SYNTHETIC SPIN-ORBIT INTERACTION FOR MAJORANA DEVICES

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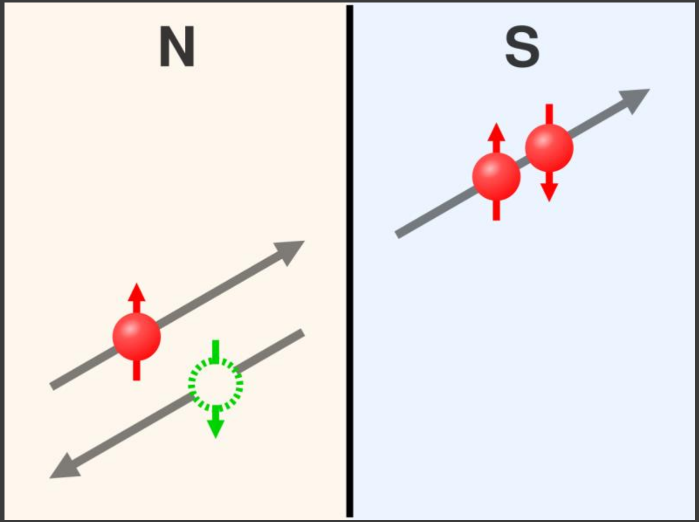
Nature Materials **18**, 1060-1064 (2019)

Peter Wild

1. Andreev and Majorana bound states
2. Rashba spin-orbit coupling
3. Device setup
4. Induced spin-orbit interaction
5. Control device
6. Zero-bias conductance peak

Andreev reflection and Andreev bound states



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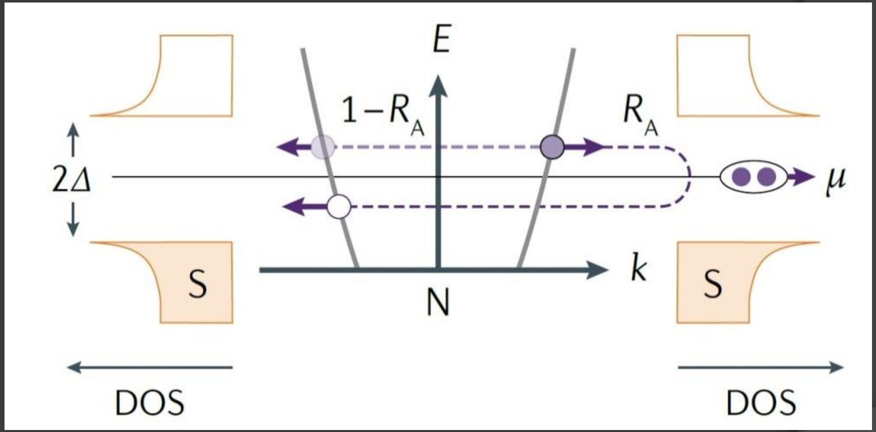

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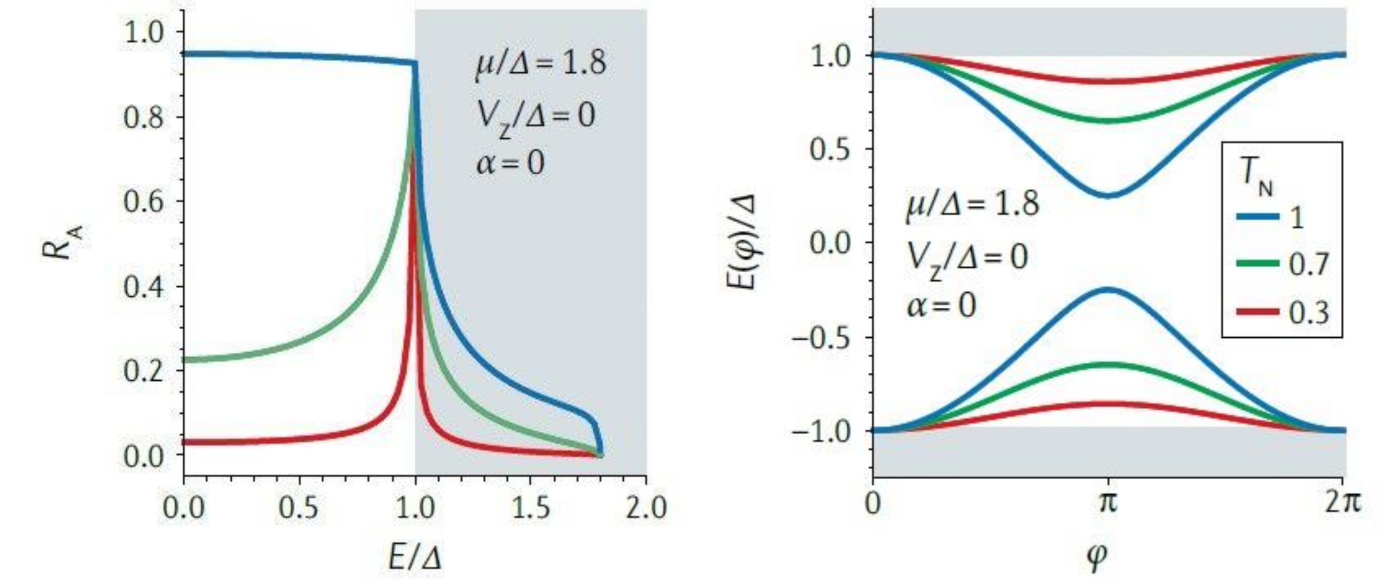
Andreev reflection and Andreev bound states



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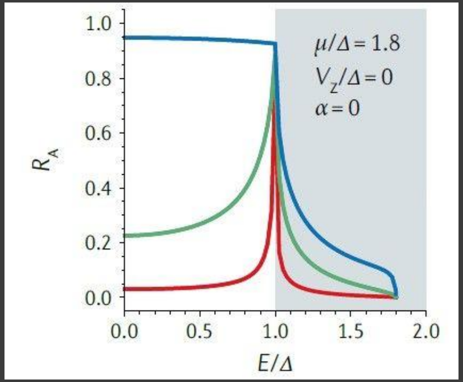
Majorana bound states

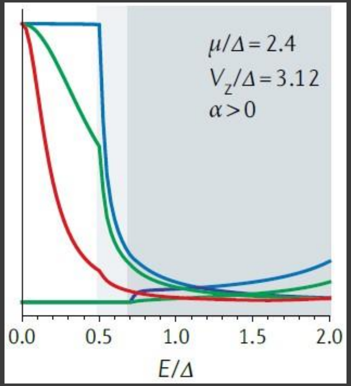
- Topologically protected zero-energy modes
- Robust against perturbations
- Exotic properties, promising for quantum computing

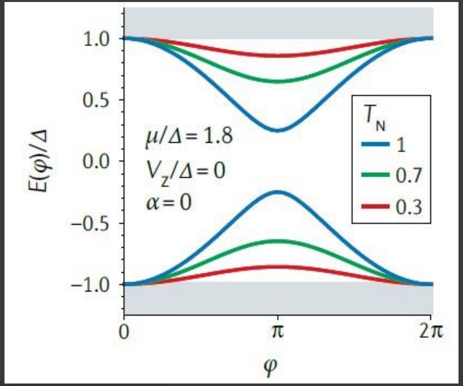
Required:

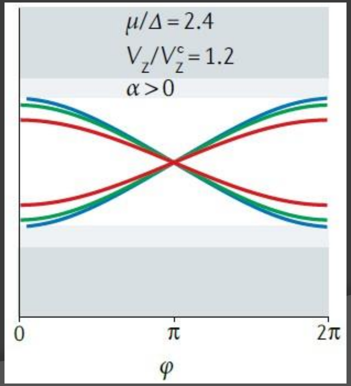
- Superconductivity
- Combination of Zeeman splitting and spin-orbit coupling
- Small chemical potential
- Comparable order of magnitude of Δ, V_Z, E_{SO}, μ

Andreev to Majorana









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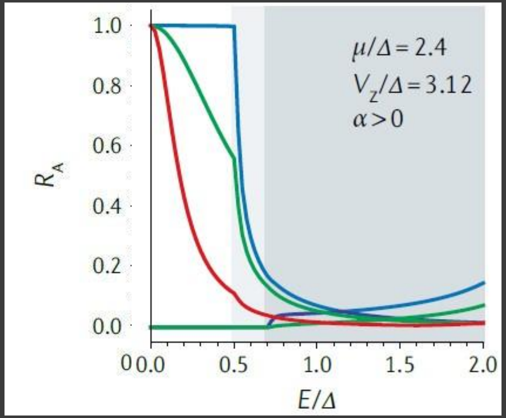

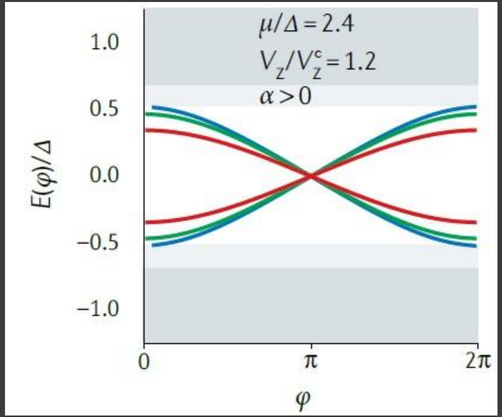

Problems:

- High Zeeman energy V_Z requires high external B-field
- High external B-field suppresses superconductivity

- Intrinsic spin-orbit coupling is property of the material (~ Z^4)
- Too weak for low-Z-materials
- Rashba spin-orbit interaction

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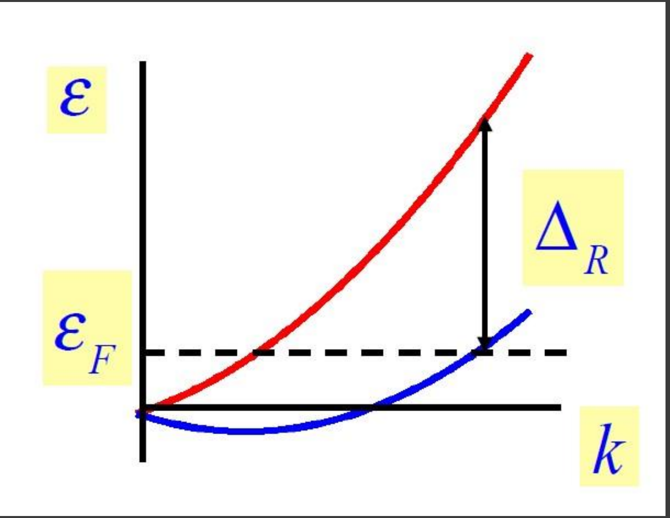
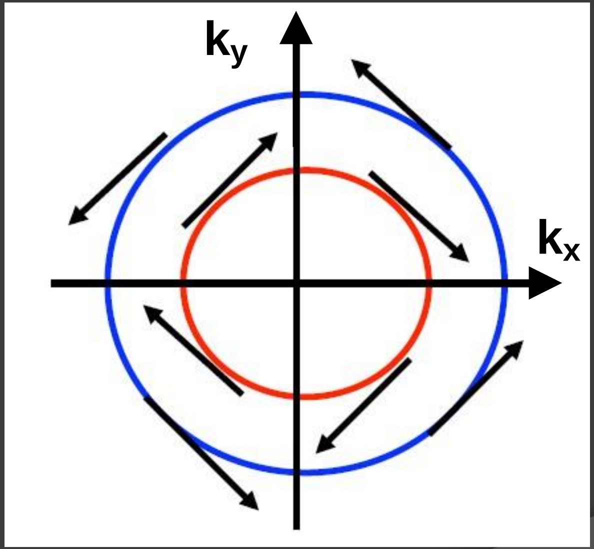
Rashba spin-orbit coupling

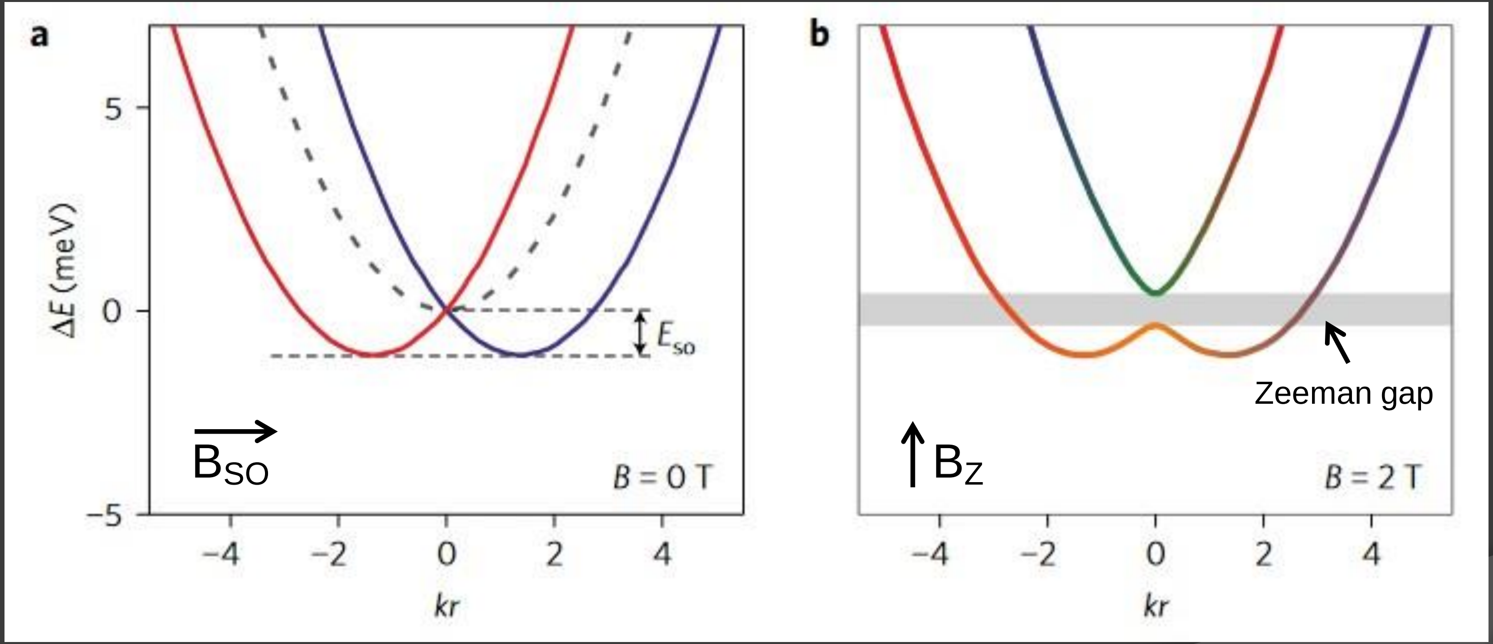


$$E_{\pm} = \frac{k^2}{2m} \pm \alpha k$$



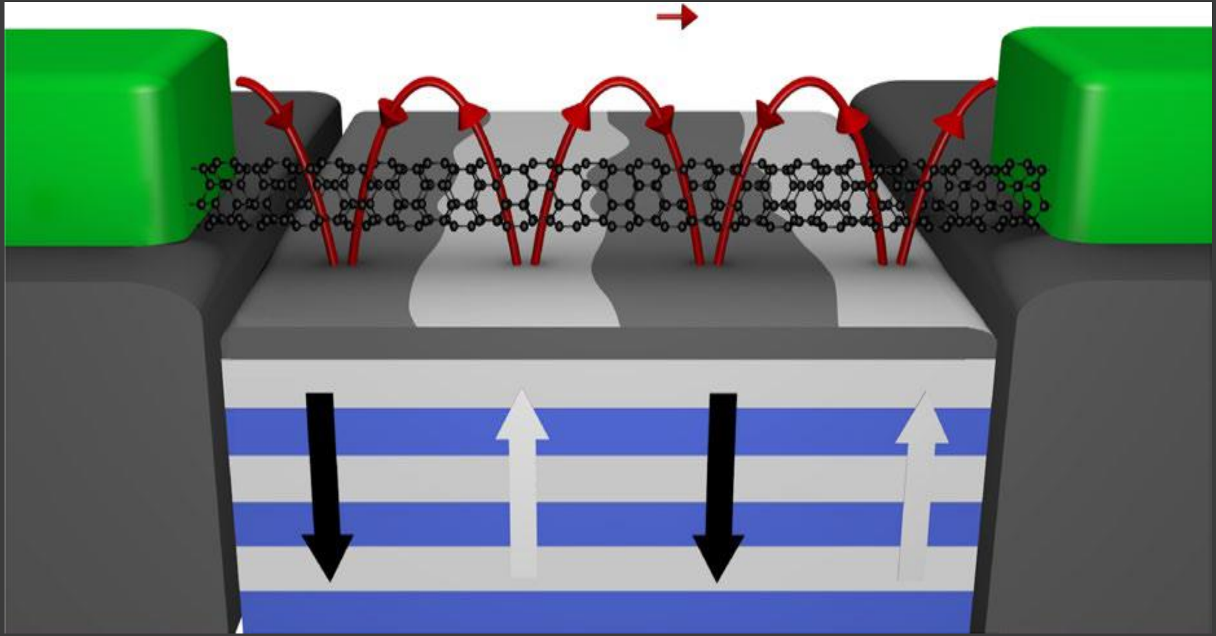
Lecture notes, D. Maslov
Florida State University, www.phys.ufl.edu

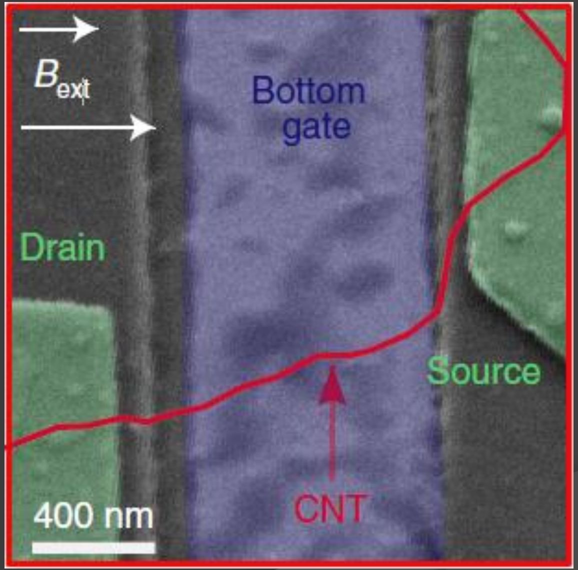
Rashba spin-orbit coupling



S. Heedt, N. Traverso Ziano
Nature Physics volume 13, pages 563–567 (2017)

Device setup





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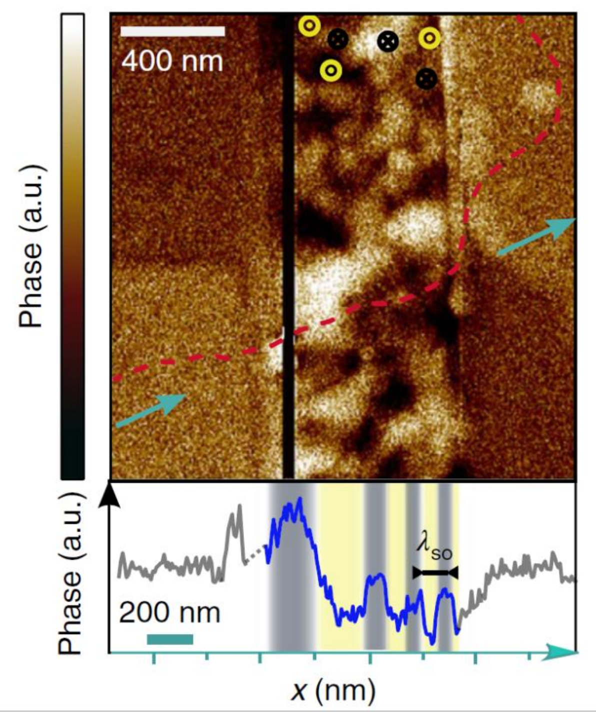

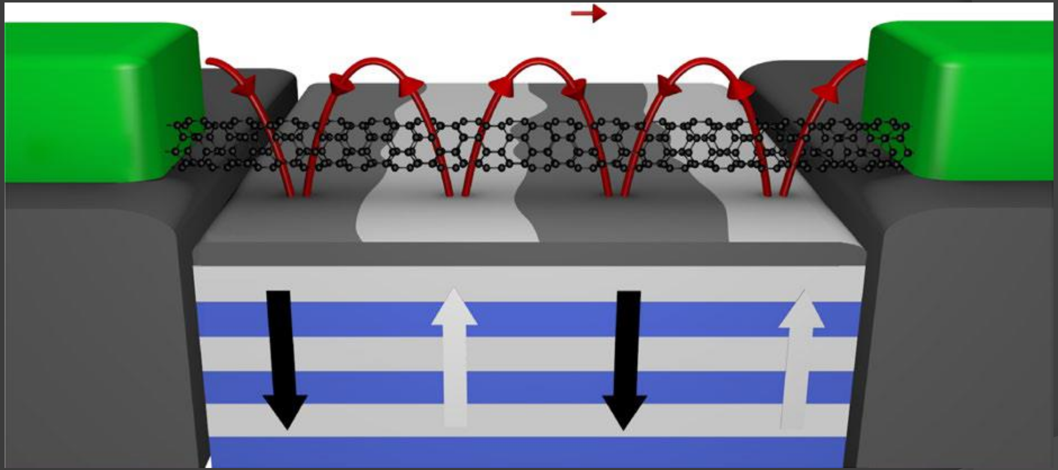

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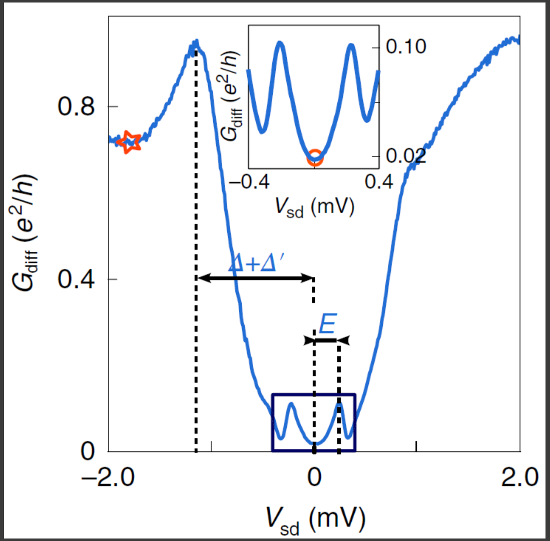
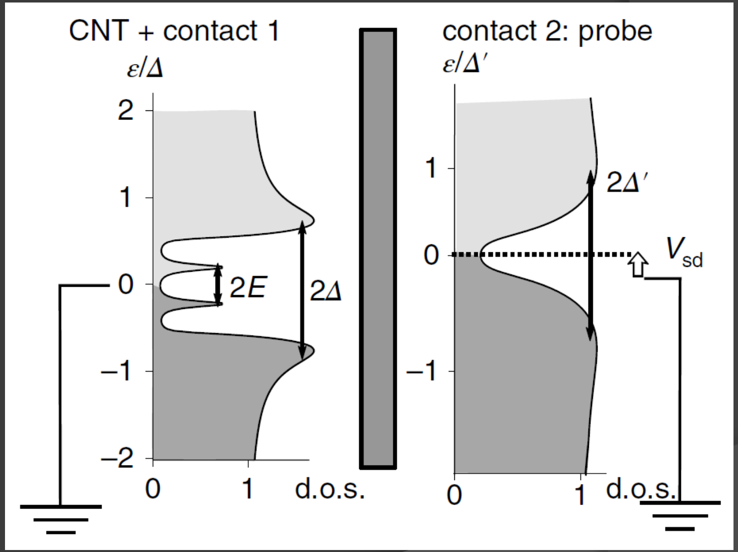


$$G_{diff} = \frac{dI}{dV}$$



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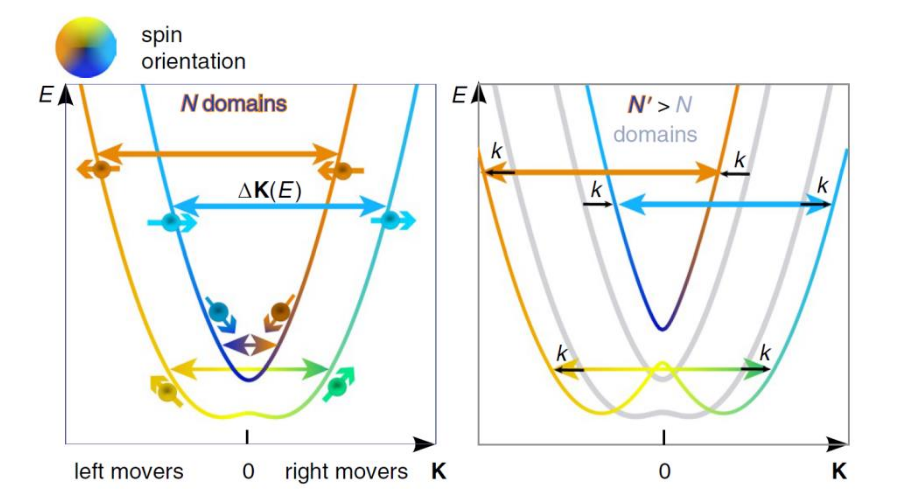
Induced spin-orbit interaction

$$\hat{H} = -\left(\frac{\hbar^2 \partial_z^2}{2m} - \mu(z)\right) + \frac{1}{2} g\mu_B \overrightarrow{B_{osc}}(z).\vec{\sigma}$$

$$k_{SO} = \frac{\partial\theta}{\partial z} \qquad E_{SO} = \frac{\hbar^2 {k_{SO}}^2}{4m}$$

$$E_\pm(k) = -\mu + \frac{E_{SO}}{4} + \frac{\hbar^2 k^2}{2m} \pm \sqrt{\frac{\hbar^2 k^2}{2m} E_{SO} + \left(\frac{g\mu_B B_{osc}}{2}\right)^2}$$



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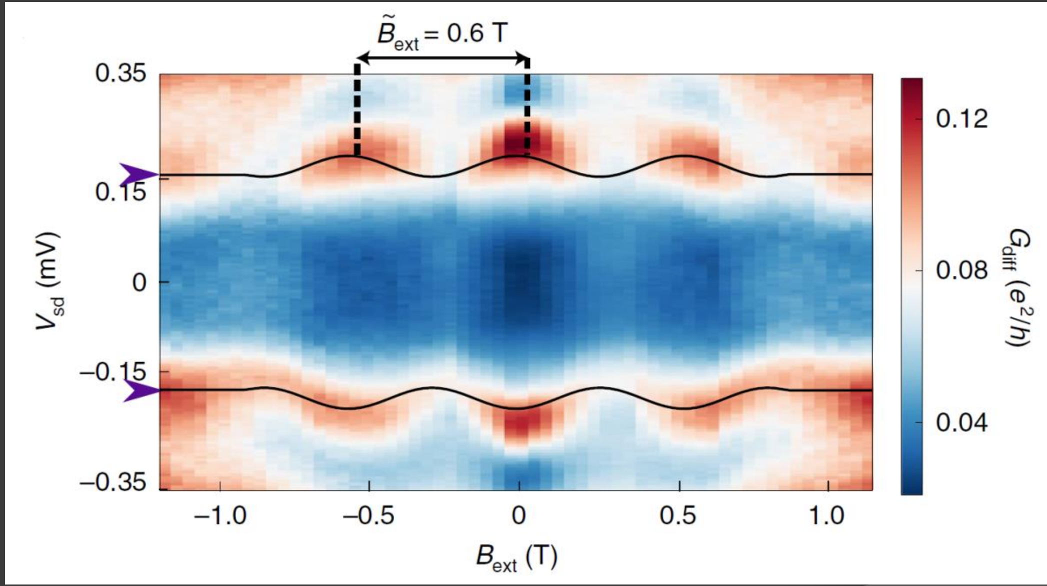
Induced spin-orbit interaction

$$E_{SGS} \approx \pm E_{SGS,\,0} * \{1 + a * \cos[2 * \Delta K(B_{ext}) * L]\}$$



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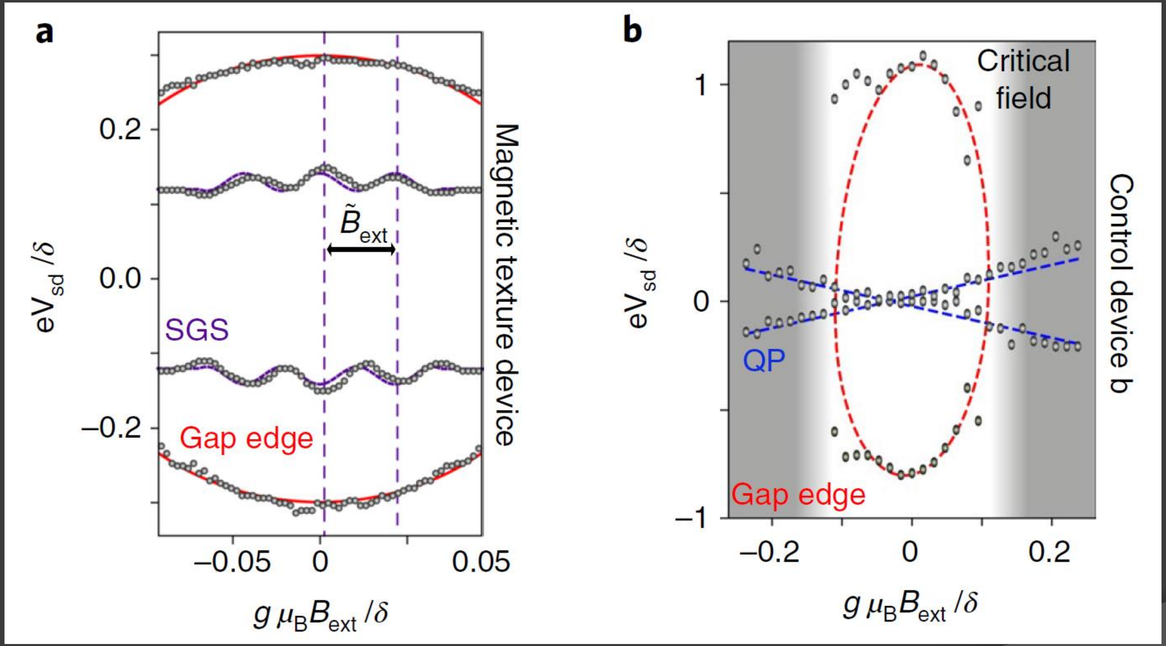
Control device



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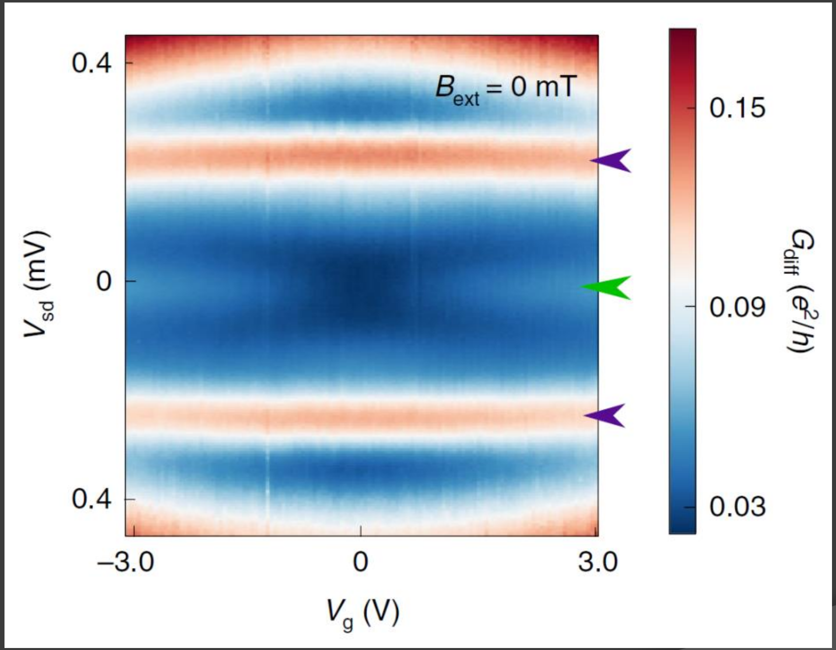
Zero-bias conductance peak



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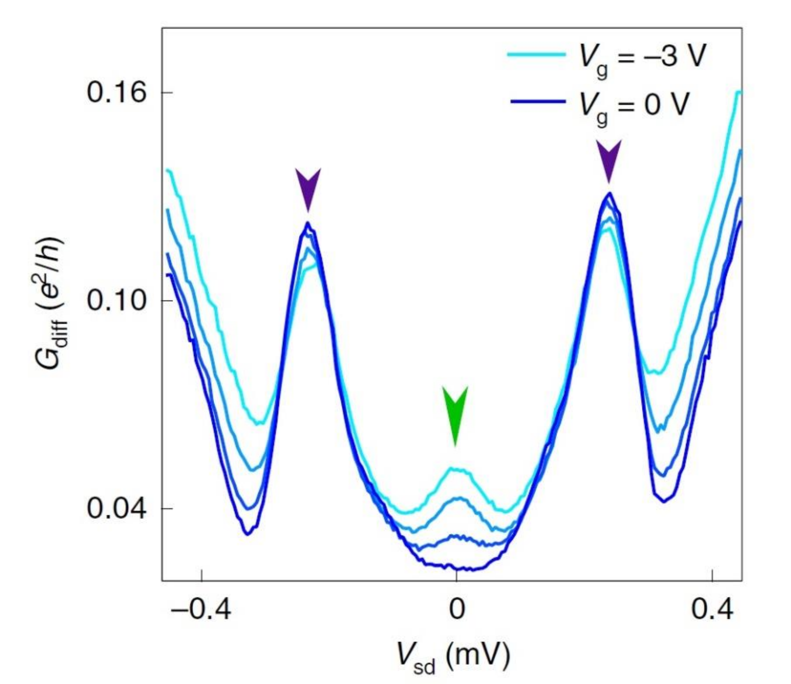

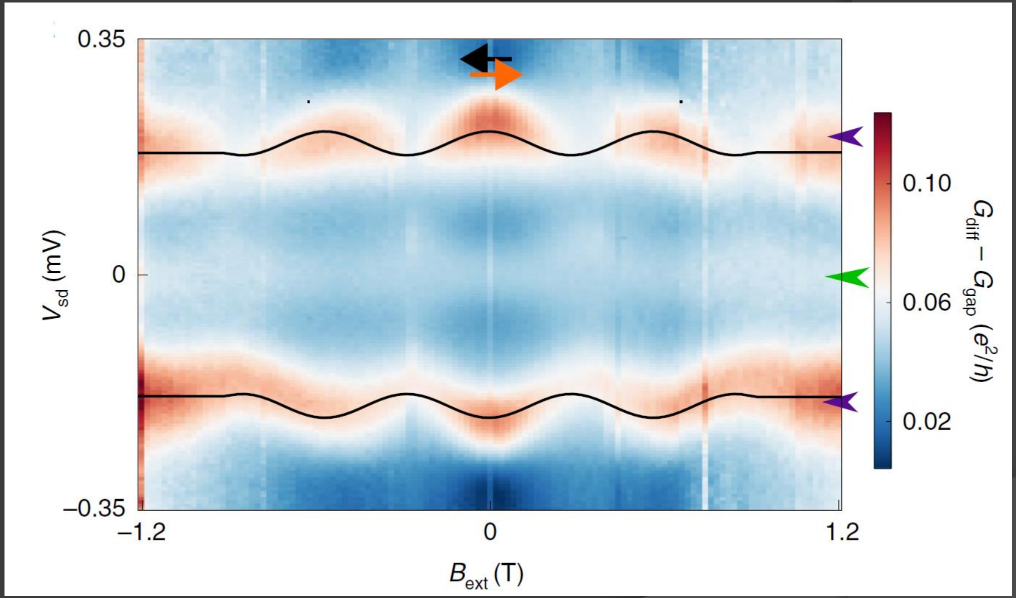

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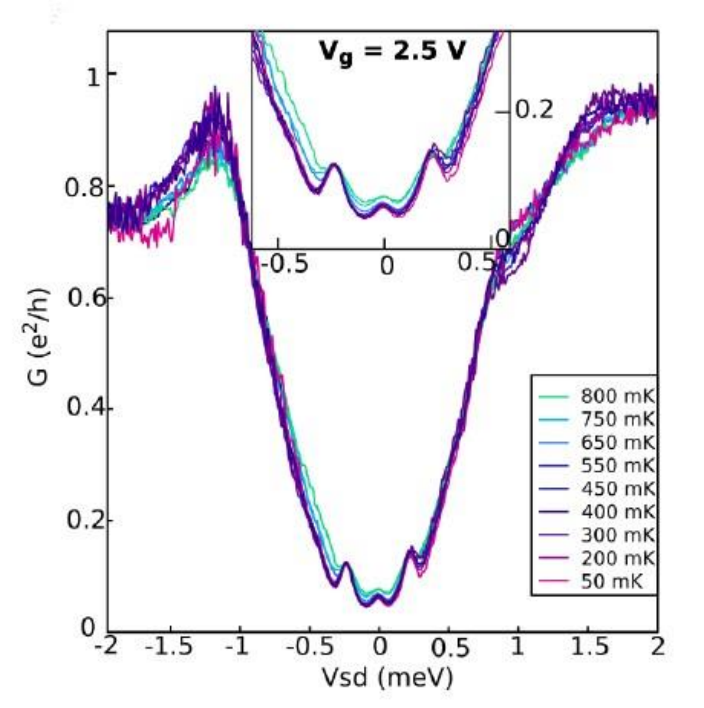

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Supplementary information

Summary

- Induced spin orbit coupling and Zeeman splitting by magnetic texture
- Oscillating subgap states (fingerprint of SOI)
- Zero-energy mode by tuning gate voltage (Majorana modes?)
- Possible without large external B-field

Thank you for your attention!