A Hydrated Superconductor

Karmela Padavic, Bikash Padhi, Akshat Puri

A brief discussion of

Superconductivity in 2D CoO_2 Layers

Kazunori Takada, Hiroya Sakurai, Eiji Takayama-Muromachi, Fujio Izumi, Ruben A. Dilanian & Takayoshi Sasaki

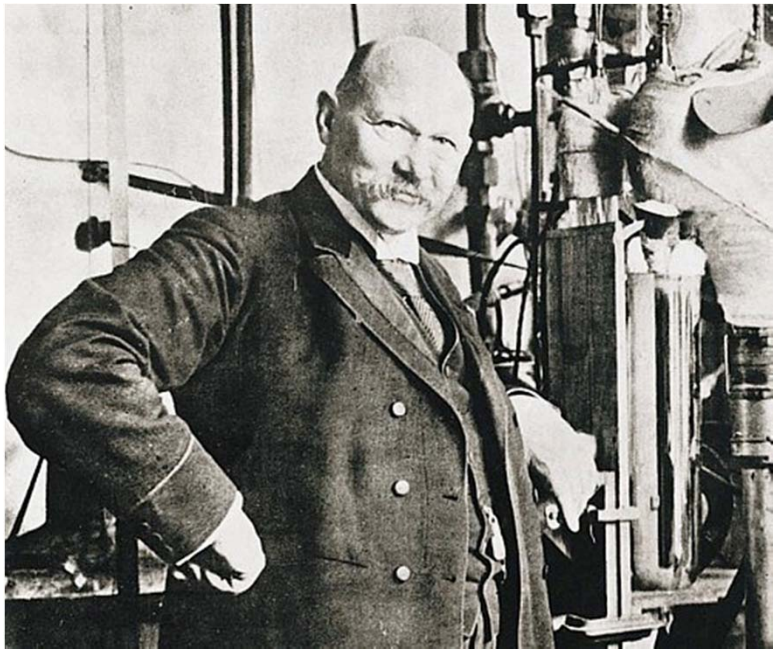
Nature **422**, 53 (2003)

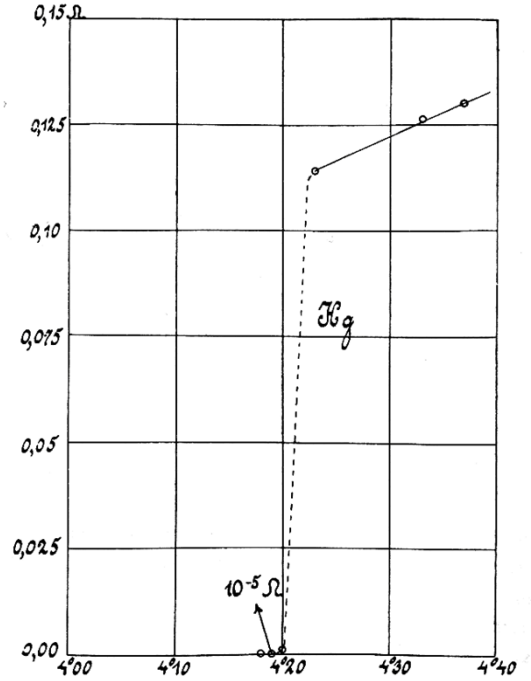
Presentation Outline

- Background: phenomenology and history
- Unconventional SCs
- Superconductivity in CuO_2 layers
- Critical assessment of the presented work
- Citation analysis and consequent studies
- Summary and conclusions

Discovery of Superconductivity

- Discovered in 1911 by Heike Kamerlingh Onnes.
- Perfect conductivity of Hg below 4.19 K.
- Perfect conductor below a critical temperature (T_c):

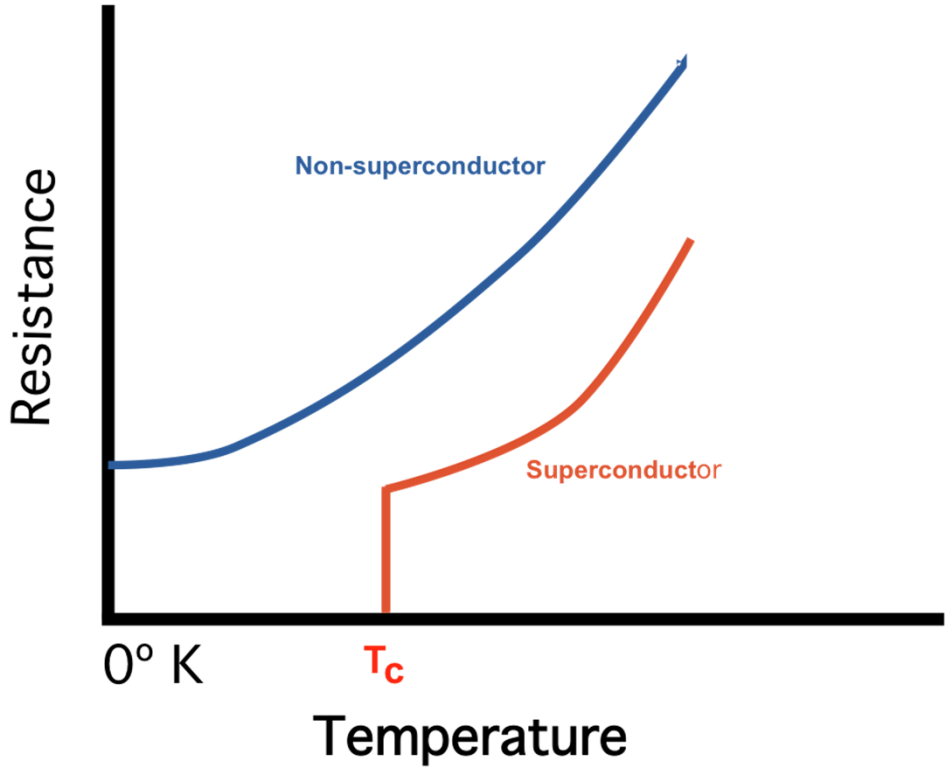




http://spectrum.ieee.org/tech-talk/semiconductors/materials/superconductivity-celebrates-100-years
http://www.writework.com/essay/superconductivity

Zero Electrical Resistance in Superconducting Phase

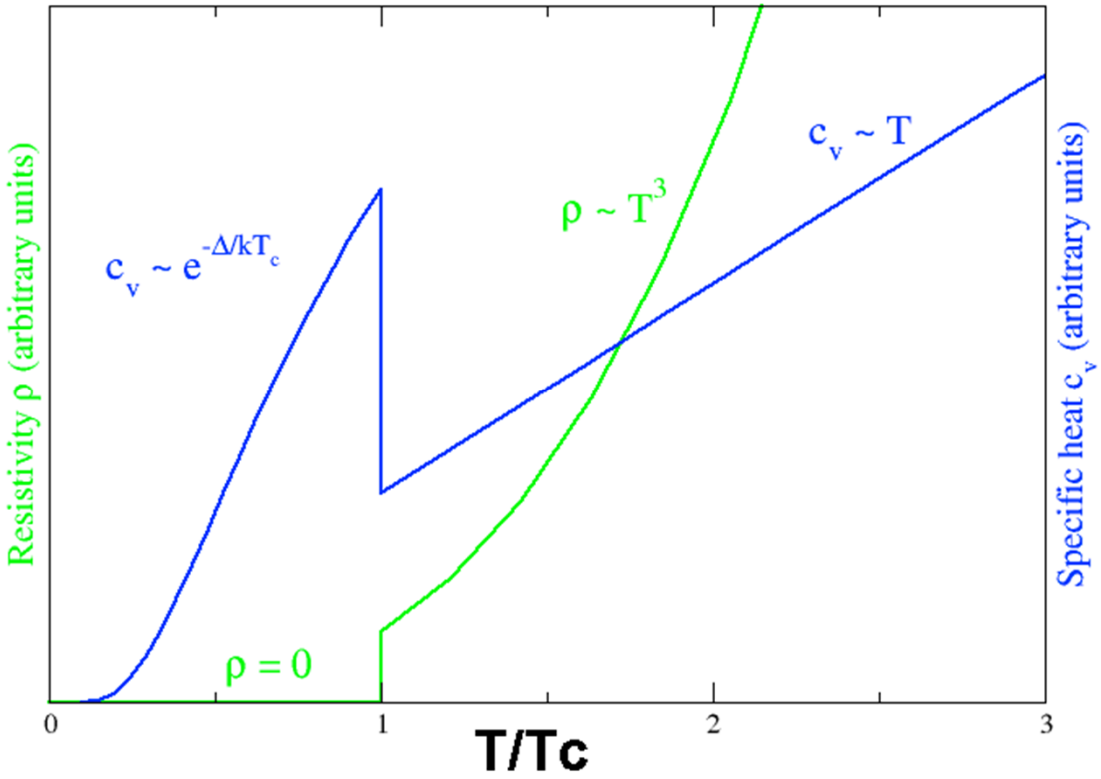
- Resistance drops to 0 at T_c



http://mri-q.com/uploads/3/2/7/4/3274160/9443800_orig.png?259

Several Properties Reveal the SC Phase Transition

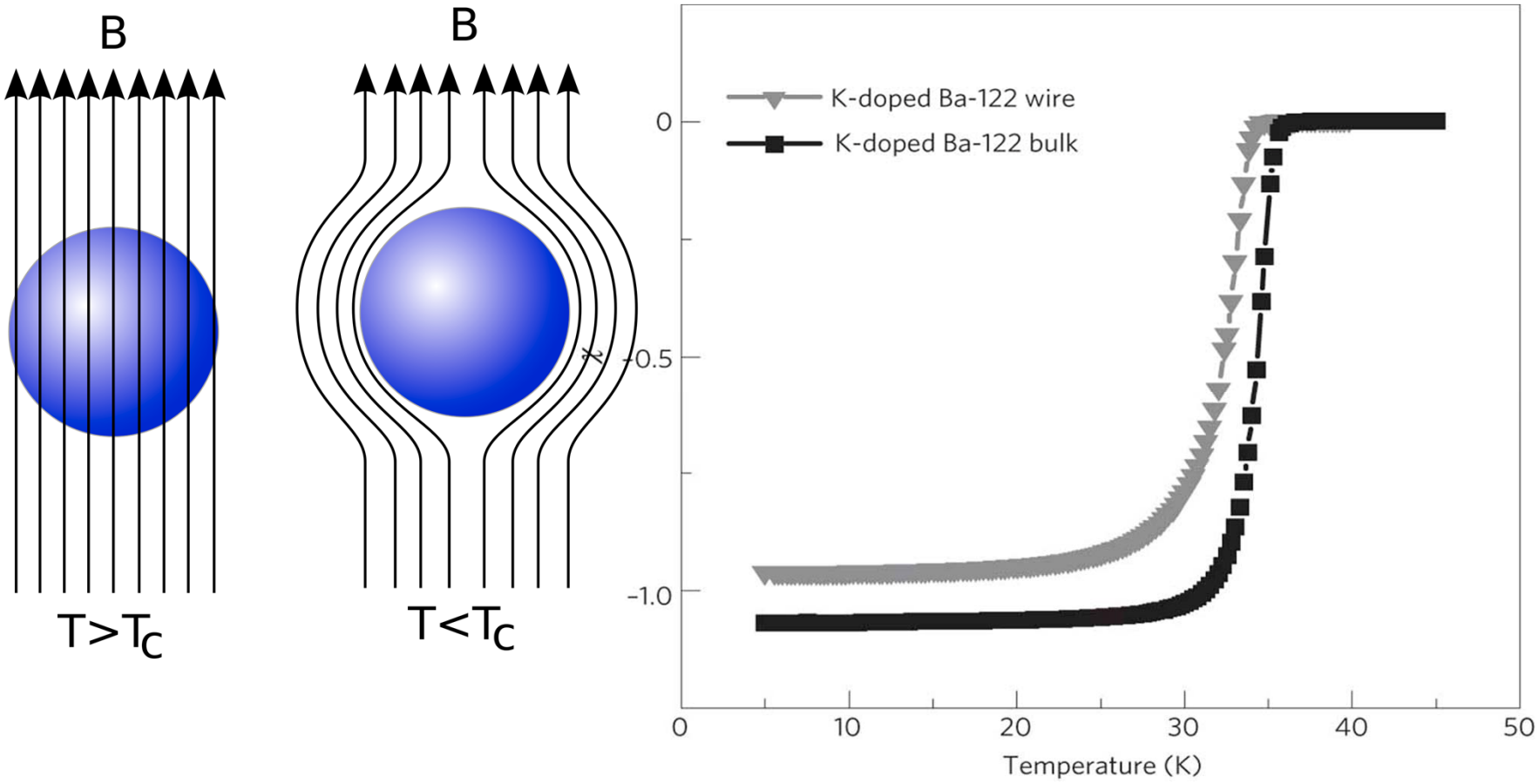
- Transitions in electronic heat capacity, resistivity.



http://upload.wikimedia.org/wikipedia/commons/0/08/Cvandrhovst.png

Superconductors exhibit a Meissner Effect

- The spontaneous expulsion of a magnetic field which occurs during transition to superconductivity.

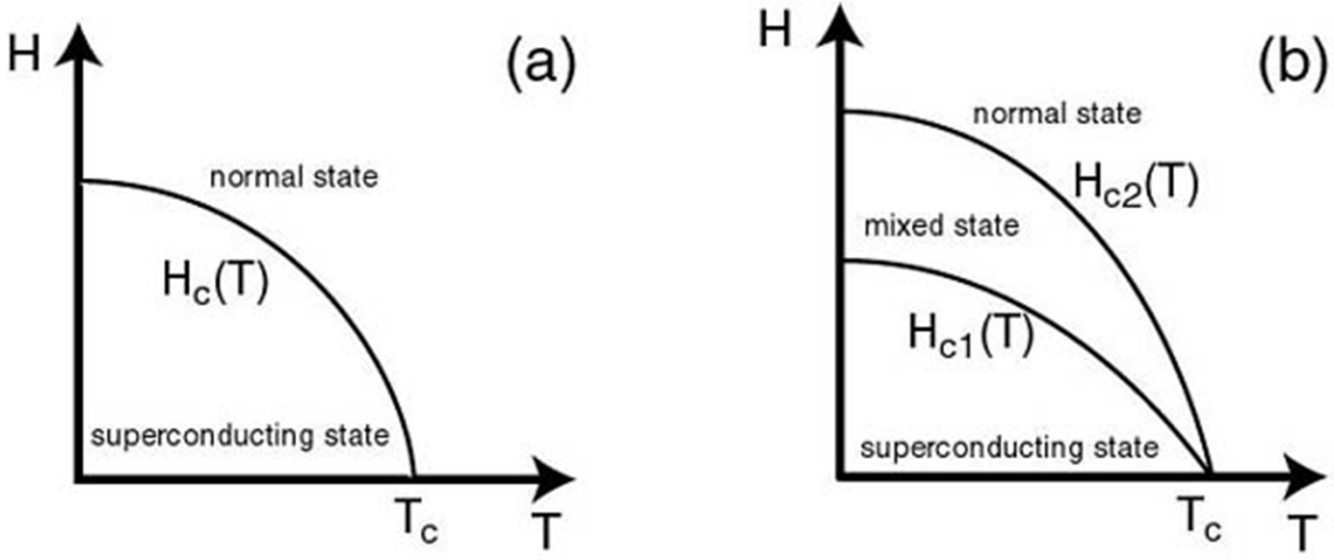


http://en.wikipedia.org/wiki/Meissner_effect
http://www.nature.com/nmat/journal/v11/n8/fig_tab/nmat3333_F1.html

Fig. from [2]

SC response to magnetic field: Type I and II

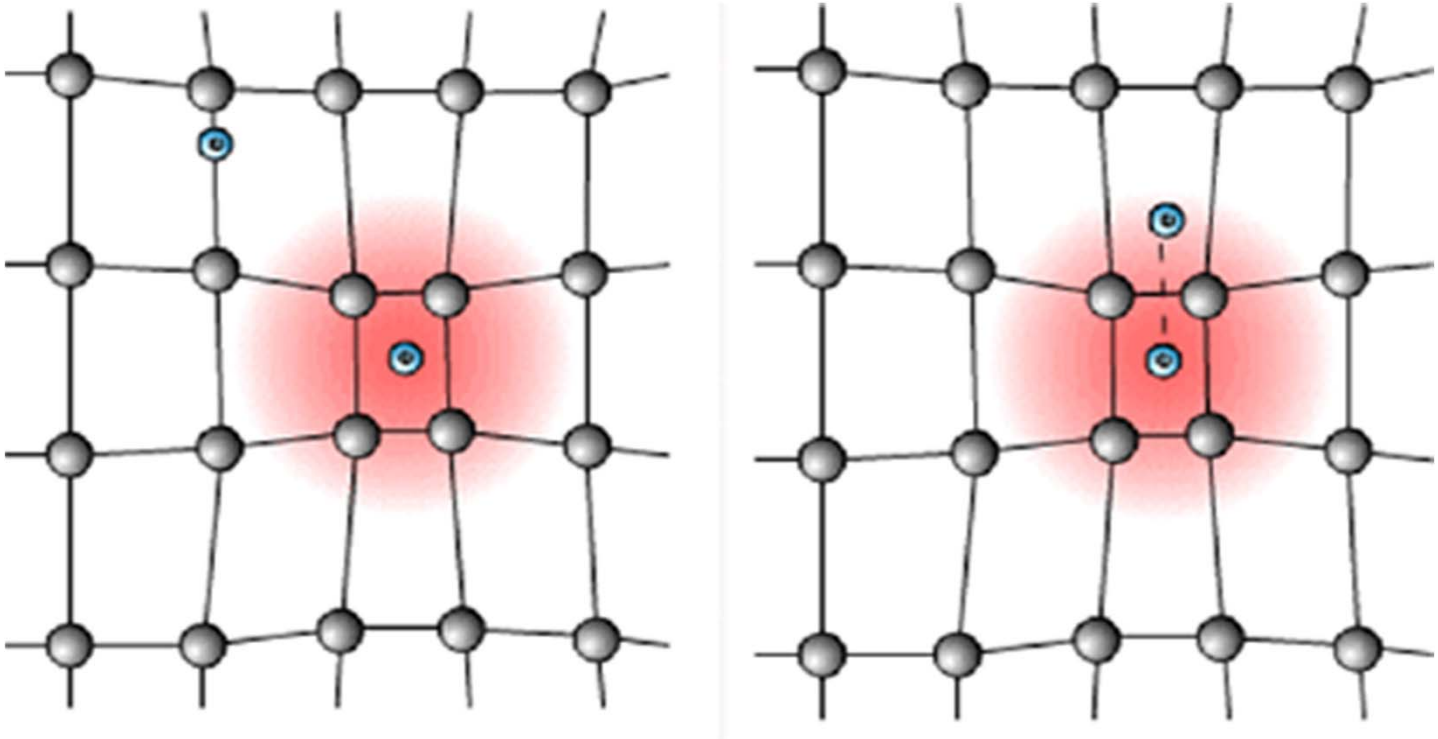
- Response to external magnetic field differs: Type I (single critical field, above which all superconductivity is lost); or Type II (two critical fields, between which there is partial penetration of the magnetic field and creation of vortices)



http://physics.aalto.fi/groups/nanospin/facilities/pulsed-laser-deposition/critical/

SC Mechanism described by BCS Theory

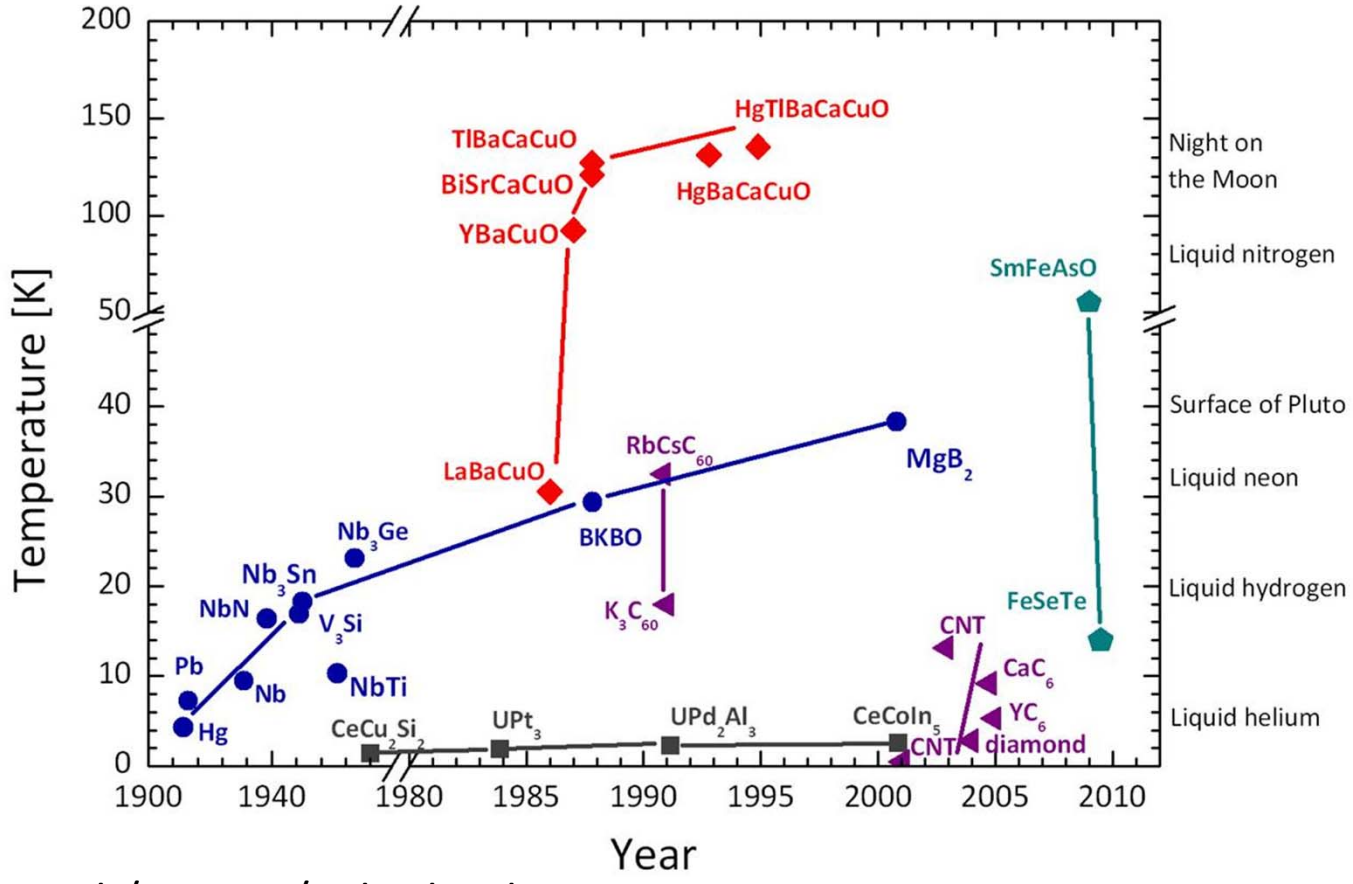
- BCS Theory (1957): Superconducting current is a superfluid of pairs of electrons interacting through an exchange of phonons (Cooper pairs).



http://www.quarkology.com/12-physics/94-ideas-implementation/94C-superconductors.html

Achieving higher T_c

- Unconventional, non-BCS superconductivity discovered in the 1980s, LaBaCuO with Tc = 35 K (1986)



http://dpmc.unige.ch/gr_gaps/index.html

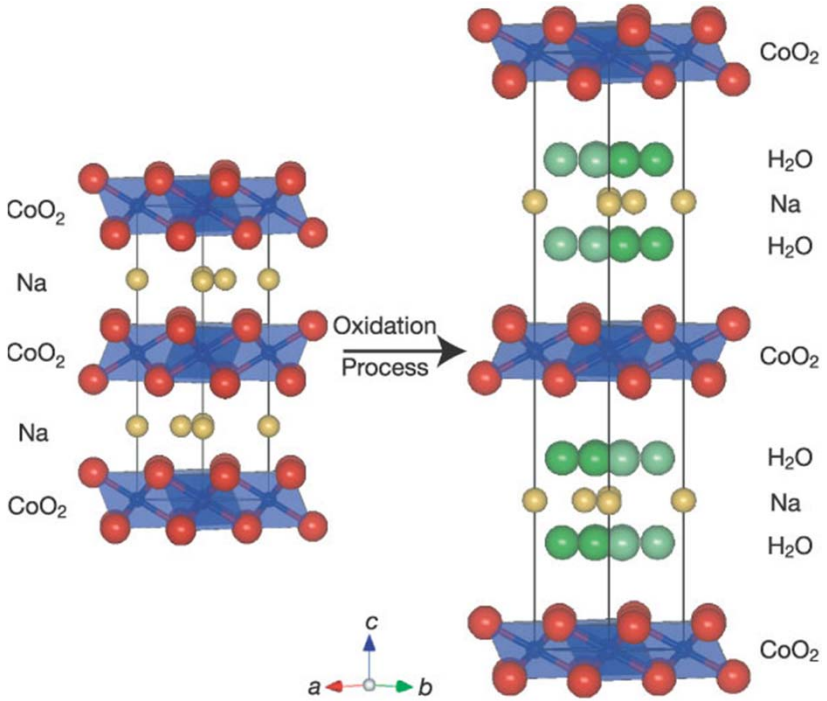
Superconductivity in CuO_2 layers: Motivation

- Discovery of high-T_c superconducting copper oxides (which have a similar layered 2D structure) has prompted a search for the same behavior in other layered metal oxides with 3d transition metals like Co and Ni.

- d-wave SCs : Antiferromagnetic spin fluctuation in a doped system causes pairing, with wave functions having a $d_{x^2-y^2}$ symmetry.

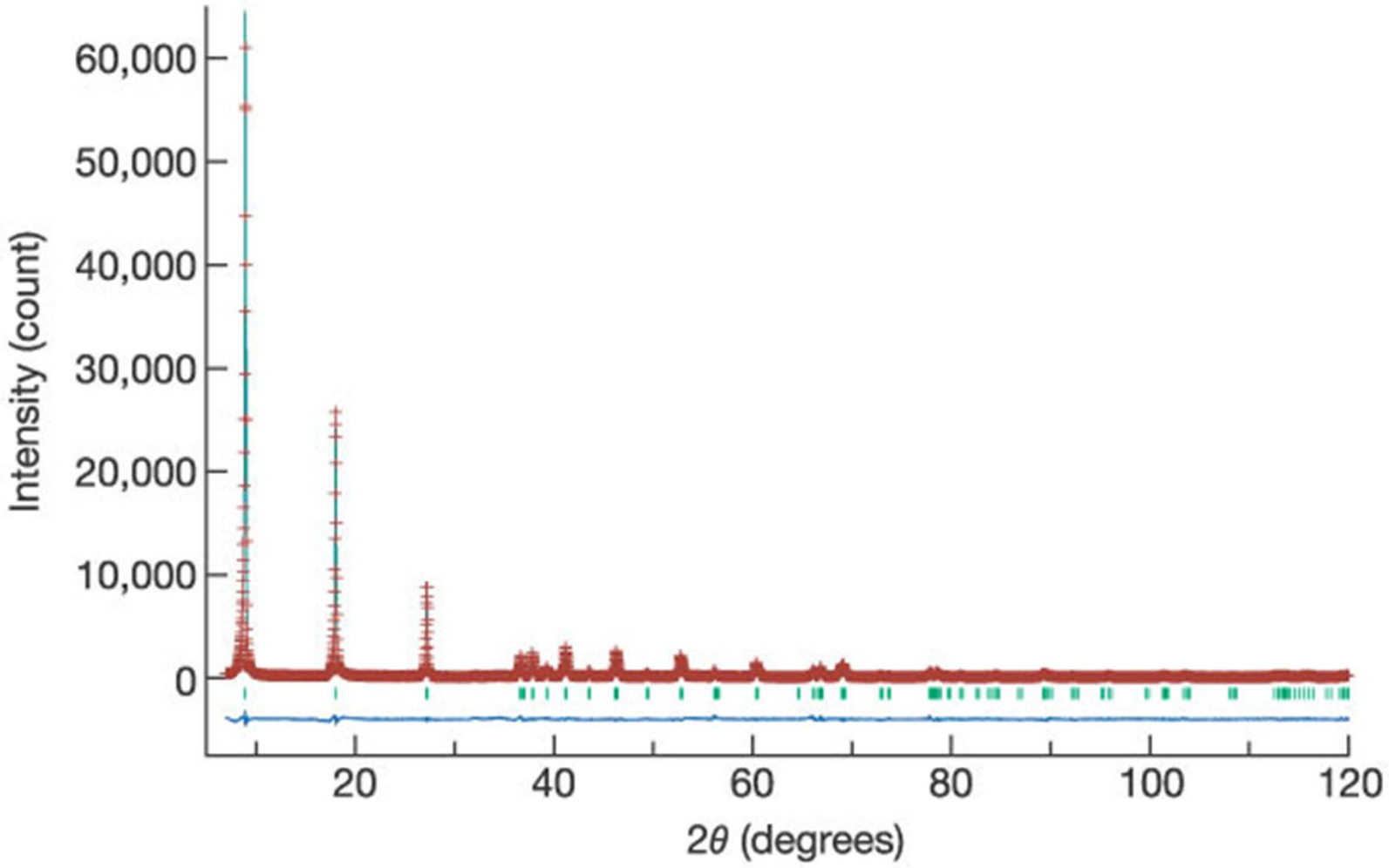
Superconductivity in CoO_2 layers: Growth and Structure

- $Na_xCoO_2yH_2O$ sample obtained through chemical oxidation process from $Na_{0.7}CoO_2$
- Intercalation of water molecules occurs in addition to the deintercalation of Na^+ ions



Nature **422**, 53 (2003)

Determining the Structure: XRD/Rietveld analysis

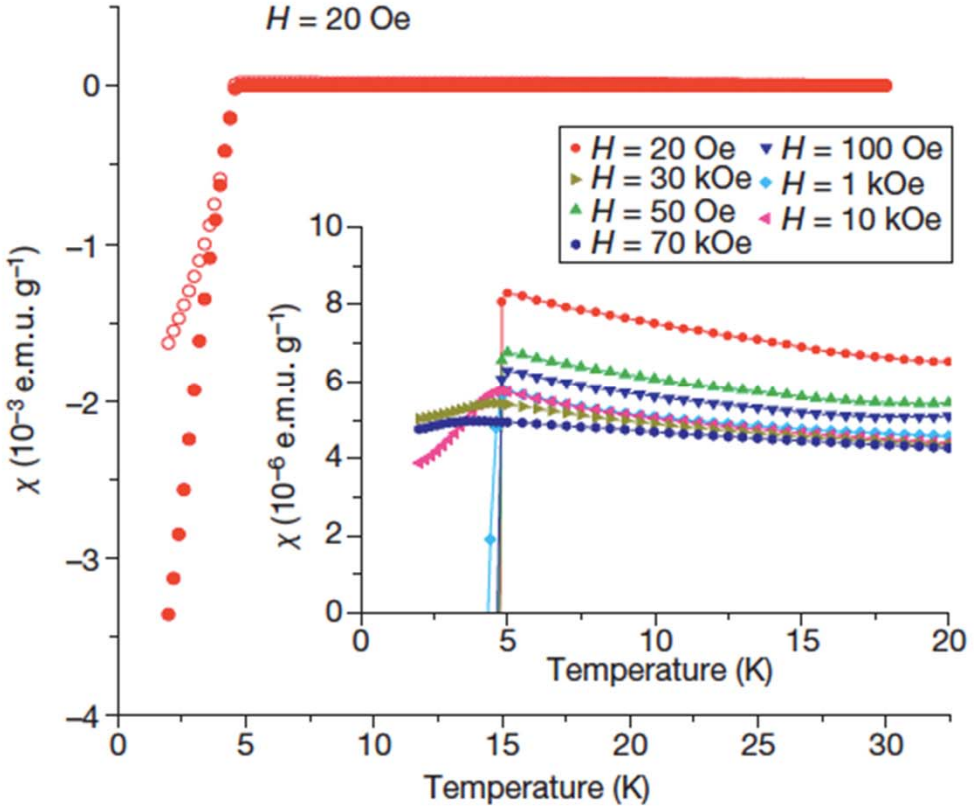


Nature **422**, 53 (2003)

Susceptibility Measurements

- In a measurement under external magnetic field H=20 Oe a steep decrease of susceptibility was observed at about 5K both in zero-field cooling and field cooling processes

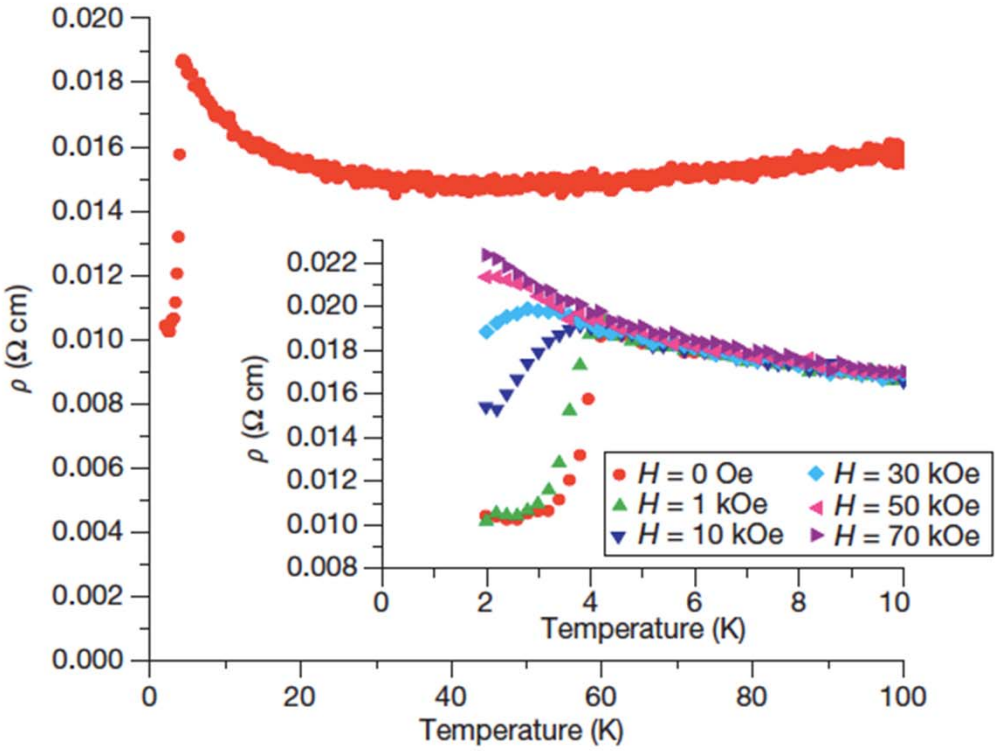
- Magnetization measurement Indicates this material is a Type II superconductor with a lower critical field of 100 Oe



Nature **422**, 53 (2003)

Resistivity Measurements

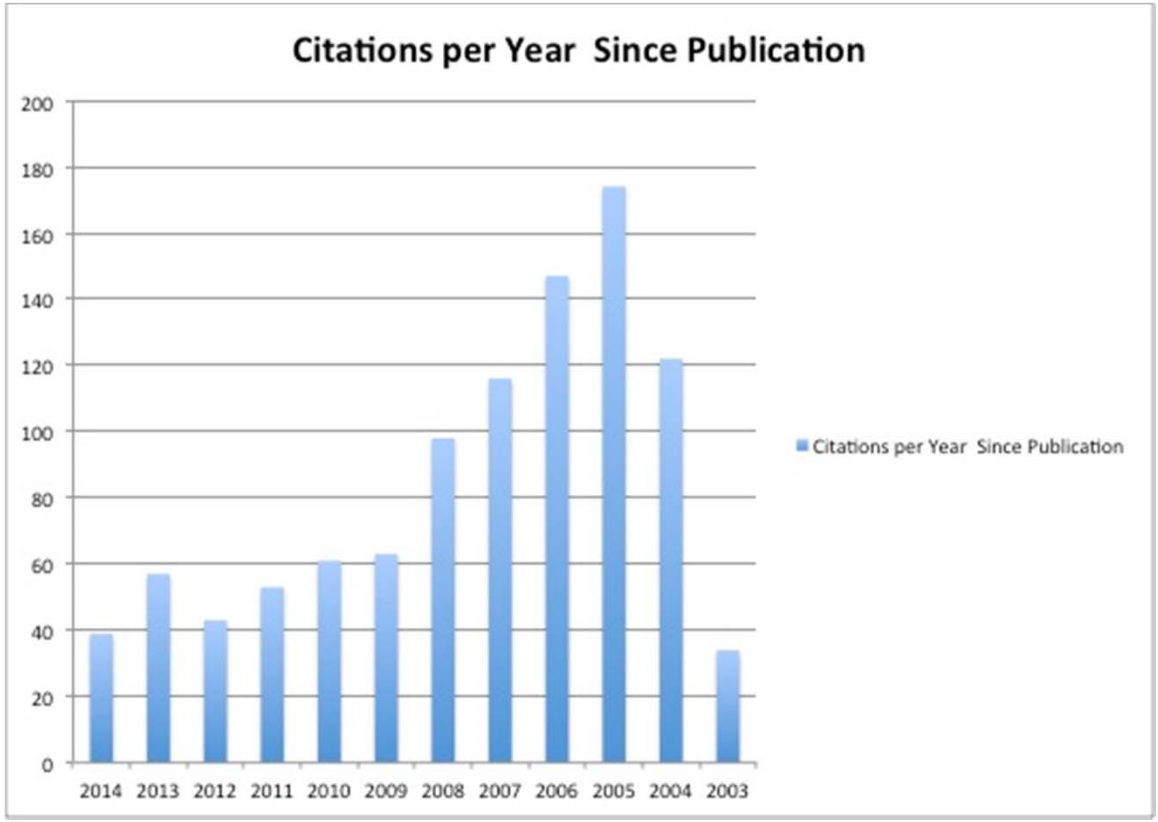
- A sharp decrease of resistivity was observed at around 4K
- Discrepancy in T_c compared to the susceptibility measurement due to variation in water content of each sample
- Experimentally challenging measurement due to the nature of the specimen



Nature **422**, 53 (2003)

Citation Analysis

- This study of $Na_xCoO_2yH_2O$ was cited more than 1100 times
- The same material was studied in depth by both theoretical and experimental works.



Subsequent Model for SC in $NaCoO_2$

- G. Baskaran, Phys. Rev. Lett. **91**, 097003 (2003)
- Resonating Valence bond Theory developed by P. W. Anderson and G. Baskaran.

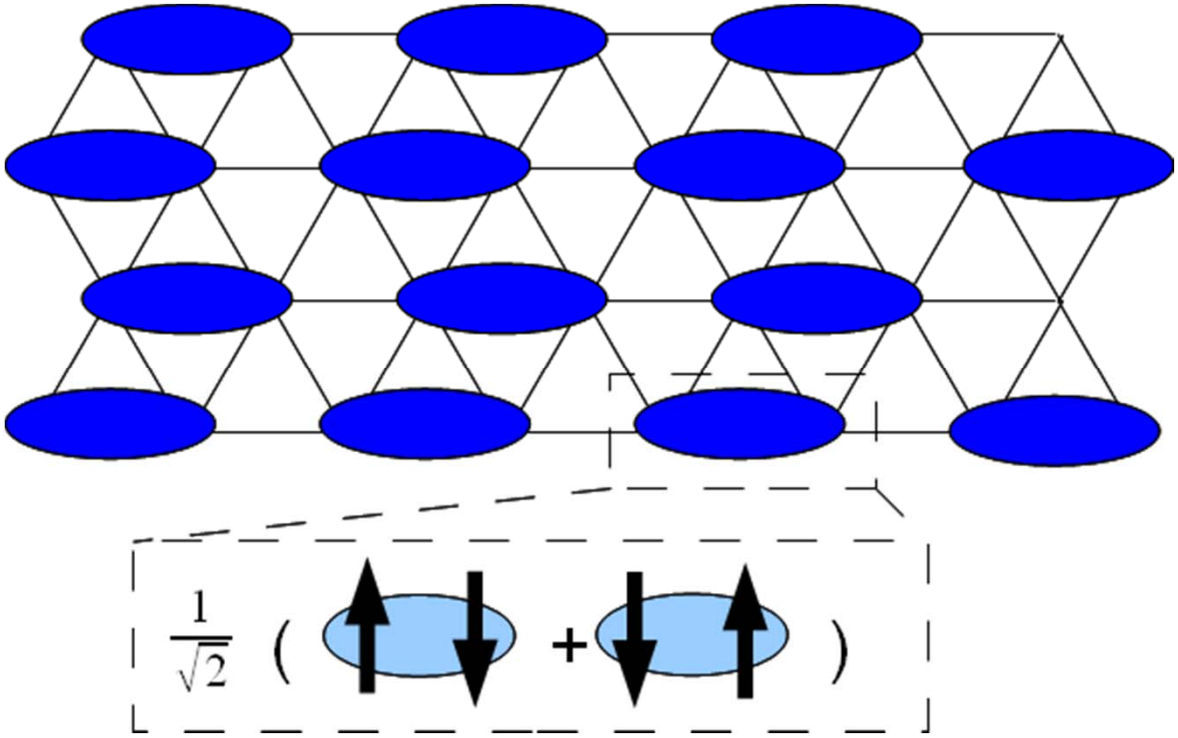


Fig. from [6]

Superconductivity in CoO_2layers: Critical Assessment

- H_20 is the most probable candidate for the new molecule that enters the structure.
- Possible trace amount of impurities.
- it was impossible to prepare a tightly sintered ceramic specimen for the resistivity measurement.
- Resistivity T_c is lower than T_c from magnetic measurements. Possibly due to varying water content
- Nothing mentioned about the triangular lattice with magnetically frustrated geometry in contrast to the square lattice of the CuO_2 plane

Thank You

http://www.jobinterviewtools.com/blog/wp-content/uploads/2010/01/dreamstimemedium_19473030-300x300.jpg