INTERNSHIP PROPOSAL

Laboratory: Laboratoire des Solides Irradiés (LSI) – UMR 7642
Supervisor: Pr. Gaël Grissonnanche
E-mail: gael.grissonnanche@polytechnique.edu, Phone: 01 69 33 45 16
Web page: www.gaelgrissonnanche.com
Location: École Polytechnique, Palaiseau, 91128, France
Funding: YES
Thesis possibility: YES

How Strange Metals defy conventional physics and lead to High-Temperature Superconductivity?

Project

The main factor holding us back from large-scale use of superconductors is the need to better understand the origin of high-temperature superconductivity. However, one favored way to study superconductivity today is to investigate the preceding phase within the same quantum material. Indeed, before they pair to form a superconducting state, electrons interact so strongly that they defy the standard theory of metals in a phase we call "strange metal". This shows up experimentally in a resistivity that follows a perfectly linear temperature dependence [1], as opposed to the expected quadratic dependence for electrons scattering with each other – a simple observation with baffling implications.

It was recently demonstrated that this strange metal behavior in quantum materials is coupled to the emergence of superconductivity [2], bridging two of the biggest mysteries of condensed matter physics today. Promising theories predict that both phases should emerge from a quantum critical transition (a transition at zero temperature) with incommensurable electronic interactions. If such a quantum critical point exists, it should leave additional exotic signatures like a logarithmic divergence of entropy, an unusual response in a magnetic field and an opposite sign in the thermoelectric response [3]. Some of these properties are indeed observed in some strange metals, but their connection to quantum criticality is questioned. If truly quantum-critical, these properties should be robust against disorder, and that's where the student will play a pivotal role in this research.

To determine if strange metals are truly quantum critical, the aim of the project (which may be pursued later in a PhD project) will be to use an electron canon to shoot at materials to increase disorder. École Polytechnique hosts the only electron canon in the world capable of creating locally small "holes", as disorder, in quantum materials. After each dose of electron irradiation, the student will systematically remeasure the properties of these strange metals at extremely low temperatures (down to 10 mK) at École Polytechnique and in large magnetic fields (up to 45 Tesla) in Tallahassee (USA) or Grenoble (France).

Following a new approach, the student will also perform numerical computations using Boltzmann transport theory and machine learning to model the measured properties in the experiment.

Your profile

- Good knowledge of condensed matter physics and superconductivity
- Taste for experimental physics and meticulous in a laboratory

References

[1] Grissonnanche *et al.* Nature **595**, 667 (2021).
[2] Yuan *et al.* Nature **602**, 431 (2022)
[3] Gourgout, Grissonnanche *et al.* Physical Review X **12**, 011037 (2022).

Condensed Matter Physics: YES	Soft Matter and Biological Physics: NO
Quantum Physics: YES	Theoretical Physics: YES