



The Abdus Salam  
International Centre for Theoretical Physics



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### Valley-valve effect in a graphene nanoribbon

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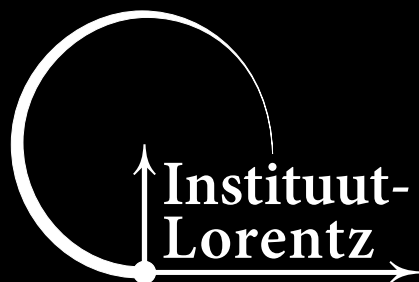
# Valley-valve effect in a graphene nanoribbon

Anton Akhmerov

with Jens Bardarson, Adam Rycerz, and Carlo Beenakker

PRB 77, 205416

ICTP Conference Graphene Week 2008, 28 August 2008

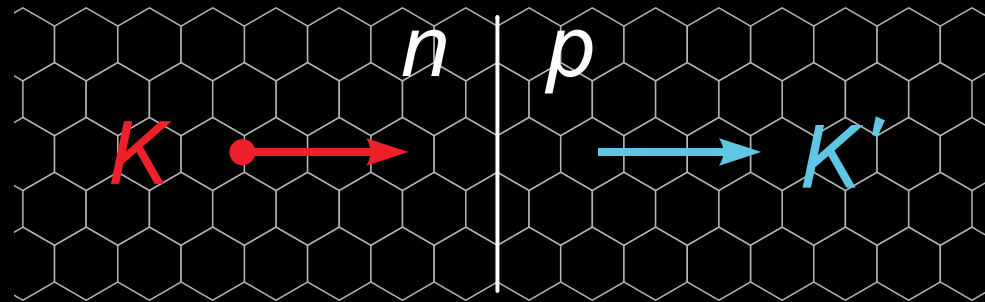


Universiteit Leiden

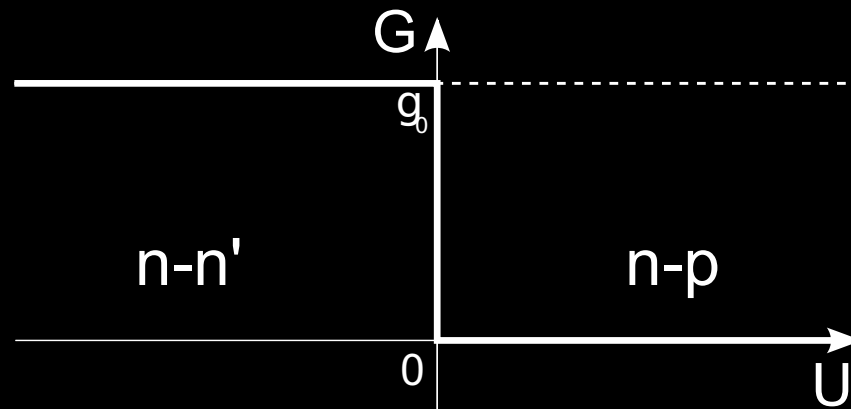
# Valley valve

Wakabayashi (PRB, 1996); Rycerz *et. al.* (N. Phys., 2007).

Zigzag ribbon,  $p$ - $n$  junction, lowest mode

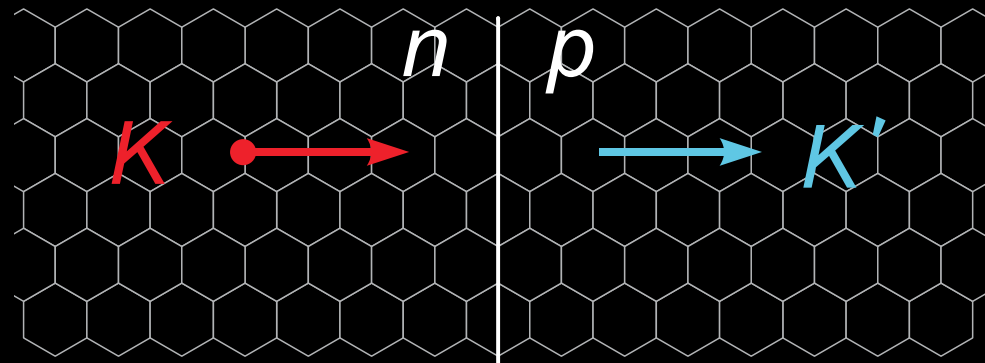


Completely blocks current

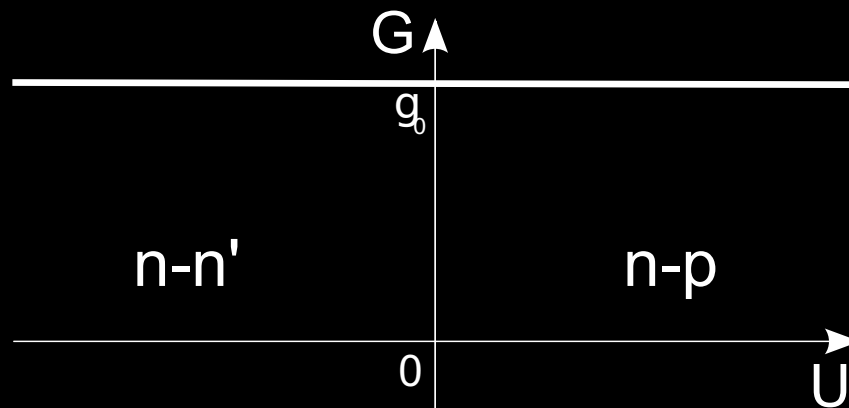


# Valley valve

Antizigzag ribbon (no difference for Dirac equation!)

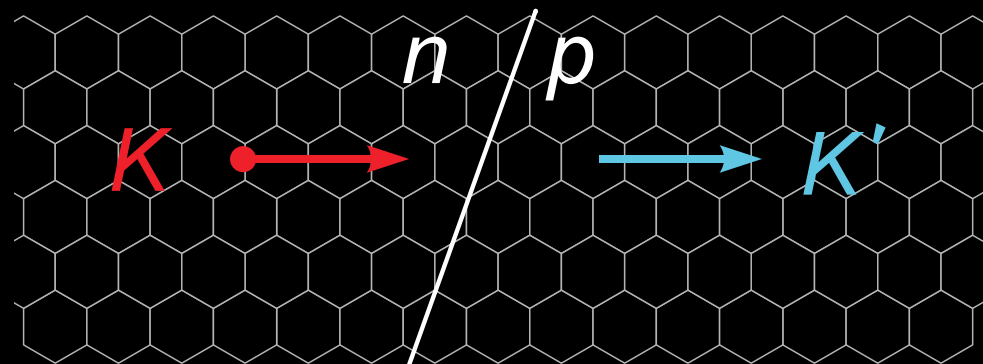


However, it does not work

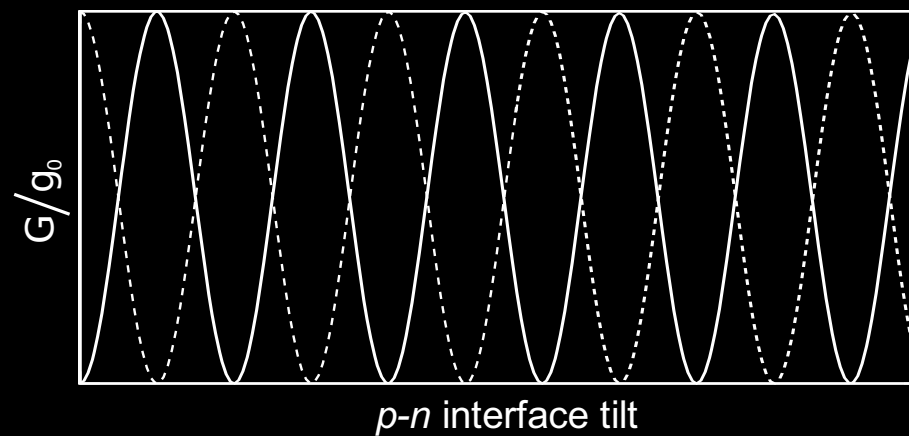


# Valley valve

Tilted  $p$ - $n$  interface

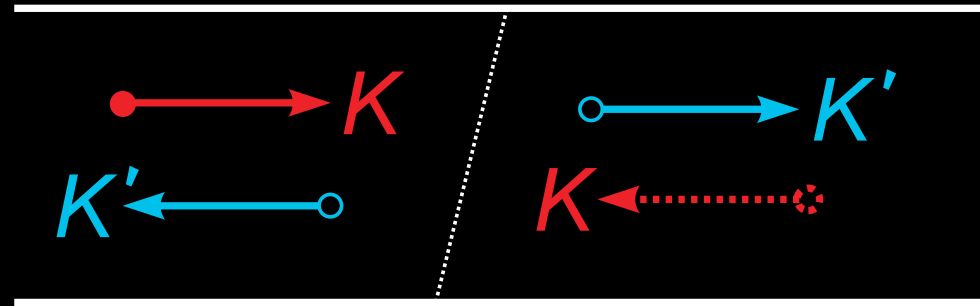


conductance switches



# Hidden scattering

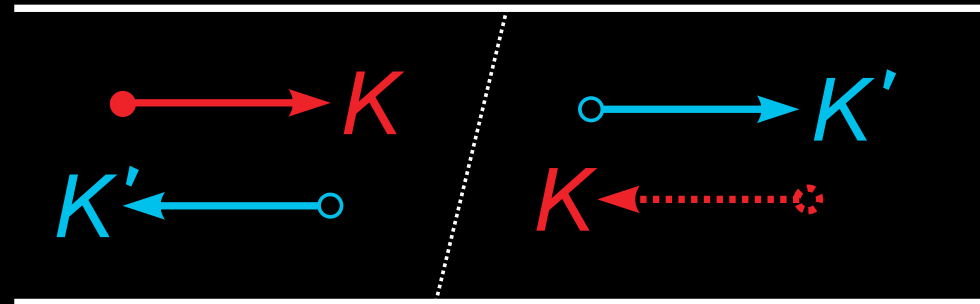
Scattering states:



Intervalley scattering is necessary to preserve unitarity  
(no matter, how smooth the potential landscape is)

# Hidden scattering

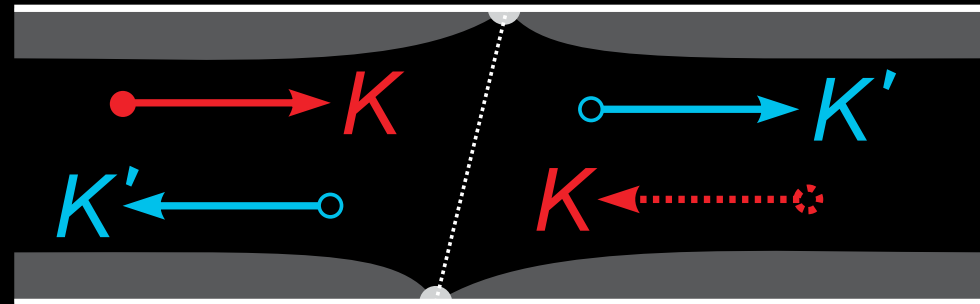
Scattering states:



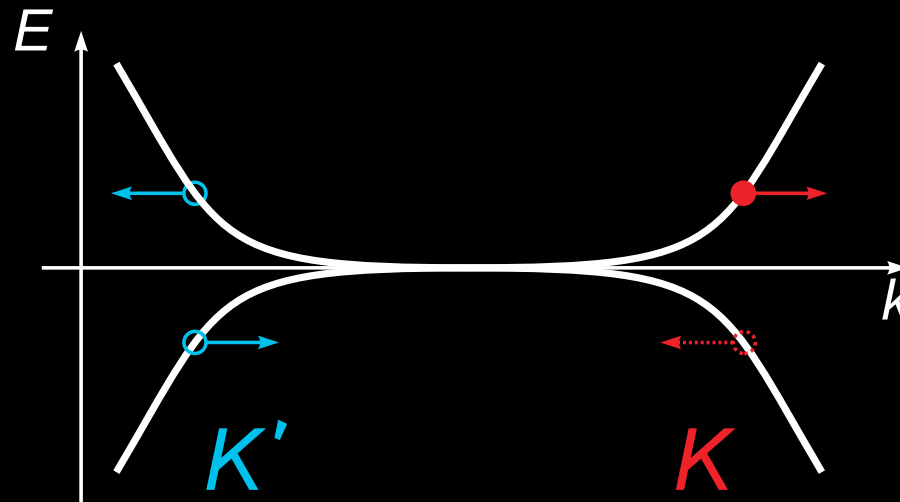
Intervalley scattering is necessary to preserve unitarity  
 $\Rightarrow$  Dirac equation breakdown!

# Hidden scattering

Wave function profile:



Scattering via the zero energy states



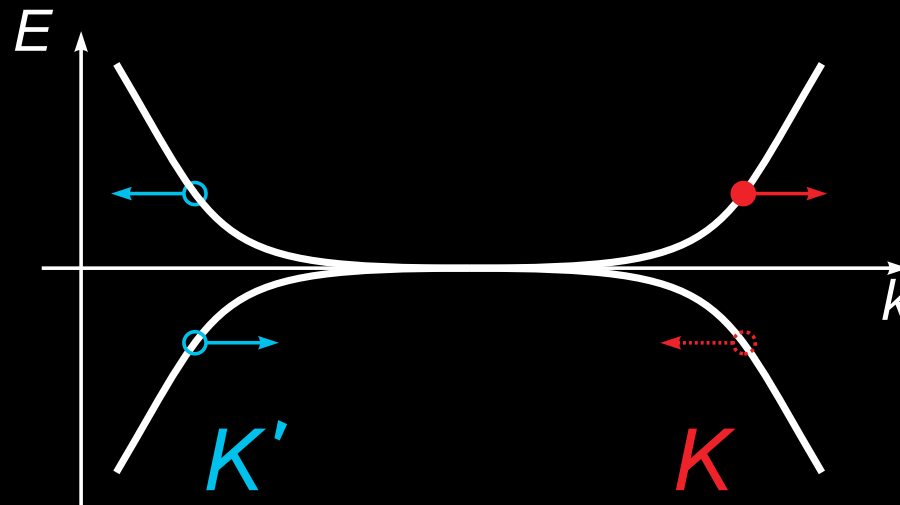


## Solution sketch

No Dirac equation  $\Rightarrow$  lattice  $\Rightarrow$  numerics :-(

# Solution sketch

Idea: projection on the lowest mode



- ▶ Wave function is well known [Nakada, *et. al.* (PRB, 1991)]
- ▶  $U(x) \rightarrow i \frac{d}{dk}$
- ▶  $K$  – incoming,  $K'$  – scattered
- ▶ States in  $p$  and  $n$  have opposite parity

# Answer

Scattering matrix:

$$S = \sigma_z^N e^{i\sigma_x 2\pi \Delta / 3a}$$

$N$  – thickness of ribbon;  $\Delta$  – tilt of the  $p$ - $n$  interface

Conductance:

$$G/g_0 = \frac{1}{2} - \frac{1}{2} \cos(N\pi + 2\pi \Delta / 3a)$$

in perfect agreement with numerics

# Conclusions

- ▶ Zigzag  $\neq$  antizigzag

See also A. Cresti *et al.*, PRB **77**, 233402

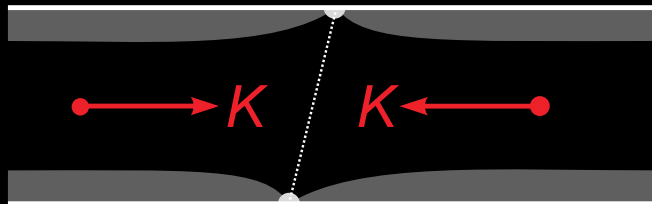
D. Rainis *et al.*, arXiv:0806.4475

J. Nakabayashi *et al.*, arXiv:0806.4978

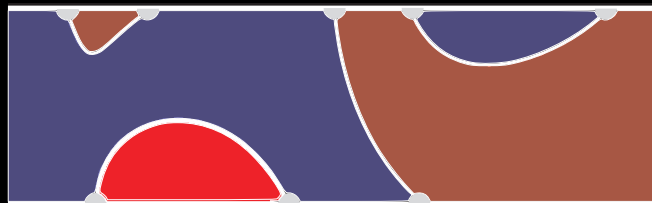
H. Yoshioka, S. Higashibata, arXiv:0807.3999

- ▶ Zigzag +  $p$ - $n$  interface  $\Rightarrow$  intervalley scattering

Breakdown of long wavelength physics



New mechanism of current blocking at charge neutrality



# Conclusions

Thank you all.  
The end.