

Investigating High Temperature Cuprate Superconductors by Scanning Tunneling Microscopy

Tejas Parasram Singar

Department of Quantum Matter Physics

University of Geneva, Switzerland

tejas.singar@unige.ch

Young Researchers Day

September 16, 2022

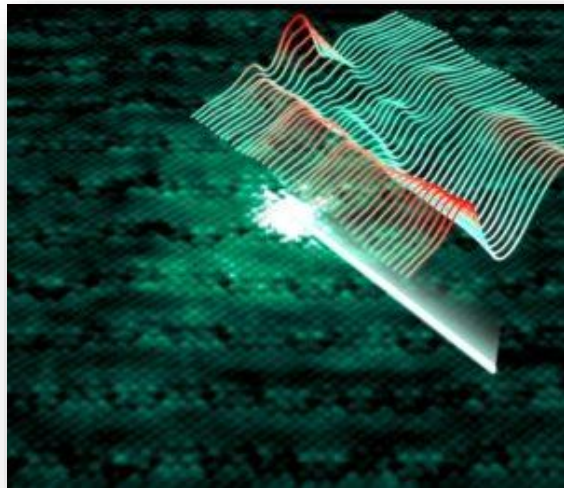
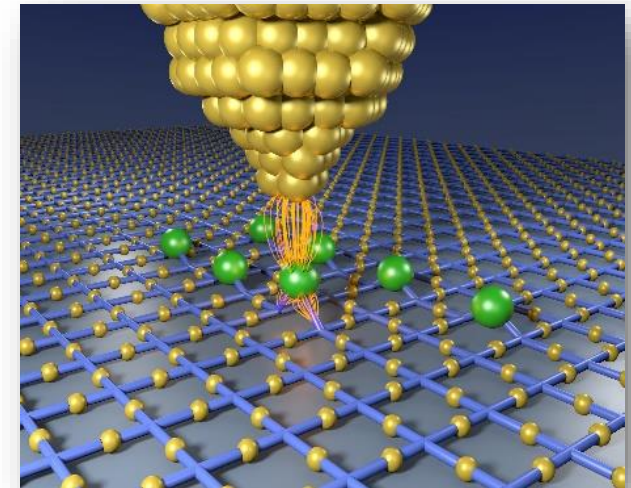


Illustration: X. Ravinet, Scientify



Credits: CFEL

Acknowledgements

► STM team Geneva

- Prof. C. Renner
- Dr. I. Maggio-Aprile
- Dr. A. Scarfato
- Dr. Á Pásztor
- Dr. L. Sun
- V. Pasquier
- T. Singar
- A. Ørsted
- I. Pushkarna
- *G. Manfrini, A. Guipet, L. Stark*

► Single Crystals

- G. Gu (Brookhaven)

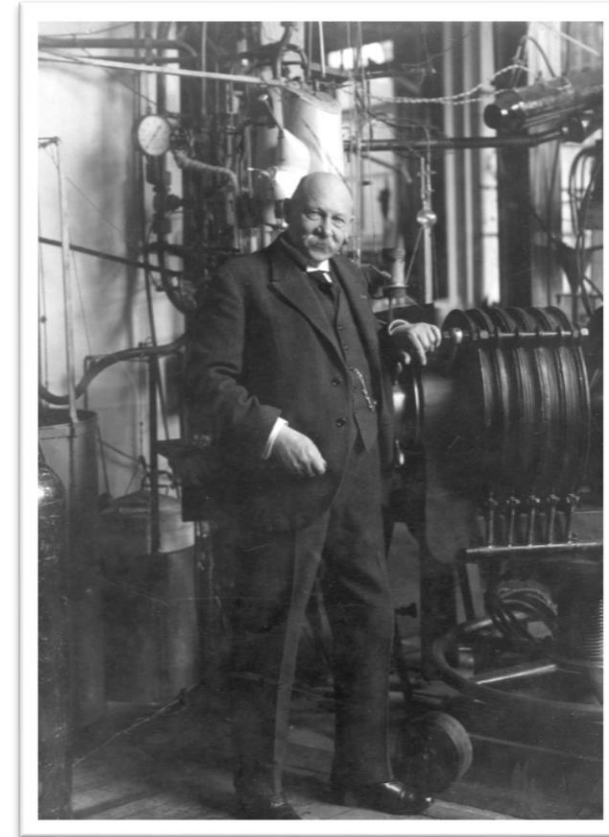
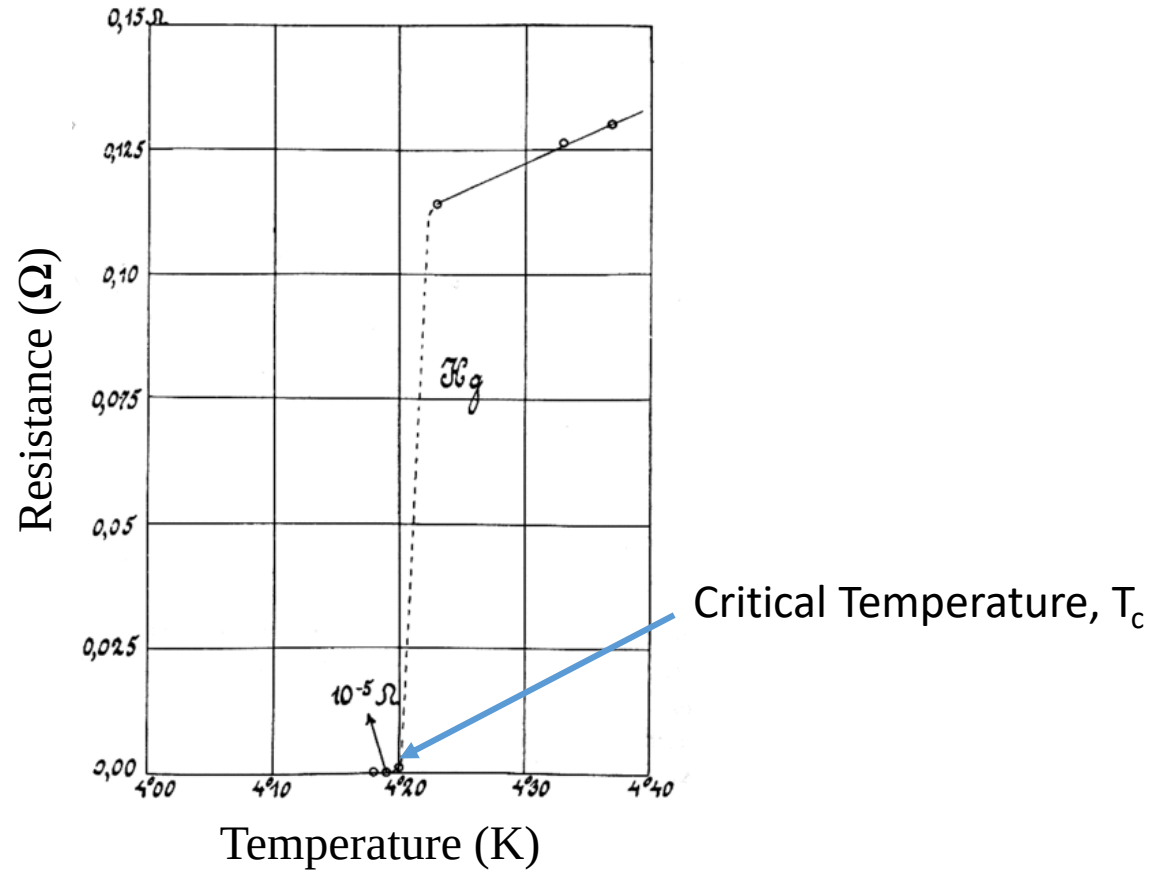
► Theory

- Ch. Berthod (UniGE)



dqmp.unige.ch/renner/

- Sudden drop in resistivity below a certain critical temperature, T_c



Heike Kamerlingh Onnes (1911)

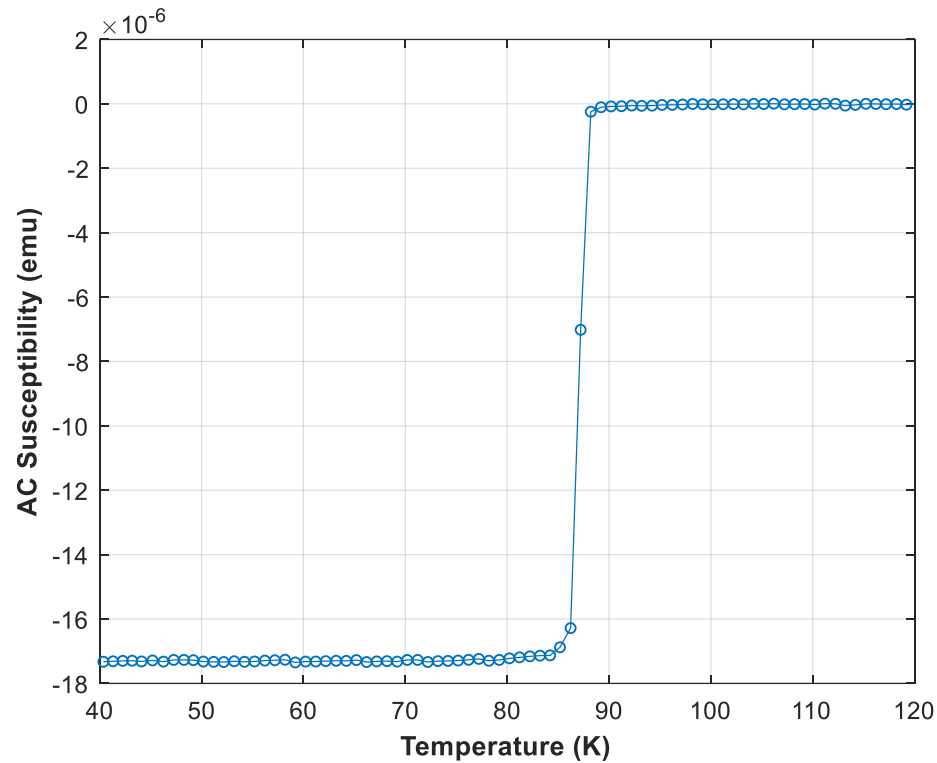


*H. Kamerlingh Onnes, Commun. Phys. Lab. Univ.
Leiden. Suppl. 29 (Nov. 1911)*

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➤ Perfect diamagnetism state

Optimally doped $\text{Bi}_2\text{Sr}_2\text{Ca}_1\text{Cu}_2\text{O}_{8+\delta}$ ($T_c \approx 88 \text{ K}$)



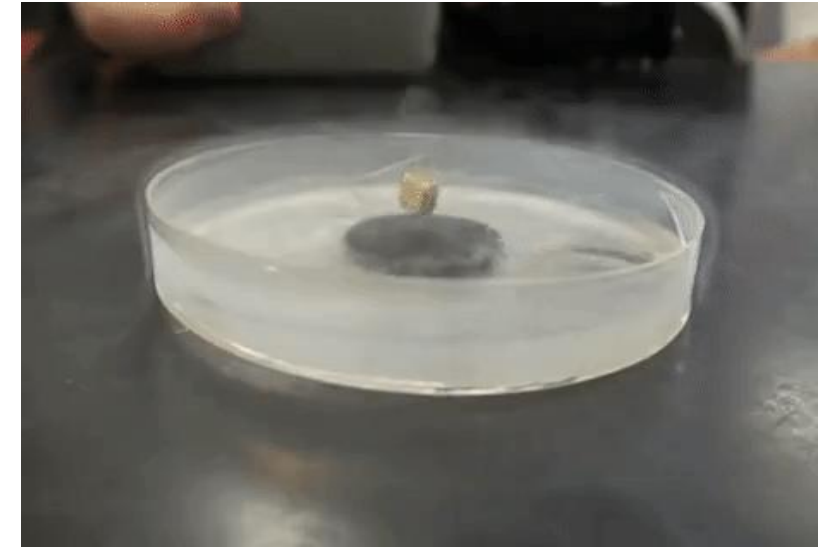
“Meissner-Ochsenfeld effect”



Walther Meissner



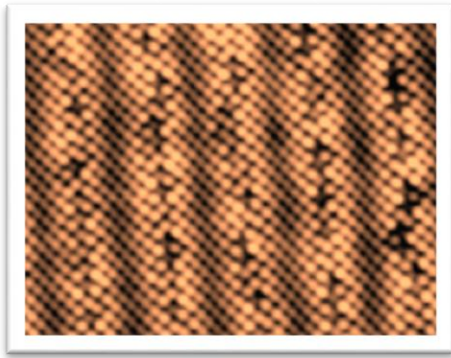
Robert Ochsenfeld



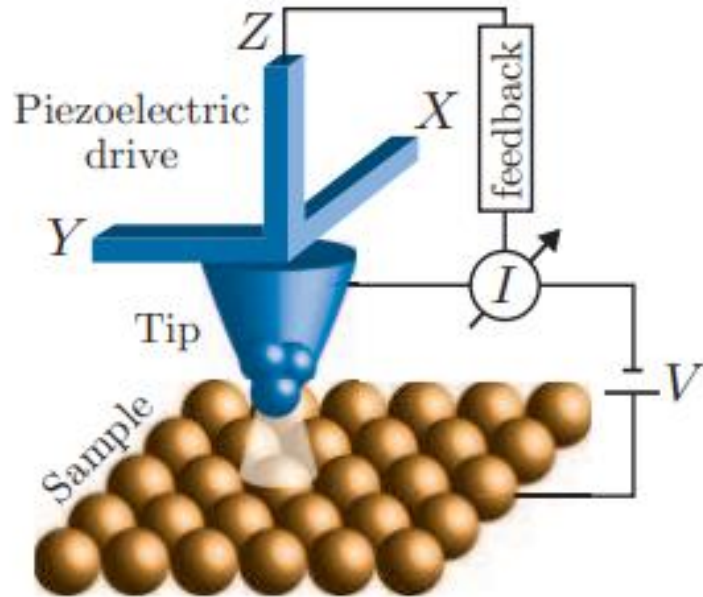
Credit: Youtube.com



Scanning Tunneling Microscope (STM) in a nutshell

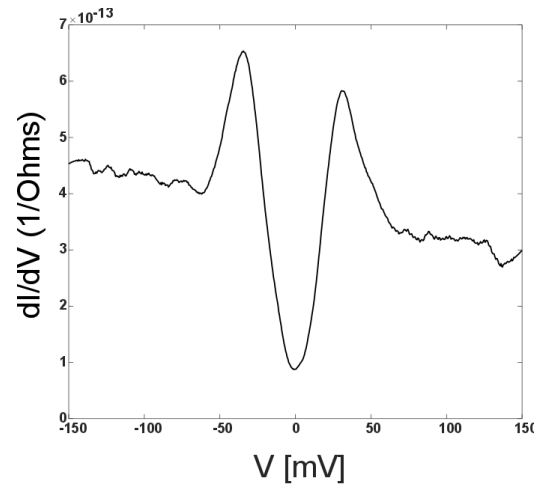
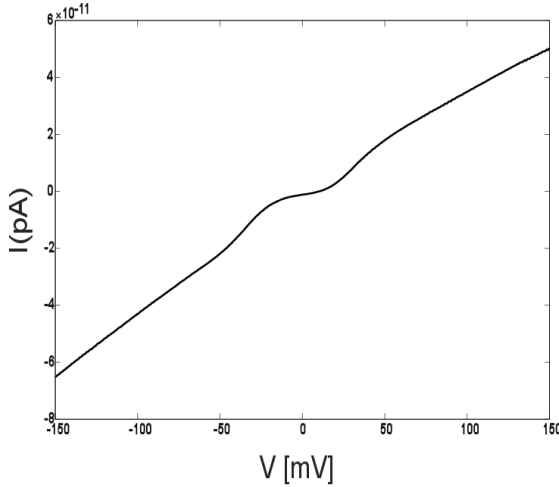


Bi-2212



Schematic of STM setup
Fischer et al. (2007)

$\text{Bi}_2\text{Sr}_2\text{Ca}_1\text{Cu}_2\text{O}_{8+\delta}$ (Overdoped, 52 K)



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Binnig & Rohrer (1982)

Credit: IBM research/Science photo library

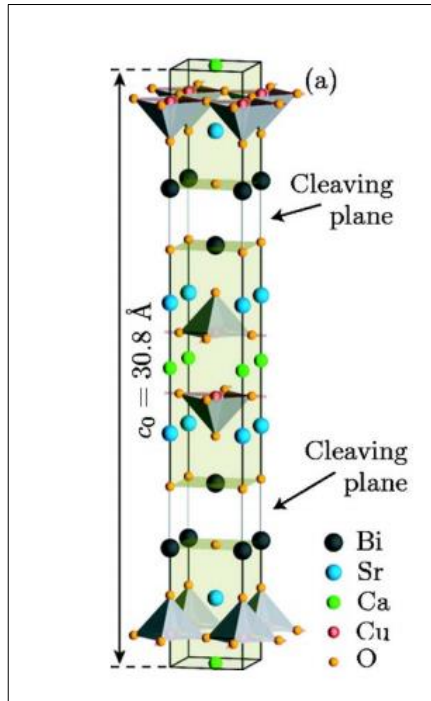
$$\frac{dI_t}{dV}(\mathbf{r}, E) \propto \int d\omega \{-f'(\omega - |e|V)\} \mathbf{N}_s(\mathbf{r}, \omega)$$

Local Density of States (LDOS) of the sample



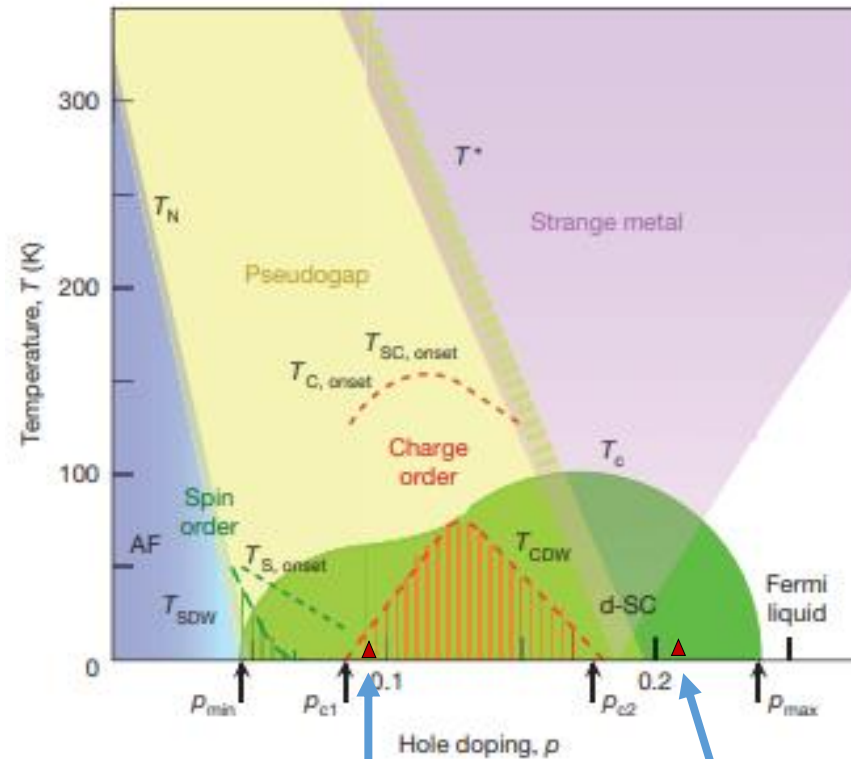
Daniel Cattermole, Getty Images

Bi-2212 Crystal structure



Fischer et al. *Reviews of Modern Physics*, 79(1):353-419, 2007

Bi-2212 Phase Diagram



Underdoped

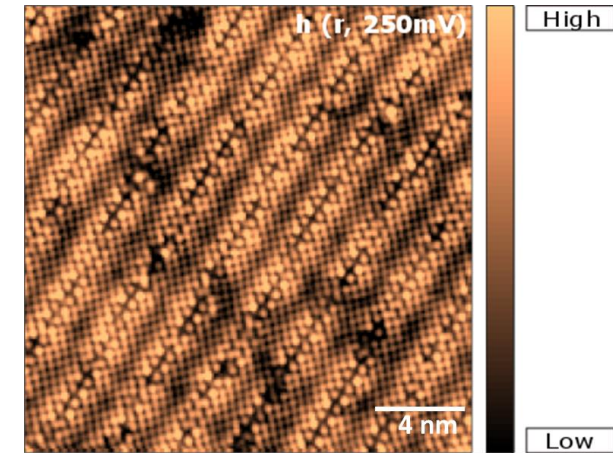
Overdoped

B. Keimer et al. *Nature*, 518(7538):179–186 (2015)

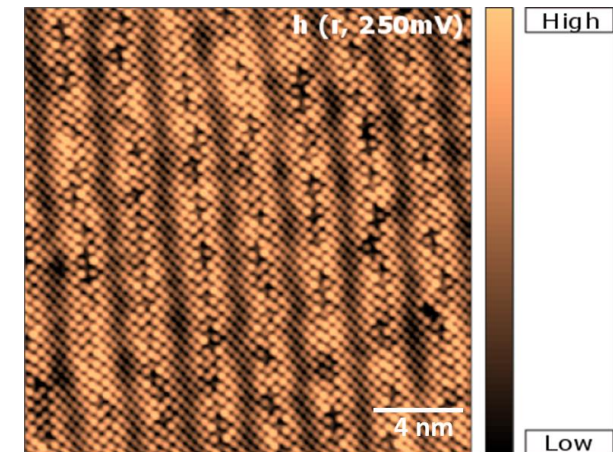
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➤ Imaging individual atoms

Heavily underdoped Bi-2212 ($T_c \approx 52 \text{ K}$)



Heavily overdoped Bi-2212 ($T_c \approx 52 \text{ K}$)

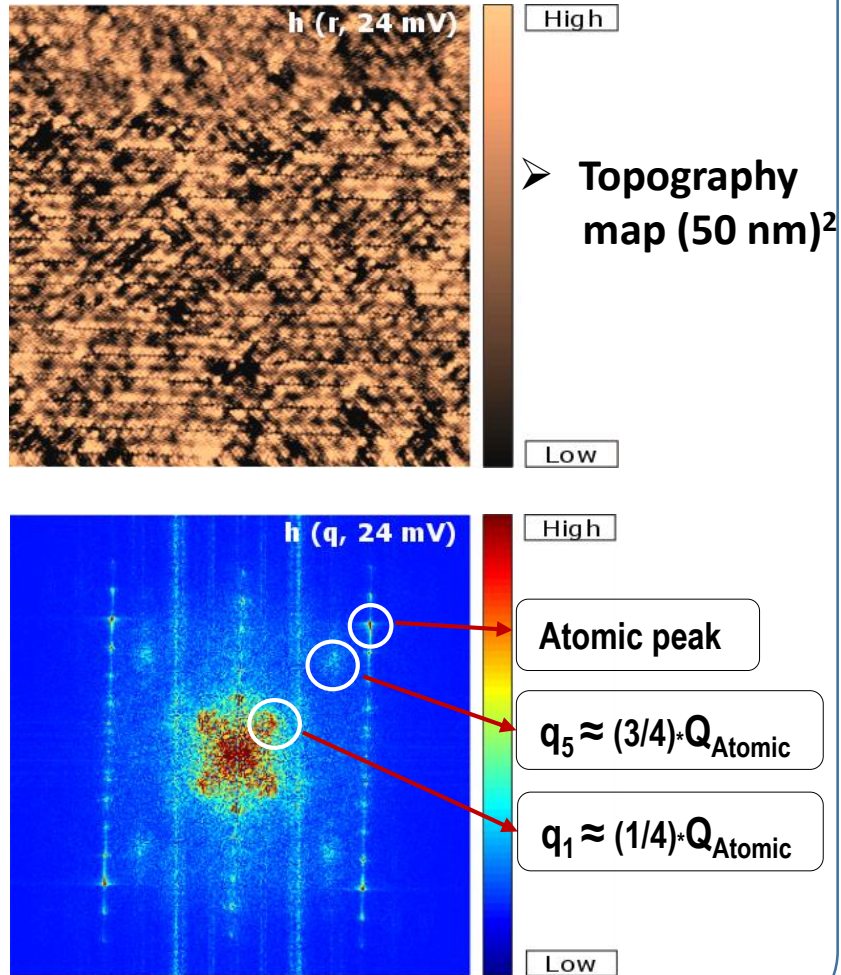


Charge Density Waves (CDW)

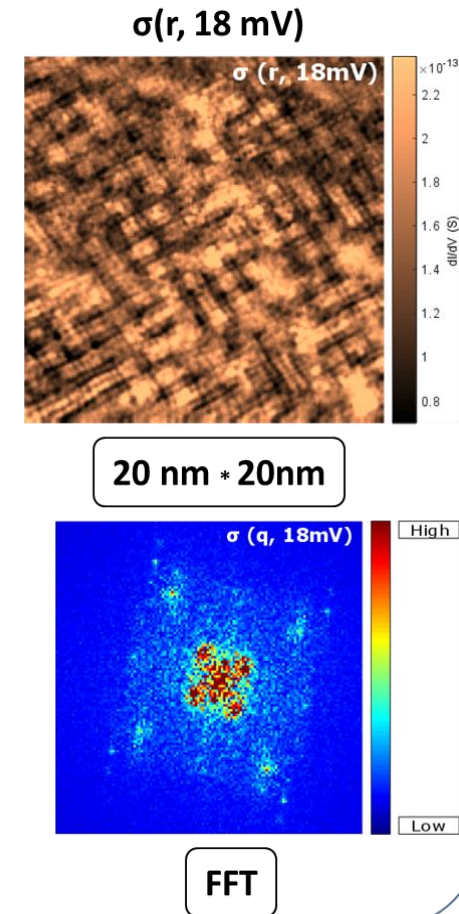
Quasi-Particle Interference (QPI)

Magnetic Vortices in Overdoped Bi-2212

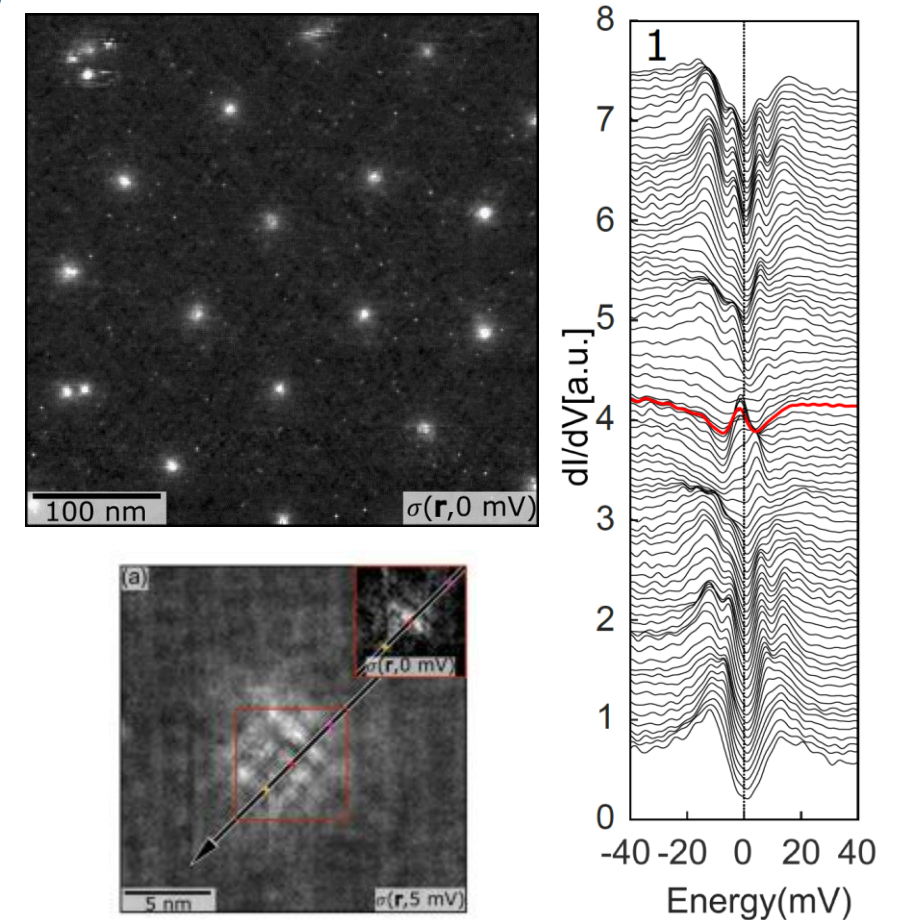
Heavily underdoped Bi-2212 ($T_c \approx 52$ K)



Periodic patterns in dI/dV maps in Bi2212



Heavily overdoped Bi-2212 ($T_c \approx 52$ K)



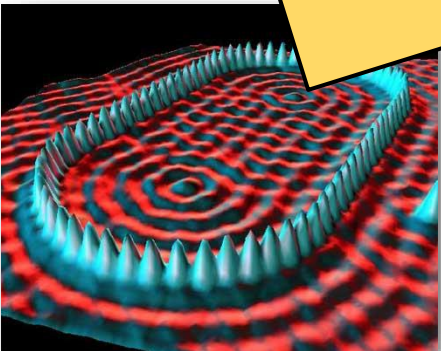
Gazdic et al. Phys. Rev. X 11, 031040, 2021

➤ A peak into the Nano world:

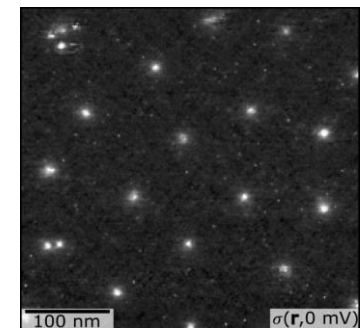
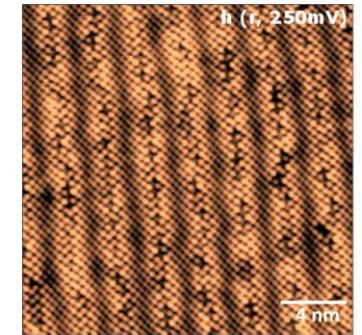
- Charge ordering in Bi-2212 system
 - Heavily underdoped Bi-2212
 - Heavily overdoped Bi-2212
- Exploiting different STM acquisition methods to study charge modulations
- Role of the hole doping on the underlying physics
- STM vortex



Thank you for your attention !!



Crommie, Lutz & Eigler; IBM (1993)



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