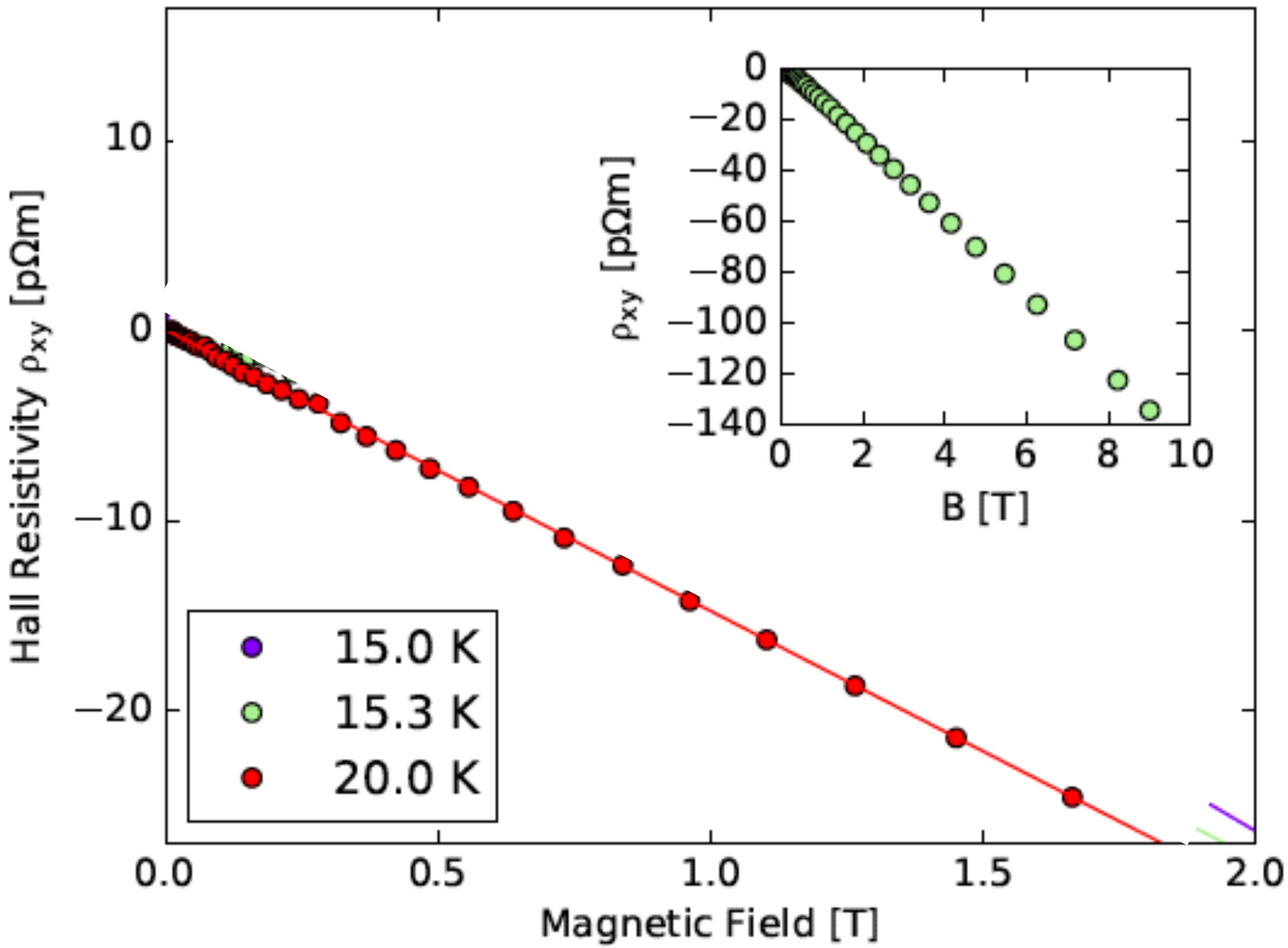
#	Dates	Title	Exercise	(1=easy, 10=hard)	Tasks
1	22.2	Introduction	VESTA	**2-3**	**Read Chap. 1**
2	01.3	Crystal structures	Daniel - info	**4**	**Read Chap. 2, Ex. 1**
3	08.03	Reciprocal space	Discuss Ex. 1	**6**	**Read Chap. 2, Ex. 2**
4	15.03	Scattering Theory	Discuss Ex. 2	**8-9**	**Read Chap. 3, Ex. 3**
5	22.03	Crystal bindings	Discuss Ex. 3	**5**	**Read Chap. 4, Ex. 4**
6	29.03	Phonons	Discuss Ex. 4	**5-6**	**Read Chap. 5, Ex. 5**
7	05.04	Thermal properties	Discuss Ex. 5	**5-6**	**Read Chap. 6, Ex. 6**
8	12.04	Electron gasses, C_{el}	Discuss Ex. 6	**5-6**	**Read Chap. 7, Ex. 7**
--	19.04	EASTER HOLIDAY	-------------------	**0**	**RECAP**
9	26.04	Electronic band struc.	Discuss Ex. 7	**5-6**	**Read Chap. 8, Ex. 8**
10	03.05	Semi-conductors	Discuss Ex. 8	**6**	**Read Chap. 9, Ex. 9**
11	10.05	Fermi surfaces & Metals - I	Discuss Ex. 9	**8**	**Read Chap. 9, Ex. 10**
12	17.05	Fermi surfaces & Metals - II	Discuss Ex. 10	**8**	**Read Chap. 9, Ex. 11**
13	24.05	Guest lecture	Discuss Ex. 11	**6-7**	
14	31.05	Repetition		**4**	

#	Dates	Title	Tasks
10	03.05	Semi-conductors	Read Chap. 6: Motion in magnetic fields p. 163-167 Read Chap. 9: Introduction to Fermi surfaces p. 235-244 Read Chap. 9: Experimental methods in FS studies p. 255-265
11	10.05	Fermi surfaces & Metals - I	Read Chap. 9: Experimental methods in FS studies p. 255-265
12	17.05	Fermi surfaces & Metals - II	Read Chap. 9 : Calculation of energy bands 244 -255 (Perhaps an extra exercise)
13	24.05	Guest lecture	
14	31.05	Repetition	

NbN a high-temperature (15 K) phonon mediated superconductor

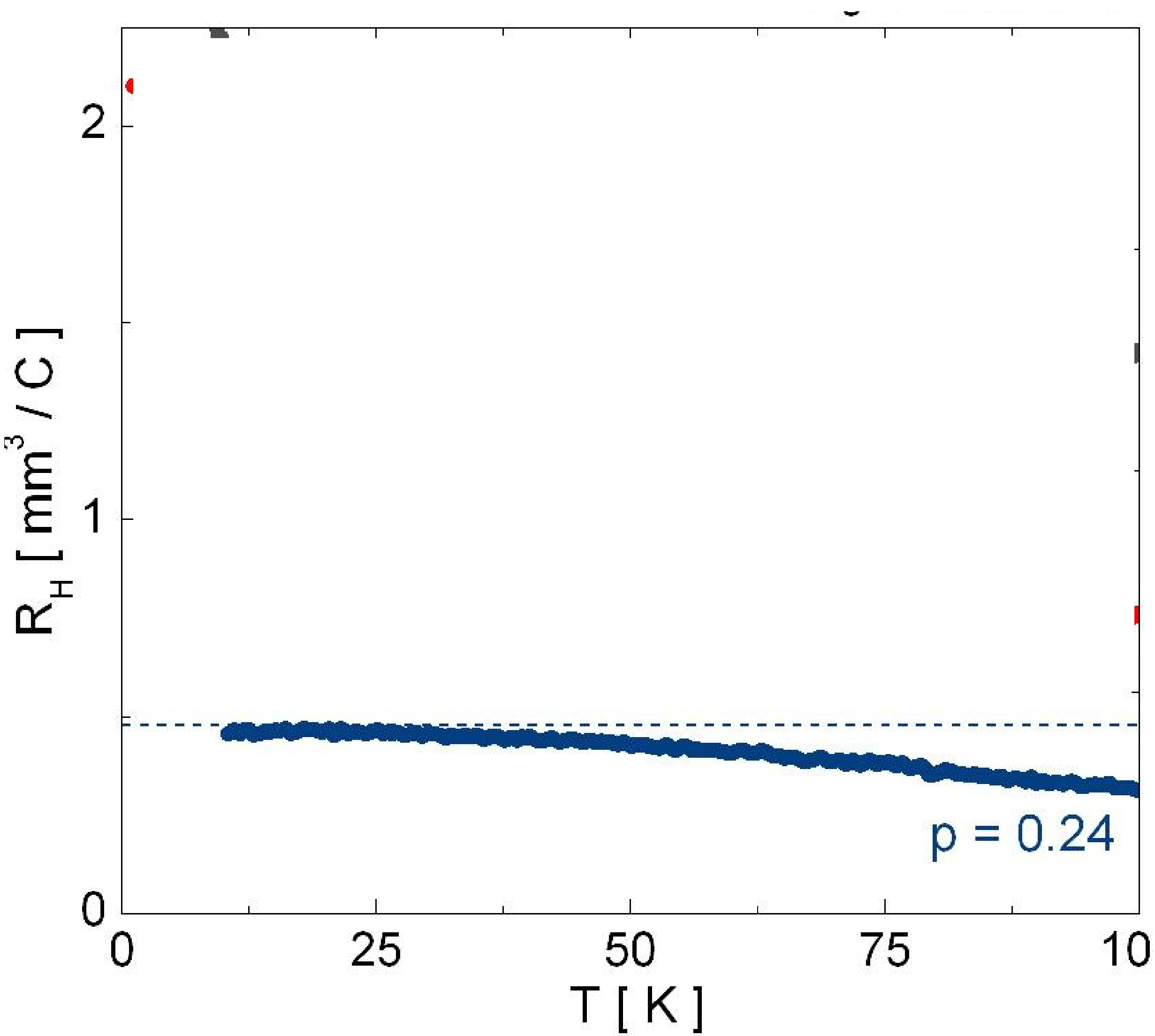


Luttinger’s Theorem

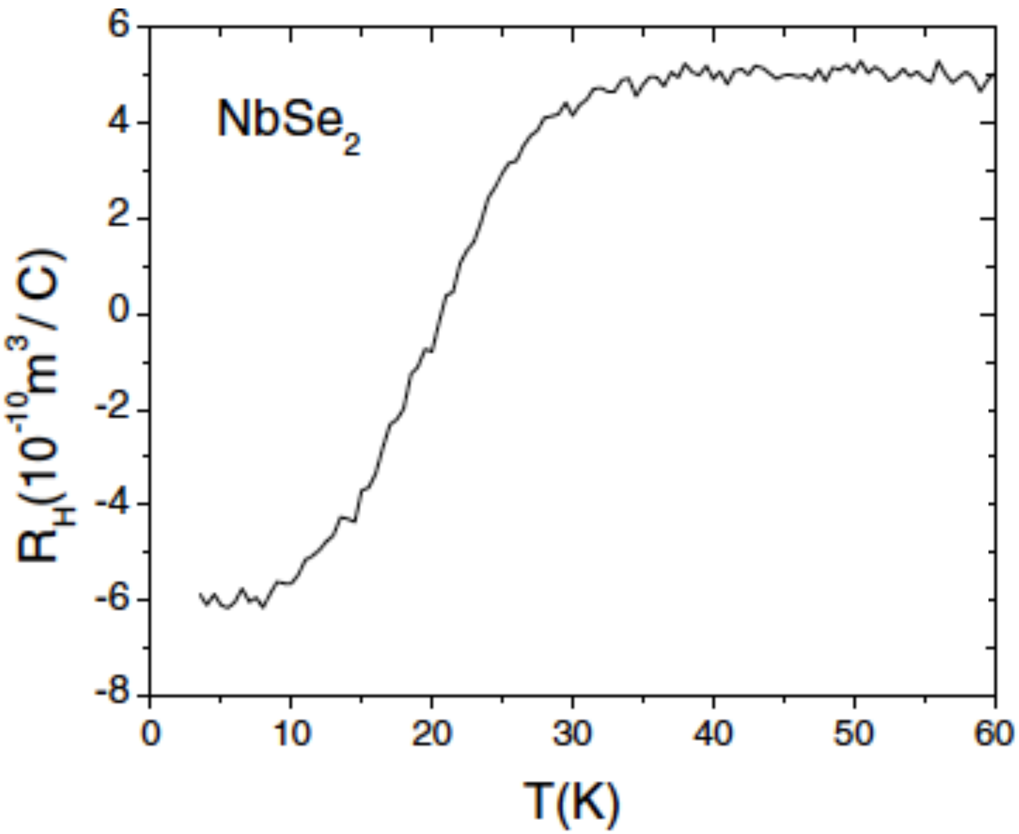
Luttinger's theorem states that **the volume enclosed by a material's Fermi surface is directly proportional to the particle density**.

$$n = \frac{N}{V} = (3\pi^2)^{-1} {k_F}^3$$

Hall effect: Carrier density



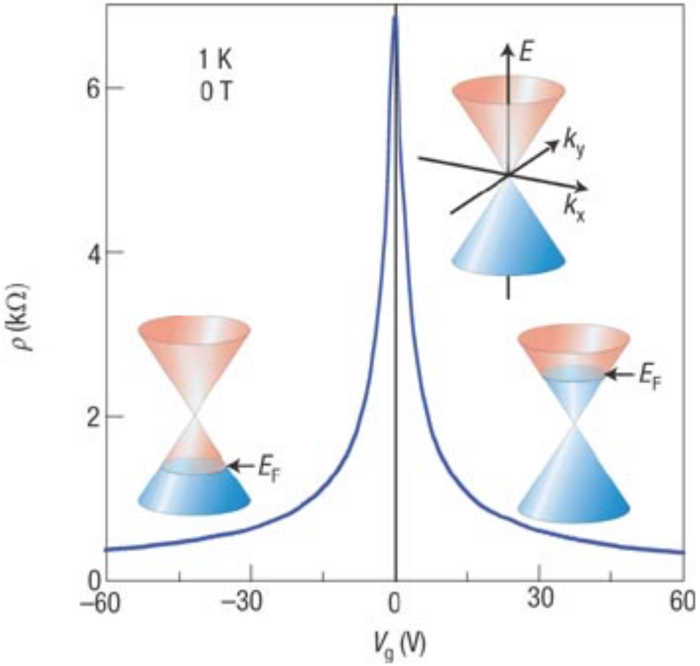
Fermi surface reconstruction



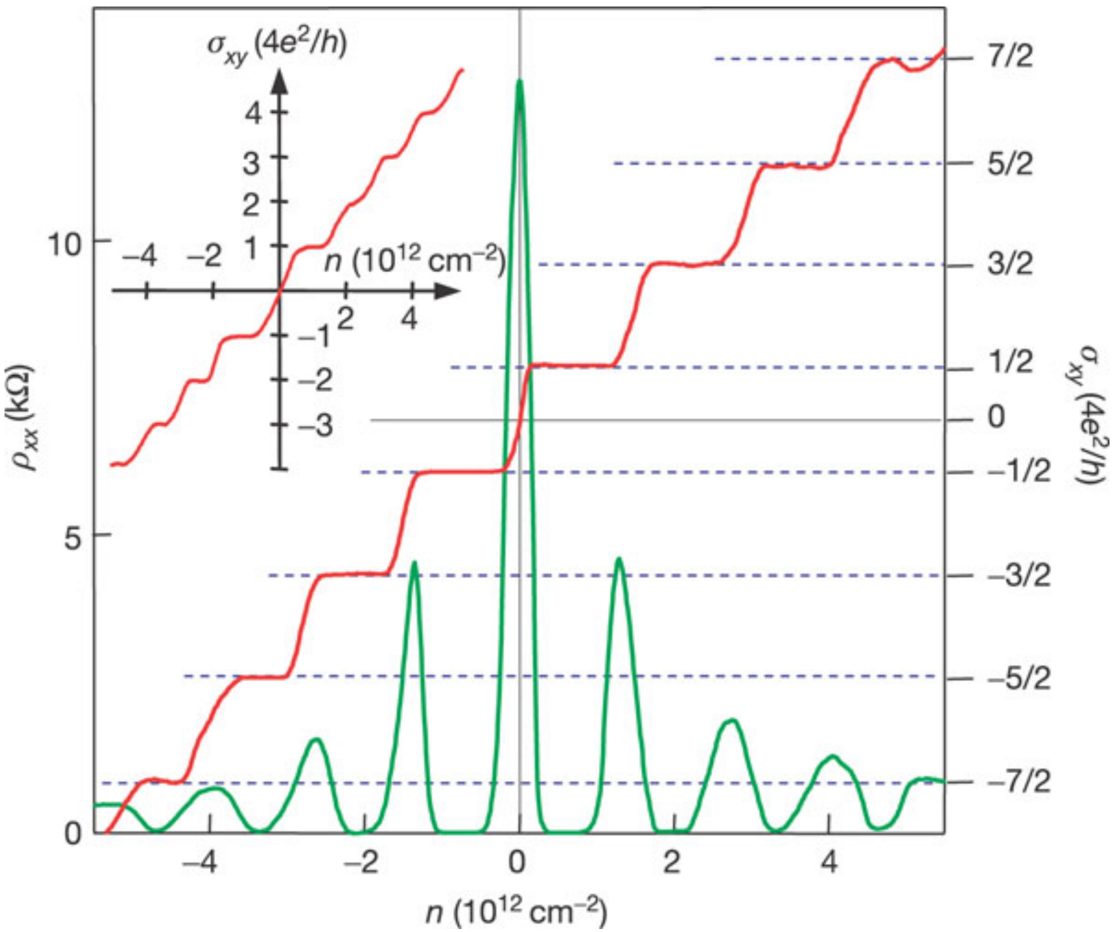
PRL 91, 066602 (2003)

Graphene: Quantum Hall effect

Nobel prize 2010

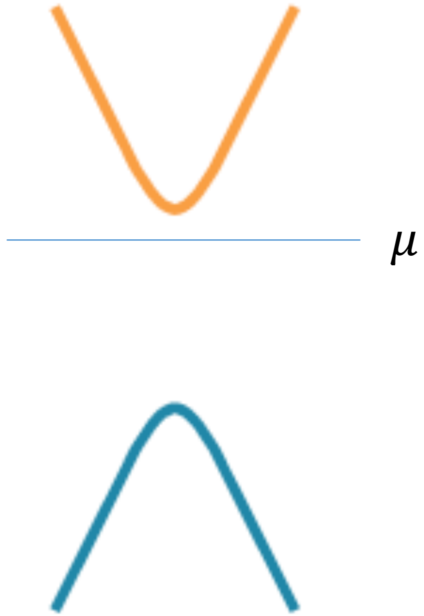


Nature Materials **6**, 183 - 191 (2007)

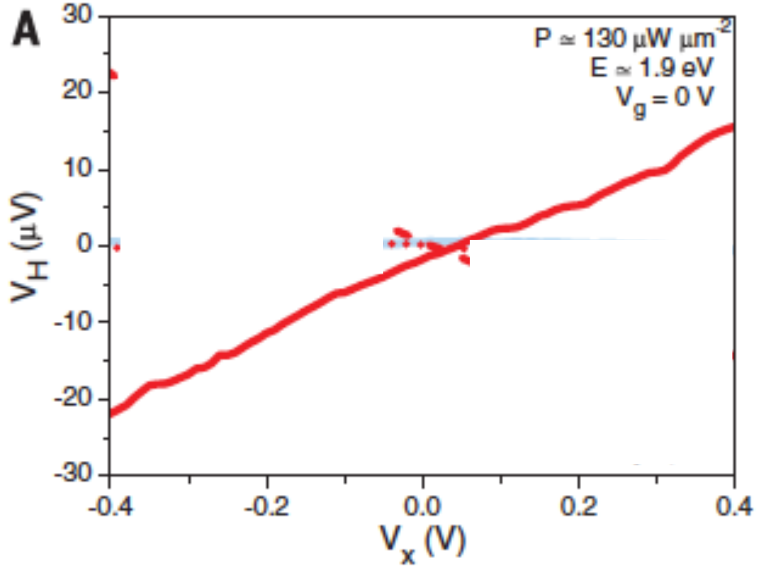


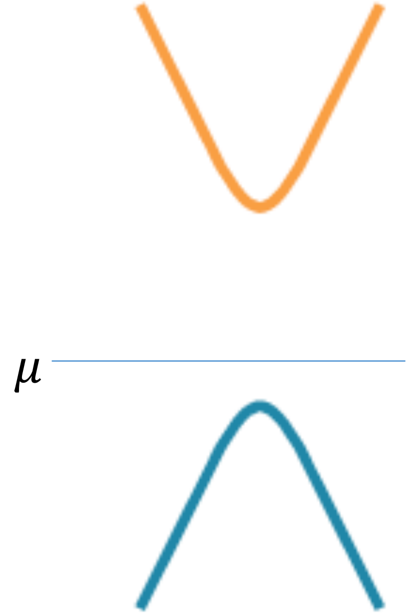
Nature 438, 197-200 (10 November 2005)

Hall effect semiconductors



MoS_2



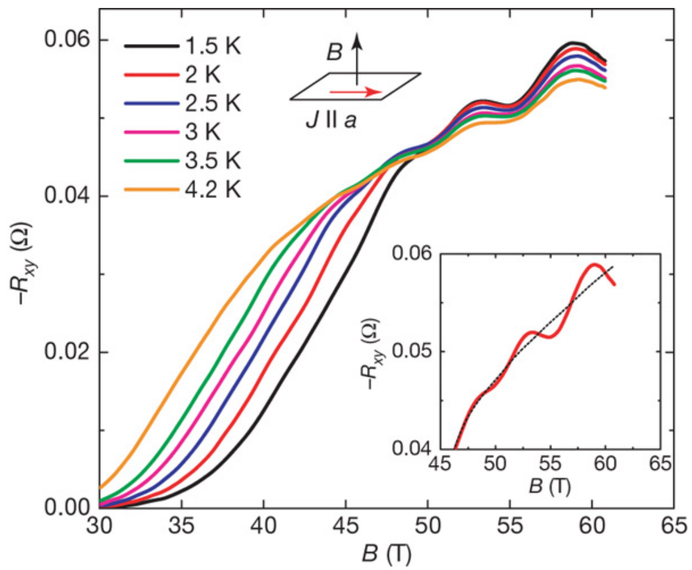


Science 344, 1491 (2014)

Quantum oscillations

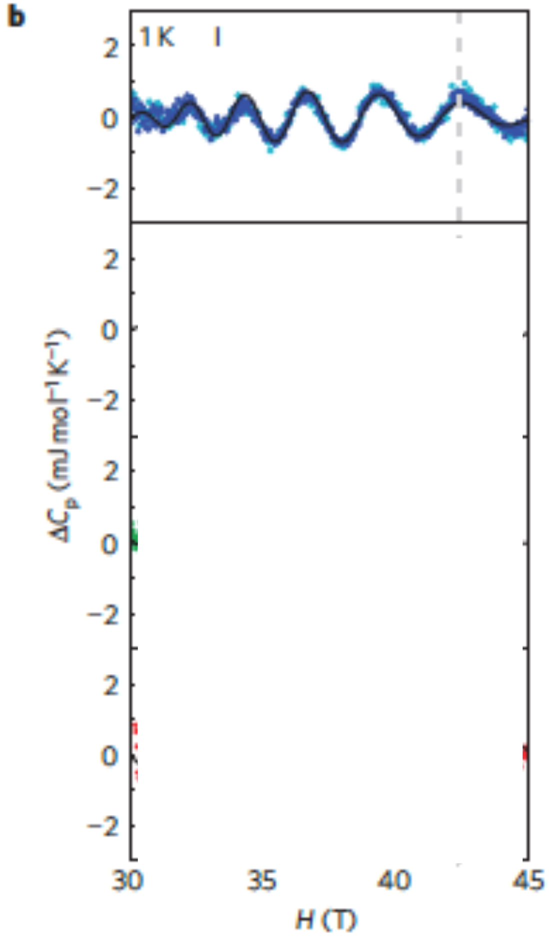
High-temperature superconductor: $YBa_2Cu_3O_{7-x}$

Hall effect

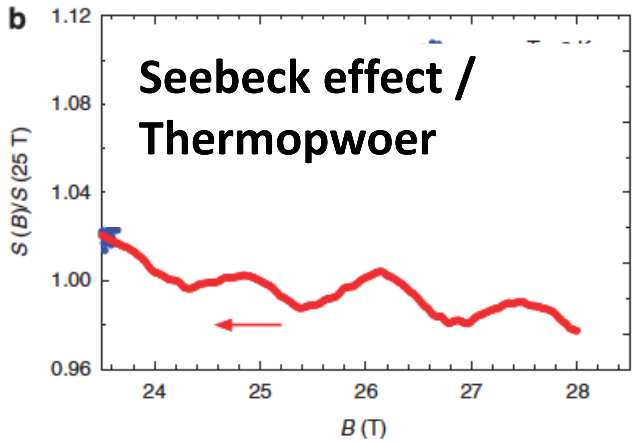


Nature 447, 565 (2007)

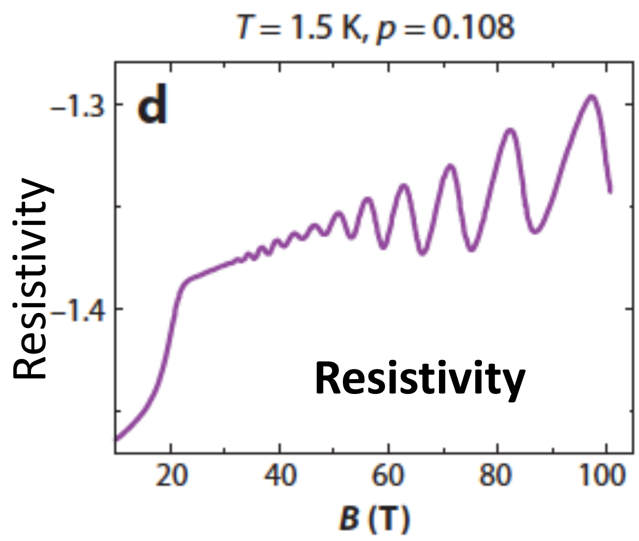
Heat capacity



Nat. Phys. 7, 333 (2011)

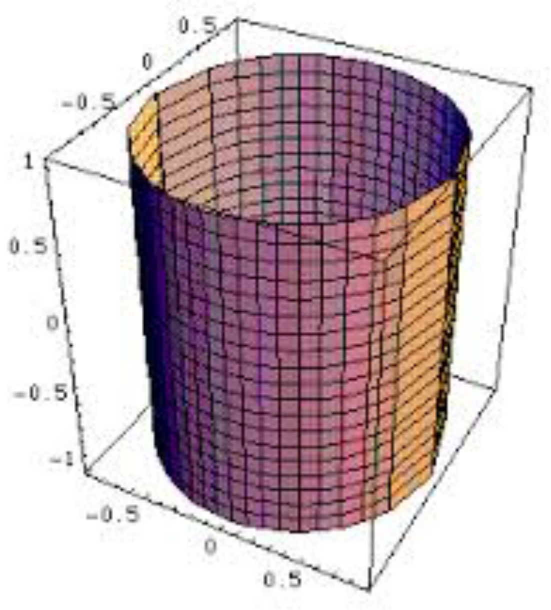


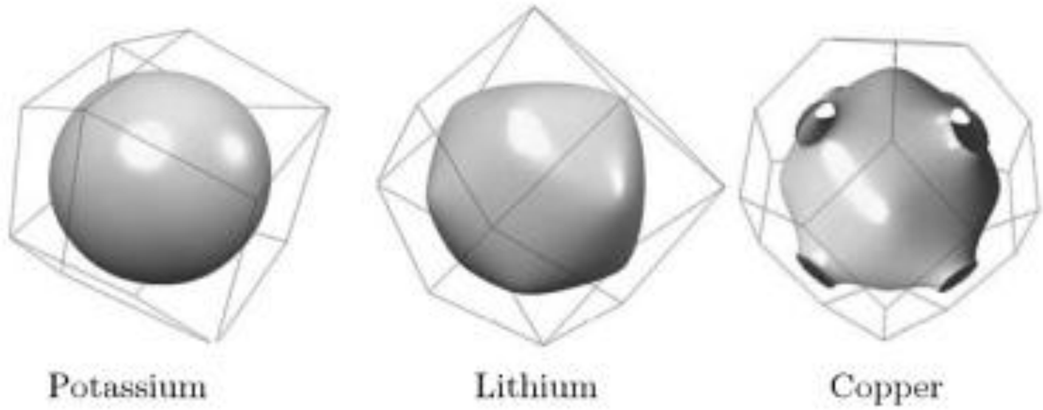
Nat. Comm. 2, 432 (2011)



Ann. Rev. Cond. Mat. Phys. 2015

2D and 3D Fermi surfaces

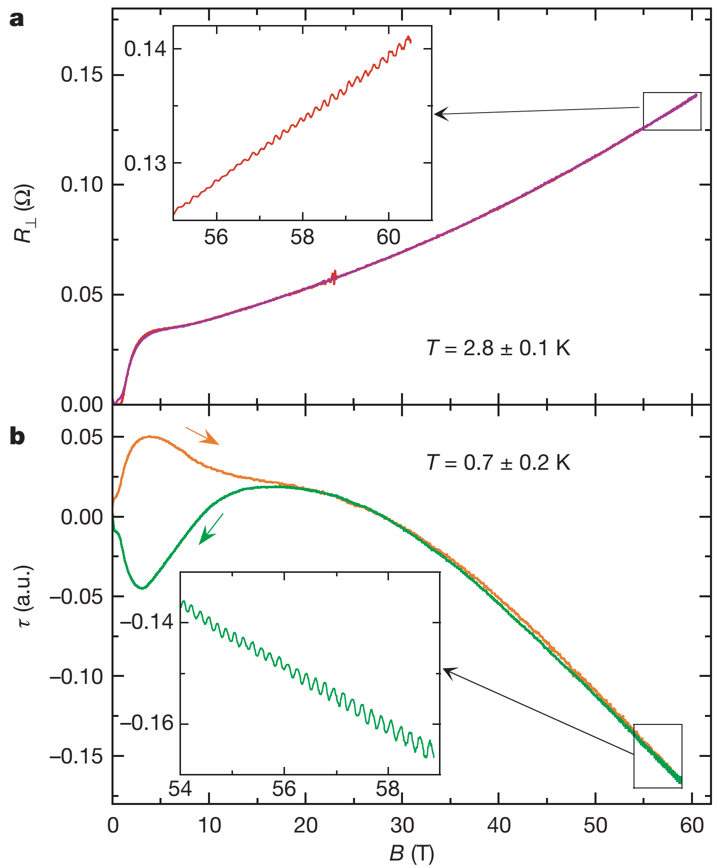




Cubic materials

Layered materials

QUANTUM OSCILLATIONS:



Nature **455**, 952 (2008)

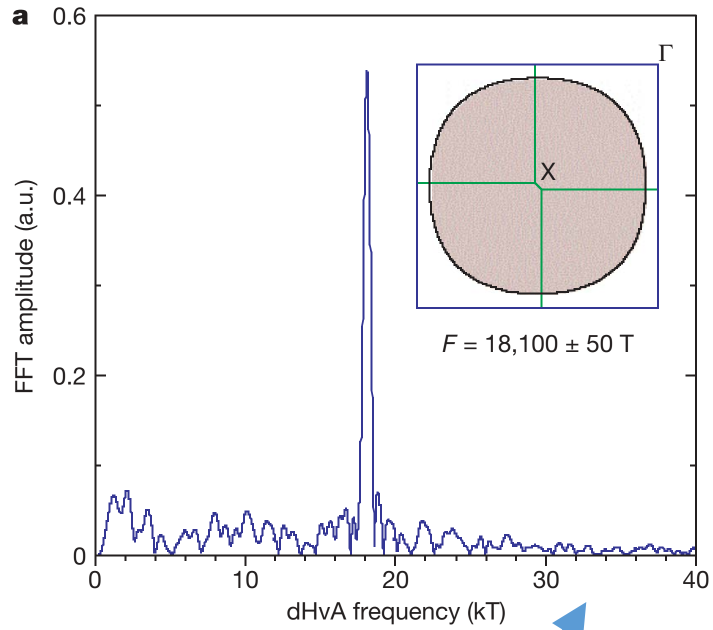
$Tl_2Ba_2CuO_{6+x}$

Shubnikov-de Haas effect =
Quantum oscillations with resistivity

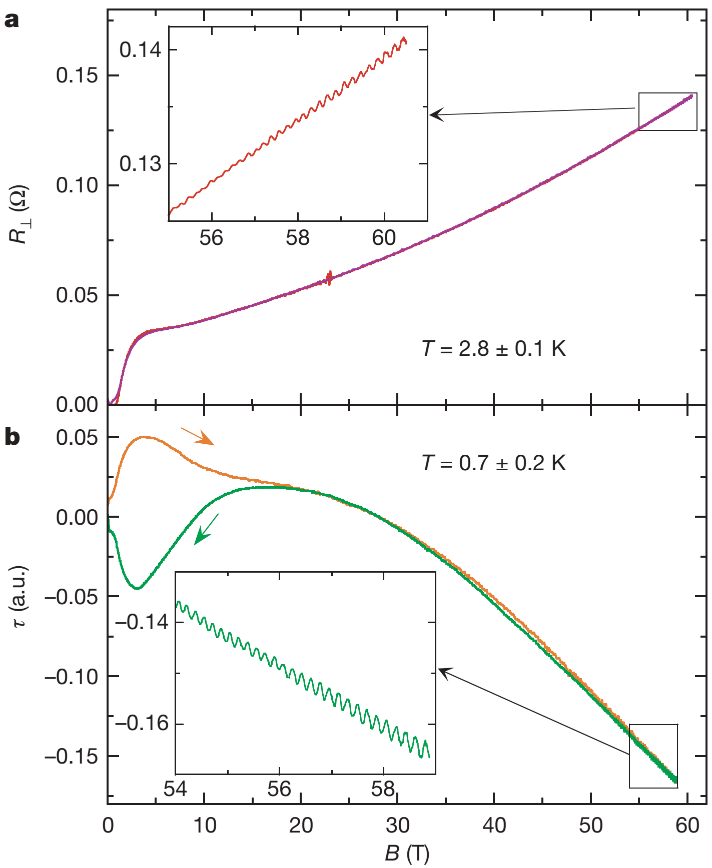
De Haas–van Alphen effect =
Quantum oscillations with magnetic susceptibility

QUANTUM OSCILLATIONS:

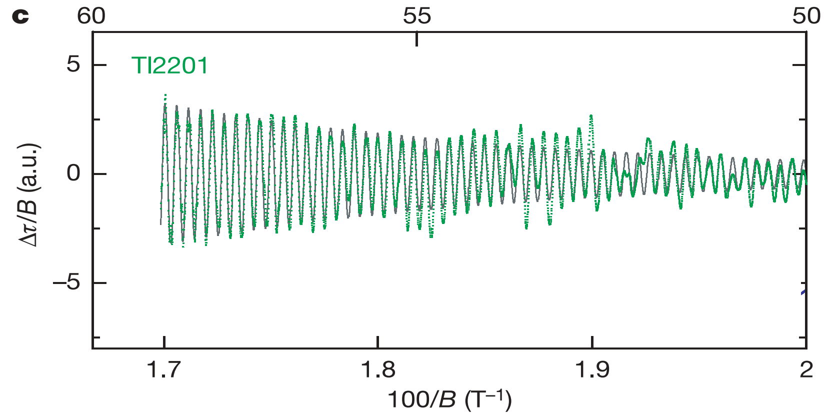
(c) Fourier Transform



(a) RAW DATA



(b) OSCILLATIONS VERSUS 1/B

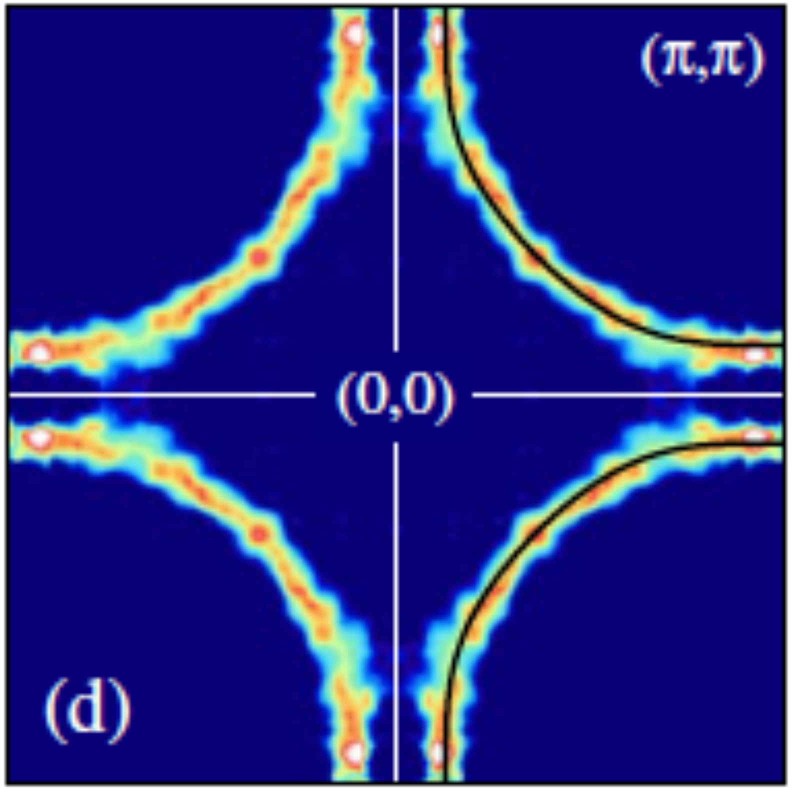


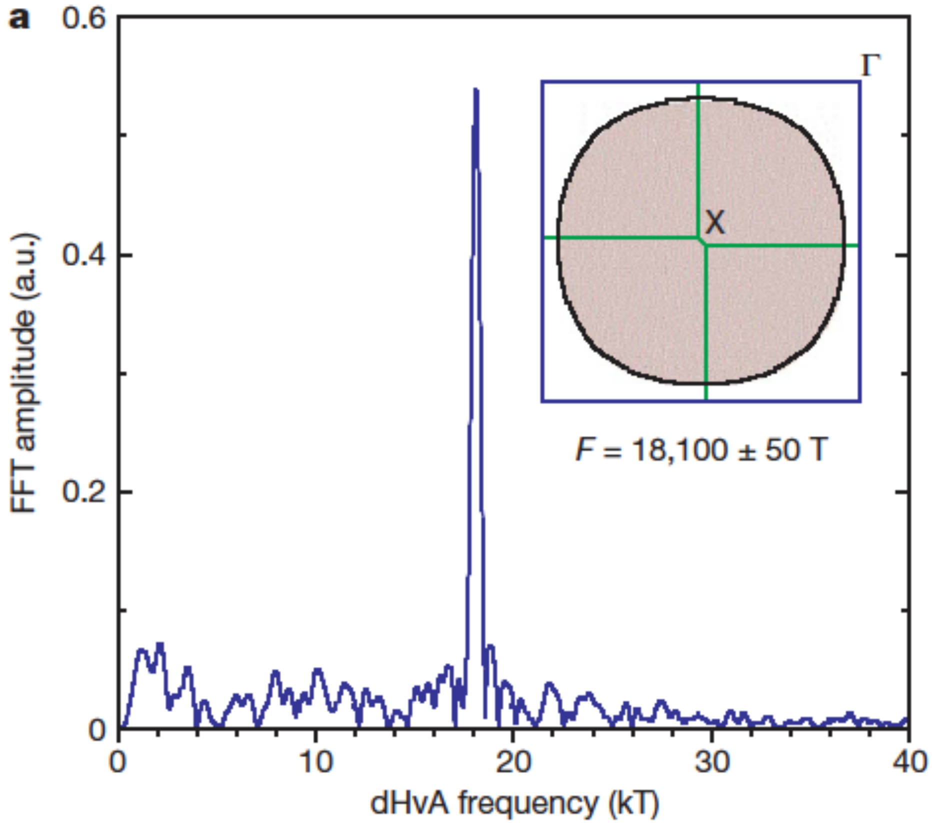
Nature **455**, 952 (2008)

$Tl_2Ba_2CuO_{6+x}$

Fermi surface:

ARPES vs Quantum Oscillations

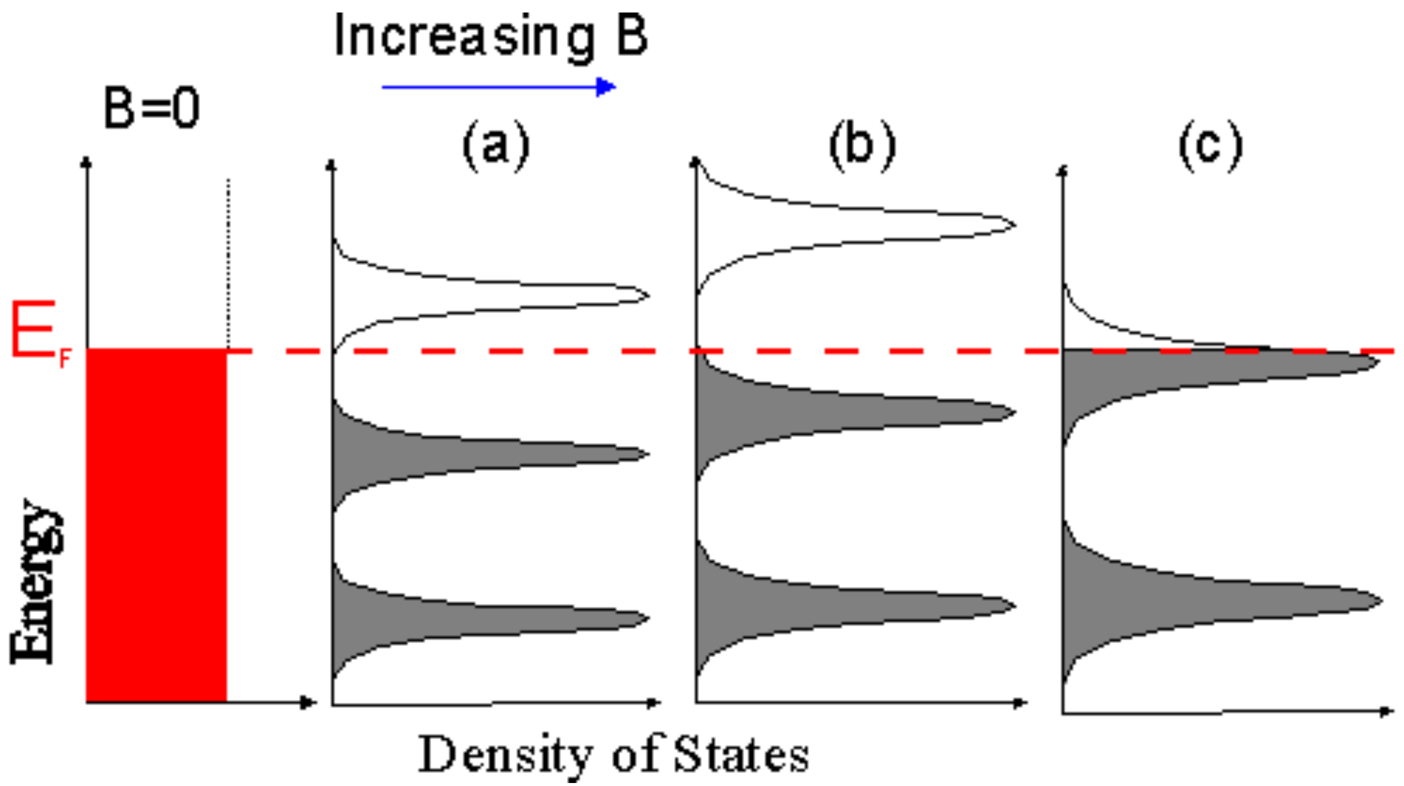




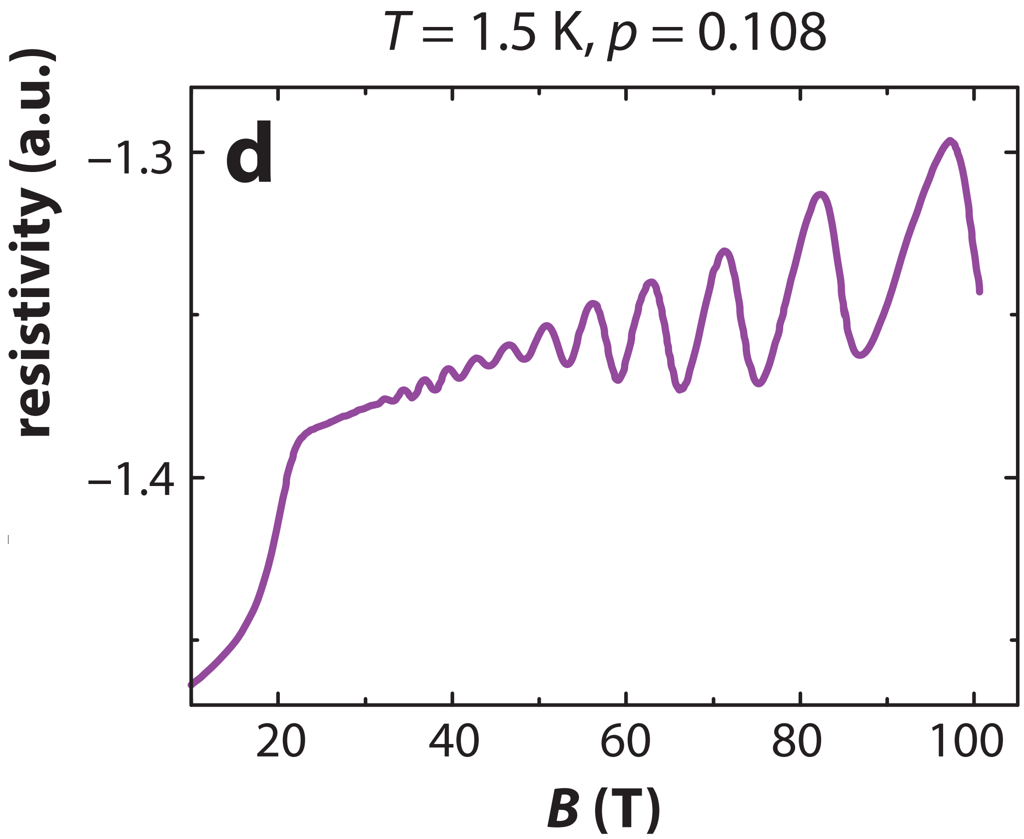
PRL **95**, 077001 (2005)
Data taken @ Swiss Light Source

Nature 455, 952 (2008)
$Tl_2Ba_2CuO_{6+y}$ (Tl2201)

Landau Levels:



QUANTUM OSCILLATIONS:



OSCILLATION AMPLITUDE

$$\propto \; e^{\left(\frac{-\pi\hbar k_F}{eB\ell}\right)}$$

Where ℓ = mean free path

Resistivity measurement of a high-temperature superconductor: $YBa_2Cu_3O_{6.51}$ (YBCO)

http://www.annualreviews.org/doi/pdf/10.1146/annurev-conmatphys-030212-184305

QUANTUM OSCILLATIONS:

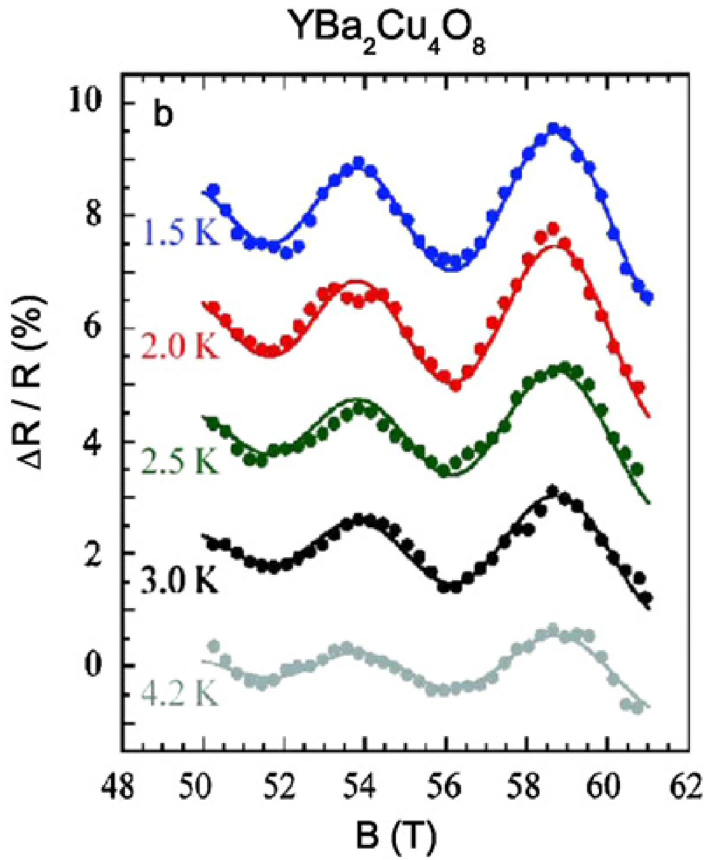
Temperature dependence

Thermal Condition:

$$\hbar\omega_c > k_B T$$

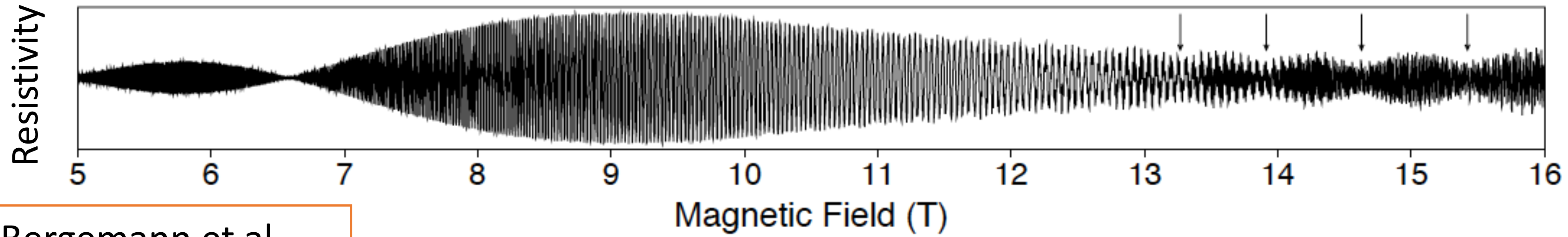
Landau level splitting > thermal energy

$$\omega_c = \frac{eB}{m}$$

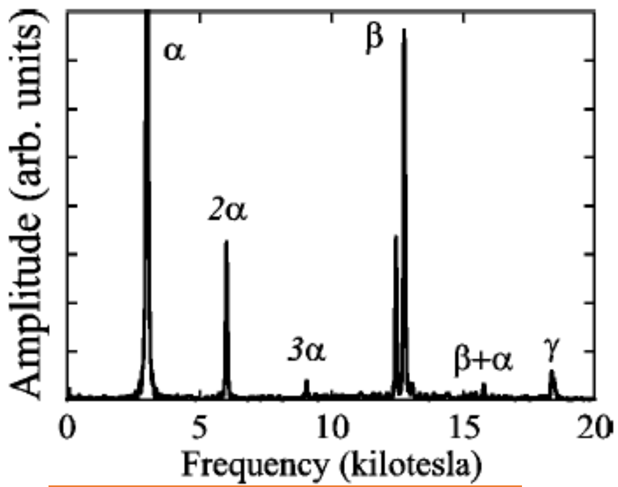


Temperature dependence of the oscillatory amplitude yield information about the electronic mass.

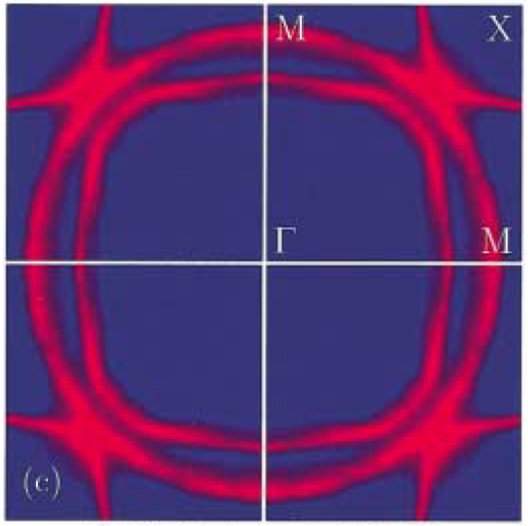
Multi – band metals



Bergemann et al,
PRL 84, 2662 (2000)



A.P. Mackenzie et al,
JPSJ 67, 385 (2003)



A. Damascelli et al,
PRL 85, 5194 (2000)