INTERNSHIP PROPOSAL

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Funding: YES
Thesis possibility: YES

Uncovering a new law of physics in quantum materials

Project

The main factor holding us back from large-scale use of superconductors is the need to better understand the origin of unconventional superconductivity. However, one favored way to study unconventional superconductivity today is to investigate the preceding phase. 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 dependence on temperature, as opposed to the expected quadratic dependence – a simple observation with baffling implications.

Recent experiments have shown that this resistivity behavior is due to a scattering time between electron collisions that reaches a universal value known as the "Planckian limit" [1, 2, 3], which only depends on universal constants no matter what the microscopic details of the materials are: $\tau = \hbar/k_B T$, where τ is the electron scattering time, $\hbar$ is Planck's constant, k_B is Boltzmann's constant, and T is the temperature. This is thought to be a new fundamental limit of quantum mechanics. Still, there is no accepted theoretical basis yet for it [4] (note, however, that an analogous limit has been derived for black holes [5]). Elucidating the origin of strange metal behavior would lead to understanding the nature of electron interactions, thereby shedding light on the origin of unconventional superconductivity.

To determine the origin of the Planckian limit, the aim of the project (which may be pursued later in a PhD project) will be to measure the transport properties of unconventional high-temperature superconductors such as cuprates or more recently discovered nickelates under extreme temperature and magnetic field conditions, with measurements at high magnetic fields in Tallahassee (USA), Nijmegen (Netherlands) or Grenoble (France). The project will be accompanied by extensive numerical modeling using Boltzmann transport theory and machine learning to determine the scattering time of the electrons in a new unique approach in condensed matter physics.

Your profile

- Good knowledge of condensed matter physics and superconductivity
- Taste for experimental and theoretical physics
- Curiosity for numerical calculation and programming

References

[1] Legros *et al.* Nature Physics **15**, 142 (2019).
[2] Grissonnanche *et al.* Nature **595**, 667 (2021).
[3] Gourgout, Grissonnanche *et al.* Physical Review X **12**, 011037 (2022).
[4] Patel *et al.* Science **381**, 6659 (2023).
[5] Patel and Sachdev, Physical Review Letters **123**, 066601 (2019).

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