GOETHE UNIVERSITÄT FRANKFURT AM MAIN

Fachbereich Physik
Institut für Theoretische Physik

CONDENSED MATTER THEORY SEMINAR

Subject: **Topological two-band electron-hole superconductors with d-wave symmetry: A possible application to magic-angle twisted trilayer graphene?**

Speaker: **C. A. R. Sá de Melo (School of Physics, Georgia Institute of Technology, Atlanta)**

Date & time: **Friday, 19th of July 2024 at 3:15 p.m.**

Venue: **Room 01.114**

Abstract:
The importance of chemical potentials in determining crossovers or quantum phase transitions in the evolution from BCS to BEC superconductivity and superfluidity in one band systems were highlighted in papers from the 1990's and 2000's. This evolution was studied in s-wave systems, where crossovers were found, and in higher angular momentum (e. g. d-wave) systems, where topological quantum phase transitions were proposed [1-2]. The evolution from weak to strong superconductivity and superfluidity was also studied in two-band systems in the 2000's for the s wave channel. With the advent of magic angle twisted systems with moiré patterns, it appears that more than one band is necessary to characterize their physical properties. Inspired by these early works and recent tunneling experiments in magic-angle twisted trilayer graphene (MATTG) [3], I discuss a two-band model for two-dimensional superconductors with electron and hole bands separated by an energy gap and singlet d-wave pairing in each band [4]. I describe the phase diagram of the model in the plane of chemical potentials and show that under certain conditions it exhibits a V- to U-shaped transition in the density of the states of the superconductor, which is like the one found in MATTG [3]. This qualitative difference in behavior arises when the electron and hole chemical potentials change, leading to topological quantum phase transitions between gapless and gapful d-wave superconducting states, due to the annihilation of chiral Dirac fermions at the critical points [1, 2, 4]. Lastly, we show that direct thermodynamic evidence of these topological quantum phase transitions can be found in measurements of the compressibility, which exhibits logarithmic singularities at the transition points [1, 2, 4].

[1] "Thermodynamic properties in the evolution from BCS to Bose-Einstein condensation for a d-wave superconductor at low temperatures", R. D. Duncan, and C. A. R. Sá de Melo, Phys. Rev. B. 62, 9675 (2000).

[2]"The Lifshitz Transition in d-wave Superconductors", S. S. Botelho and C. A. R. Sá de Melo, Phys. Rev. B 71, 134507 (2005).

[3] "Evidence for unconventional superconductivity in twisted trilayer graphene", H. Kim, Y. Choi, C. Lewandowski, A. Thomson, Y. Zhang, R. Polski, K. Watanabe, T. Taniguchi, J. Alicea, and S. Nadj-Perge, Nature 606, 494 (2022).

[4] "Topological two-band electron-hole superconductors with d-wave symmetry: a possible application to magic-angle twisted trilayer graphene", Senne Van Loon and C. A. R. Sá de Melo, arXiv:2303.05017v1 [cond-mat.supr-con] 9 Mar 2023.