PhD in PHYSICS – University of Trieste – XXXVIII cycle

Candidate presentation

Candidate: **Roberta Favata**
Cycle: XXXVIII
Supervisor: Federico Becca
Co-supervisor: Antimo Marrazzo (now at SISSA)
Research Title: **Disorder and Interaction Effects in Topological Insulators**

The Candidate has successfully accomplished the required educational activities as approved by the Teachers Board, including the Ph.D. courses, exams and the attendance of schools and conferences.

Brief description of the candidate research activity:

The research has followed two main directions. The first concerns interacting topological insulators, studied through variational Monte Carlo methods and many-body topological markers, investigating correlation-driven phases in topological insulators both in one- and two-dimensions. The second concerns disordered topological systems, including the development of topological invariants for detecting topological phases in non-crystalline systems and the application of local topological markers to characterize disorder-driven topological phase transitions. These methods have also been applied to realistic systems, such as a monolayer of Jacutingaite in the presence of atomic vacancies, modelled through Wannier Hamiltonians from first-principles calculations.

Role of the Candidate and main achievements:

A major achievement was the investigation of a one-dimensional two-orbital fermionic model with on-site and nearest-neighbor interactions using a Jastrow-Slater variational Monte Carlo approach. This work, published in Physical Review B 111, 155105 (2025), showed that electronic correlations generate emergent phases not captured by the non-interacting theory, including a spin-gapless insulating phase separating the trivial and topological phases. The candidate also extended this approach to two-dimensional interacting systems, identifying signatures of excitonic insulating phases at strong coupling. In the field of disordered systems, the candidate contributed to the development of single-point invariants for non-crystalline systems, published in Electronic Structure 5, 014005 (2023), and studied the role of fluctuations and correlations of local topological markers in disorder-driven topological phase transitions in Physical Review Letters 135, 026603 (2025). The candidate further contributed to implementing these approaches in an open-source Python package available on GitHub.

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General evaluation of the candidate by the supervisor:

During her doctoral studies, Roberta worked in parallel on two distinct research projects: the effects of disorder in topological insulators (primarily in collaboration with Antimo Marrazzo) and the role of electron-electron interactions (conducted mainly with me).

Throughout the PhD program, she has performed excellently, demonstrating a high level of intellectual maturity in addressing both the conceptual and technical challenges that arose. Roberta is a highly motivated and assiduous researcher; she is reliable in executing complex simulations and proactive in mastering new physical concepts. Her strong analytical drive is particularly evident in her desire to achieve a deep, fundamental understanding of her research.

Furthermore, Roberta has consistently demonstrated remarkable teamwork and communication skills. She has been an active collaborator within the research group, working effectively with other PhD students, such as Davide Piccioni and Nicolas Baù. Her ability to engage in productive scientific dialogue and contribute to a collective research environment makes her a valuable asset to any team.

In addition to her theoretical insights, she has demonstrated exceptional computational skills, notably in coding sophisticated algorithms from scratch, including a variational Monte Carlo code. Along the course of her PhD, she also significantly developed her scientific writing abilities. The broad skillset Roberta has developed demonstrates that she is well-prepared for a and highly capable of pursuing a career in academia. In summary, Roberta has reached a high level of professional maturity across all the dimensions discussed, and I recommend her for the PhD degree with the highest enthusiasm.

Summary:

The Teachers Board agrees that the candidate fully achieved the training and scientific targets set at the beginning of the Ph.D. program

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Presentations to Conferences, workshops, and meetings

• Fluctuations and correlations of topological local order parameters in 2D disordered topological insulators (APS March Meeting 2025, Anaheim)

POSTERS:
• Total Energy and Force Methods (ICTP, Trieste, Italy, January 2023)

• CMT@BRIXEN (Bressanone, Italy, June 2023)

• Topological Matter School TMS23 (San Sebastian, Spain, August 2023)

• Workshop on Twistronics and Moiré Materials (ICTP, Trieste, Italy, January 2023): Winner of the poster session with the work ``Topological phase diagram of two-band fermionic chain in presence of Hubbard interaction"

• 2024 Arnold Sommerfeld School (Munich, Germany, September 2024)

• Conference on Advances in Topological Condensed Matter (ICTP, Trieste, Italy, December 2024): APS poster prize for early career researcher with the work ``Topological phase diagram of two-band fermionic chain in presence of Hubbard interaction"

• Topology and Geometry Beyond Perfect Crystals (Nordita, Stockholm, Sweden, June 2025)

Publications:

- R. Favata and A. Marrazzo, Electron. Struct. **5**, 014005 (2023)
- R. Favata, D. Piccioni, A. Parola, and F. Becca, Phys. Rev. B **111**, 155105 (2025)
- R. Favata, N. Baù, and A. Marrazzo, Phys. Rev. Lett. **135**, 026603 (2025)