HELLO!

I am Essghaier Shayma

I am here because I love cookies and presentations

It is my first time presenting in english … (suspense)

MY ADVENTUDRE IN LAB :

UNCONVENTIONAL SUPERCONDUCTORS

ET_2X

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unCONVENTIONAL

SUPERCONDUCTORS

ET_2X

A few years before my birth ...

(1878)

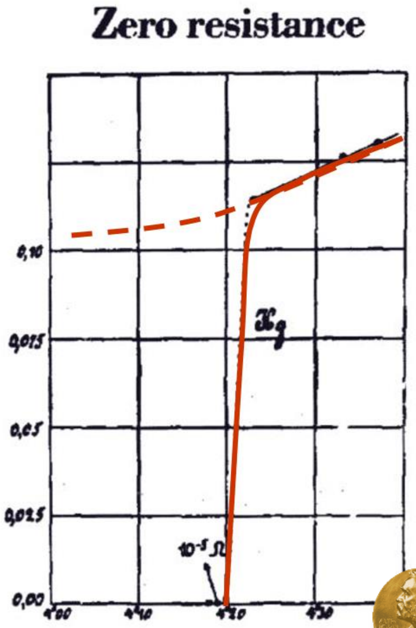
- In 1908, Heike Kamerlingh Onnes succeeded in liquefying Helium

"Mmmmmh ...what happens to the resistance of a metal near absolute zero?"

H. K. Onnes

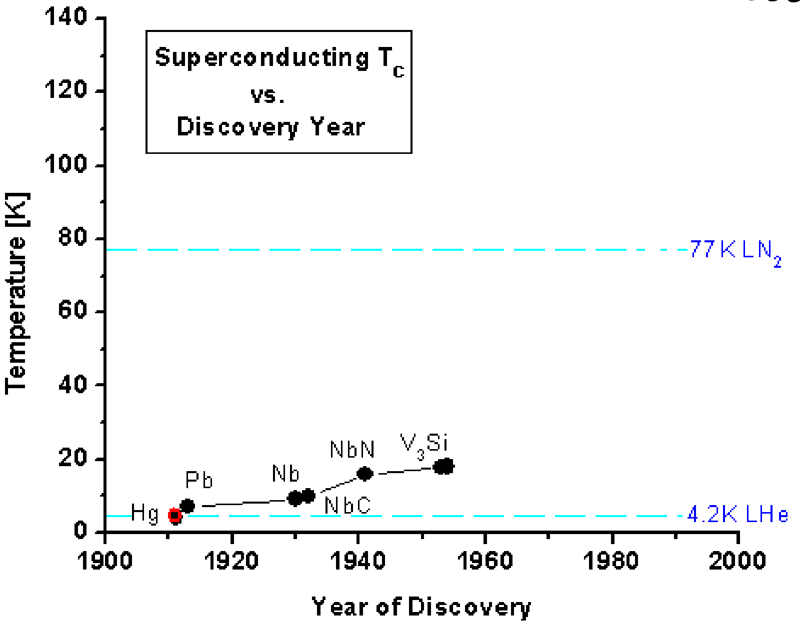
1911 … IT'S SUPERCONDUCTIVITY ….!!

- Discovered by **Kamerlingh Onnes** in 1911 during first low temperature measurements to liquefy helium
- Whilst measuring the resistivity of Hg he noticed that the electrical resistance dropped to zero at 4.2K
- In 1912 he found that the resistive state is restored in a magnetic field or at high transport currents



1913

911 ... THERE IS NO THEORY ...!!



BCS THEORY ... 1957

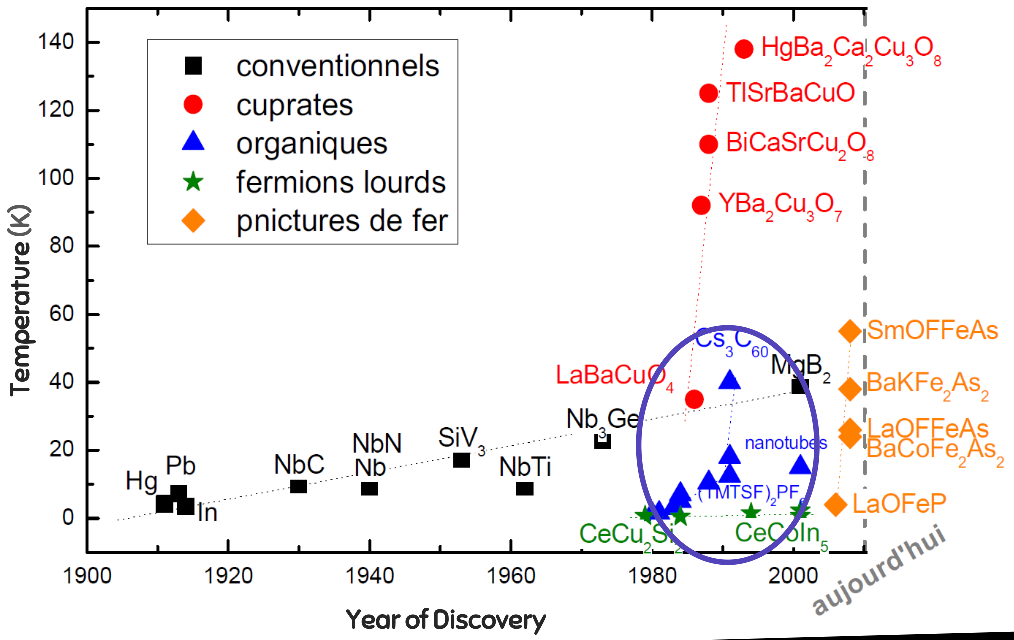
- The BCS theory proposed by Bardeen, Cooper, and Schrieffer, in 1957, was the first to offer a **microscopic** explanation to amazing properties of superconductors

- A key conceptual element in this theory is the pairing of electrons close to the Fermi level into **Cooper pairs** through interaction with the crystal lattice

- This paring results from **a slight attraction between the electrons** related to lattice vibrations

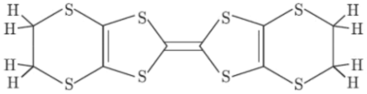
John Bardeen   Leon Neil Cooper   John Robert Schrifffer

Beyond BCS theory ...

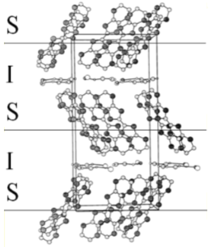


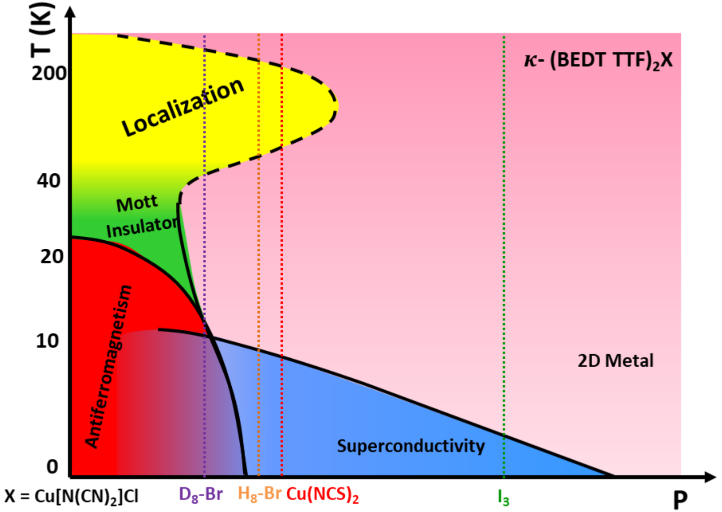
κ-(BEDT-TTF)$_2$X FAMILY

- The κ–(BEDT–TTF)$_2$X family compounds are formed by a stack of **conductor planes (BEDT-TTF)** separated by **insulating planes (anions X)**



Bis Ethylenedithio-tetrathiafulvalene molecule (BEDT TTF)

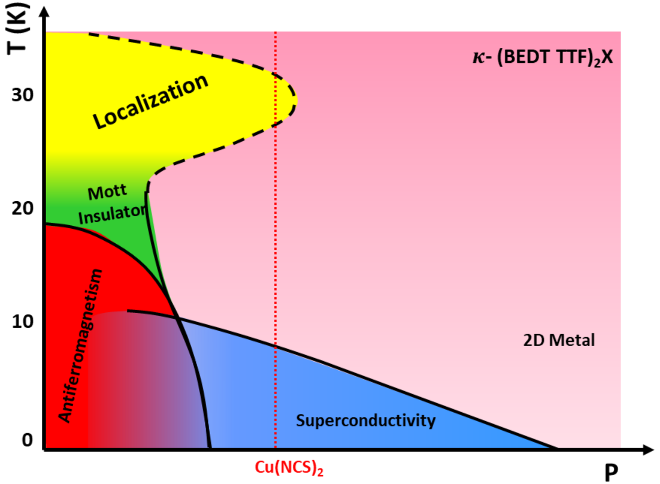




WHY κ-$(ET)_2$ CU NCS_2 ?

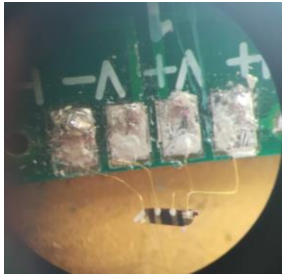
κ-(BEDT-TTF)$_2$CuNCS$_2$

- κ–(BEDT TTF)$_2$Cu (NCS)$_2$ is a superconductor in the vicinity of the Mott insulator phase
- Superconductivity below T_C= 10.4 K
- Superconductivity is suppressed at the rate of $dT/dP = -3K/1kbar$

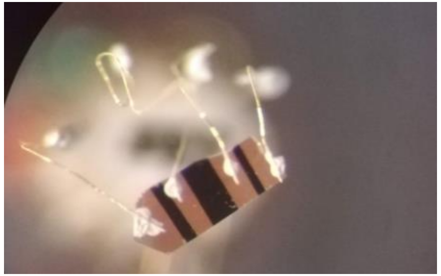


BEFORE MEASUREMENTS …

preparation of gold contacts



sample assembly

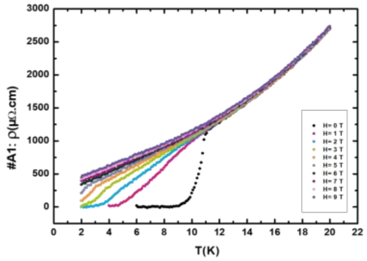


How the sample looks like

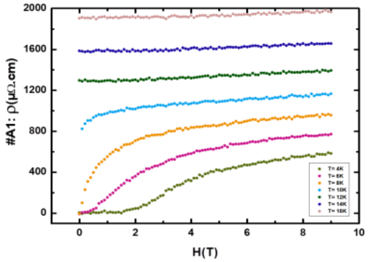
SAMPLE #1: RESISTIVITY AT AMBIENT PRESSURE IN κ-(ET)$_2$Cu(NCS)$_2$

We are using the fact that high magnetic field kills superconductivity :

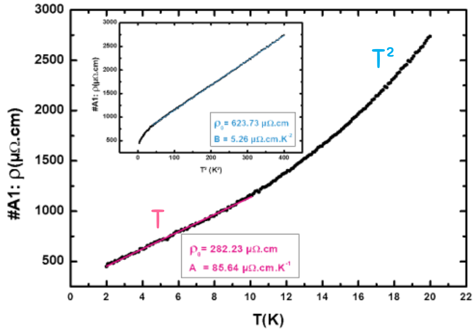
$\rho(T)$ under magnetic field



$\rho(H)$ at different T



$\rho(T)$ at H = 9 Tesla

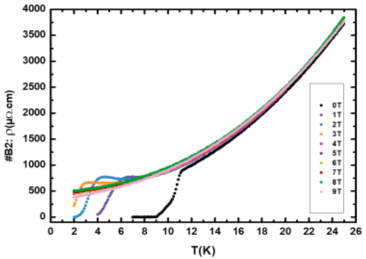


- At H = 9T, ρ follows a **purely linear law as a function of temperature** $\mathbf{for}\ T < 10K$, $\rho = \rho_0 + AT$ with $A = 86\ \mu\Omega.cm.K^{-1}$ and $\rho_0 = 282\ \mu\Omega.cm$
- ρ follows a **purely quadratic behavior for** $T > 10K$, $\rho = \rho'_0 + BT^2$ with $B = 5\ \mu\Omega.cm.K^{-2}$ and $\rho'_0 = 623\ \mu\Omega.cm$

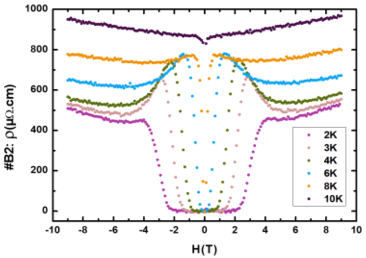
Sample #2: Resistivity at ambient pressure in κ-$(ET)_2Cu(NCS)_2$

Big contribution of transverse resistivity ρ_c :

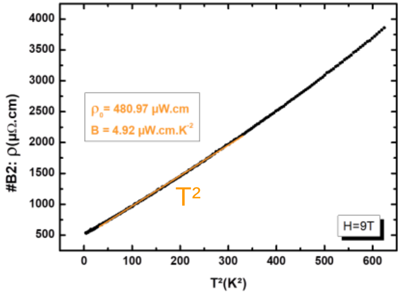
$\rho(T)$ under magnetic field



$\rho(H)$ at different T



$\rho(T)$ at H = 9 Tesla



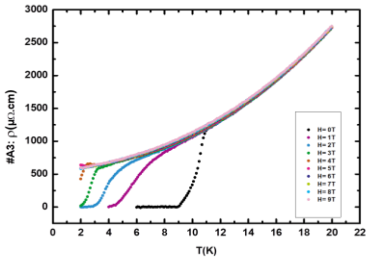
- At H = 9T, the electrical resistivity as a function of temperature follows a pure quadratic law: $\rho = \rho_0 + BT^2$ (Large ρ_c component)
- We obtain $B = 5\ \mu\Omega.cm.K^{-2}$ and $\rho_0 = 480\ \mu\Omega.cm$

Sample #3: Resistivity at ambient pressure in κ-$(ET)_2Cu(NCS)_2$

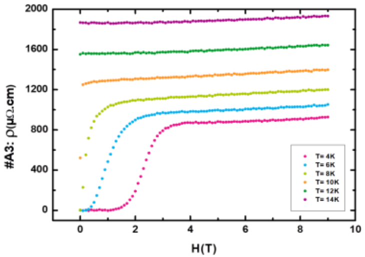
Big contribution of transverse resistivity ρ_c :

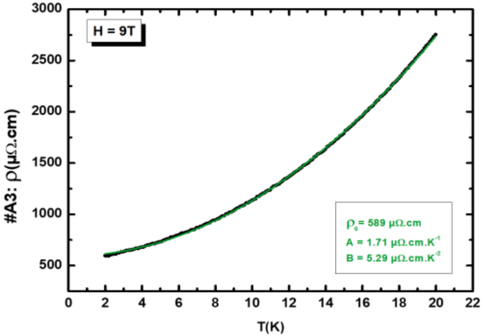
$\rho(T)$ at H = 9 Tesla

$\rho(T)$ under magnetic field



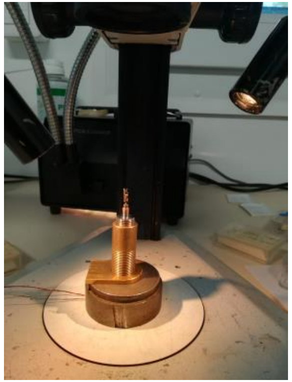
$\rho(H)$ at different T

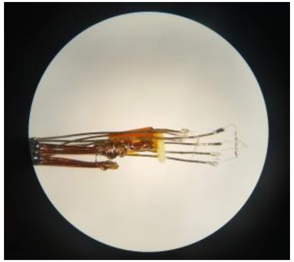




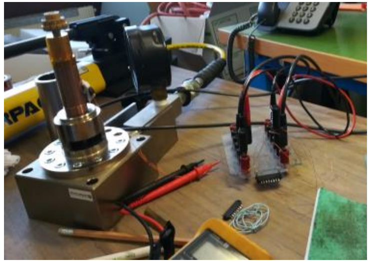
- At H = 9T, the electrical resistivity as a function of temperature follows neither a linear law nor a pure quadratic law: $\rho = \rho_0 + AT + BT^2$ (weak ρ_c component visible)
- We obtain $A = 2\ \mu\Omega.cm.K^{-1}$, $B = 5\ \mu\Omega.cm.K^{-2}$ and $\rho_0 = 589\ \mu\Omega.cm$

APPLYING PRESSURE ...



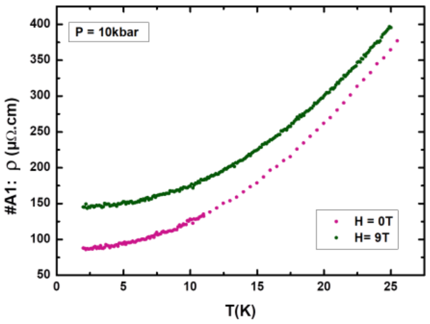


The pressure cell ...

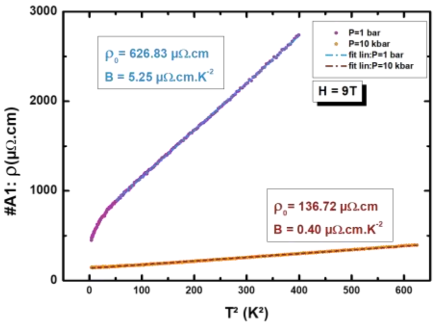


Sample #1: Pressure effect (P = 10 kbar) in κ-$(ET)_2Cu(NCS)_2$

$\rho(T)$ under magnetic field



$\rho(T)$ at H = 9 Tesla



- Under a hydrostatic pressure of 10kbar, the electrical resistivity follows a pure quadratic law as a function of temperature : $\rho = \rho_0 + BT^2$
- We obtain $B = 0.4\ \mu\Omega.cm.K^{-2}$, $\rho_0 = 136\ \mu\Omega.cm$. The residual resistivity was divided by factor of 2. The value of B was divided by a factor of 10 which demonstrates the weakening of the e–e– interactions upon applying pressure

BIG PUZZLE

- Many exotic compounds exhibit a resistivity linear in temperature, the origin of which is not well understood ...

Linear resistivity in different compounds … ☺

For non interacting electrons :

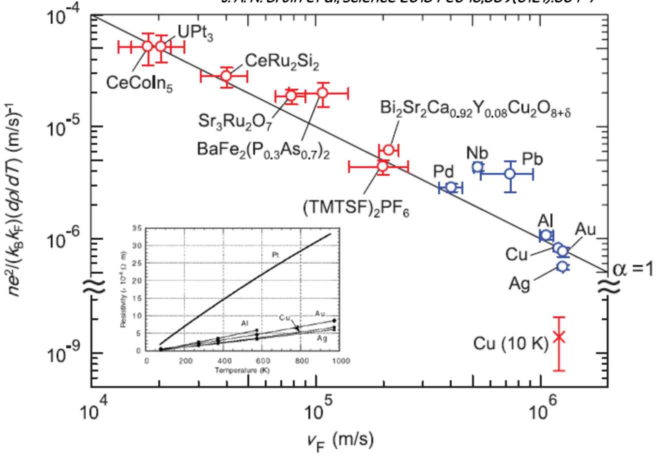
Drude Formula : $\rho = \frac{m^*}{ne^2}\frac{1}{\tau}$, n: carrier density , m^*: effective mass

At T → 0, $\tau = \alpha\frac{\hbar}{k_B T}$, α =1 : Planck time

At T → 0, $\rho(T) = \rho_0 + AT$, $A = \frac{m^*}{ne^2}\frac{1}{\tau}\frac{1}{T} = \alpha\frac{m^*}{n}\frac{k_B}{e^2\hbar}$

In 2D system, $A^{\blacksquare} = \alpha\frac{h}{2e^2}\frac{1}{T_F}$ with $T_F = \frac{\pi\hbar^2}{k_B}\frac{nd}{m^*}$

J. A. N. Bruin et al, science 2013 Feb 15;339(6121):804-7



Linear resistivity in different compounds ... ☺

Material	Doping (p) Pressure (P)	n $(10^{27} m^{-3})$	m^* (m_0)	A/d (Ω/K)	$h/(2e^2 T_F)$ (Ω/K)	α
* LSCO	p = 0.26	7.8	9.8 ± 1.7	8.2 ± 1.0	8.9 ± 1.8	0.9 ± 0.3
Nd-LSCO	p = 0.24	7.9	12 ± 4	7.4 ± 0.8	10.6 ± 3.7	0.7 ± 0.4
PCCO	x = 0.17	8.8	2.4 ± 0.1	1.7 ± 0.3	2.1 ± 0.1	0.8 ± 0.2
LCCO	x = 0.15	9.8	3.0 ± 0.3	3.0 ± 0.45	2.6 ± 0.3	1.2 ± 0.3
$(TMTSF)_2PF_6$	P = 11kbar	1.4	1.15 ± 0.2	2.8 ± 0.3	2.8 ± 0.4	1.0 ± 0.3
$ET_2Cu(NCS)_2$		** 0.6	3.5	560	260	2

* A.Legros *et al*, *arXiv:1805.02512v1 (2018)*

** *K. Murata Solid State Communications, Vol.75, (1990)*

CONCLUSION

In-plane resistivity, ρ_{ab}, exhibits a linear behavior at low temperature in $(ET)_2CuNCS_2$

The linear term is suppressed at large pressure which suggests that it is directly related to the superconductivity

Study of other κ–(BEDT TTF)$_2$ X materials and comparison with cuprates and $(TMTSF)_2PF_6$

THANKS!

Any questions?

MAPS