Fluxoid valve effect in full-shell nanowire Josephson junctions

Carlos Payá

QTYR25 - July 8th, 2025

About us

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Fluxoid Valve Effect in Full-Shell Nanowire Josephson Junctions
Carlos Payá, F. J. Matute-Cañadas, A. Levy Yeyati, Ramón Aguado, Pablo San-Jose, Elsa Prada
arXiv:2504.16989 (2025)

Josephson effect and critical currents in trivial and topological full-shell hybrid nanowires
Carlos Payá, Ramón Aguado, Pablo San-Jose, Elsa Prada
Phys. Rev. B **111**, 235420 (2025)

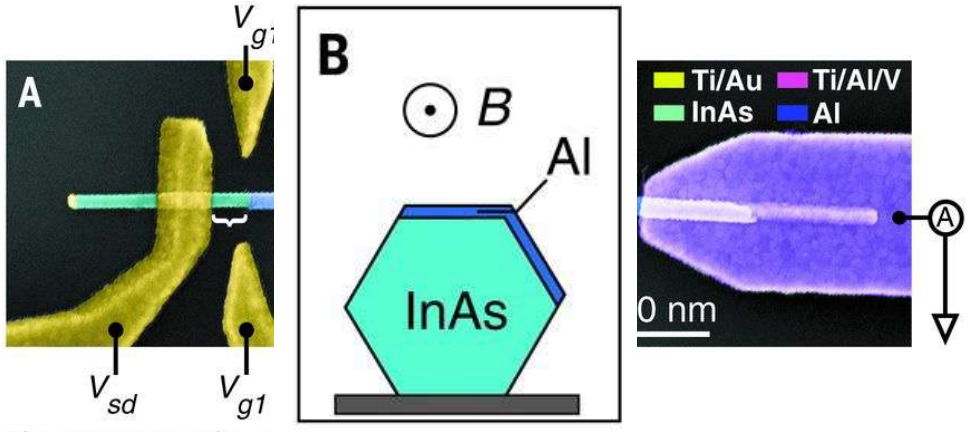
Full-shell nanowire junctions can work as **magnetic-field controlled supercurrent valves**

How does **radii mismatch** in a full-shell **junction** affect the supercurrent?

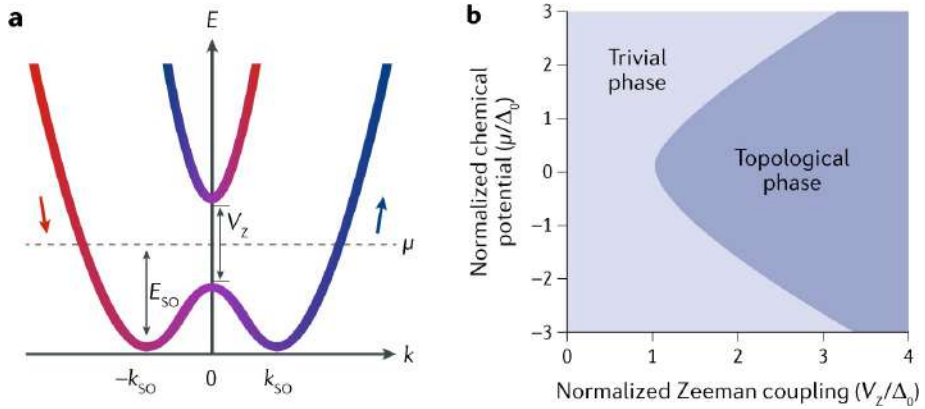
What about **Majoranas**?

Why do we care about full-shells?

Partial-shell

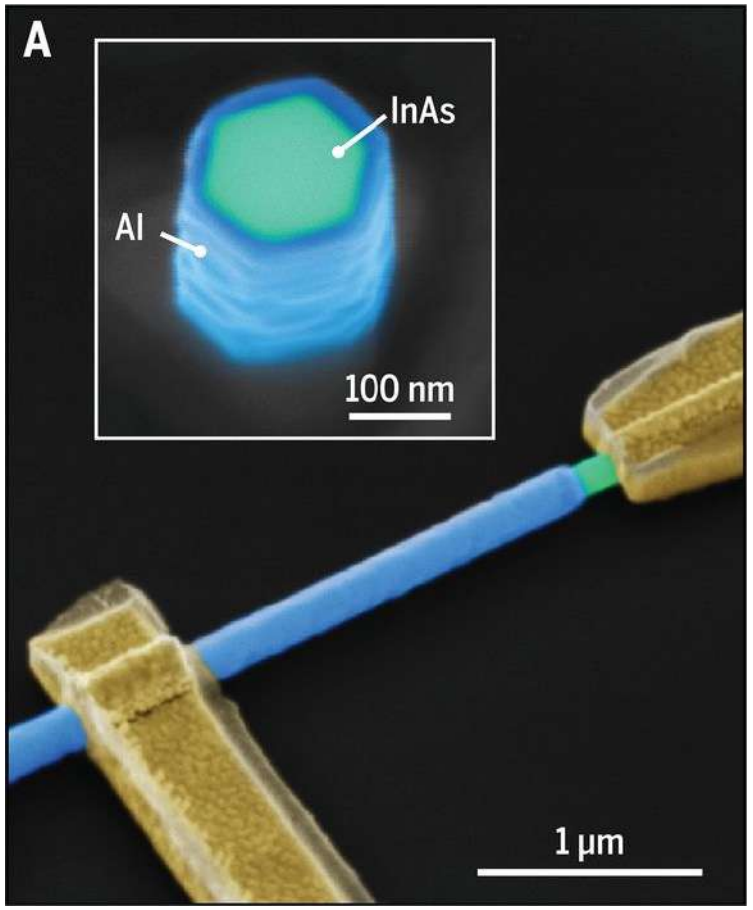


M. T. Deng *et al. Science* 354, 6319 (2016)



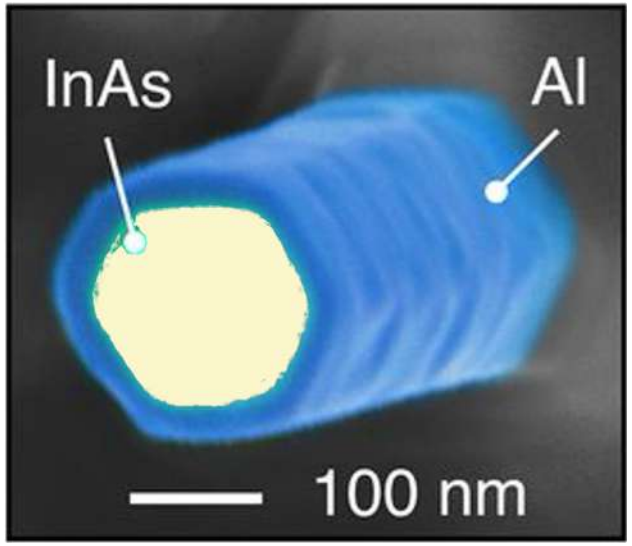
R. M. Lutchyn *et al. Nature Reviews Materials* 3, 52-68 (2018)

Full-shell

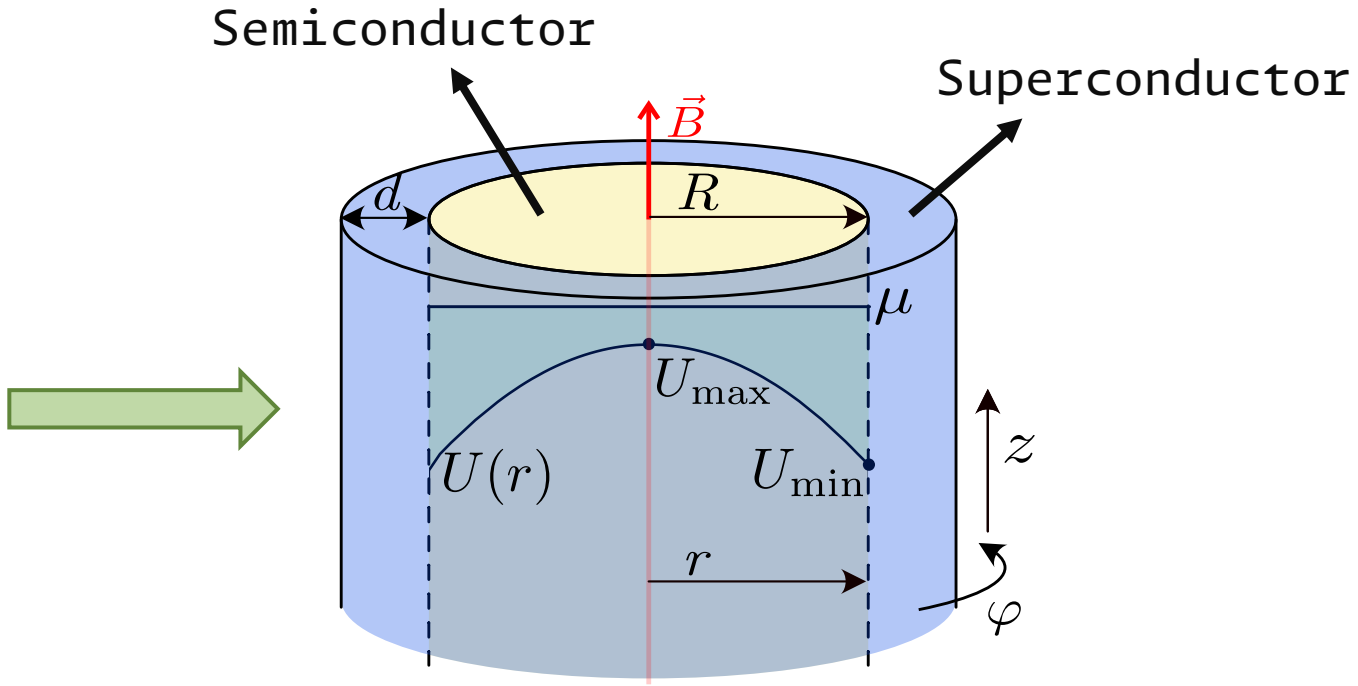


S. Vaitiekėnas *et al. Science* 367, 1442 (2020)

A full-shell hybrid nanowire



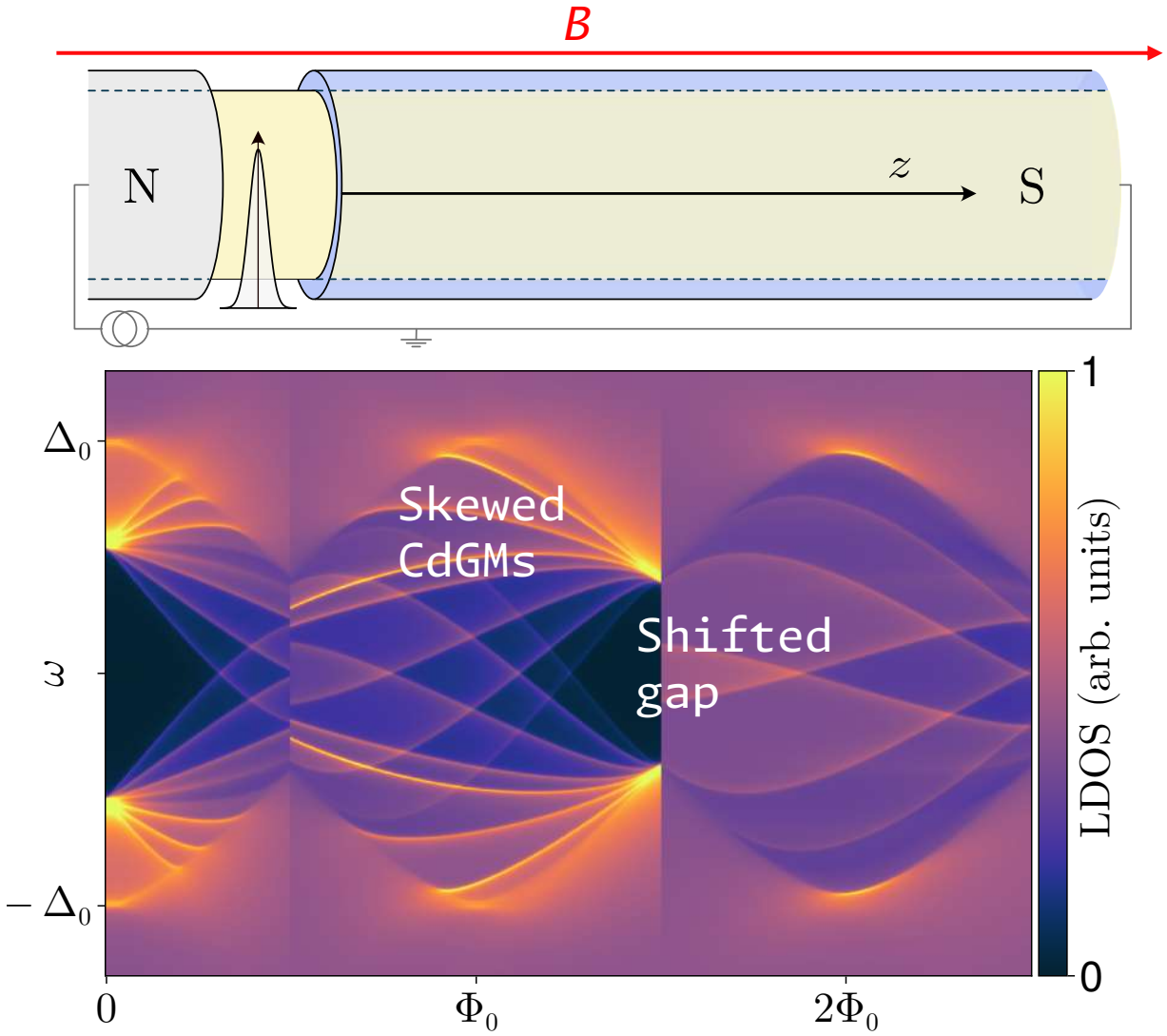
S. Vaitiekėnas *et al.*, Science, 2020

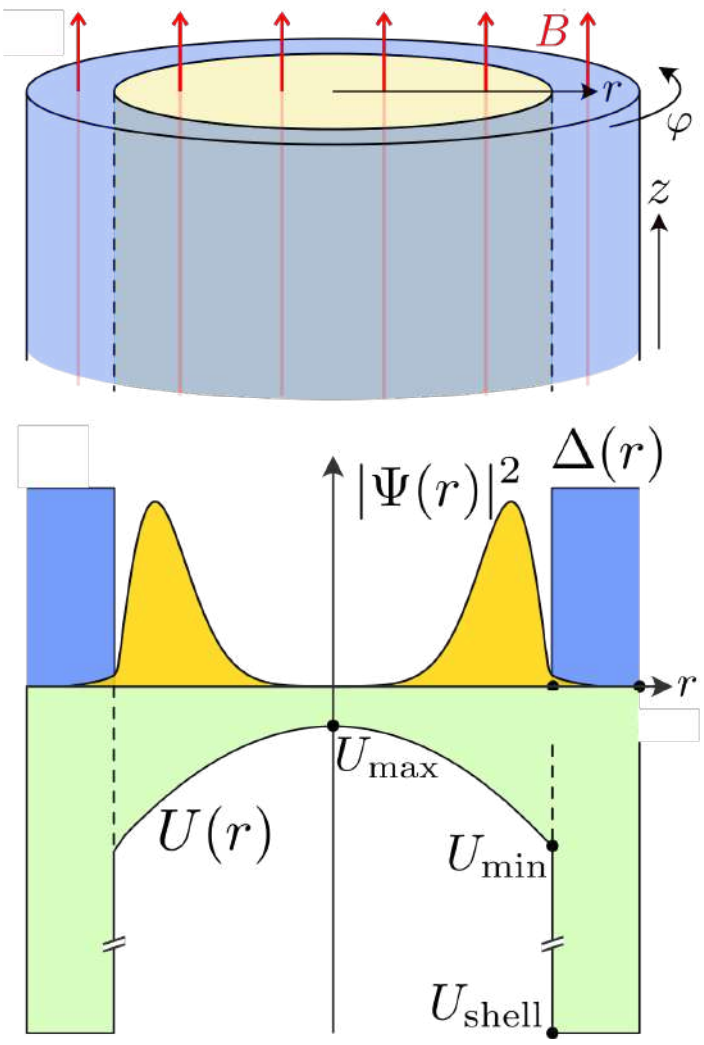


- Topological at lower magnetic fields
- Protected from charge noise

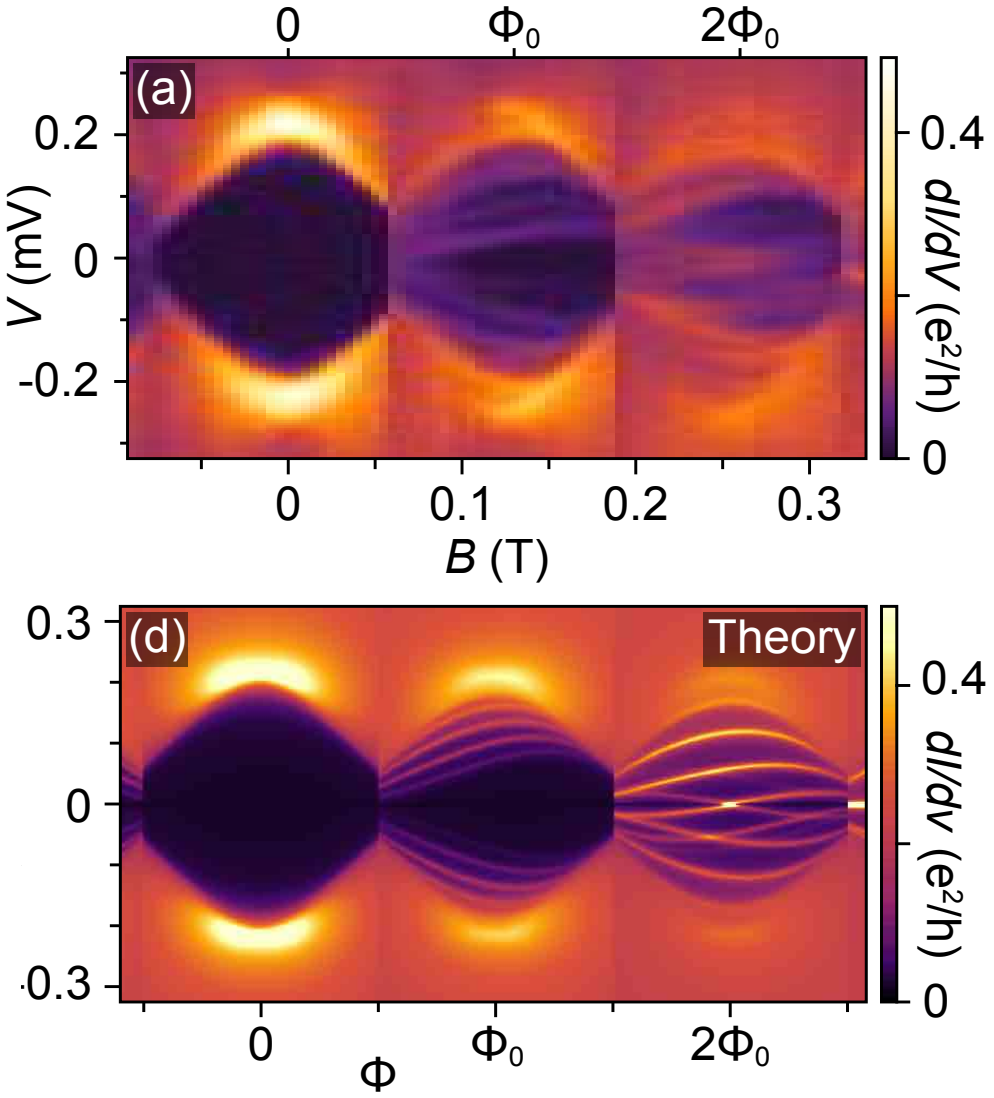
- Cylindrical symmetry
- Charge at interface
- SOC induced by band bending

Sub-gap levels skewness at the edge





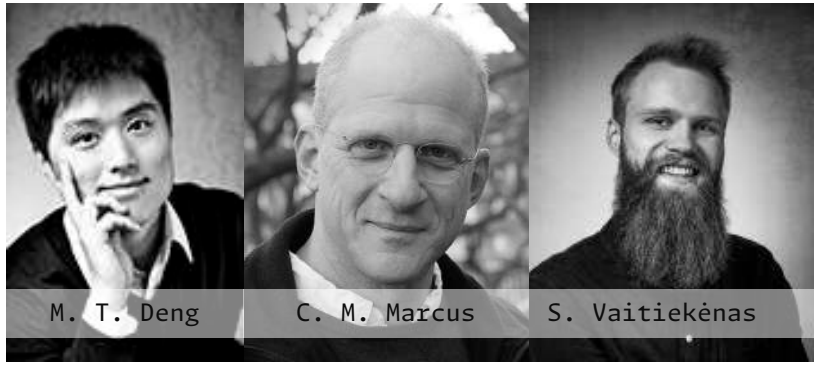
CdGMs experimental demonstration



Caroli-de Gennes-Matricon Analogs in Full-Shell Hybrid Nanowires

M. T. Deng, **Carlos Payá**, Pablo San-Jose, Elsa Prada, C. M. Marcus, S. Vaitiekėnas

Phys. Rev. Lett. 134, 206302 (2025)

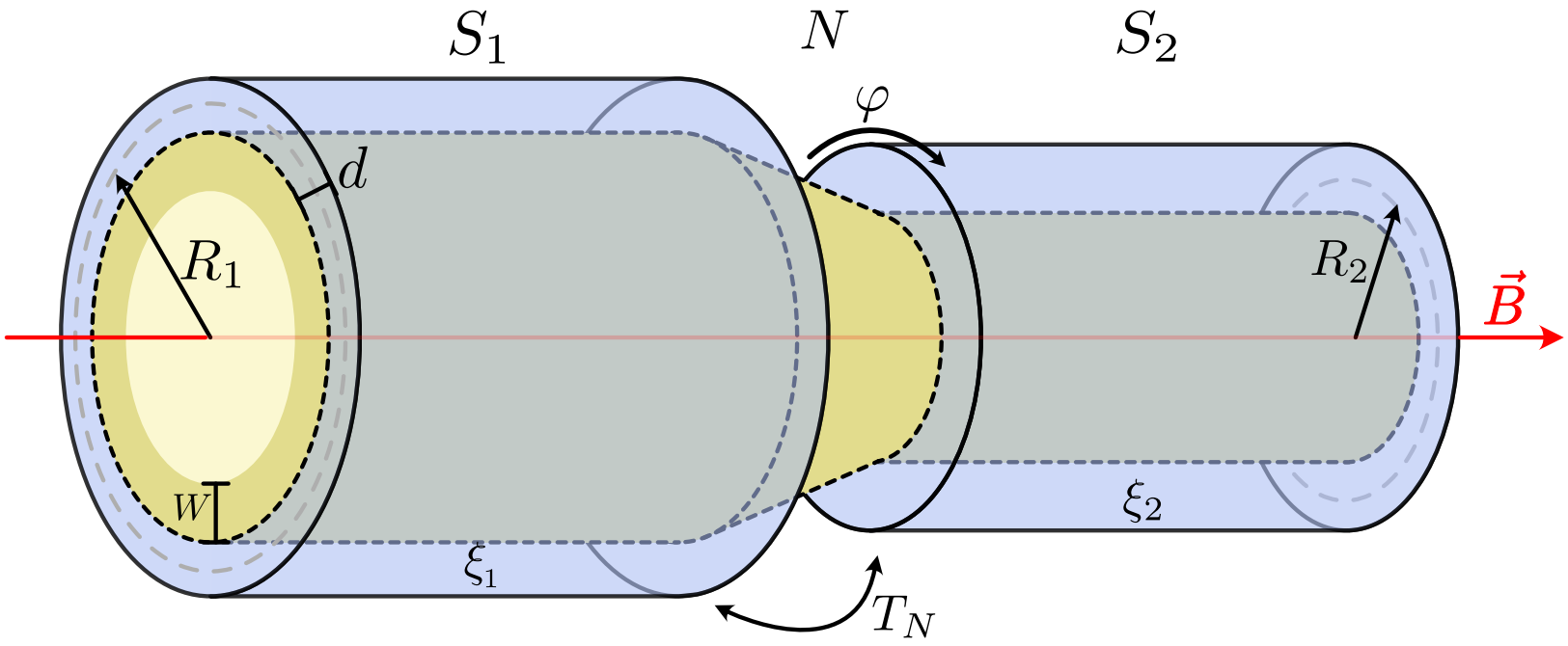


PRL

UNIVERSITY OF COPENHAGEN

What happens in a Josephson junction with different radii?

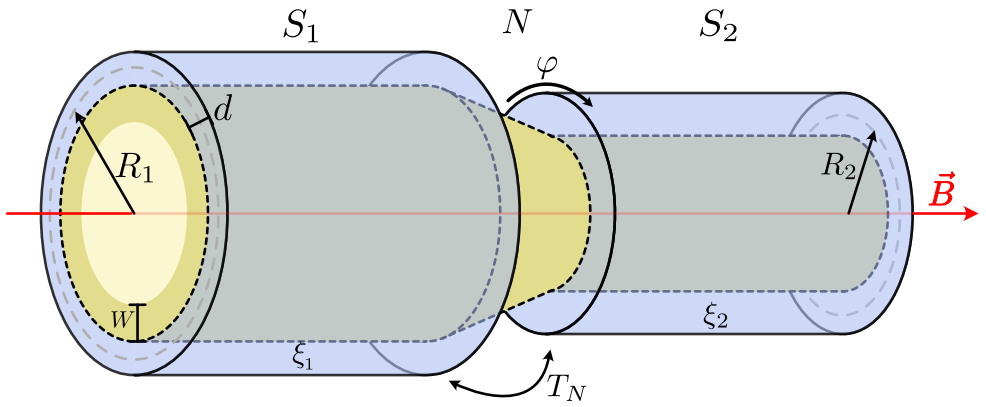
A full-shell Josephson junction



- Short junction, $L_N \ll \xi_{SC}$
- Controlled transparency T_N
- No voltage bias ⇒ dc Josephson

Fluxoid mismatch blocks current

$$n_1 = \lfloor \frac{\pi R_1^2 B}{\Phi_0} \rceil$$



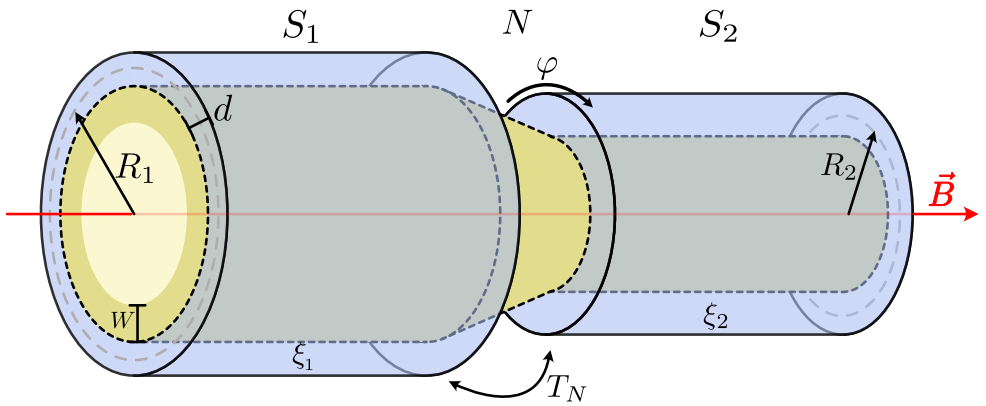
$$n_2 = \lfloor \frac{\pi R_2^2 B}{\Phi_0} \rceil$$

No current flow if $n_1 \neq n_2$

Fluxoid mismatch blocks current

No current flow if $n_1 \neq n_2$

$$\Delta_1(\varphi) = \Delta_1(0)e^{in_1\varphi}$$



$$\Delta_2(\varphi+\delta\varphi) = \Delta_2(0)e^{in_2(\varphi+\delta\varphi)}$$

phase bias ϕ ⇒ $\delta\varphi = \frac{\phi}{n_1 - n_2}$

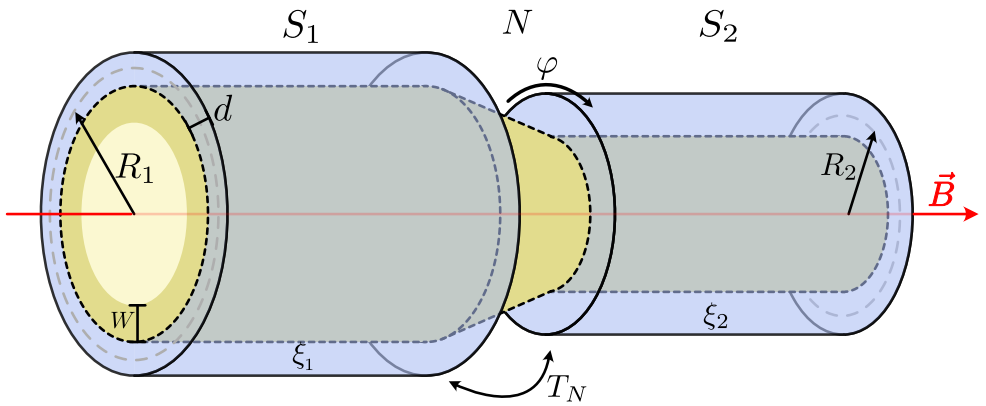
But there is cylindrical symmetry! ⇒ $\delta\varphi$ cannot change the free energy

$$\partial_\phi F(\phi) = 0 \Rightarrow J = 0$$

Fluxoid mismatch blocks current

Current flows if $n_1 = n_2$

$$\Delta_1(\varphi) = \Delta_1(0)e^{in_1\varphi}$$

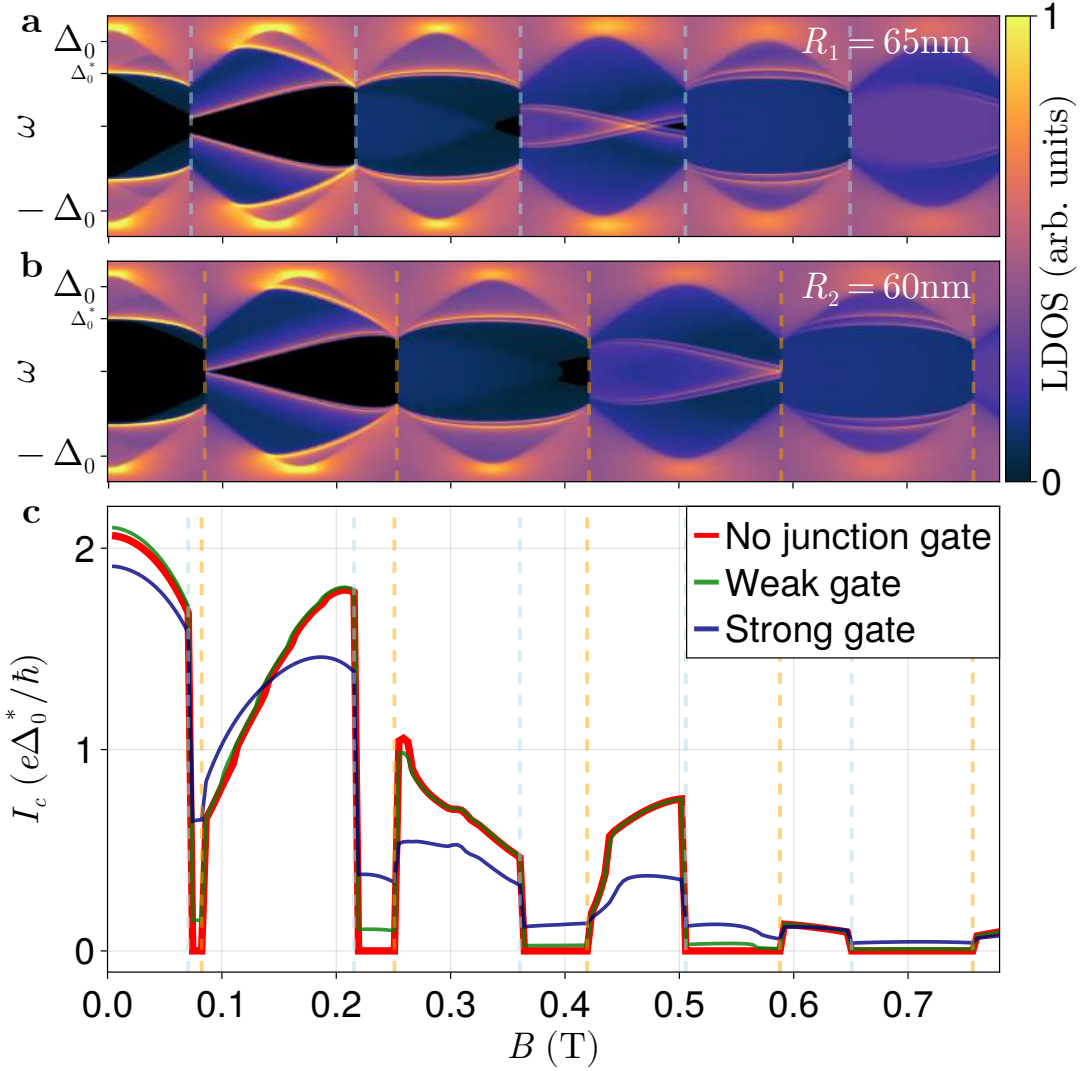


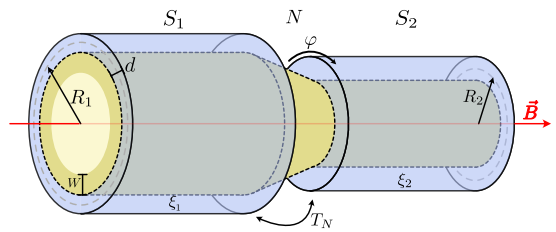
$$\Delta_2(\varphi + \delta\varphi) = \Delta_2(0)e^{n_2(\varphi+\delta\varphi)}$$

phase bias ϕ ⇒ $\delta\varphi = \frac{\phi}{n_1 - n_2}$

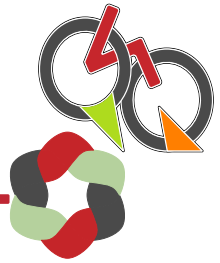
$$\delta\varphi(n_1 = n_2) \to \infty$$

Fluxoid valve effect





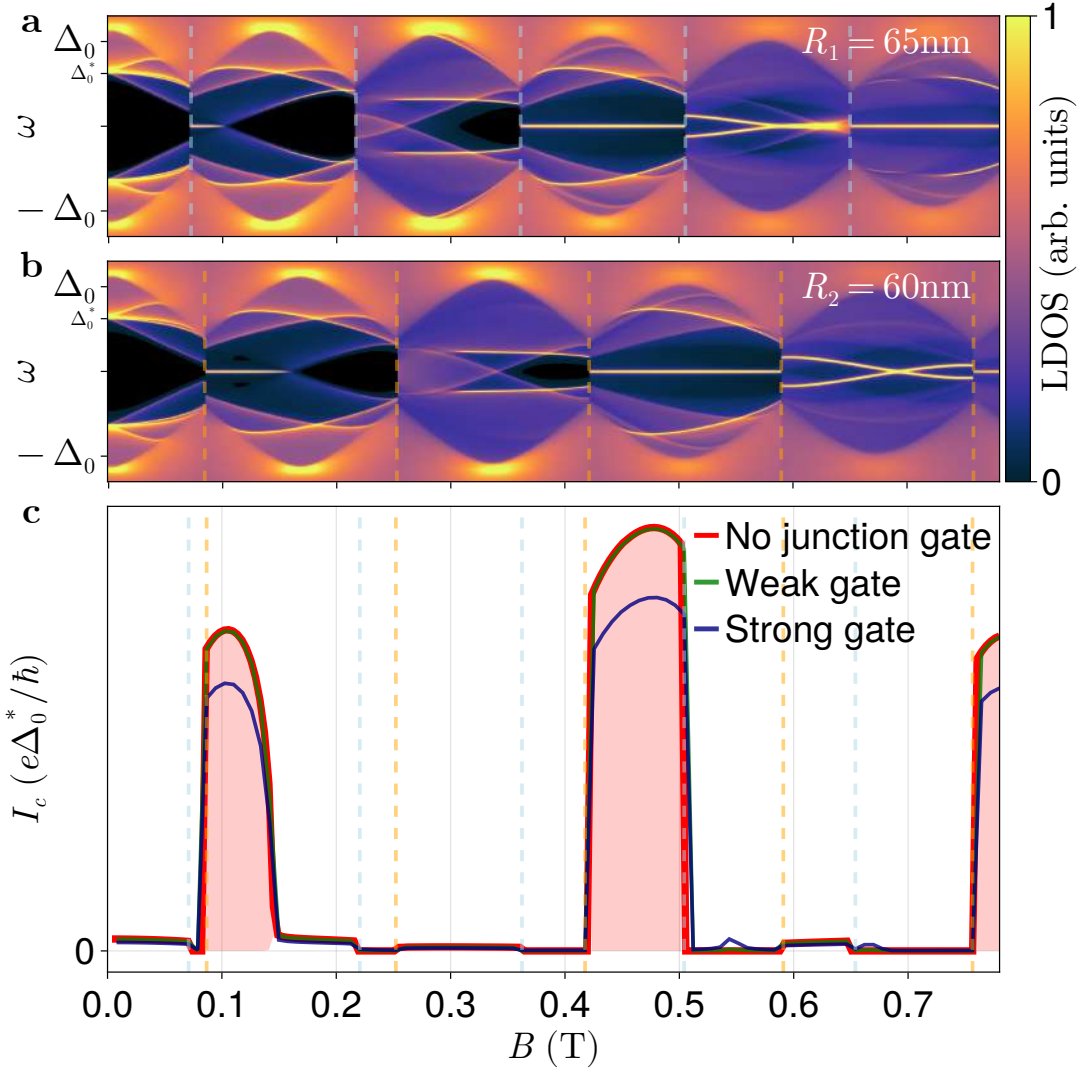
Worsens if symmetry is broken

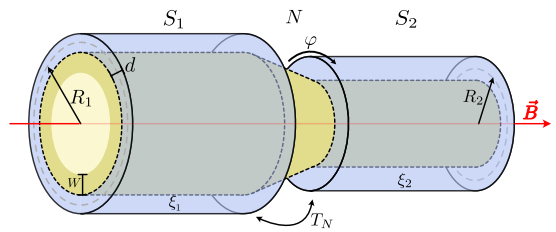


What if there are Majoranas?

Majoranas improve valve

$T_N \to 0$





Majorana conductance goes with

$\sqrt{T_N}$

Full story here!

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arXiv:2504.16989 (2025)

Jesper Nygård

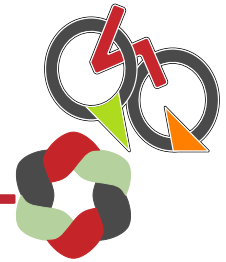
Eduardo Lee

Experiments ongoing by

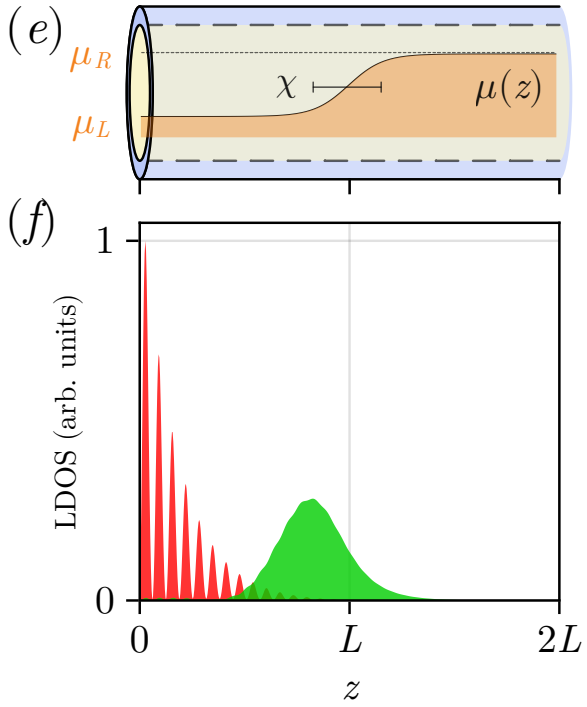
J. Nygård group, NBI, Copenhagen

E. Lee group, IFIMAC, Madrid

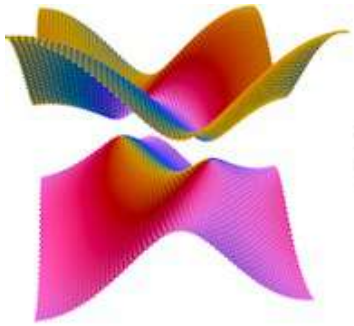
SPAM!



Chemical potential inhomogeneities…
Fake Majoranas?!?



Check poster!



Quantica.jl

github.com/pablosanjose/Quantica.jl

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