2d conducting structures

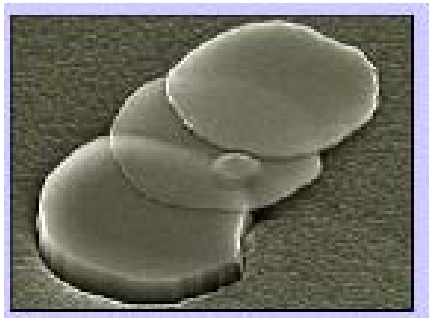
L. Falkovsky

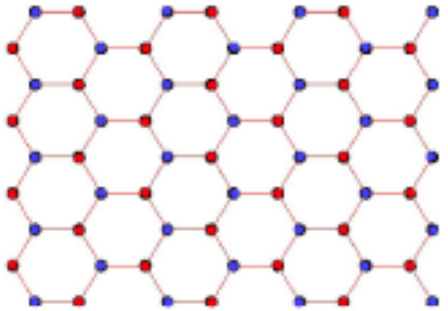
Landau Institute

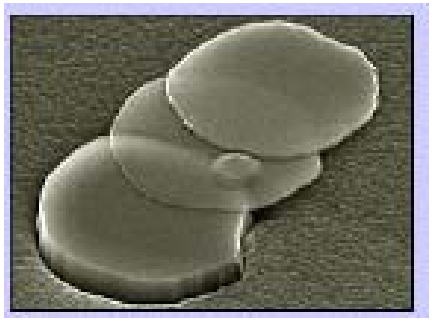
Graphene discovery (2005)

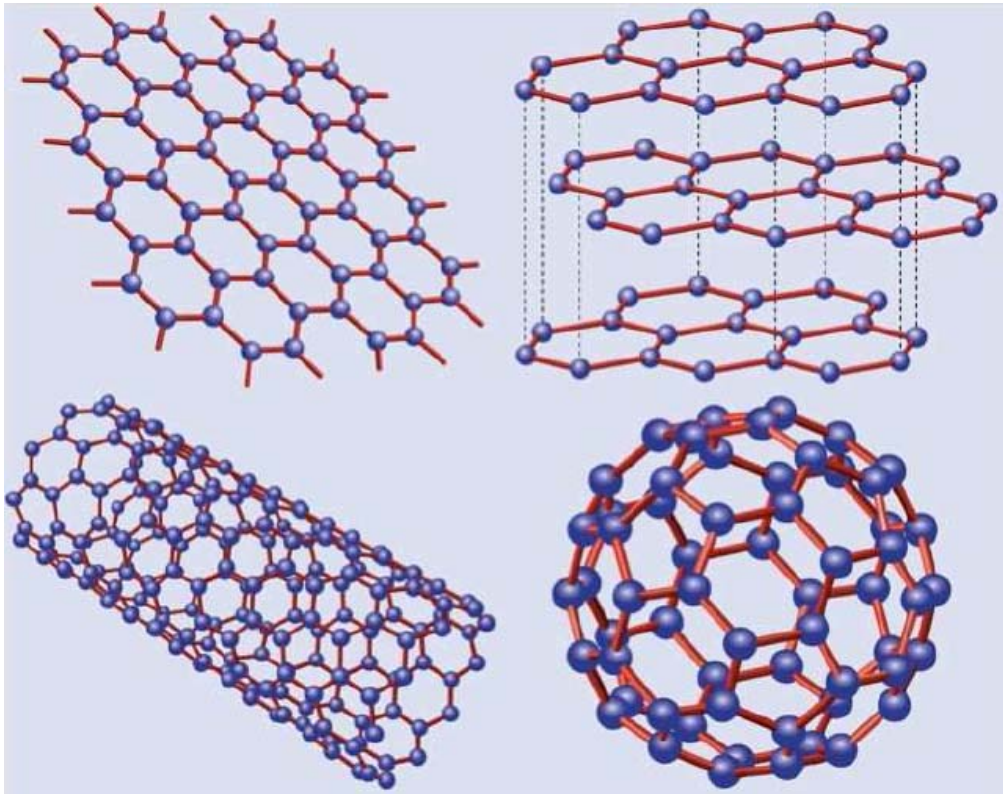

Kostya Novoselov


Andrey Geim

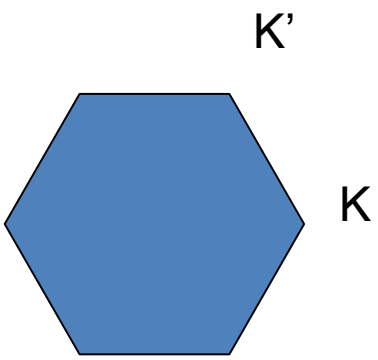






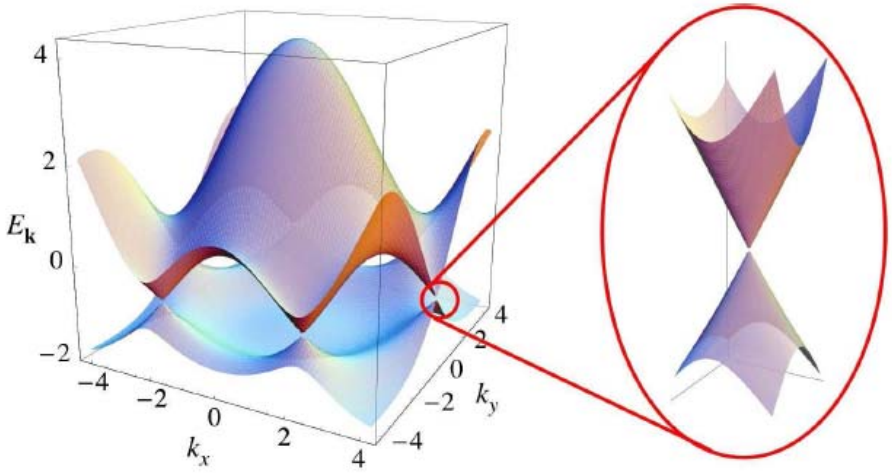


Massless Dirac electrons



$$\varepsilon = \pm v\sqrt{p_x^2 + p_y^2}$$

$$v = 10^8 cm/sec$$



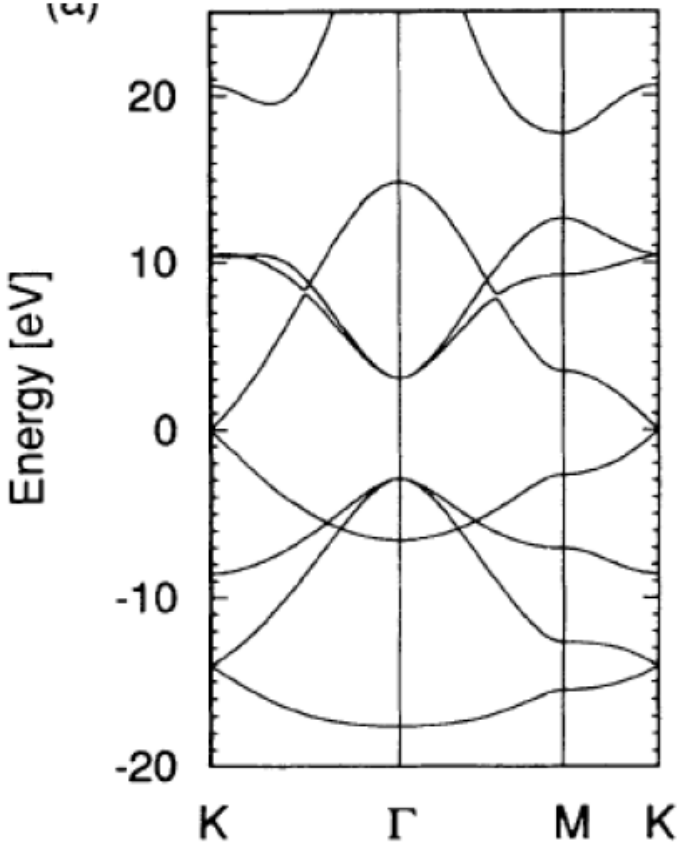


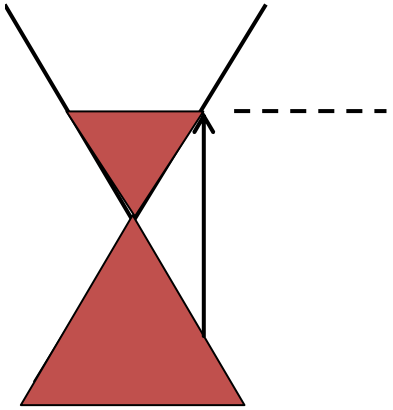
Рис. 2: Электронный спектр графена.

Optic conductivity

Gusynin , Sharapov (2006)
Falkovsky, Varlamov (2006)

$$\omega \gg (kv, \tau^{-1})$$

$$\sigma(\omega) = \frac{e^2\omega}{i\pi\hbar}\left[\int_{-\infty}^{+\infty} d\varepsilon \frac{|\varepsilon|}{\omega^2}\frac{df(\varepsilon)}{d\varepsilon} - \int_{0}^{+\infty} d\varepsilon \frac{f(-\varepsilon)-f(\varepsilon)}{(\omega+i\delta)^2-4\varepsilon^2}\right]$$

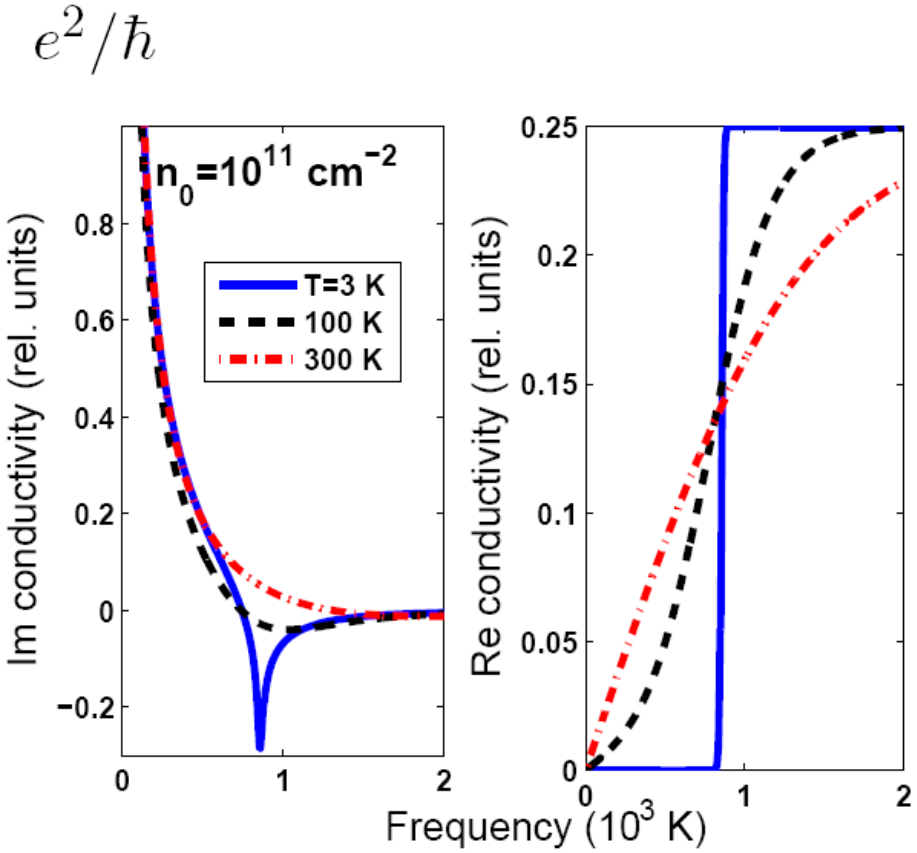


$$\sigma^{intra}(\omega) = \frac{2ie^2T}{\pi\hbar(\omega+i\tau^{-1})}\ln\left[2\cosh(\mu/2T)\right]$$

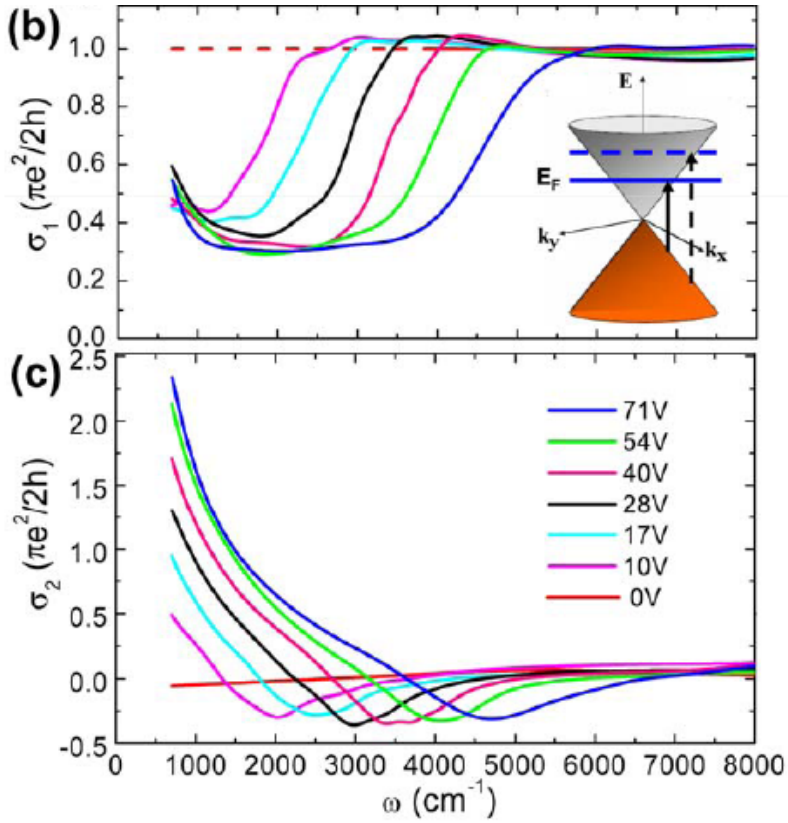
$$\sigma^{inter}(\omega) = \frac{e^2}{4\hbar}\left[\theta(\omega-2\mu) - \frac{i}{2\pi}\ln\frac{(\omega+2\mu)^2}{(\omega-2\mu)^2}\right]$$

$T = 0$

Optic conductivity

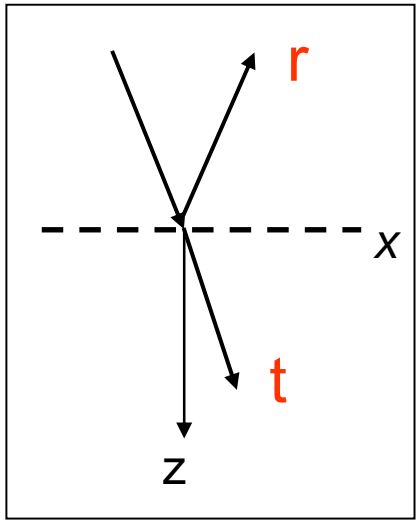


Falkovsky, Pershoguba (2007)



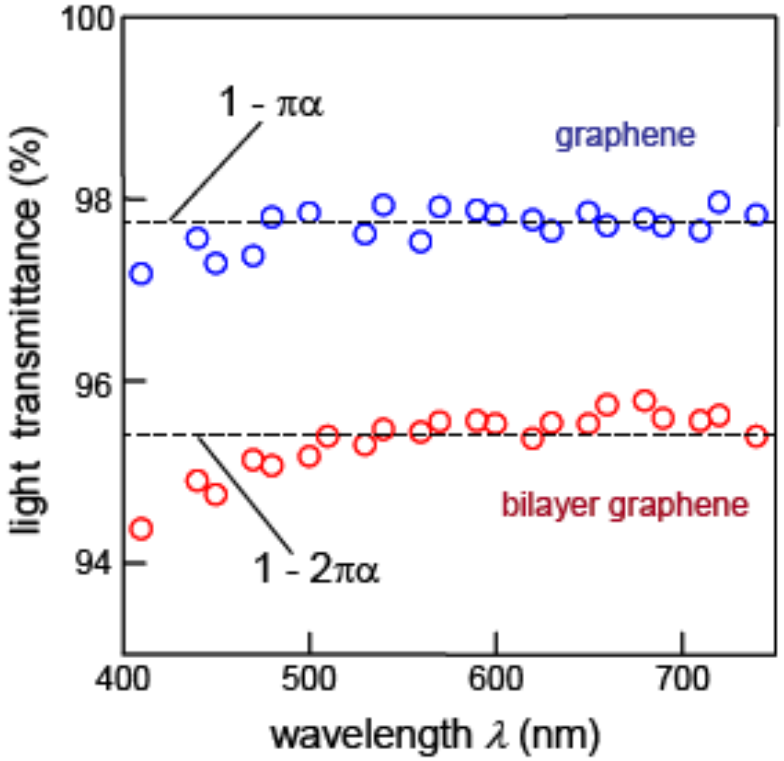
D. Basov et al (2008)

light transmission and reflection



$$T = 1 - \pi \frac{e^2}{\hbar c}$$

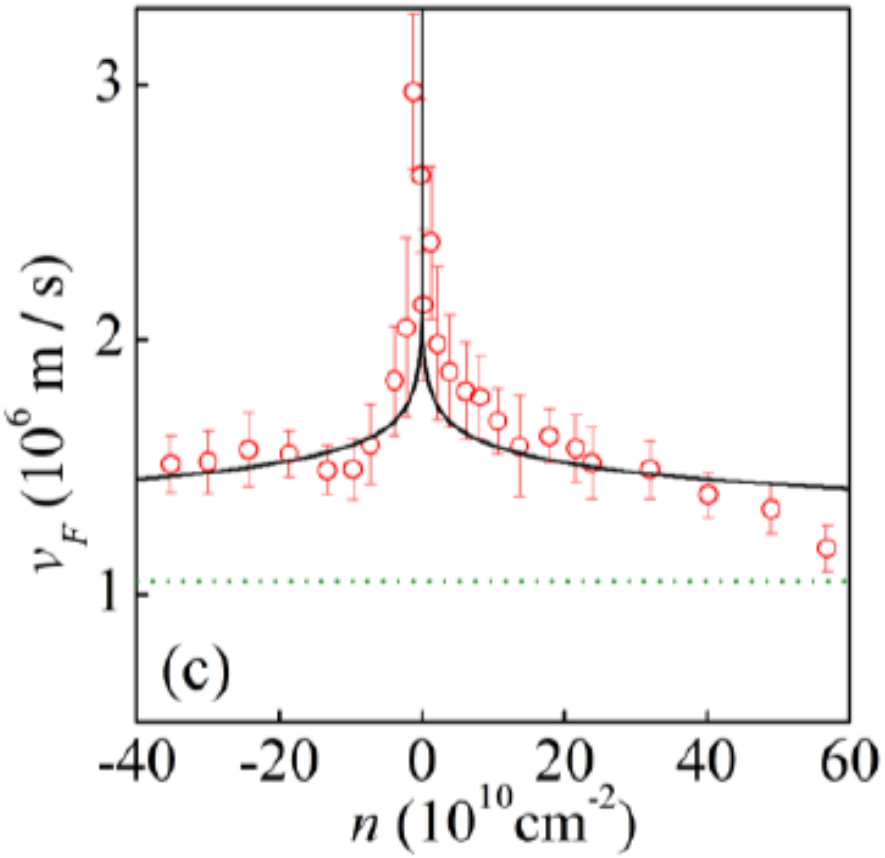
normal incidence



1) fine structure constant
2) no material parameters
3) no effect of e-e interactions

Nair et al (2008)
Mak et al (2008)

Coulomb renormalization



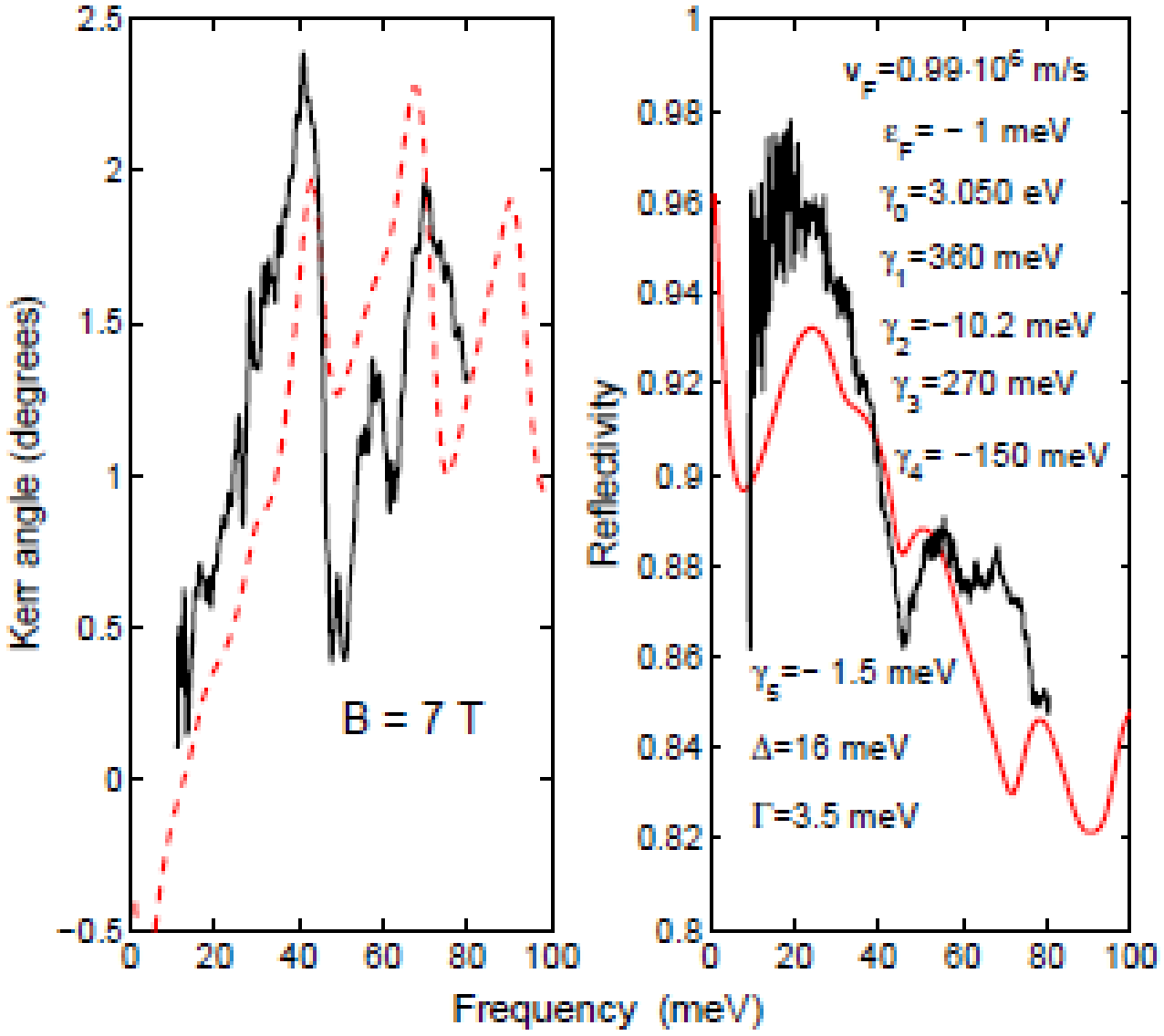
Elias, Novoselov et al (2011)

$$v = v_0 \left(1 + \frac{e^2}{8\hbar v_0 \varepsilon_0} \ln(n_0/n)\right)$$

$$n(\mu) = \frac{\mu^2}{\pi \hbar^2 v^2}$$

Abrikosov, Beneslavskii, 3d (1970)
Mishchenko (2007)

Kerr rotation and reflectivity of graphite in B field

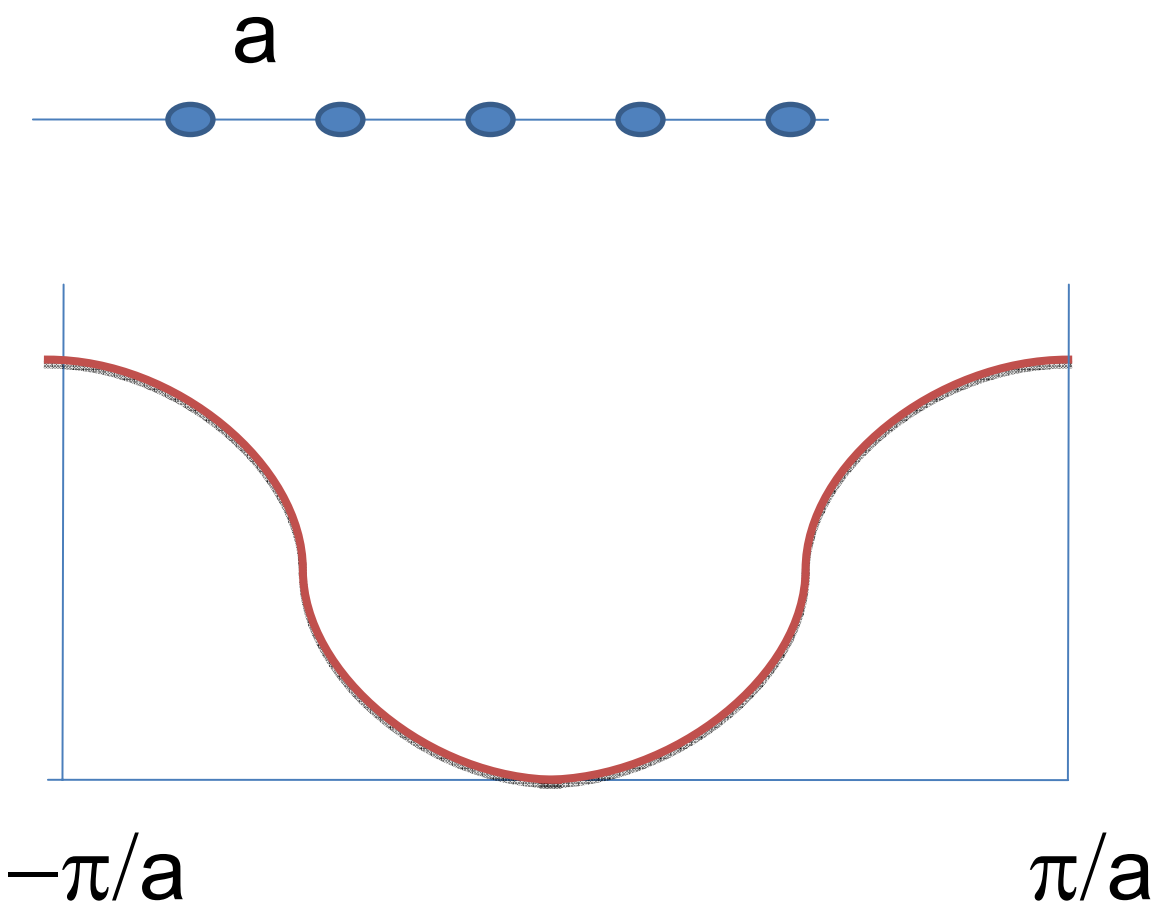


Phosphorus allotropes

A-17 (orthorhombic) → A-7 (rhombohedral) at 4.5 GPa

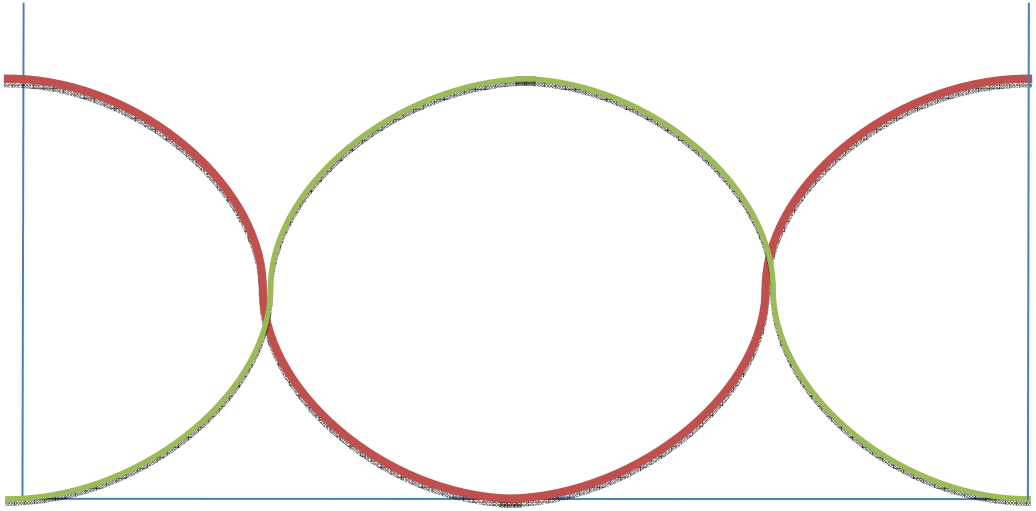
A-7 (rhombohedral) → simple cubic at 10 GPa

Peierls doubling



Peierls doubling

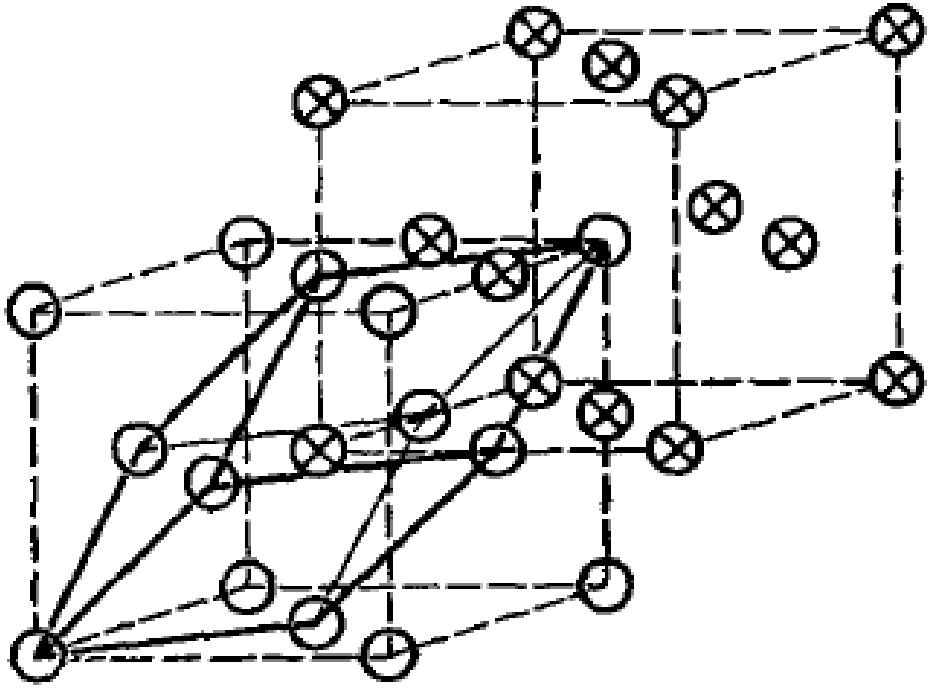
2a



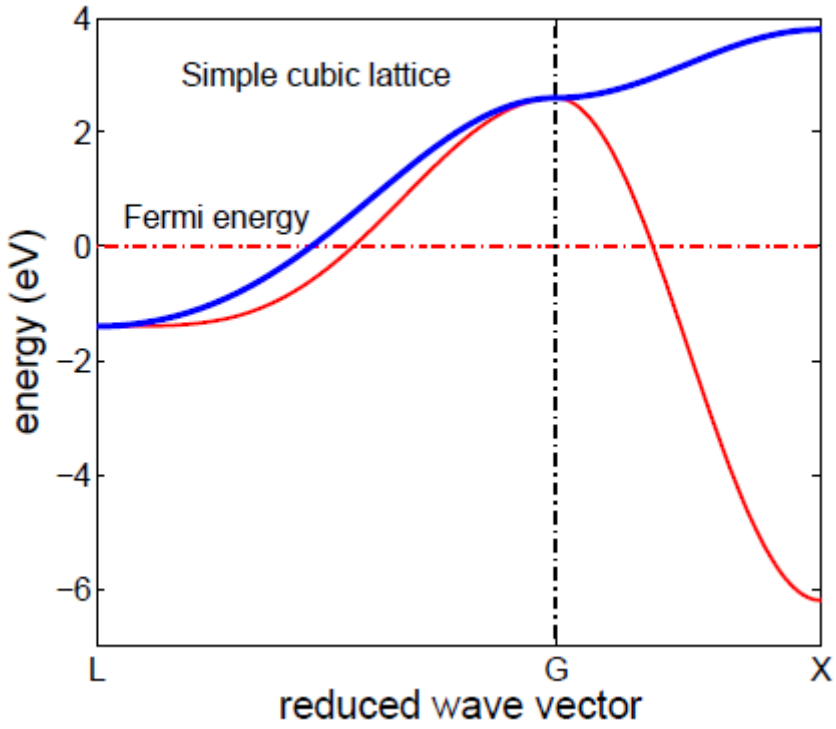
$-\pi/a$ π/a

$-\pi/2a$ $\pi/2a$

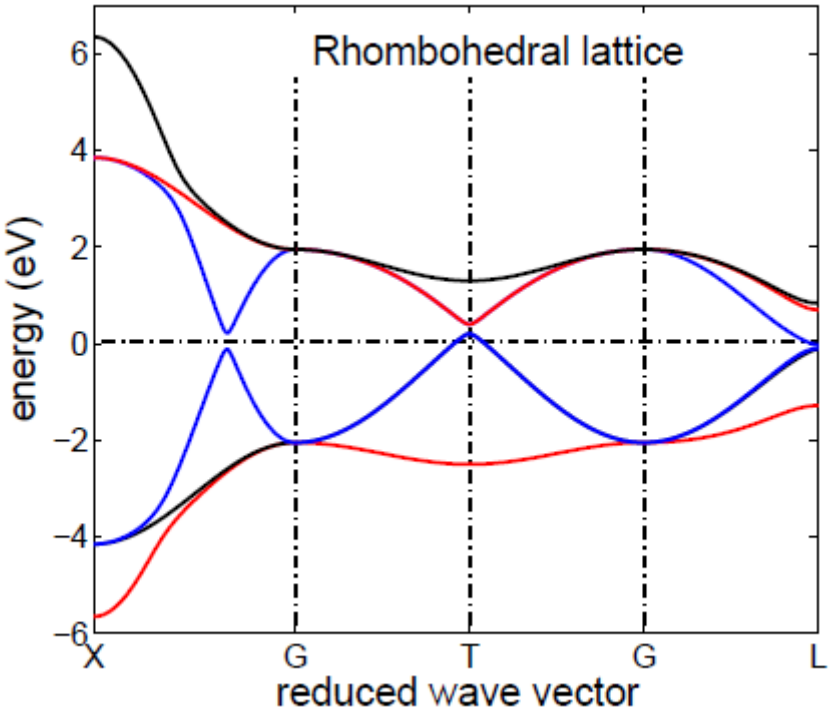
Rombohedral phase



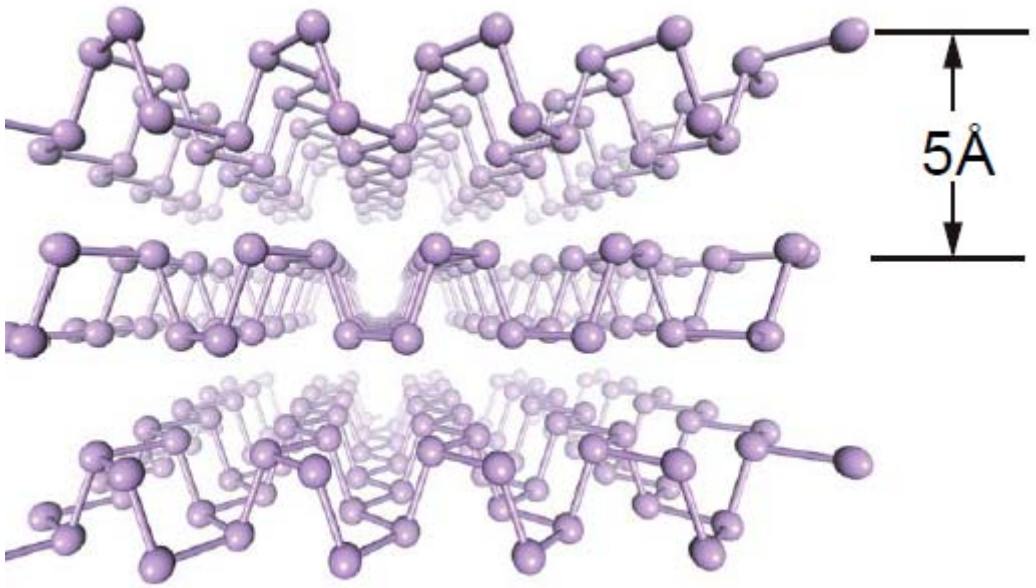
Electron bands in simple cubic lattice

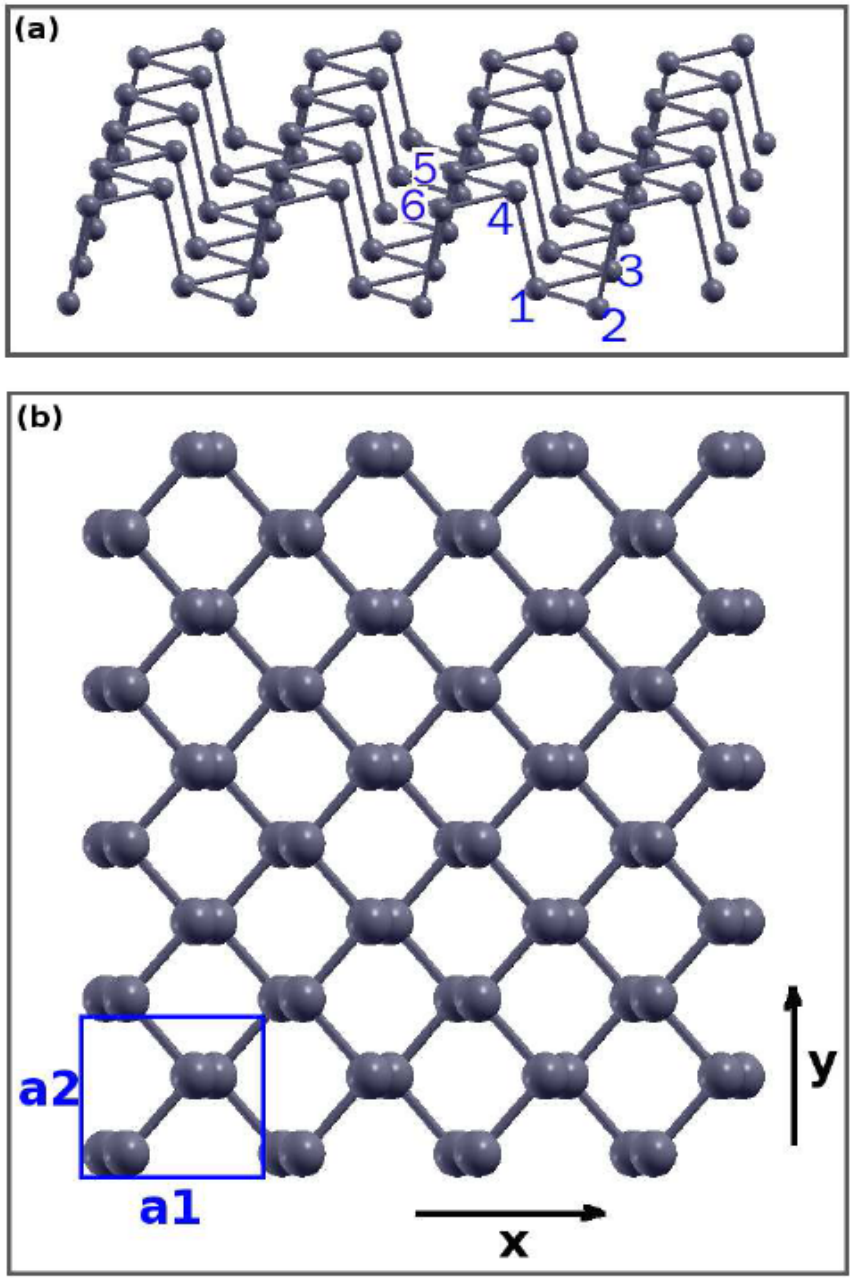


Electron dispersion in Bi-type lattice



Phosphoren





Electron dispersion in phosphorene