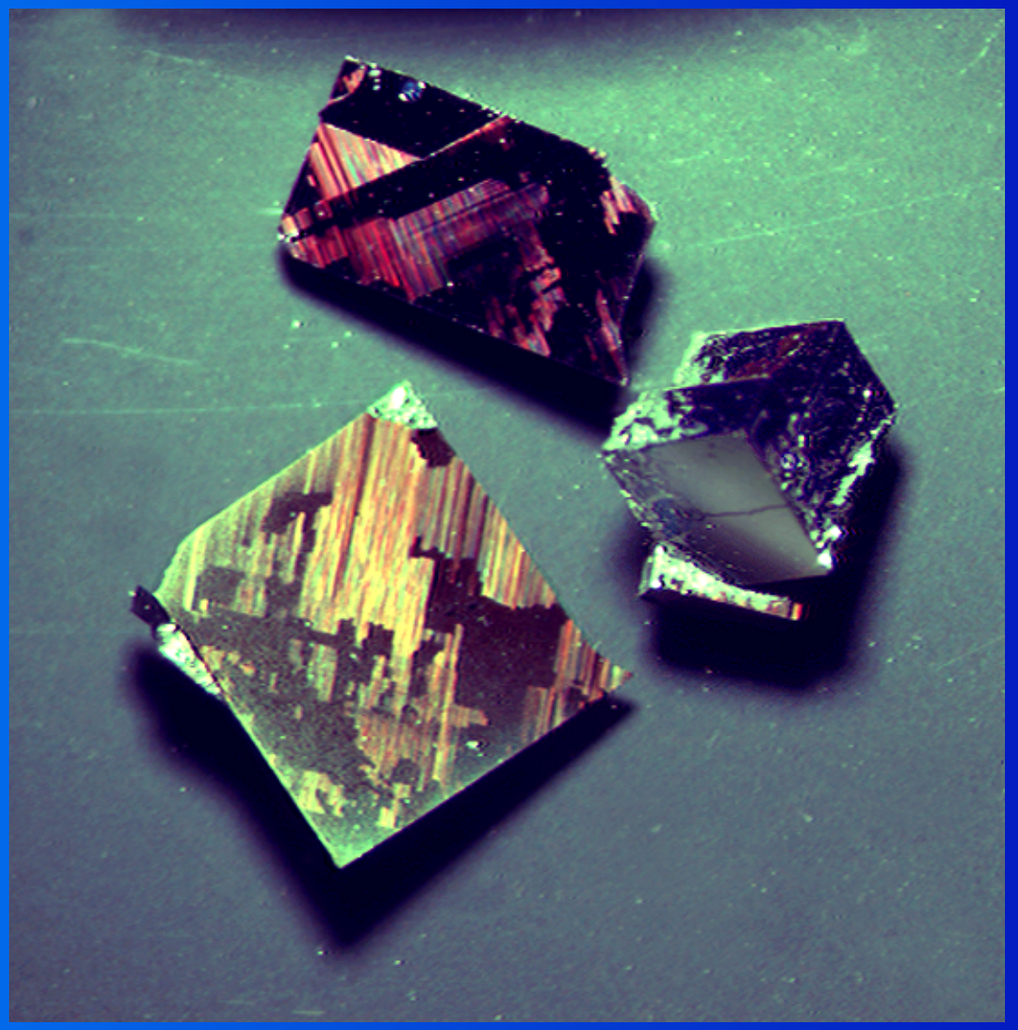
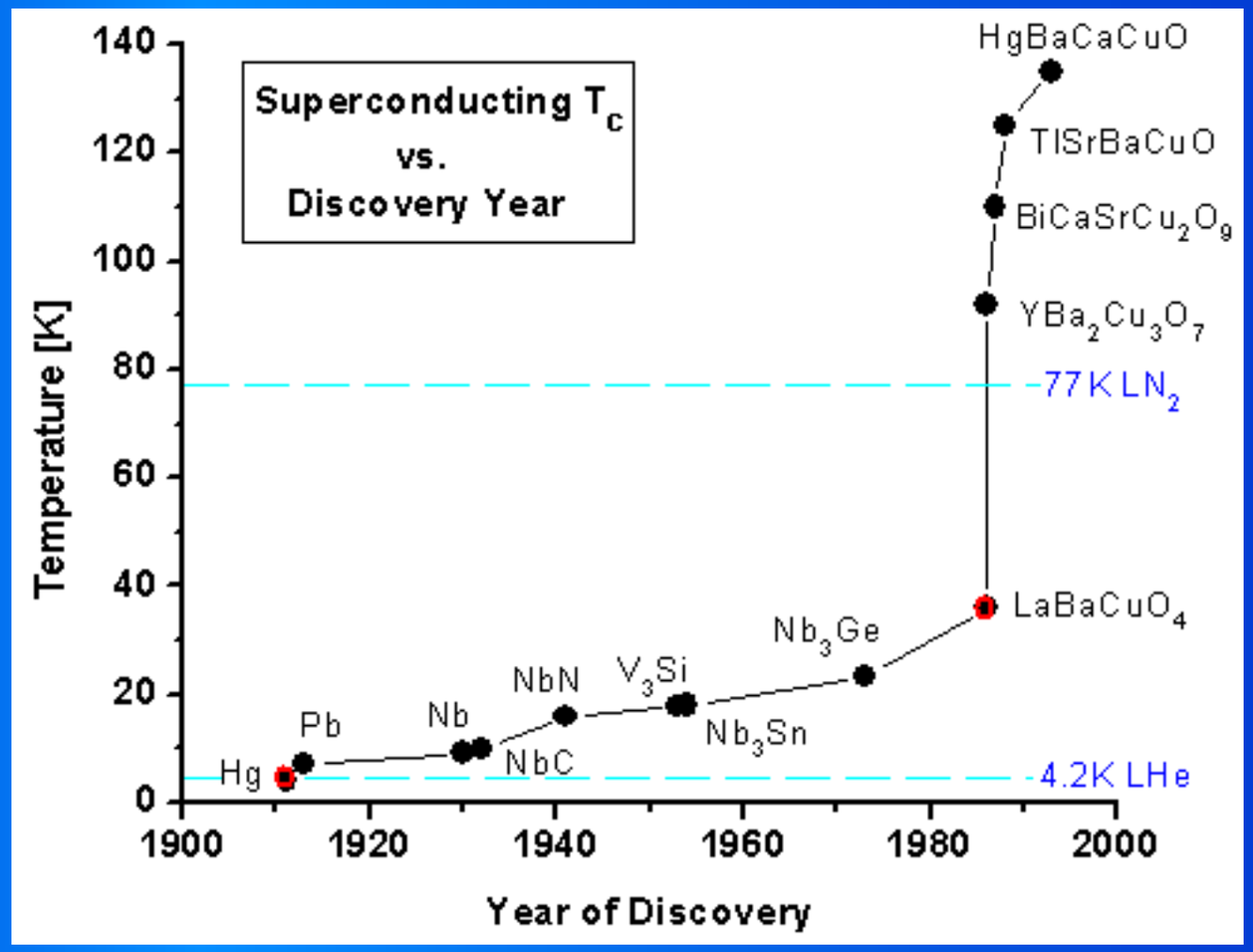
What is Exotic about High Temperature Superconductors?



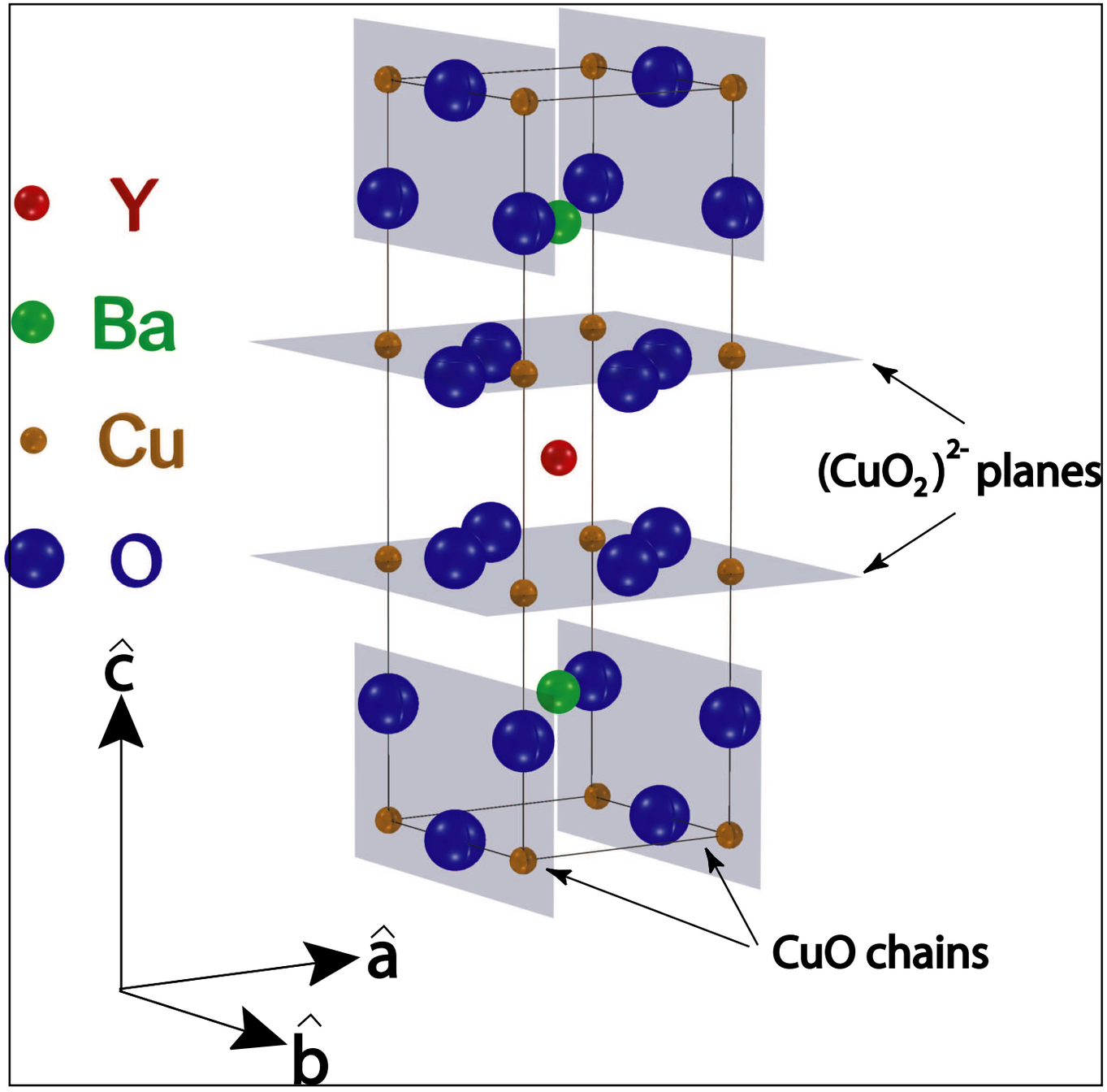
D. Bonn - TRIUMF 2006

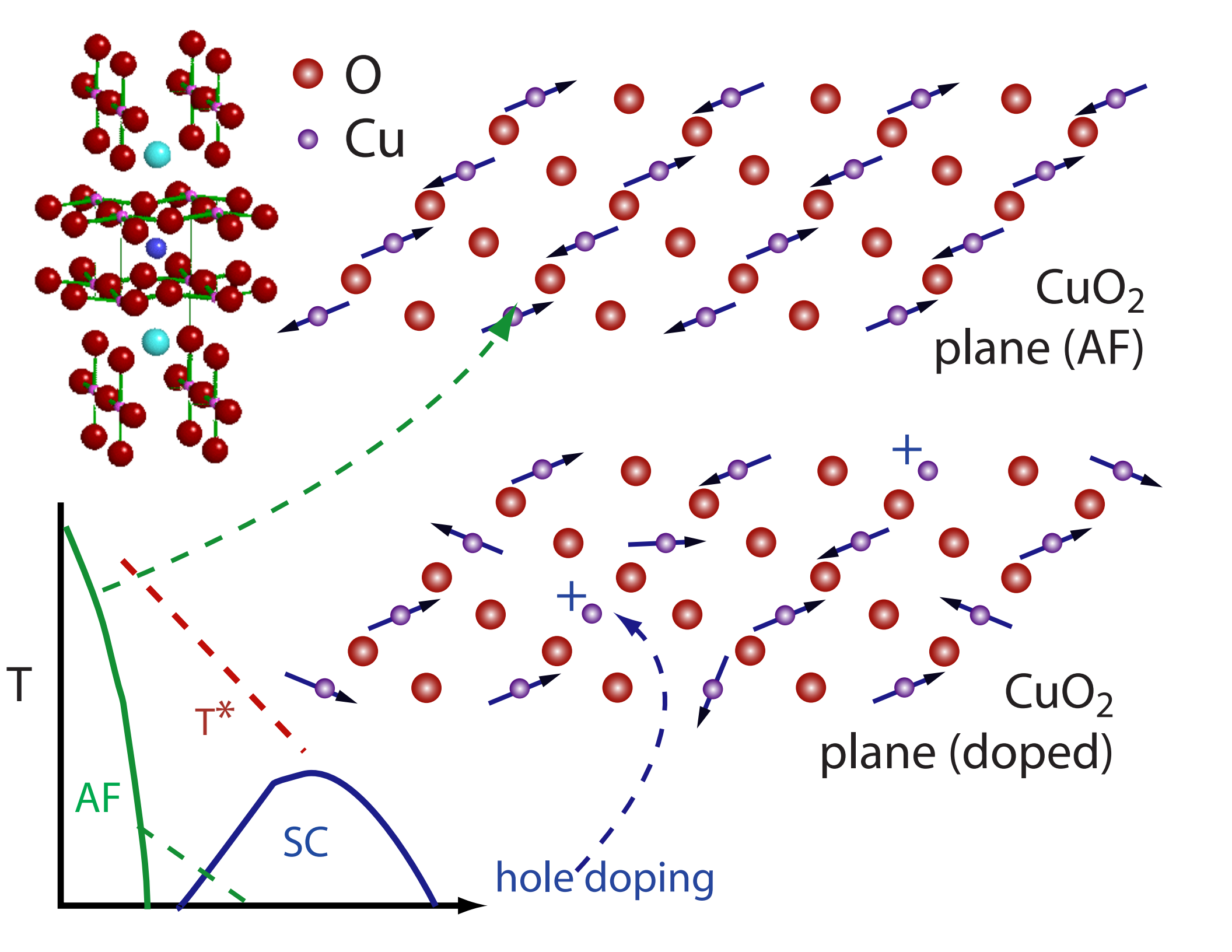
Transition temperature

The leap up to a very different range of superconducting transition temperature was the first sign that new physics had been discovered.



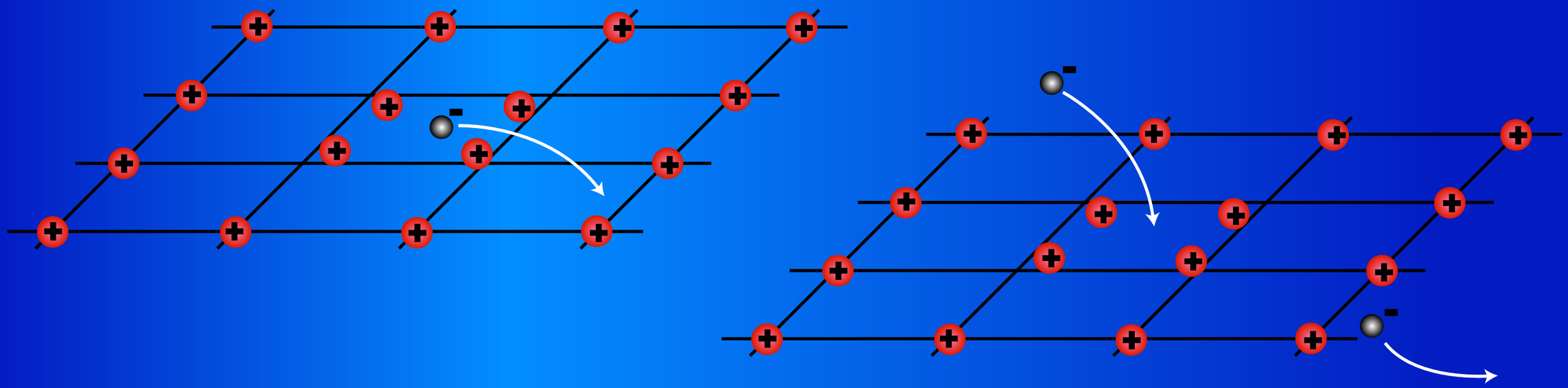
$YBa_2Cu_3O_{7-x}$ - first compound with $T_c > 77$ K




O
Cu
CuO_2
plane (AF)
CuO_2
plane (doped)
T
T^*
AF
SC
hole doping

'Conventional' Superconducting State

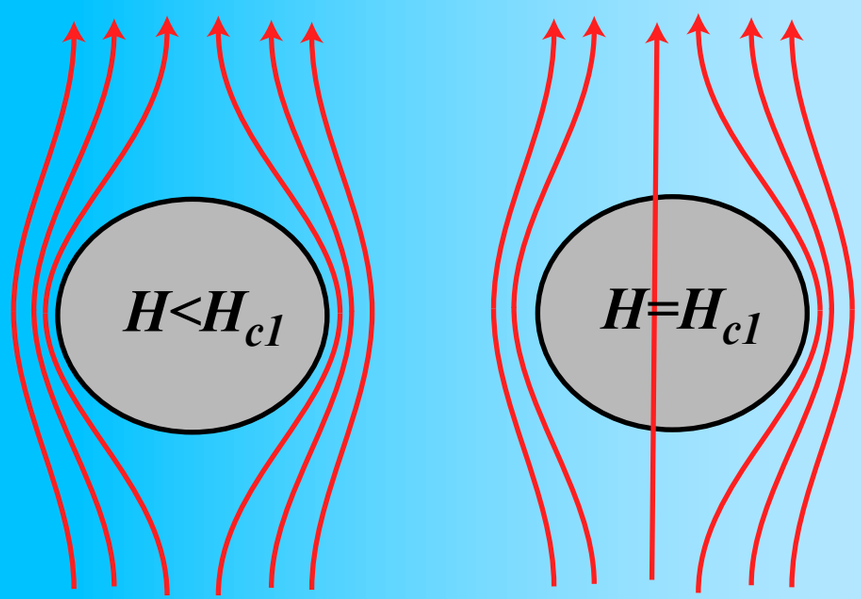
The superconducting state consists of pairs of electrons, bound by interaction with the lattice.



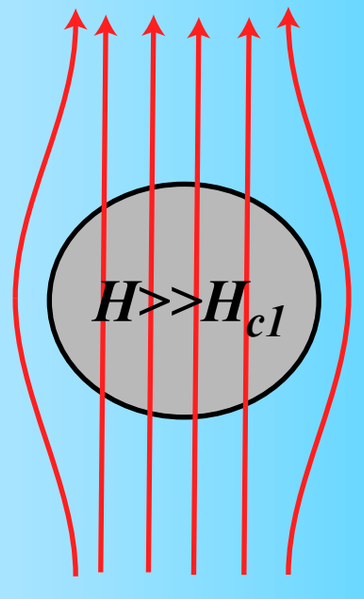
The pairs are condensed into a single quantum mechanical wavefunction denoted by a complex order parameter

$$\Delta e^{i\Phi}$$

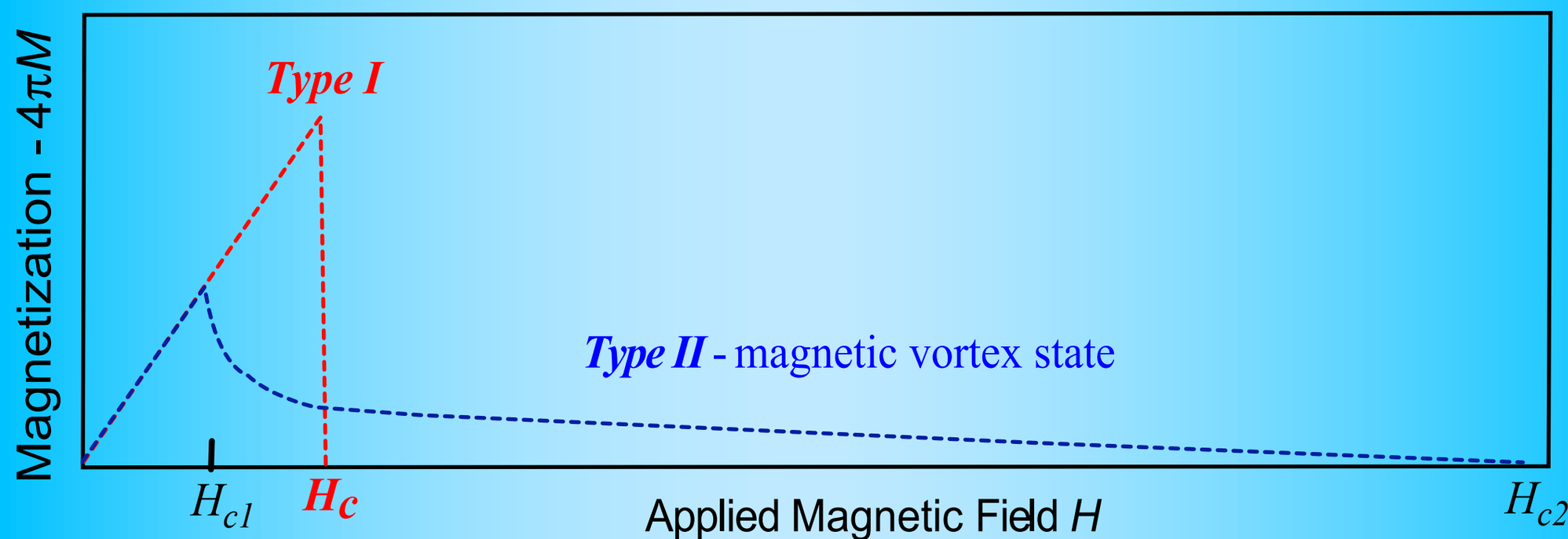
Magnetic Fields in Type II Superconductors



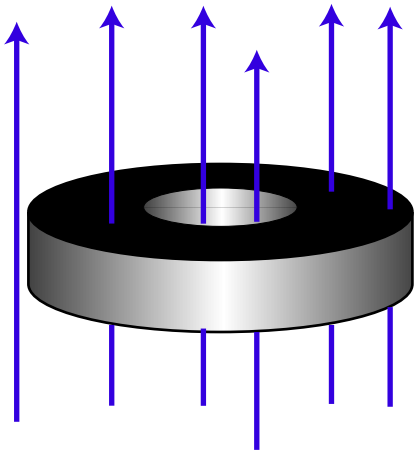
Meissner State



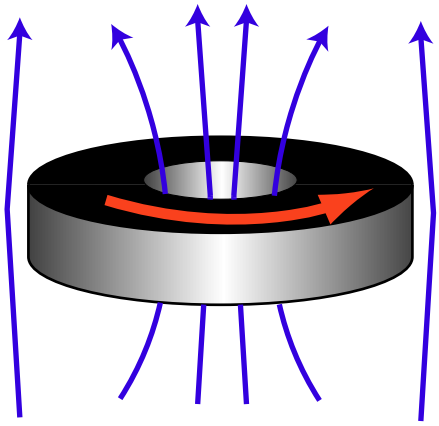
Vortex State



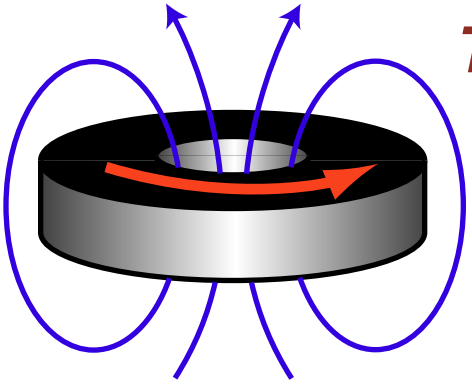
Flux Quantization in a Superconducting Ring



$T > T_c$ - applied magnetic field penetrates sample

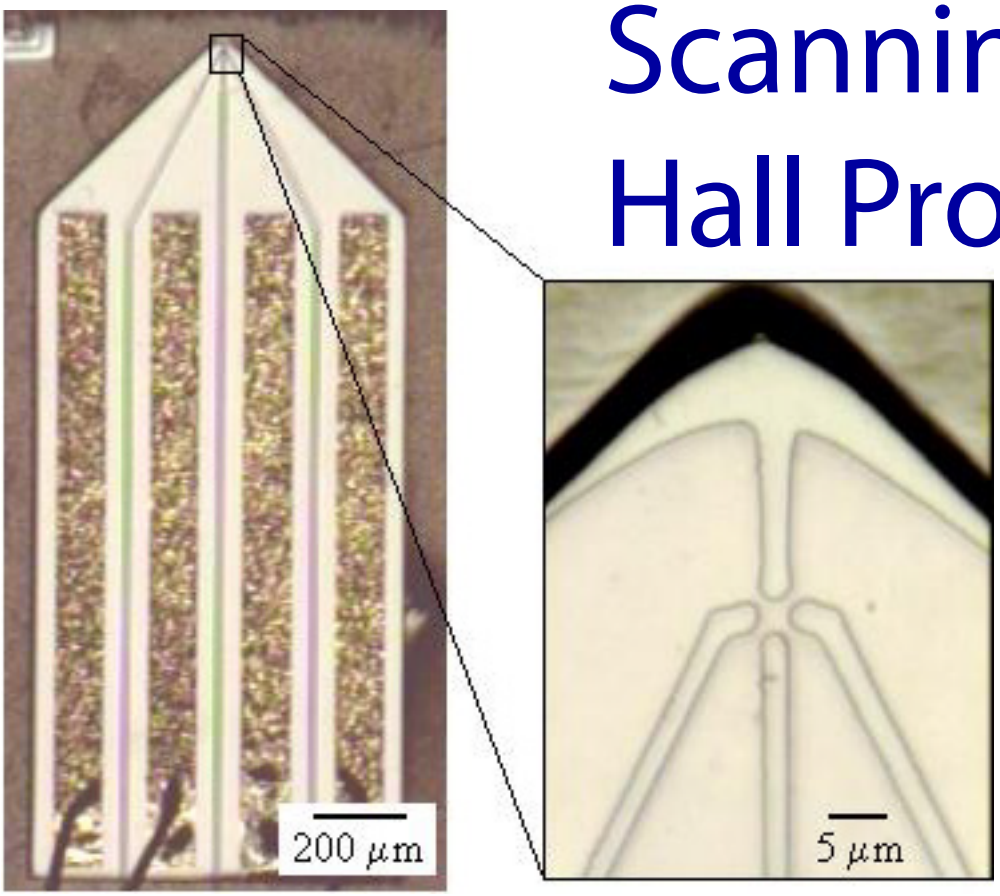


$T < T_c$ - when cooled below Tc the magnetic flux is expelled and any flux trapped in the ring is quantized in units of h/2e

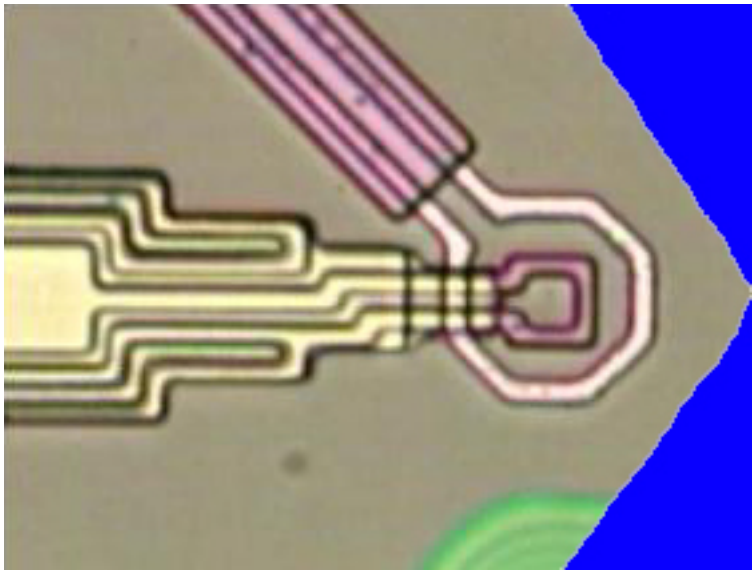


$T < T_c$ - flux quantum remains trapped even when the external field is nulled

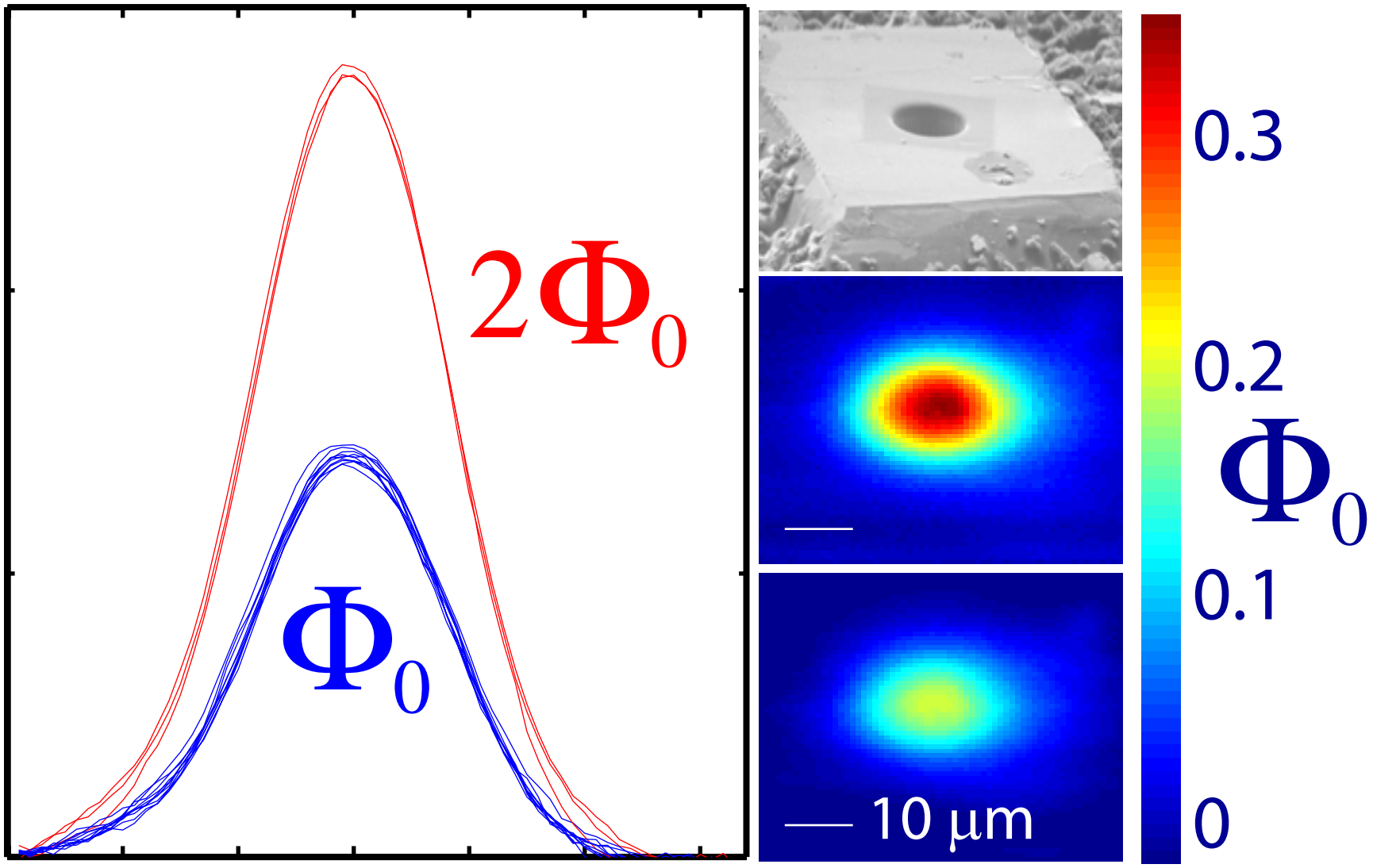
Scanning Hall Probe



Scanning SQUID

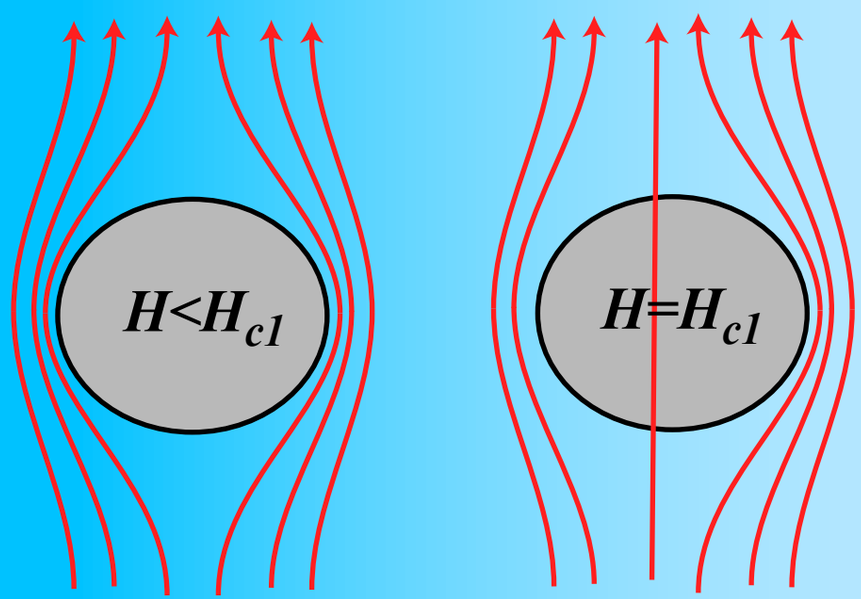


Flux quanta in a YBCO ring with $T_c = 6.0K$

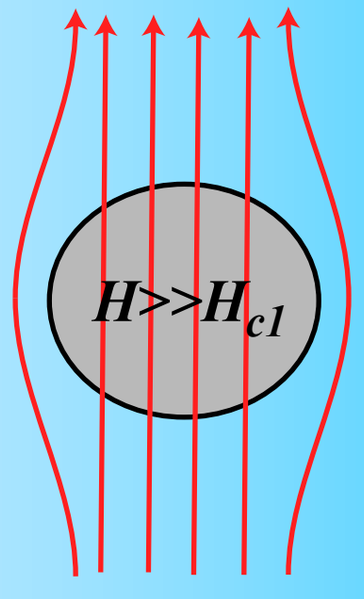


Flux in YBCO rings is quantised in units of $\Phi_0 = hc/2e$ ⇨ Cooper pairs

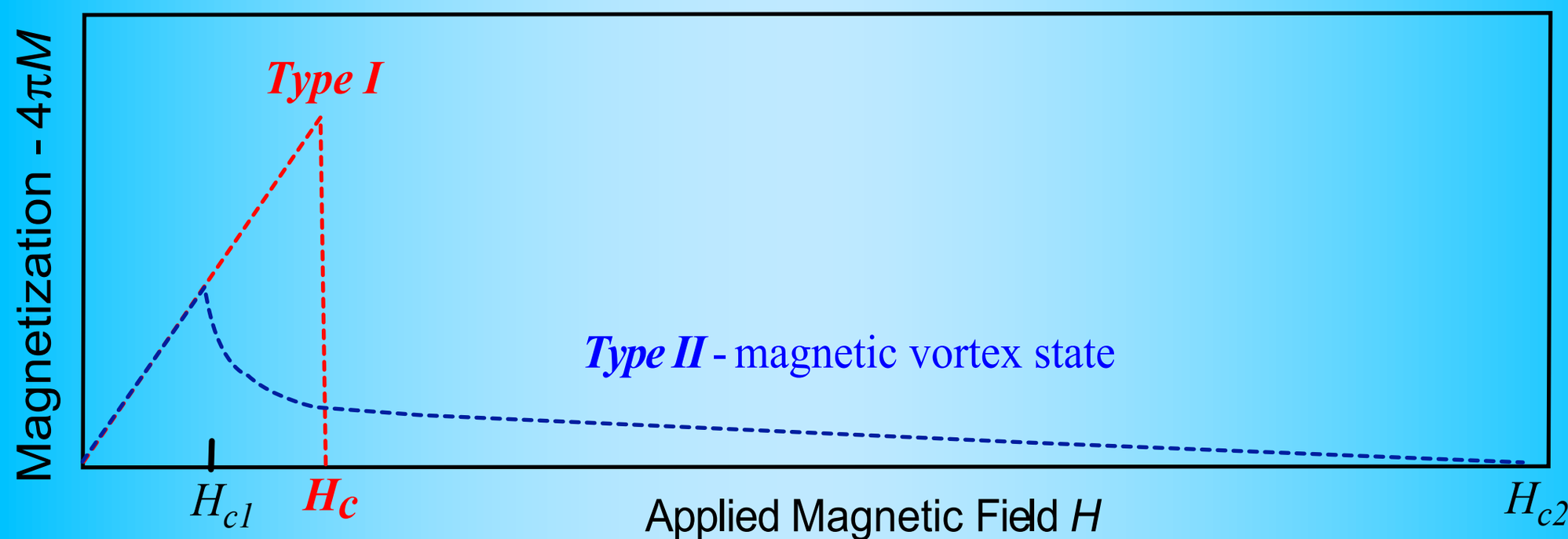
Magnetic Fields in Type II Superconductors



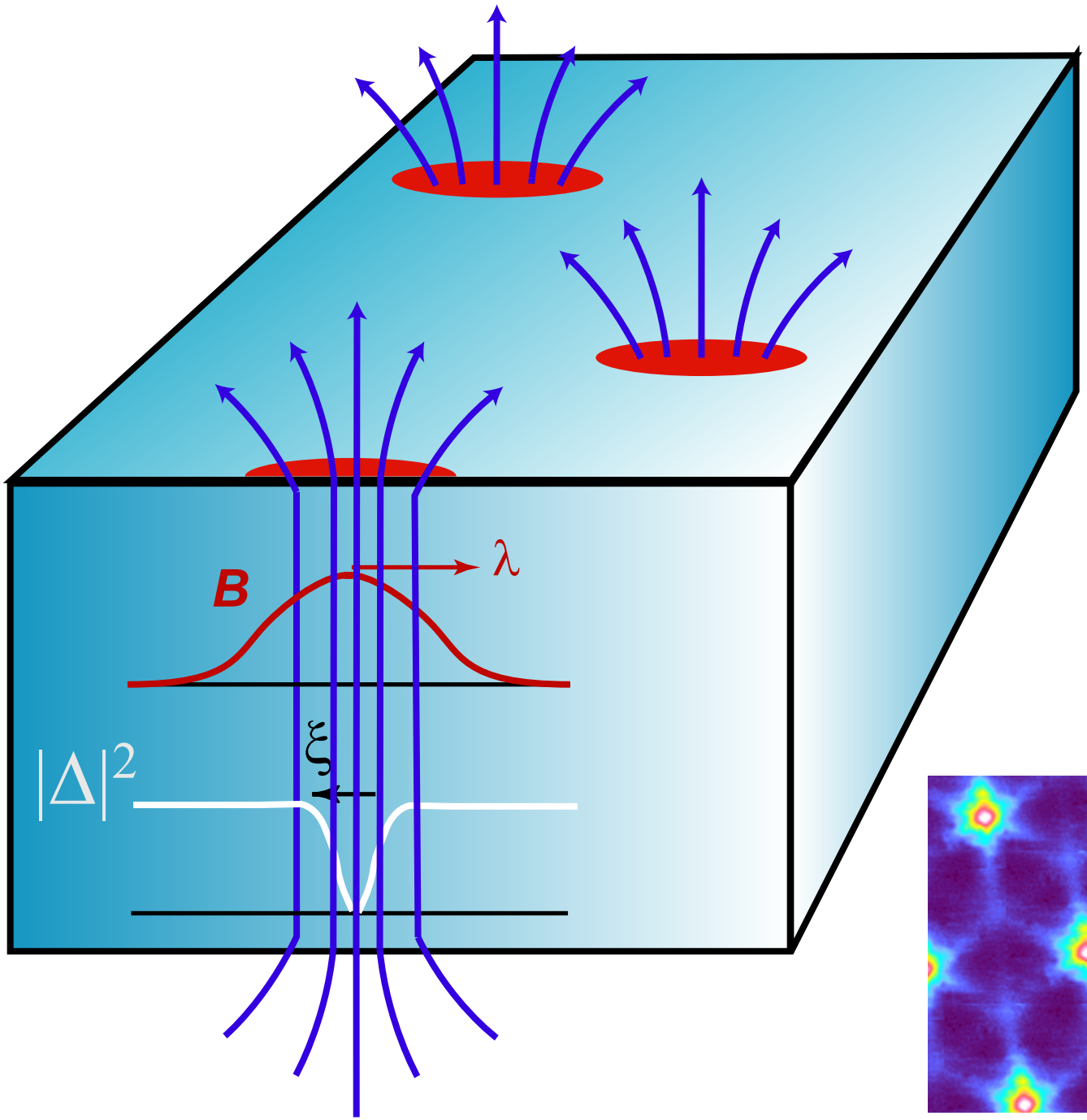
Meissner State

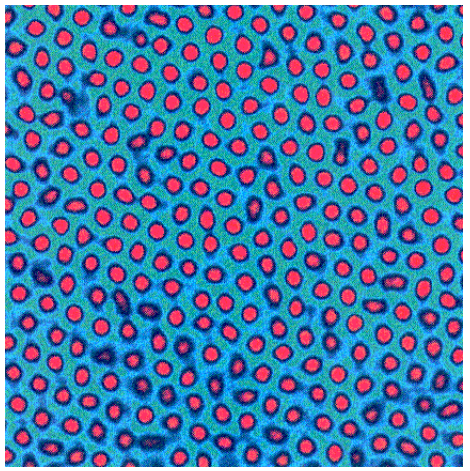


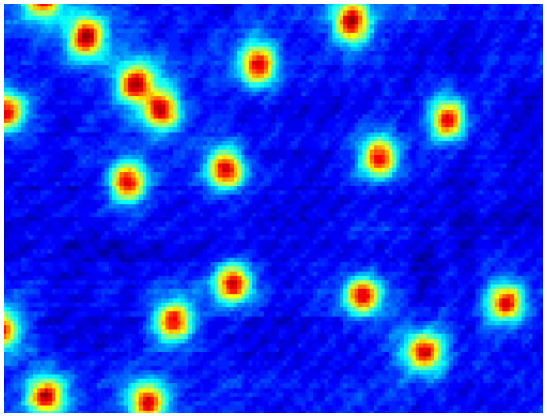
Vortex State

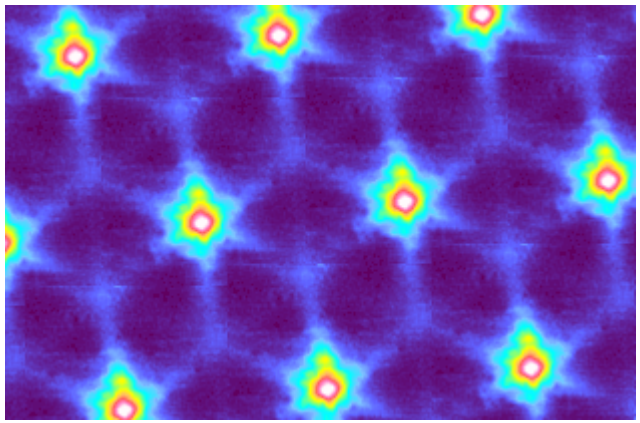


Vortices in a Type II Superconductor



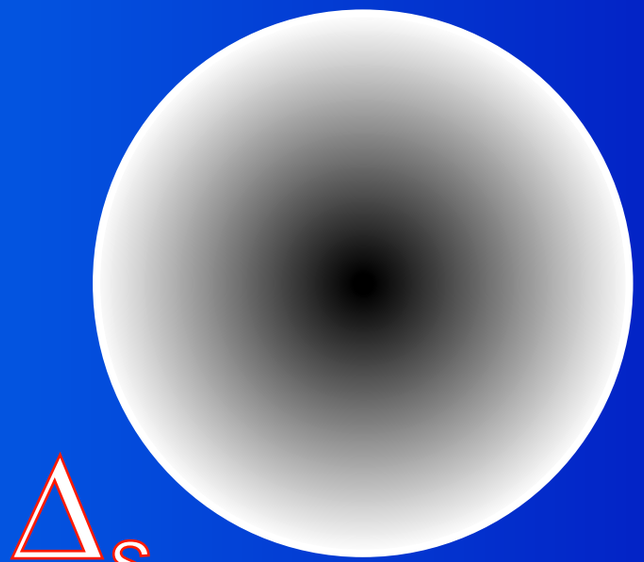




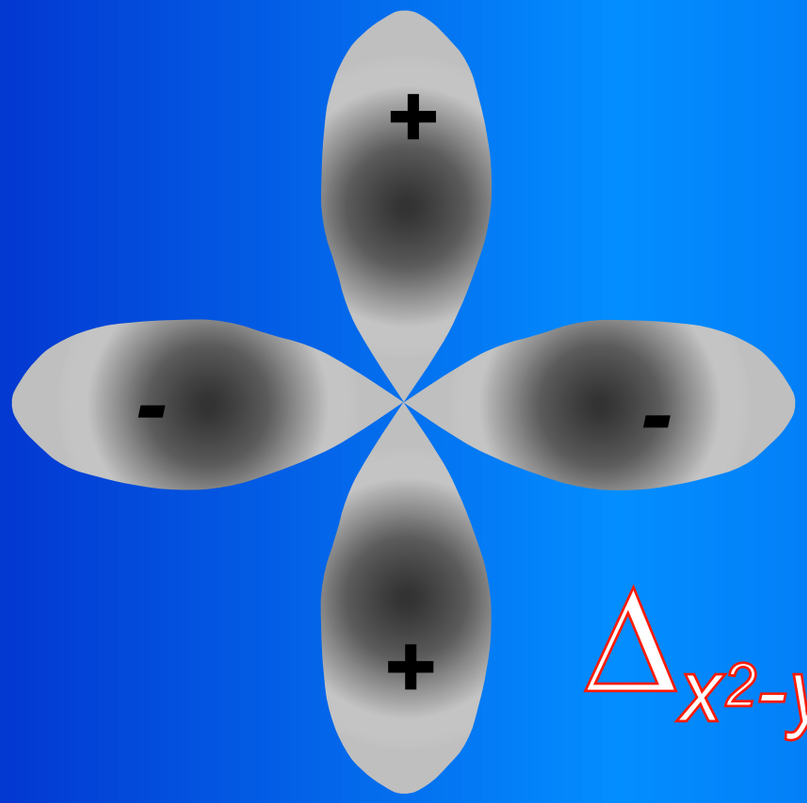


Anisotropic Pairing

Conventional superconductors have electron pairs in an '***s-wave***' state.



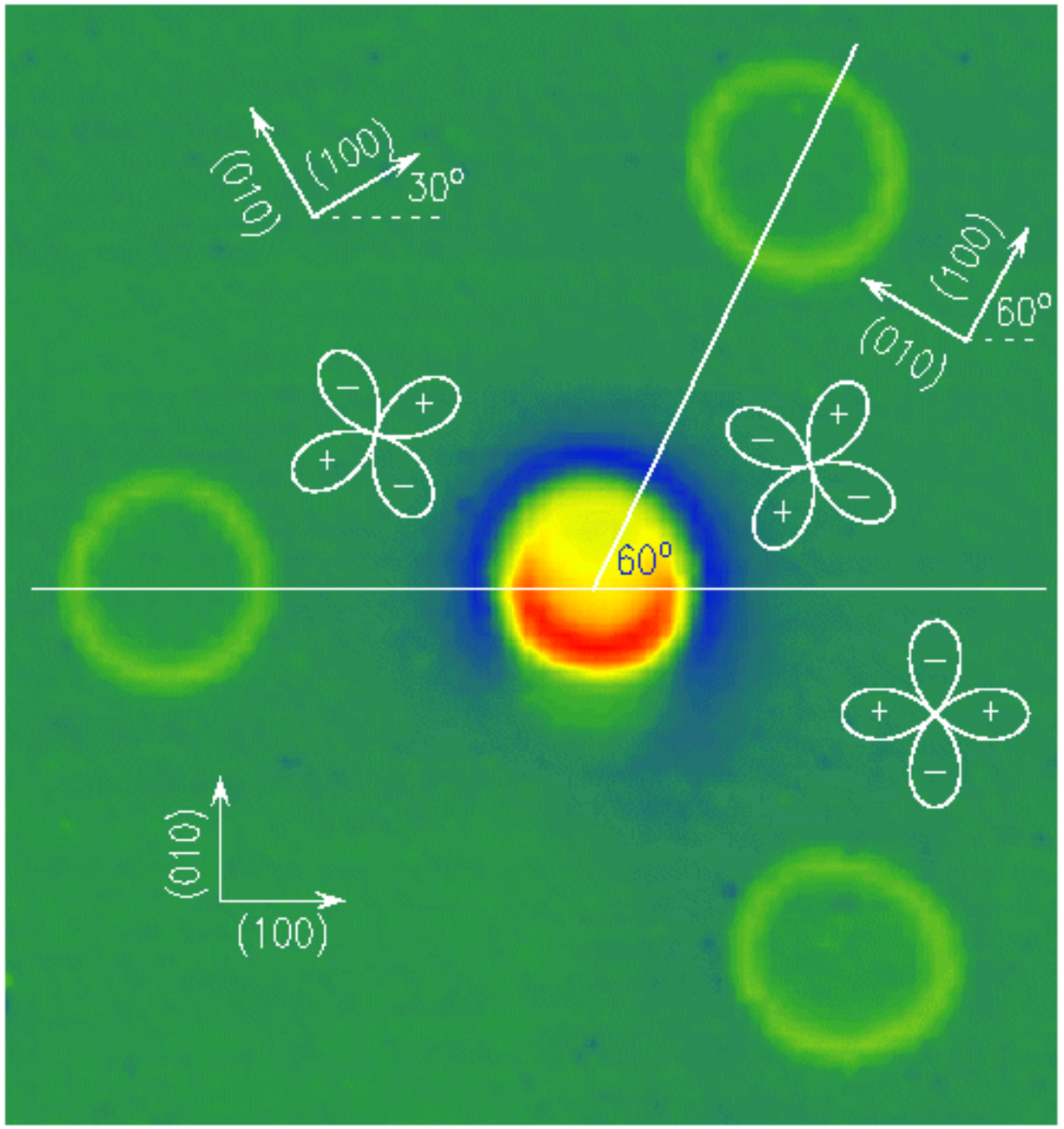
Δ_s



$\Delta_{x^2-y^2}$

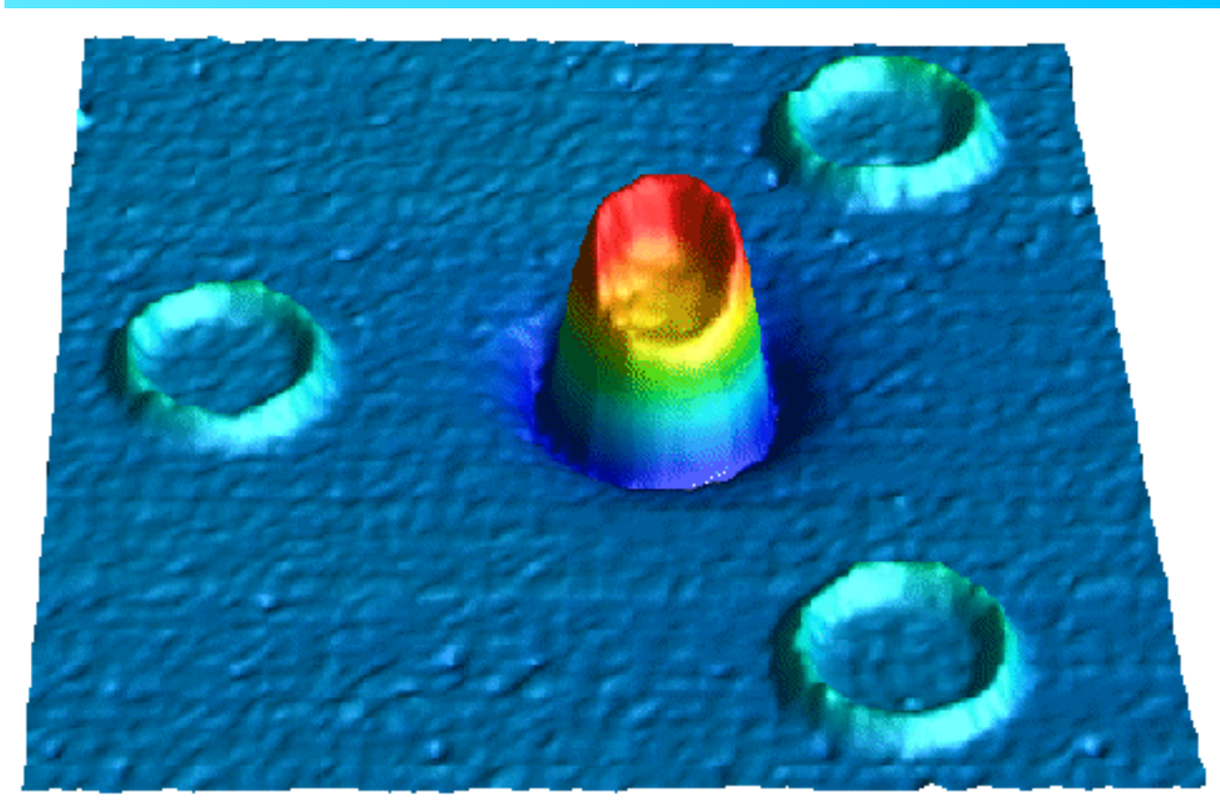
The high temperature superconductors have electron pairs in a '***d-wave***' state

- a new state of matter.

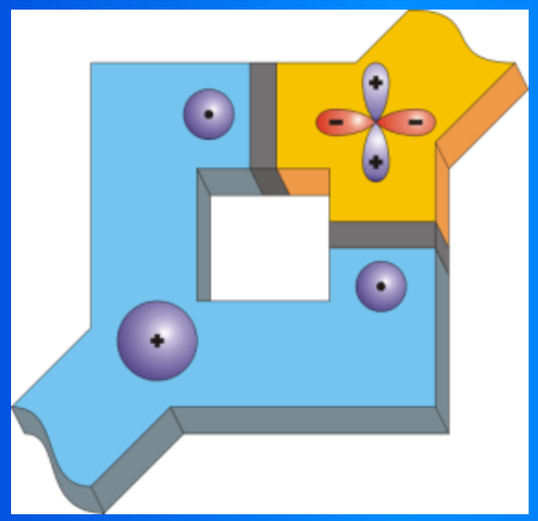


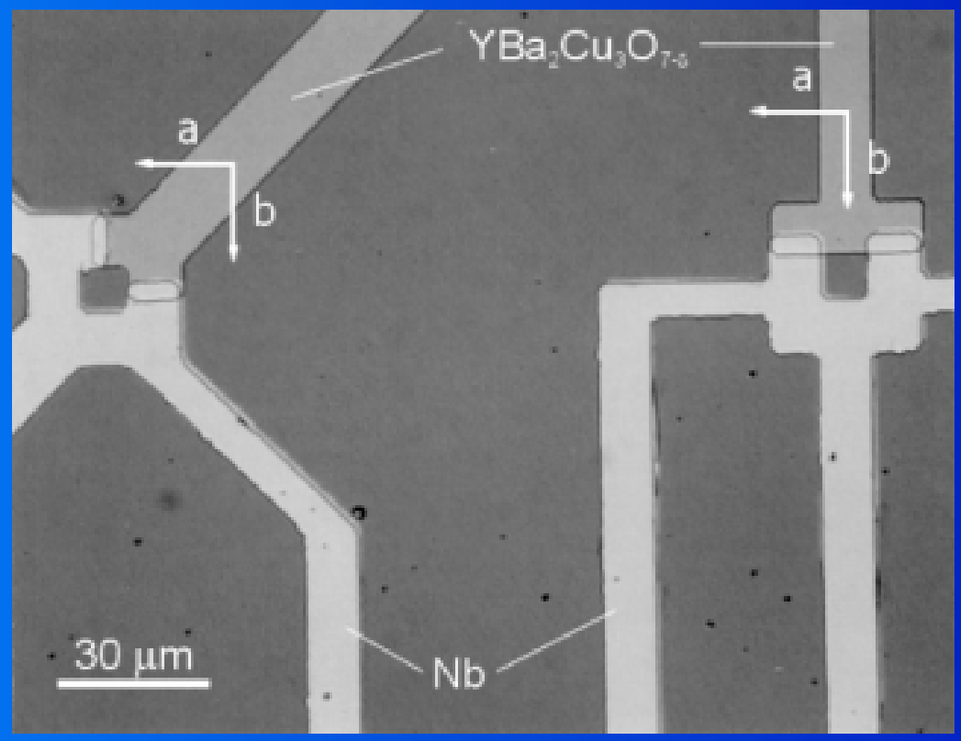
The sign change of a d-wave order parameter as it winds around a tricrystal junction is compensated by the generation of a supercurrent with a half flux quantum in the ring.

1/2 Φ_0 flux quantum spontaneously generated in a ring of YBCO that encircles a frustrated tricrystal junction. (Kirtley, Tsuei et al.)



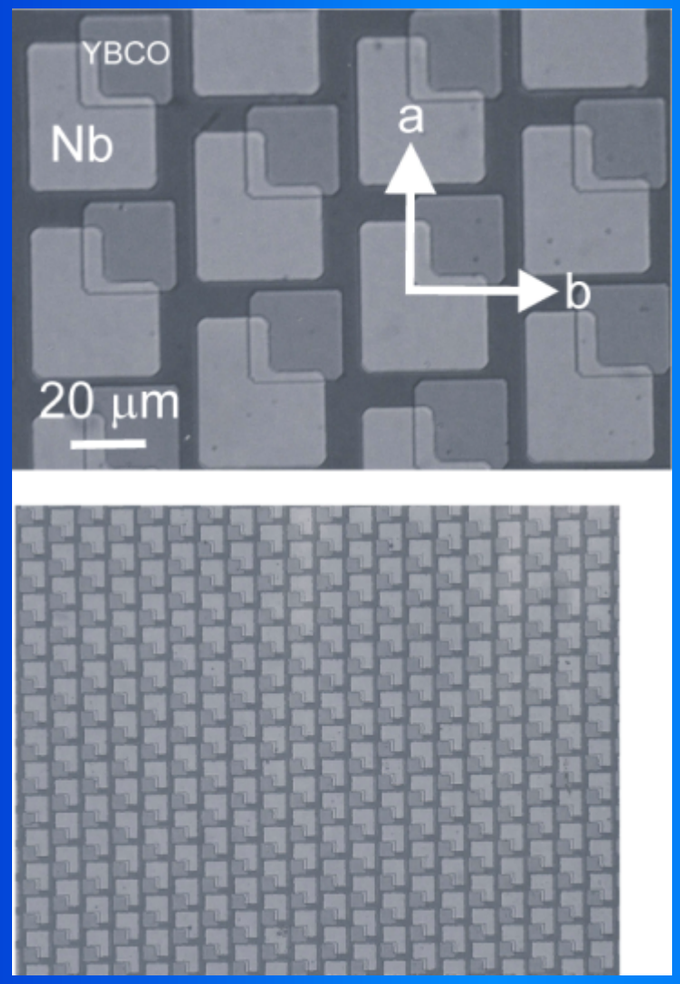
Anisotropic Pairing Goes to Work



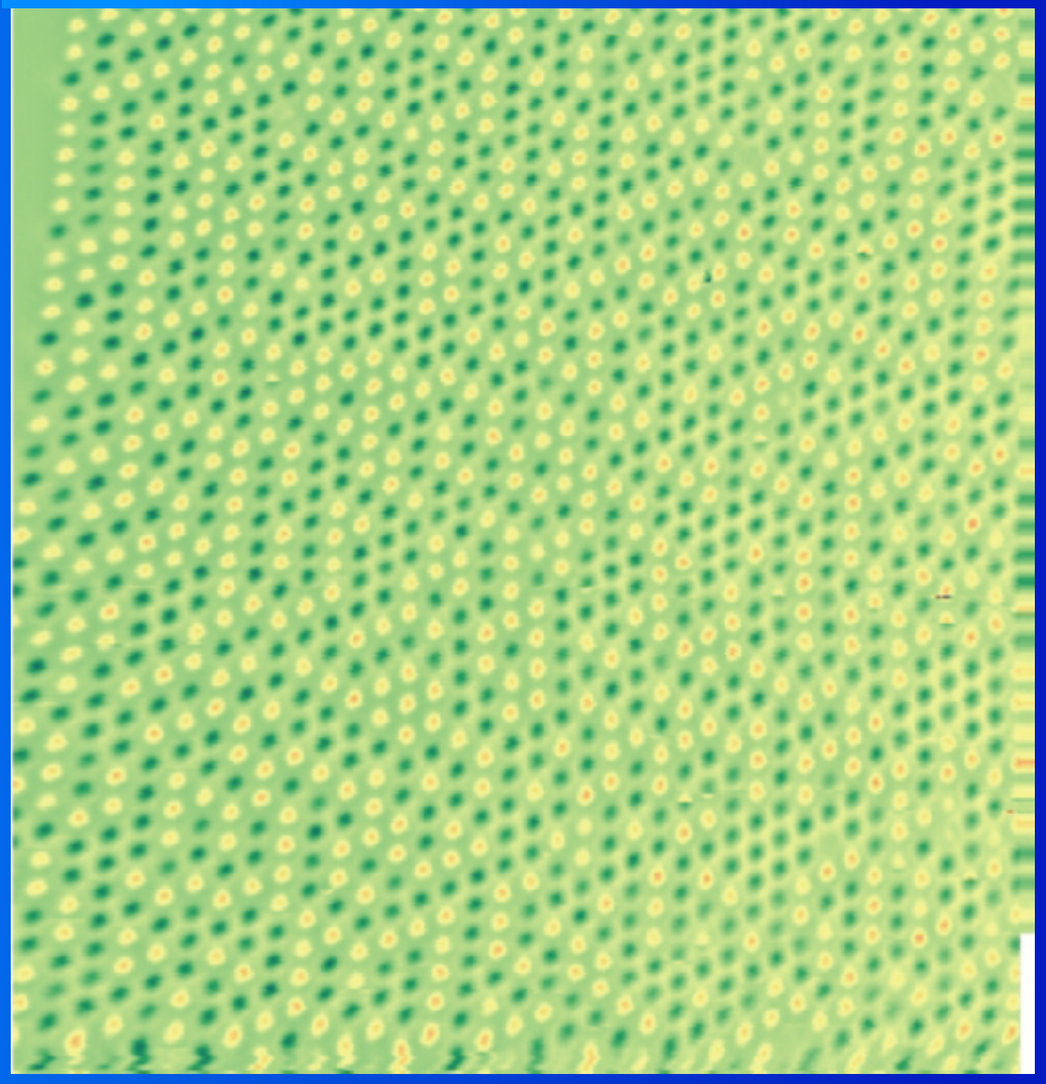


Hilgenkamp group - Twente

Anisotropic Pairing Goes to Work



Hilgenkamp group - Twente



The new superconducting state found in the copper oxides has changed the way we think about applications of high temperature superconductivity.

It has also changed the way we look at materials - leading to the invention of new experimental techniques - some here at TRIUMF and others just a short walk away in AMPEL...