Non-Majorana states yield nearly quantized conductance in superconductor-semiconductor nanowire devices

P. Yu,[1] J. Chen,[1] M. Gomanko,[1] G. Badawy,[2] E.P.A.M. Bakkers,[2] K. Zuo,[3] V. Mourik,[4] and S.M. Frolov[1]

[1] *University of Pittsburgh, Pittsburgh, PA 15260, USA*
[2] *Eindhoven University of Technology, 5600 MB, Eindhoven, The Netherlands*
[3] *Center for Emergent Matter Science (CEMS), RIKEN, Wako 351-0198, Saitama, Japan*
[4] *Centre for Quantum Computation and Communication Technologies, School of Electrical Engineering and Telecommunications, UNSW Sydney, Sydney, New South Wales 2052, Australia*

(Dated: April 21, 2020)

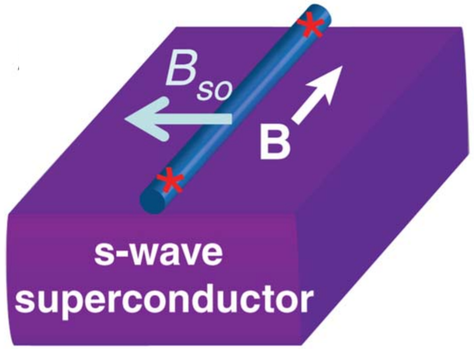
UNI BASEL

Proposal for Realization of Majorana states in 1D systems

One-dimensional Spinless p-wave superconductor

Effctively

- 1D nanowire with spin-orbit interaction
- Proximity with an s-wave superconductor
- Applying magnetic field along the nanowire (perpendicular to B_{so})



10.1126/science.1222360

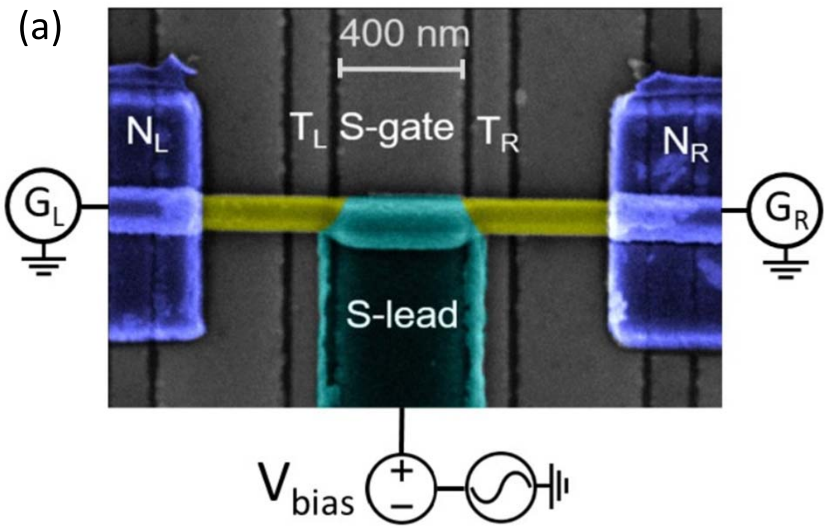
For $E_Z > E_c$ $\longrightarrow$ topological phase transition $\longrightarrow$ 2 unpaired Majorana states at 2 ends of Nanowire

Tunneling into a Majorana bound state sould be seen as a quantized ZBCP at exactly $2e^2/h$

UNI BASEL

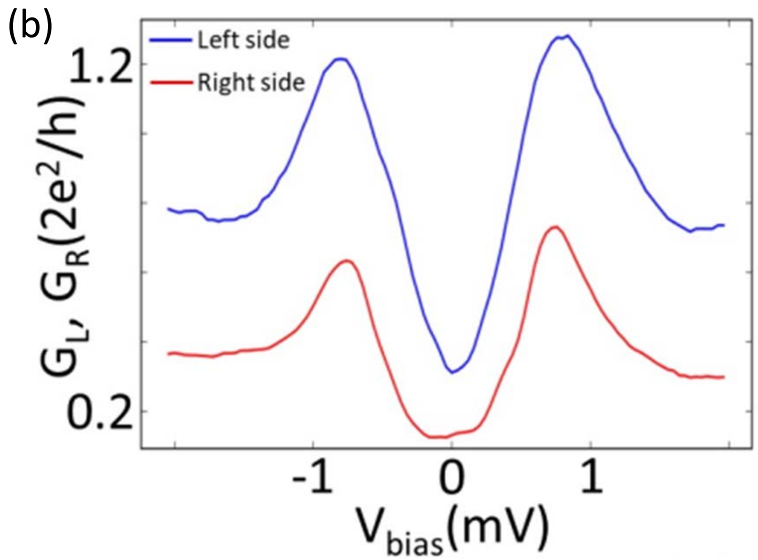
Device and characterization of soft superconductivity

(a)



Nanowire	→	InSb (d=120nm)
S-lead	→	NbTiN
N_L, N_R	→	Pd contacts

(b)

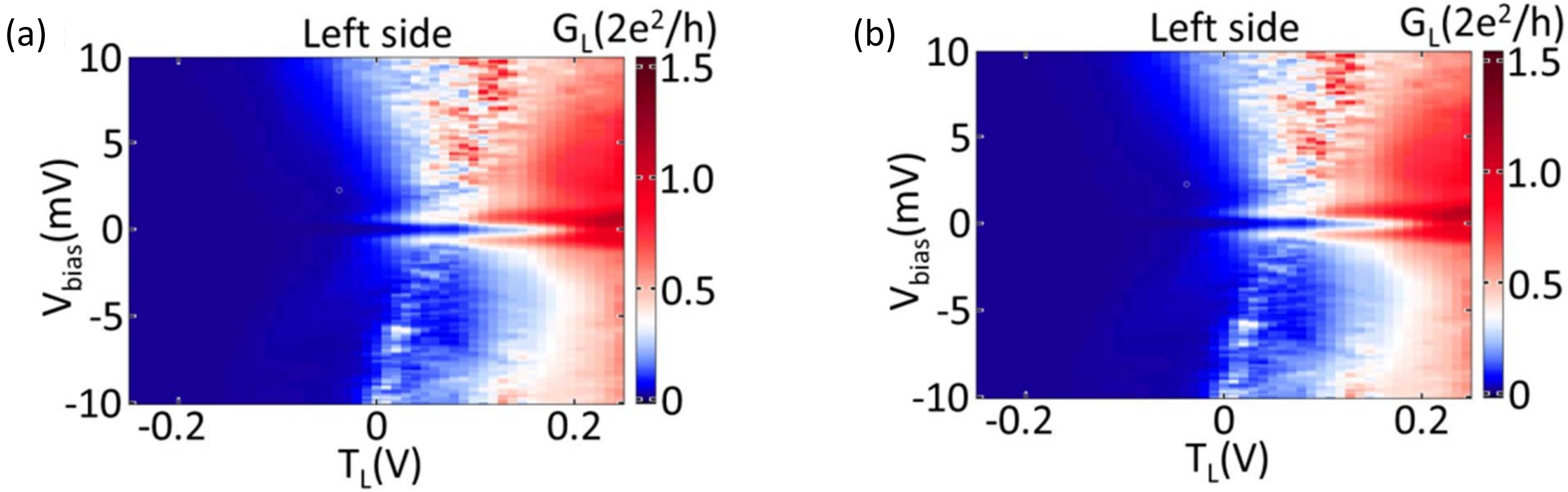


$B = 0$ T_R = -0.075 V

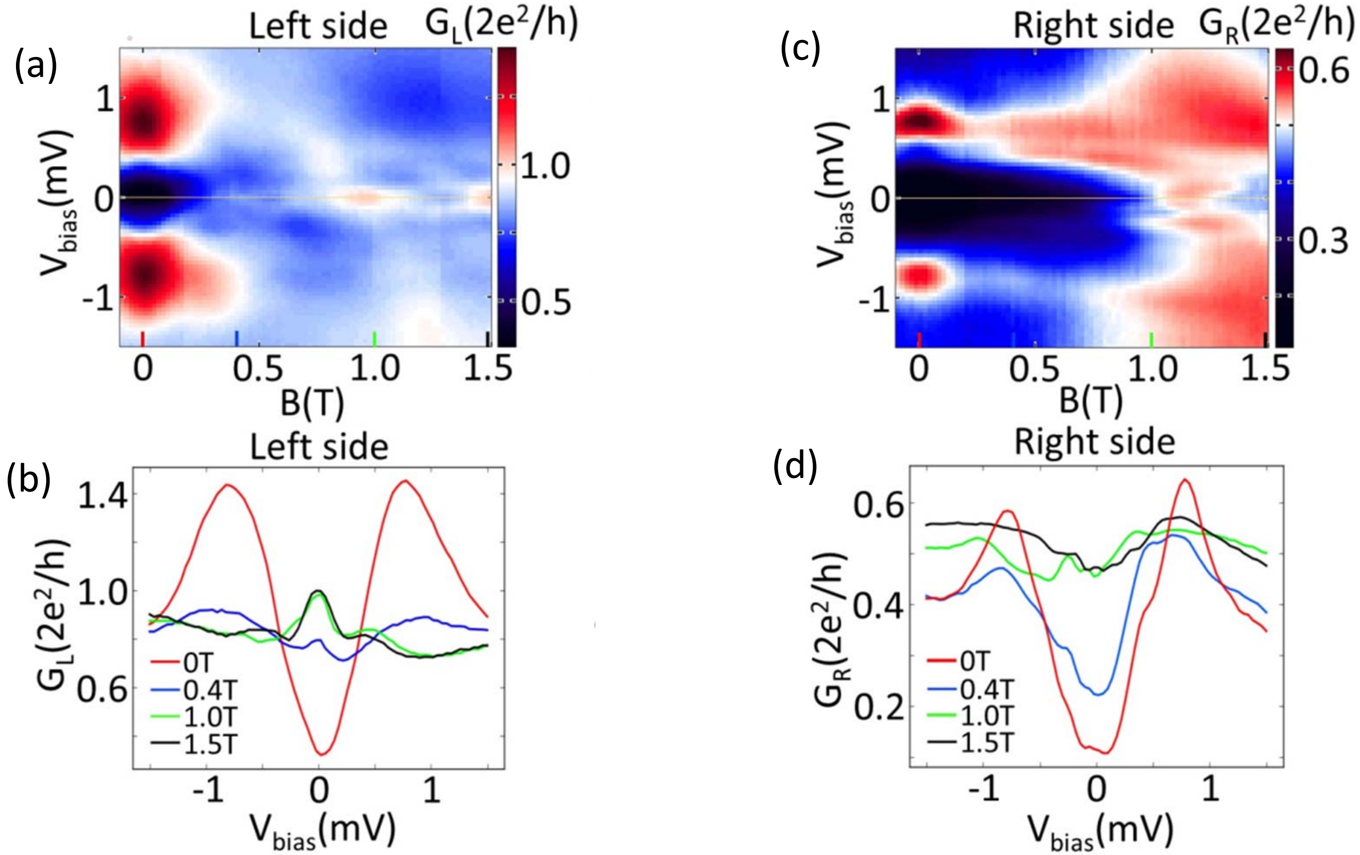
S-gate = -0.75 V T_L = -0.015 V

Superconducting gap 716-800 μeV

Charactrization of tunnel barriers



❖ **By applying and increasing a magnetic field along the NW (perpendicular to B_{so}), ZBCP should reach to $\frac{2e^2}{h}$**



T_R=-0.105 V

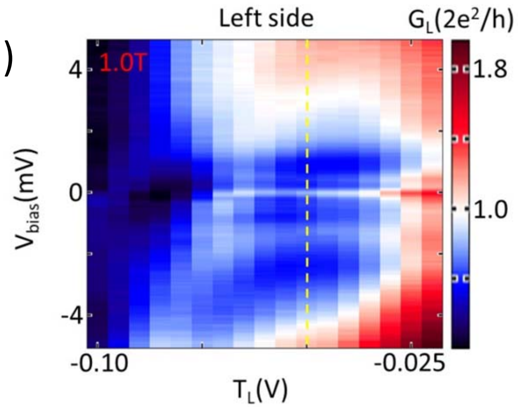
T_L = -0.045 V

S-gate = -0.17 V

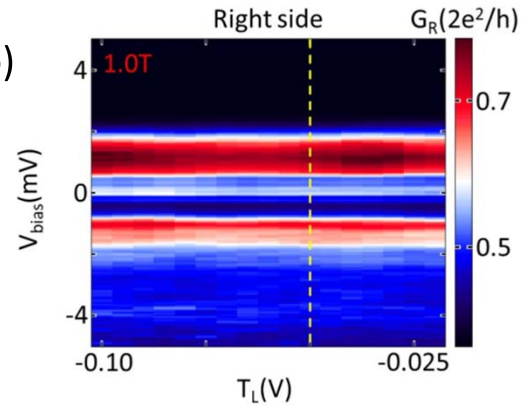
UNI BASEL

❖ Changing tunnel barrier transparency should not split the ZBCP, nor make it disappear [1]

(a)

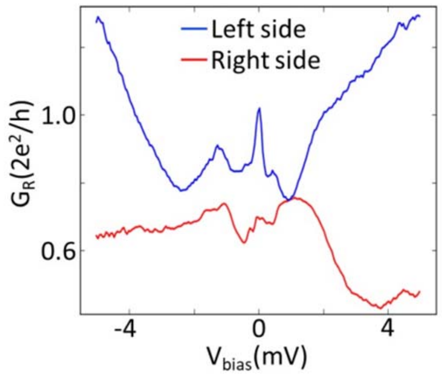


(b)



- ❖ Majorana conductance exceed 2e^2/h only if the barrier has multiple transmitting channels [2] .

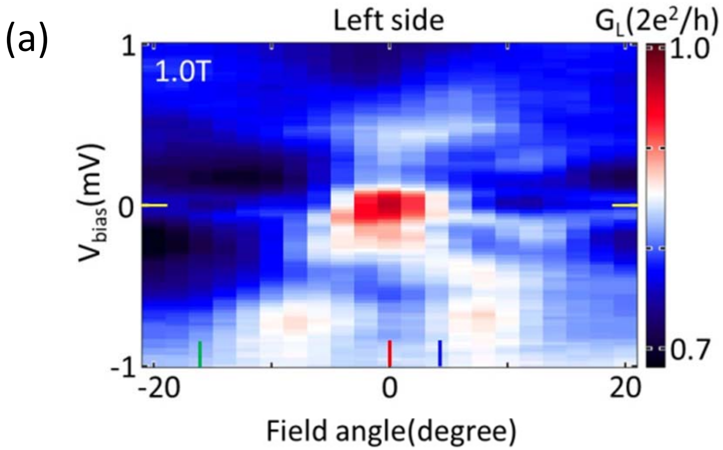
(c)

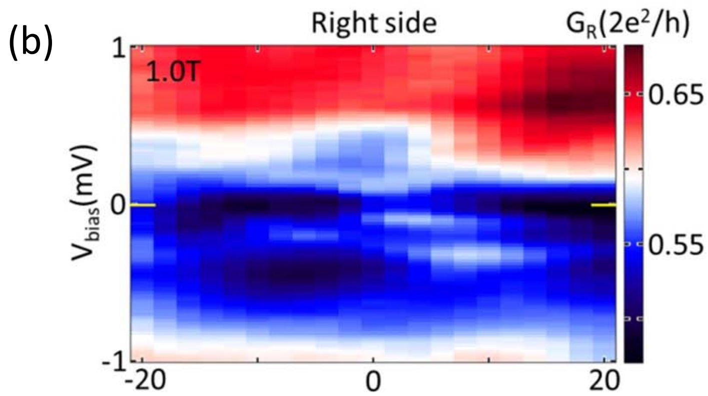


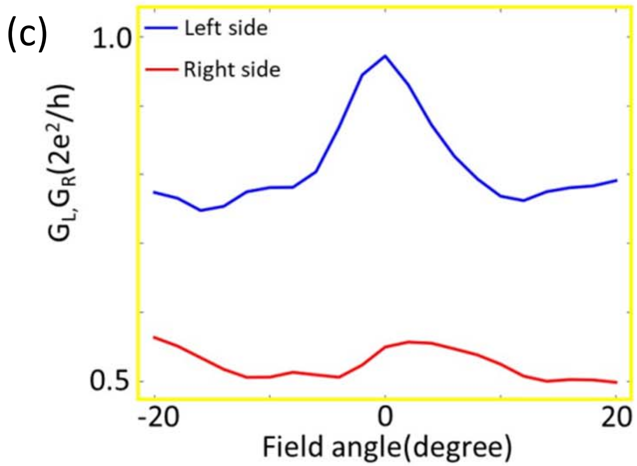
[1] ÖGül et al, *Nature nanotechnology*, *13*(3), 192-197
[2] M. Wimmer et al, *New Journal of Physics* **13**, 053016 (2011).

T_R = -0.105 V S-gate = -0.17 V

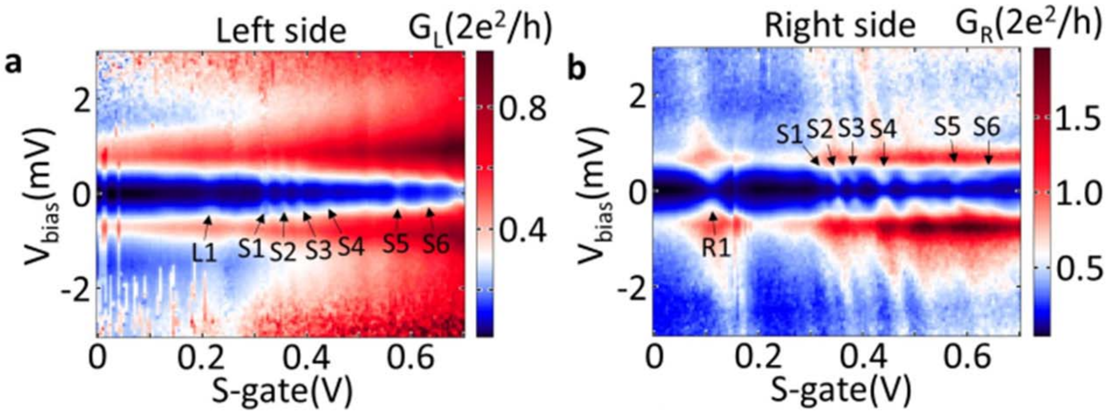
❖ Majorana states are predicted to appear only when B is perpendicular to the effective B_{so}

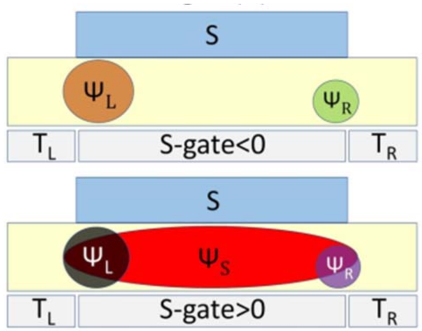






Delocalized states at high electron density regime (S-gate>0)





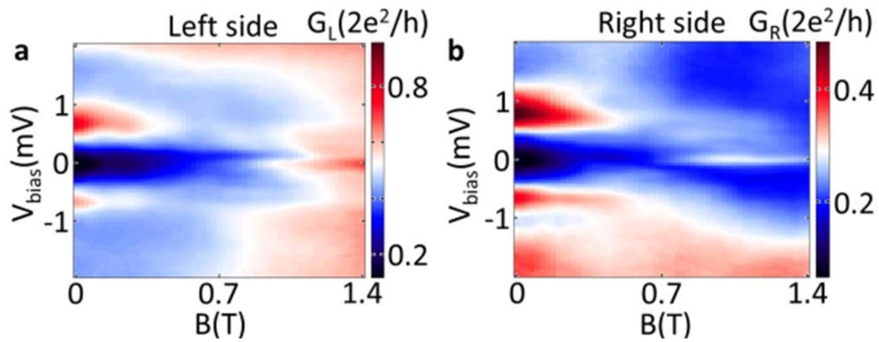
$B = 0,$

$T_L =$ -0.175 V

$T_R =$ 0.09 V

Even the three-terminal geometry is not immune to fine tuning

S-Gate = 0.6 V, T_L = -0.15 V and T_R = 0.09 V



Summary and conclusion

- By using a three terminal device they could not find correlated transport resonances simultaneously at both ends of the nanowire
- They find states delocalized between left and right ends only around zero field and at **at high electron density regime.**
- further efforts are required to understand and optimize nanowire devices, while any claim of Majorana bound state observation should be verified

Thanks for your attention

UNI BASEL

Kitaev’s toy model