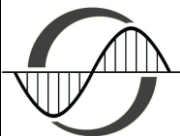




UNIVERSITÀ  
degli STUDI  
di CATANIA



DIPARTIMENTO DI FISICA E ASTRONOMIA  
“ETTORE MAJORANA”

DOTTORATO DI RICERCA IN FISICA  
CICLO XLI A.A. 2025/2026

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## Modern Quantum Chromodynamics

CFU: 2

### Teaching staff

**Name Surname:** Marco Ruggieri

**Email:** marco.ruggieri@dfa.unict.it

**Office:** 326

**Reception hours:** Monday and Tuesday, 09:00 -11:00

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### Program of the course:

This course provides a comprehensive overview of Quantum Chromodynamics (QCD) and gauge theories, with a focus on the behavior of strongly interacting matter under extreme conditions of temperature and density. Starting from the fundamentals of gauge theories and QCD, the course explores key phenomena such as color confinement, chiral symmetry breaking, and color deconfinement. Particular attention is given to modern aspects of QCD, including recent advances on the QCD phase diagram, confinement mechanisms and their relation with chiral symmetry breaking, superdense quark matter phases, the QCD topological term and the QCD axion, as well as phenomenological applications including the early stage of high energy nuclear collisions.

In detail, the topics of the course are the following.

- 1) Introduction to gauge theories and Quantum Chromodynamics
- 2) Color confinement and chiral symmetry breaking: a modern overview, confinement via vortices, spectral density of the

Dirac operator, BRST charges

- 3) Quantum Field Theory at finite temperature and density in the real-time formalism
  - 4) Color deconfinement at finite density, 1: critical endpoint of the QCD phase diagram (theory and phenomenology)
  - 5) Color deconfinement at finite density, 2: superdense phases of QCD, Dyson-Schwinger equations in dense QCD, superfluidity and superconductivity of dense quark matter
  - 6) Topological term in QCD and the QCD axion
  - 7) Gluon saturation and the early stage of high energy nuclear collisions
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## **Bibliography:**

Lecture notes of the course, prepared by the teacher

Slides of the lectures

Kapusta and Gale, Finite-Temperature Field Theory, Cambridge University Press, seconda edizione (2023)

Mussardo, Statistical Field Theory, OUP Oxford seconda edizione (2022)

Pokorski, Gauge Field Theories, Cambridge University Press, seconda edizione (2000)