

Study Plan

Topic 1: Methods and Techniques in Cosmology, Astrophysics and Particle Physics

ECTS Credits	9
Type	Compulsory
Duration	Annual

Contents

Computational methods (3 ECTS): Numerical methods (interpolation, integration, differential equations, N-body problems). Computational tools for modelling, simulation, data processing and analysis.

Statistical methods and techniques (3 ECTS): Basic statistics, data analysis, statistical tests, detection sensitivity, software applications, data processing and analysis in particle physics, astrophysics and cosmology.

Specialised methods and techniques (3 ECTS): Simulation techniques in particle physics and astrophysics, astrophysical and cosmological databases, fundamentals of differential geometry, tensor calculus, Lie groups and algebras.

Topic 2: Current Topics in Cosmology, Astrophysics and Particle Physics

ECTS Credits	6
Type	Compulsory
Duration	Annual

Contents

Updated reviews in cosmology, major facilities, particle physics, astroparticle physics, relativity and gravitational waves, and astrophysics.

Seminars: evolution of the Universe, black holes and gravitational waves, exoplanets, astrophysical simulations, tests of the Standard Model, dark matter detection, cosmic multi-messengers, neutrino mass, lattice particle physics.

Training visits to the Canfranc Underground Laboratory (LSC) and the Javalambre Astrophysical Observatory (OAJ/CEFCA).

Topic 3: Cosmology and Gravitation

ECTS Credits 6/course

Type Elective

Courses

Cosmology (1S): history of the Universe, Hubble law, FRW models, thermodynamics of the Universe, nucleosynthesis, baryogenesis, cosmic microwave background, anisotropies, inflation, dark matter, structure formation.

General Relativity and Gravitation Waves (2S) : Einstein equations, Schwarzschild and FRW solutions, compact objects, Tolman–Oppenheimer–Volkoff equation, black holes, gravitational waves and detection.

Course 4: Particle Physics

ECTS Credits 6/course

Type Elective

Courses:

Field and Particle Theory (S1): electromagnetic field, radiation and matter, scalar and spinor fields, gauge symmetry, QED, Feynman rules, spontaneous symmetry breaking, Higgs mechanism, non-Abelian gauge theories, QCD.

Particle Physics Phenomenology (S2): Standard Model, electroweak interactions, Higgs physics, flavour physics, neutrinos, quantum corrections, Standard Model problems, dark matter, axion, search for new physics.

Topic 5: Astroparticle Physics

ECTS Credits 6/course

Type Elective

Courses

Astroparticle Physics: Gamma Rays, Neutrinos, and Cosmic Rays (S1): history, origin, sources, acceleration mechanisms, gamma rays, detection techniques, neutrinos, neutrino telescopes, multi-messenger astronomy.

Astroparticle Physics: the Dark Universe (S2): astrophysical and cosmological evidence, WIMPs, direct and indirect searches, accelerators, neutrinos, axions, ALPs and other candidates.

Topic 6: Astrophysics

ECTS Credits 6/course

Type Elective

Courses

Stellar and Extragalactic Astrophysics (S1): stellar properties, HR diagram, stellar structure and evolution, supernovae, stellar remnants, galaxies, AGNs, Milky Way, galaxy formation and evolution.

Observational astrophysics (S2): electromagnetic radiation, detectors, instrumentation, telescopes, spectrographs, interferometry, gravitational-wave astronomy.

Topic 7: Technology and Instrumentation

ECTS Credits 6/course

Type Elective

Courses

Particle Detectors: Physical Principles, Design, and Operation (S1): physical principles, gaseous detectors, scintillators, semiconductors, bolometers, electronics, calibration, automatic control and remote laboratories.

Applications of Particle Detectors in Science and Technology (S2): background radiation, radioactive background suppression, radiopurity, applications in energy, industry and medical physics.

Topic 8: Interdisciplinary

ECTS Credits 6

Type Elective

Duration Semester-based

Contents

Selection of courses from related master's degrees, defined by the Quality Assurance Committee.

Topic 9: Master's Thesis

ECTS Credits	15
Type	Master's Thesis
Duration	Annual

Contents

Research initiation. Completion and public defence of an original research project in cosmology, astrophysics, particle physics or astroparticle physics.