

# Course Specifications

Valid in the academic year 2022-2023

# Strongly Correlated Quantum Systems (CO04071)

Master of Science in Physics and Astronomy

Exchange Programme in Mathematics (master's level)

Exchange Programme in Physics and Astronomy (Master's Level)

Course size	(nominal values; actual values may	depend on programme)			
Credits 6.0	Study time 180 h	Contact hrs	52.5h		
Course offerings and	teaching methods in academic year 20	22-2023			
A (semester 2)	English Gent		lecture		42.5h
			seminar: coached	exercises	7.5h
			project		2.5h
Lecturers in academic	year 2022-2023				
Haegeman, Jutho		WEO5	lecturer-in-charge		
Vanderstraeten, Laurens		WEO5	co-lecturer		
Offered in the following programmes in 2022-2023			crdts	offering	
Master of Science in Teaching in Science and Technology(main subject Mathematics)			) 6	Α	
Master of Science in Teaching in Science and Technology(main subject Physics and Astronomy)			6	Α	
Master of Science in Mathematics			6	Α	

## Teaching languages

English

## Keywords

Spin systems, quantum phase transistions, topological order, entanglement.

# Position of the course

The goal of this course is to teach a number of general concepts and recent developments from the field of quantum many body physics, complemented by a modern point of view using the theory of entanglement.

### Contents

- 1 Introduction: second quantisation, interacting electrons, the Hubbard model and its descendants
- 2 Quantum Ising model in transverse magnetic field: exact solution via Jordan Wigner, Fourier and Bogoliubov transform. Quantum phase transitions and criticality. Order an disorder. Duality. Excitations and domain walls. Entanglement entropy: area laws and logarithmic divergence.
- 3 Half-integer spin chains: Heisenberg antiferromagnets, Lieb-Schultz-Mattis theorem, order and disorder, Goldstone-bosons, Mermin-Wagner theorem, exact solution via coordinate Bethe ansatz.
- 4 Integer spin chains: Haldane's conjecture, Affleck-Kennedy-Tasaki-Lieb model, introduction to MPS (Matrix Product States) and tensor networks. Gapless edge modes and symmetry protected topological order.
- 5 Topological classification of free fermion systems: periodic table of topological insulators and superconductors, Su-Schriefer-Heeger model and Kitaev's quantum wire: topological degeneracy and majorana edge modes.
- 6 Spin models in higher dimensions, spin liquids, gauge theories and Kitaev's toric code model, topological order and anyons

There will also be a group project, which can be chosen as either a literature review (e.g. quantum hall effect, Levin-Wen string net models, topological insulators,

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entanglement renormalization for critical systems, entanglement entropy in conformal field theory, ...) or (density matrix renormalization group algorithm, tensor renormalization group, ...).

#### Initial competences

Proper knowledge of quantum mechanics, basic knowledge of quantum field theory.

#### Final competences

- 1 Familiarity with a number of basic concepts in quantum many body systems and condensed matter physics.
- 2 Having an overview about different phases of quantum matter, and the associated phenomenology (gapless edge modes, topological entanglement entropy,...)
- 3 Ability to read scientific papers about recent developments and to start research in this field.

#### Conditions for credit contract

Access to this course unit via a credit contract is determined after successful competences assessment

#### Conditions for exam contract

This course unit cannot be taken via an exam contract

#### Teaching methods

Lecture, Project, Seminar: coached exercises

#### Extra information on the teaching methods

Project: students make a literature review or a computational assignment in small teams. They make a report and a presentation about this work.

## Learning materials and price

Lecture notes and research papers Available via Ufora

## References

- Assa Auerbach, "Interacting electrons and quantum magnetism" (Springer, 1998)
- Eduardo Fradkin, "Field theories of Condensed Matter Physics" (2nd edition, Cambridge University Press, 2013)

## Course content-related study coaching

Outside lecture hours, the teachers are available for further explanation.

## Assessment moments

end-of-term assessment

#### Examination methods in case of periodic assessment during the first examination period

Oral examination, Open book examination

# Examination methods in case of periodic assessment during the second examination period

Oral examination, Open book examination

## Examination methods in case of permanent assessment

Report

#### Possibilities of retake in case of permanent assessment

examination during the second examination period is possible

# Extra information on the examination methods

- Periodic evaluation: Oral exam (with written preparation)
- · Project: report and presentation

# Calculation of the examination mark

- 35% continuous assessment (project assignment)
- 65% end-of-term evaluation (oral examination)

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