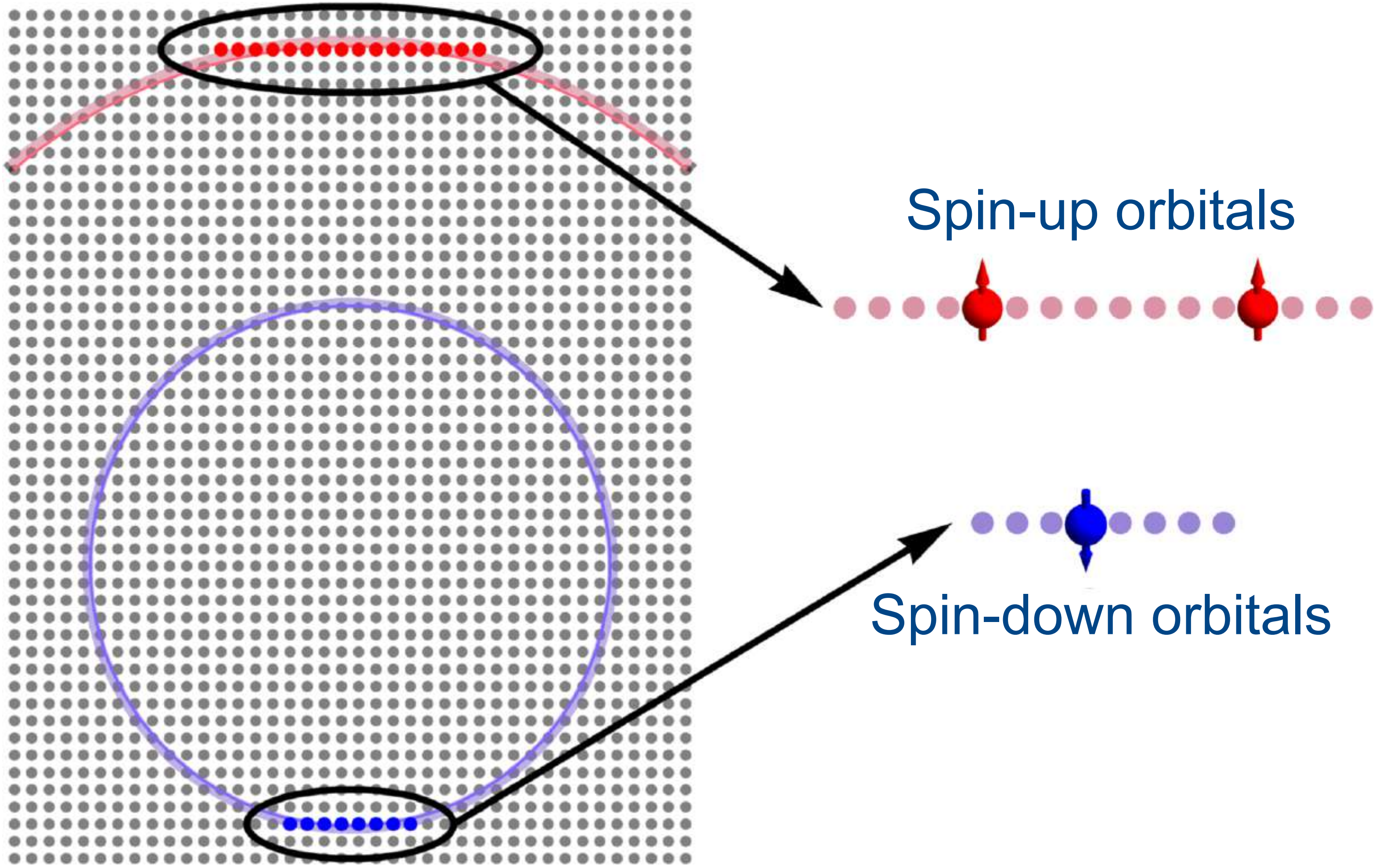
$$E = 2\,\omega_D \exp\left(-\frac{2\,\xi'}{g\,\nu}\right)$$

One-dimensional result ($v_\uparrow = v_\downarrow$)

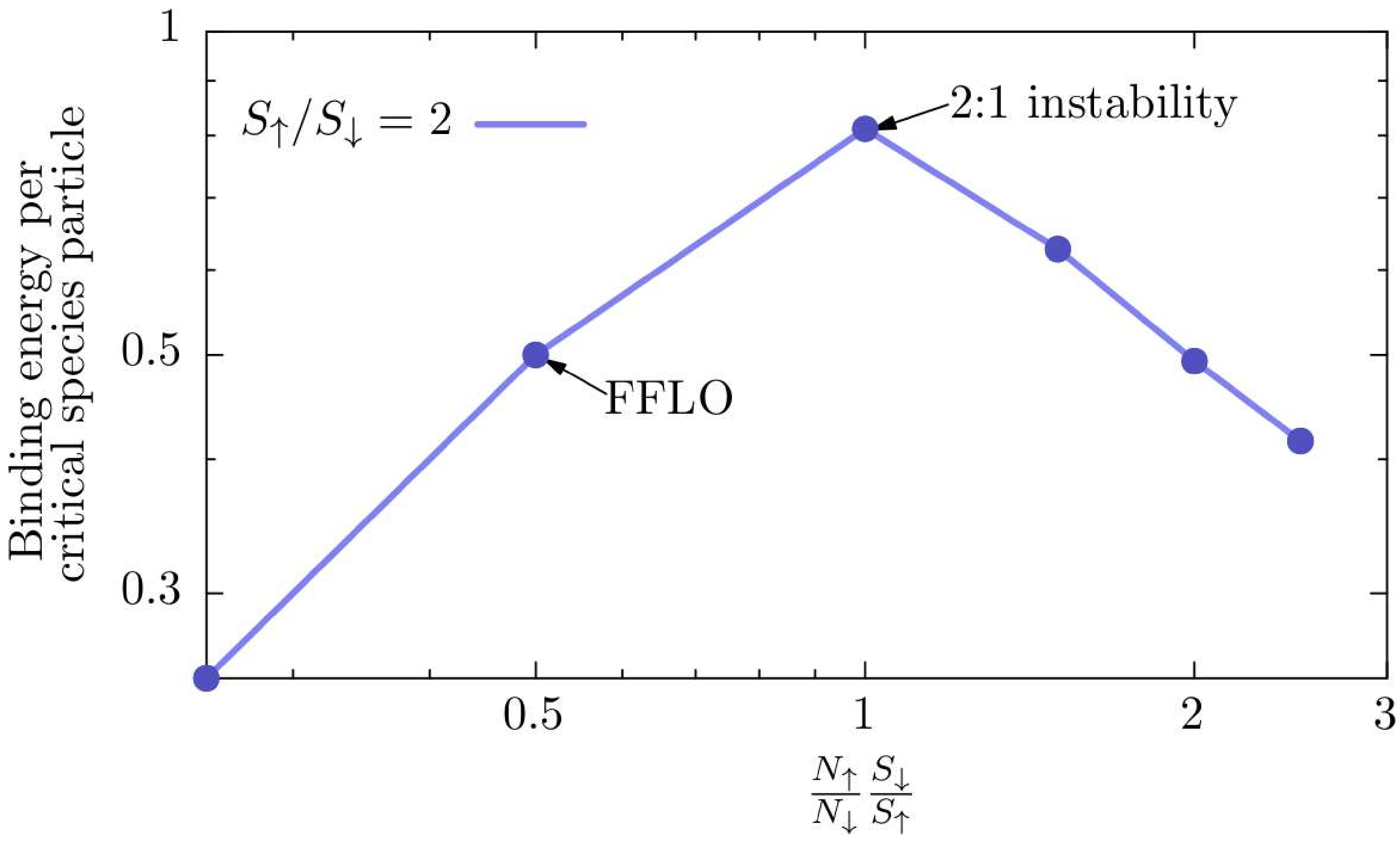
$$E = 2\,\omega_D \exp\left(-\frac{2\,\xi'}{g\,\nu}\right)$$

Polaron limit ($v_\uparrow \gg v_\downarrow$)

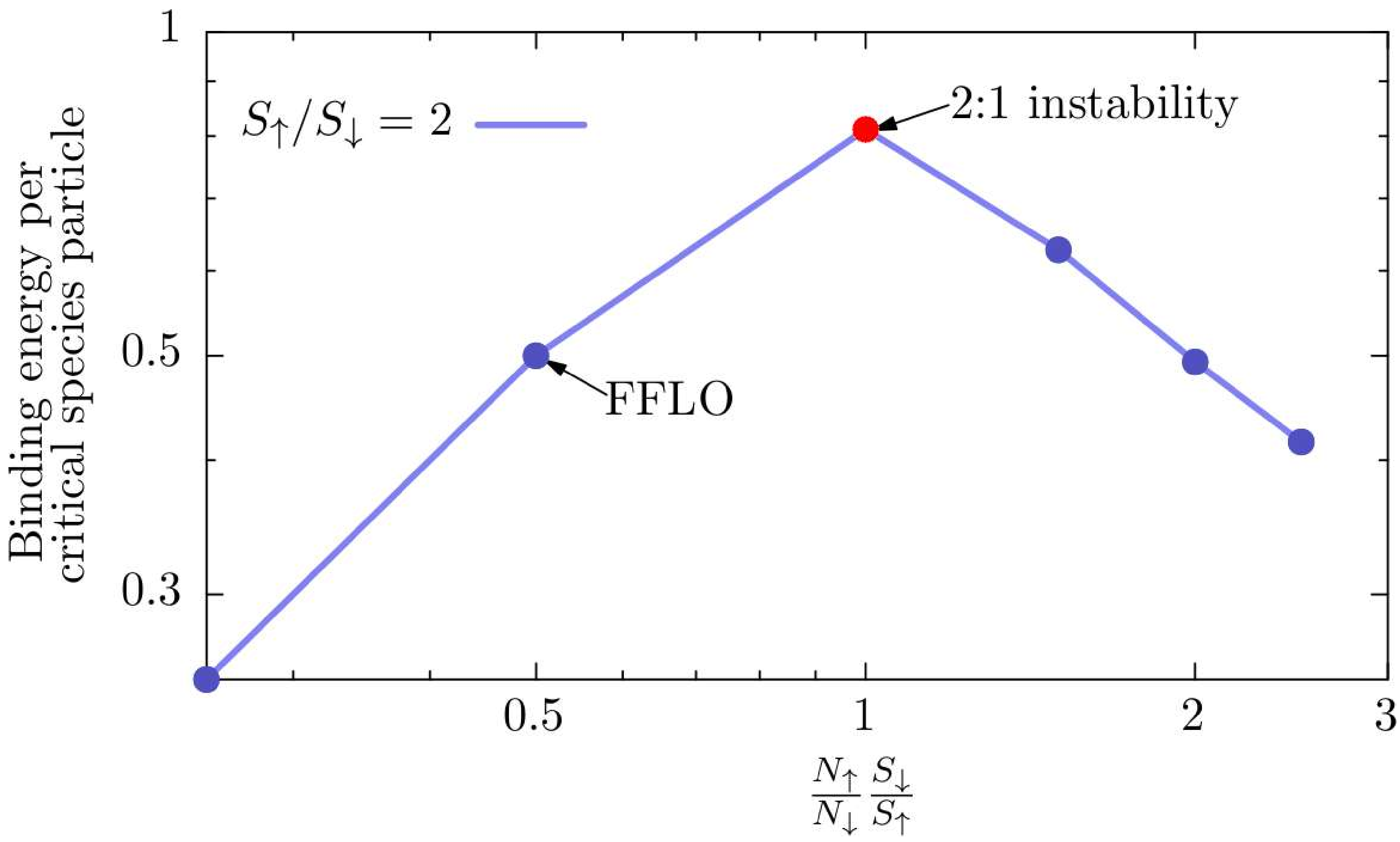
Exact diagonalization



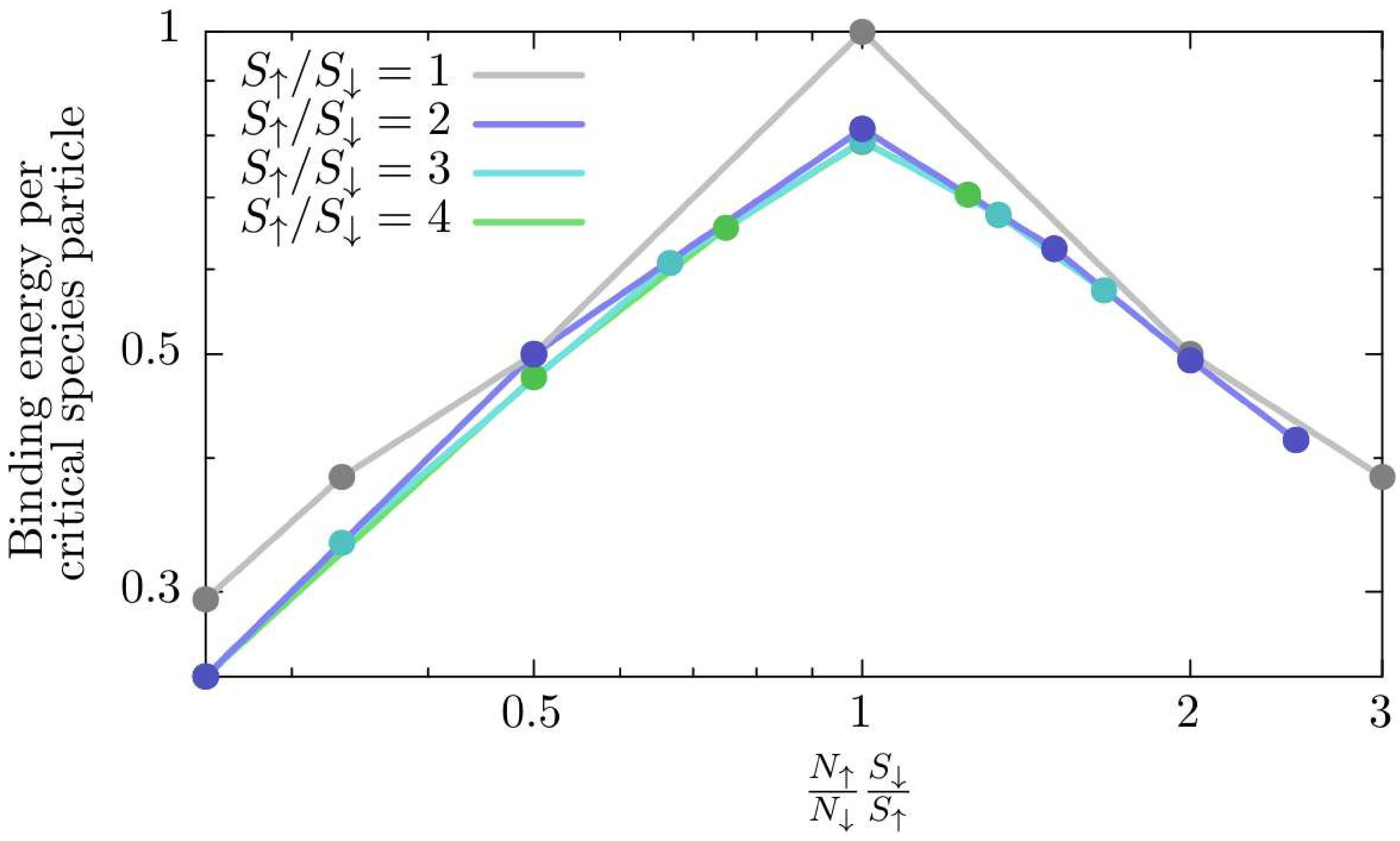
Exact diagonalization for 2:1 system



Analytical result for 2:1 system



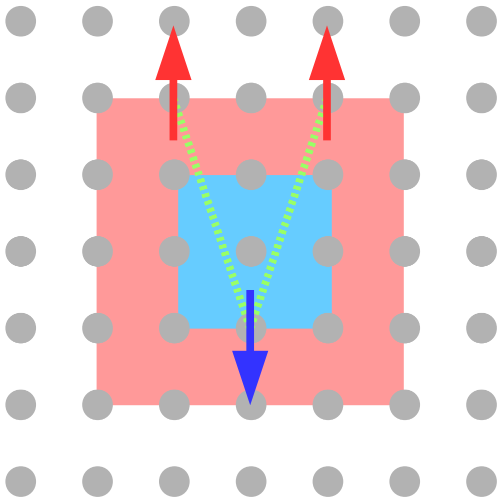
Exact diagonalization for S:1 systems



Diffusion Monte Carlo: 25 up, 9 down spins

Three-particle superconducting correlations

$$\Delta_{\boldsymbol{q}} = \left\langle c^{\dagger}_{\uparrow \boldsymbol{k}_1} c^{\dagger}_{\uparrow \boldsymbol{k}_2} c^{\dagger}_{\downarrow \boldsymbol{q}-\boldsymbol{k}_1-\boldsymbol{k}_2} \right\rangle$$



q_x	q_y	Δ_q
0	0	0.01
1	0	0.02
1	1	0.01
2	0	0.02
2	1	0.01
2	2	0.01
3	0	0.57
3	1	0.00
3	2	0.01
4	0	0.03