Universidade de São Paulo

Instituto de Física

Multi-orbital topological Anderson models for twisted bilayer graphene

Report on the activities of the Master's degree project supported by the São Paulo Research Foundation.

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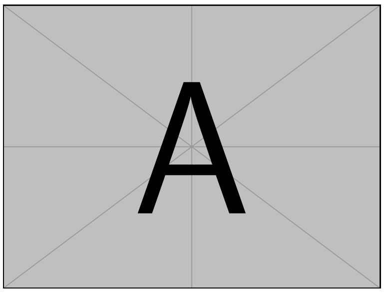
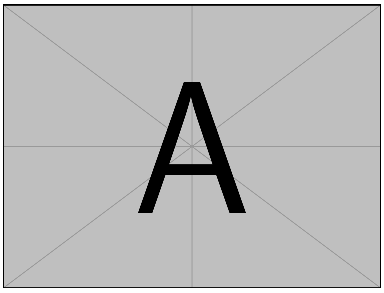


Researcher



Advisor

São Paulo, December 6, 2023

Project

- Title:

  Multi-orbital topological Anderson models for twisted bilayer graphene

- Advisor:

  Prof. Dr. Luis Gregório G. V. Dias da Silva

- Project host institution:

  Instituto de Física da Universidade de São Paulo

- Research team:

  Mateus Marques
  Luis Gregório G. V. Dias da Silva

- Research project number:

  2023/02913-5

- Validity period:

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- Period covered by this scientific report:

  January 1, 2023 to December 6, 2023

Contents

1 Abstract “OF THE RESEARCH PROJECT”

Magic-angle twisted bilayer graphene (MATBG) is a fascinating system that displays a plethora of intriguing physical phenomena such as correlated insulators, superconductivity, and unconventional quantum Hall effects, among others. Several recent experiments have demonstrated the rich electronic properties of MATBG, which exhibits correlated insulating and superconducting phases. In spite of such a vast amount of experimental data, there are still several open questions regarding the theoretical description of this material in different regimes. While there is some consensus that these phenomena are related to the formation of flat bands near the Fermi level captured by non-interacting band structure models, the description of MATBG as a strongly correlated system is nonetheless challenging. In this Master’s project, we propose a description of the correlated electronic properties of MATBG in terms of multi-orbital topological Anderson models (both as a single impurity and as a periodic Anderson lattice), building on the framework recently developed describing MATBG as a topological heavy fermion problem. By employing a combination of analytical and numerical methods, we aim to study the low-energy physics of such models and identify the emergent energy scales and the nature of the Mott transition. We expect that our results can provide some additional insight into the nature of the electronic states in MATBG and suggest new avenues for experimental investigation of this fascinating material system.

2 Achievements in the period TRADUÇÃO?

In the year of 2023 our main activities consisted in the three main steps: the familiarization with the basic theory in Condensed Matter Physics, the study of the numerical techniques that will be used in the project and the reading of literature with respect to the system studied in this project (MATBG).

- The student took the three courses Solid States I, II and Statistical Mechanics. They were very important to provide the necessary tools to study many-body systems. In particular, the MATBG system can be modelled in the second quantization formalism in a way that is very similar to the Hubbard Model, which was studied in the Solid State II course.

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3 Resumo do projeto proposto

O presente projeto, na área de Física de Partículas Elementares, propõe um estudo teórico e computacional da fenomenologia das oscilações de neutrinos. A investigação desse fenômeno é o principal tópico da fronteira de pesquisa em neutrinos. Como pode ser visto na Seção II.A de [?], o Modelo Padrão implica que a massa dos neutrinos é nula. No entanto, a oscilação de sabor leptônico implica, dentre diversas coisas, a existência de autoestados de massa não-nula. Atualmente, essa é uma das mais fortes evidências de que deve haver física além do Modelo Padrão. Neste projeto exploraremos as oscilações de neutrinos em dois contextos.

Primeiramente consideramos os neutrinos trafegando na presença de matéria. Em particular enfatizaremos os neutrinos solares, que possuem imensa relevância histórica devido ao famoso *problema do neutrino solar* (Seção IV.B de [?]) e que, ainda hoje, mostram-se de grande interesse experimental, havendo associados a eles grandes experimentos mundo à fora, como SuperKamiokande, SNO e Borexino (Seção IV.A de [?]). Exibiremos nossa simulação numérica e seus resultados, onde utilizamos os parâmetros do grupo NuFIT [?] e dados do modelo solar `BS2005` de J. N. Bahcall [?, ?].

Em seguida, no contexto de oscilações no vácuo, apresentaremos nossa simulação numérica do experimento de antineutrinos em reatores nucleares KamLAND [?] para os dados coletados entre 9 de Março, 2002 e 11 de Janeiro, 2004. Realizamos os cálculos das distribuições de eventos para os casos sem oscilação e com oscilação e comparamos nossos resultados com os eventos observados no KamLAND [?] durante o período considerado.