Striping in Cuprates

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Outline

• Introduction
• Basics of Striping
• Implications to Superconductivity
• Experimental Findings
• Conclusion
Introduction

- Superconductivity
- Discovered in 1911: still a mystery
- Related interesting phenomena
- Striping
Basics

- Used in 1990s to describe electrical/magnetic property interactions
- What is striping?
  - 1D periodic ordering in 2D plane
  - Charge, spin, both
Basics

- Electronic behaviour: 2 regimes
  - Kinetic energy dominated
  - Potential energy dominated
- Between 2 regimes: stripes
  - neither rigid lattice, nor delocalized
Where Is Striping Found?

- High $T_c$ superconductors: Cuprates
- Cuprates
- 2D layered structure: sheets between doping material
- AFM spin orientation
What is Striping?

- Doping can introduces spinless free-charges
  - Movement frustrated by spins
- Holes orient in 1D stripes to allow movement at lower energy cost
- No holes in regions between stripes
- Spins in AFM order
What is Striping?

- Electronic behaviour is quasi-1D
- Coulomb coupling falls off exponentially
- Anisotropic: metal or insulator
Implications to Superconductivity

- Cuprates doped below SC level show striping
  - Doping corresponds to low $T_c$
  - Striping competes with SC, with some overlap
Implications to Superconductivity

- Only small overlap
Experimental Findings

• Striping initially difficult to detect

• Believed that stripes are mobile in the lattice

• Tranquada et al.: appropriate doping can immobilize stripes

• Neutron scattering on $La_{1.48}Nd_{0.4}Sr_{0.12}CuO_4$
Experimental Findings

- \(\text{La}_{1.48}\text{Nd}_{0.4}\text{Sr}_{0.12}\text{CuO}_4\)
- \(\sim 0.1 cm^3\) sample at 11 K
- Observed diffraction peaks corresponding to Cu spin ordering
Experimental Findings

- Sample at 11 K
- Observed diffraction peaks corresponding to Cu spin ordering in La$_{1.48}$Nd$_{0.4}$Sr$_{0.12}$CuO$_4$-

Figure 2: Schematic identifying the ordering of magnetic spin and charge in the cuprate lattice.

Figure 3: Neutron scattering data indicating magnetic spin stripe ordering. Peaks indicate the locations of the spins.
Experimental Findings

- Diffraction peaks characterized by temperature
- Magnetic stripes found below 3 K
- Both stripes disappear before 70 K
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Figure 4: Data showing spin-ordering (see Figure 3) as a function of temperature [6].

![Graph showing temperature vs. integrated intensity with data points and error bars, indicating LTT and LTO phases and magnetic and charge components.](image)
4-probe resistivity measurements

Stripe ordered phase measurements

Striping frustrates 3D SC, not 2D

In-plane resistivity: SC

Out-of-plane resistivity: non-SC

$La_{2-x}Ba_xCuO_4$
La\(_{2-x}\)Ba\(_x\)CuO\(_4\)

- Spin incommensurability
- Periodicity of spins are not aligned with lattice
- Also seen in \(YBa_2Cu_3O_{7-x}\)
- May be common feature of cuprates
More Experiments!

- U. of Connecticut group: phase separation
- Used $La_{2-x}Sr_xCuO_{4+y}$
  - Excess oxygen gives $T_c$ of 40 K
- Observed simultaneous phase separation
Simultaneous Phases

• Competing phases coexist in sample:
  • Stripe ordered region with SC suppressed
  • SC region exhibiting no stripe ordering
Simultaneous Phases

• Competing phases coexist in sample:
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Figure 5: Demonstrating the combined striped superconducting phases observed by Mohotalla and his research group.

The findings by Mohotalla et al. are indeed exciting as we attempt to better understand the superconductivity in cuprates. However, it is still not clear what role striping plays in this or whether the mechanism for striping is helpful or hinders superconductivity. The current state of the theory causes experimental research in striping and superconductivity to be crucial at this stage. Yet what impact do the results of Tranquada’s work and experimental evidence of 1D spin-charge ordering have on the study of copper oxides and superconductivity?
Conclusions

- Anisotropic ordering of charge/spin
- Striping is competing phase with SC
  - Exists in same temperature/doping regime
- Much work is needed to understand its mechanism and role in SC
References

[1] X.J. Zhou et al. One dimensional electronic structure and supression of d-wave node state in \((La_{1.28}Nd_{0.6}Sr_{0.12})CuO_4\). *Science*, 286, 1999.


