

Research Topic for the ParisTech/CSC PhD Program

Subfield: (Condensed-Matter physics)

ParisTech School: ESPCI

Title: Ferroelectricity and superconductivity as competing and cooperative orders

Advisor(s): (Kamran Behnia)

Short description of possible research topics for a PhD:

SrTiO₃ is the most dilute superconductor currently known. With only 10⁻⁵ electron per formula unit, the system becomes superconducting. The insulating parent of this remarkable superconductor is a quantum paraelectric, which becomes a true ferroelectric by replacing strontium with calcium. We have recently discovered that the two orders coexist in Ca-substituted-oxygen-deficient strontium titanate. This coexistence is surprising. Ferroelectricity is a state of matter with a macroscopic reversible static electric dipole and expected in an ionic insulator without inversion symmetry. Superconductivity occurs in a metal leading to a macroscopic condensate of Cooper pairs. These two states of matter have little in common. However, we find that not only they tolerate each other, but quantum fluctuations of the ferroelectric order strengthen superconductivity. The aim of this research project is to explore this intriguing case of ferroelectric quantum criticality.

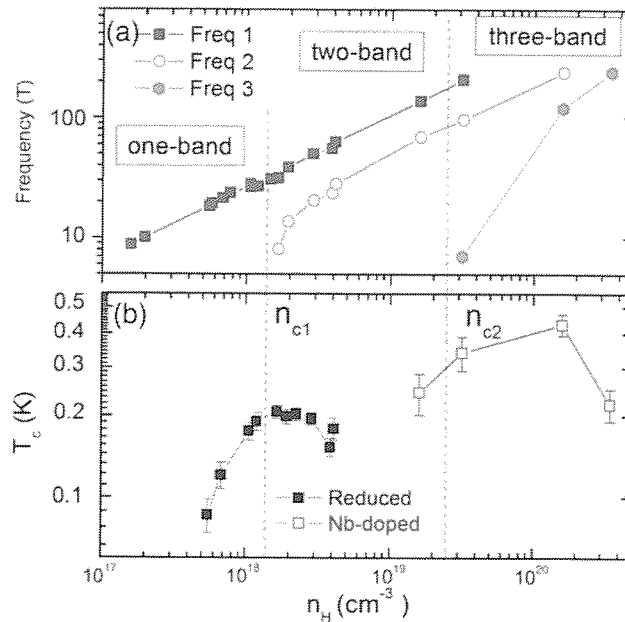


Fig. 1- Evolution of the frequency of quantum oscillations and the superconducting critical temperature with carrier concentration in strontium titanate.

Required background of the student: (Background in solid-stat physics and material science)

A list of 5 (max.) representative publications of the group: (Related to the research topic)

- 1) X. Lin, C.W. Rischau, L. Buchauer, A. Jaoui, B. Fauqué, K. Behnia, Metallicity without quasi-particles in room-temperature strontium titanate, *NPJ Quantum Materials* **2**: 41 (2017).
- 2) C. W. Rischau, X. Lin, C. P. Grams, D. Finck, S. Harms, J. Engelmayer, T. Lorenz, Y. Gallais, B. Fauqué, J. Hemberger and K. Behnia, "A ferroelectric quantum phase transition inside the superconducting dome of Sr_{1-x}Ca_xTiO_{3-δ}", *Nature Physics* **13**, 643 (2017).
- 3) X. Lin, B. Fauqué and K. Behnia, "Scalable T² resistivity in a small single-component Fermi surface", *Science* **349**, 945 (2015).
- 4) Xiao Lin, German Bridoux, Adrien Gourgout, Gabriel Seyfarth, Steffen Krämer, Marc Nardone, Benoît Fauqué and Kamran Behnia, "Critical doping level for the onset of a two-band superconducting ground state in SrTiO_{3-δ}", *Phys. Rev. Lett.* **112**, 207002 (2014).
- 5) Xiao Lin, Zengwei Zhu, Benoît Fauqué, and Kamran Behnia, "The Fermi surface of the most dilute superconductor", *Phys. Rev. X* **3**, 021002 (2013).