GOETHE UNIVERSITÄT
FRANKFURT AM MAIN

Fachbereich Physik
Institut für Theoretische Physik

CONDENSED MATTER THEORY SEMINAR

Subject: **Strong coupling theory of twisted multilayer graphene systems: correlated insulators, collective excitations and superconductivity**

Speaker: **Dr. Eslam Khalaf (Harvard University, Cambridge, MA, United States)**

Date & time: **Friday, January 14th, 2022 at 3:15 p.m.**

Venue: **Online Seminar**

In this talk, I will discuss a recently developed strong coupling theory of magic-angle twisted bilayer graphene. I will begin by showing how the electronic structure of twisted bilayer graphene makes it possible to relate its flat bands to the lowest Landau levels. This leads to a model of twisted bilayer graphene consisting of two sets of U(4) symmetric Landau-level-like Chern bands with opposite Chern numbers that are tunnel-coupled. I will show how this model broadly captures most of the observed features of twisted bilayer graphene: correlated trivial and topological Chern insulators at integer fillings, fractional Chern insulators and superconductivity. The correlated insulators are understood as generalized quantum Hall ferromagnets. Neutral excitations on top of the correlated insulator are of two types: (i) spin-valley waves similar to the soft modes of a ferromagnet and (ii) nematic modes corresponding to particle-hole excitations in the opposite Chern sectors. I will then discuss the nature of charged excitations on top of such correlated insulators showing that they admit non-trivial charged excitations in addition to single-particle excitations. These excitations are intimately tied to band topology and can take the form of skyrmions -- real space spin textues -- or spin polarons -- bound states of an electron and a spin waves. I will show that there is a very natural mechanism for superconductivity which leads to pairing of these charged excitations. This mechanism is purely repulsive in origin and relies on band topology in a fundamental way. At the end, I will discuss how these insights generalize to a class of multilayer graphene systems with alternating twist angle and contrast the properties of these systems compared to their bilayer counterpart.