

Degree programme	Type	Course
High Energy Physics, Astrophysics and Cosmology	OP	1

Contact lecturer

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Teaching staff

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Group languages

You can consult this information at the [end](#) of the document.

Prerequisites

It is mandatory to have followed the course of Introduction to the Physics of the Cosmos. It is also recommended - but not mandatory - to have followed the Observational Techniques course.

Objectives

Students should become familiar with the basics of High Energy Astrophysics, not only with respect to the sources and astrophysical processes that produce X rays, gamma rays and cosmic rays in our universe, but also with the instruments that detect these photons / particles. The course is divided into three blocks. The first part is a theoretical description of the main processes of interaction of matter and radiation in the X- and gamma-ray energy domain. The second one describes the detectors that are currently operating, those under construction and those being designed. The third and final block presents the phenomenology of several cosmic sources of X rays, gamma rays, cosmic rays that have been observed so far.

Learning outcomes

- CA14 (To adapt knowledge about the physics of cosmic radiation to new situations in high-energy astrophysics.) To adapt knowledge about the physics of cosmic radiation to new situations in high-energy astrophysics.
- KA22 (Identify the physical processes responsible for the emission, propagation and absorption of cosmic radiation (charged particles, photons and neutrinos).) Identify the physical processes responsible for the emission, propagation and absorption of cosmic radiation (charged particles, photons and neutrinos).
- SA51 (Apply the physical processes responsible for the emission, propagation and absorption of cosmic radiation (charged particles, photons and neutrinos).) Apply the physical processes responsible for the

- emission, propagation and absorption of cosmic radiation (charged particles, photons and neutrinos).
- SA52 (Compare the different types of cosmic radiation detectors.) Compare the different types of cosmic radiation detectors.
- SA53 (Analyze the different types of cosmic radiation detectors.) Analyze the different types of cosmic radiation detectors.
- SA54 (Analyze the different sources of cosmic radiation.) Analyze the different sources of cosmic radiation.
- SA55 (Use bibliographic tools, online and in English, to delve into the key concepts of high-energy astrophysics.) Use bibliographic tools, online and in English, to delve into the key concepts of high-energy astrophysics.

Contents

Outline of the Course

1. Introduction. Physical processes

Production of high-energy (X- and gamma-ray energy range) photons and cosmic rays.

Particle acceleration in the universe.

2. Observation methods

X- and gamma-ray instrumentation from space and ground-based. Cosmic-ray detectors.

Neutrino astronomy. Direct dark matter detection techniques.

3. The high-energy sky

Accretion-powered sources: white dwarfs, neutron stars and black holes in binaries. Active galactic nuclei.

Nova and supernova explosions. Supernova remnants, pulsars and pulsar wind nebulae

Gamma-ray emission related to nucleosynthesis. Diffuse and line emission

Gamma-ray emission related to matter anti - matter annihilation

Gamma-Ray Bursts

Cosmic rays: origin and propagation; possible acceleration sites

Gamma rays as probes of the intergalactic medium (extragalactic background light, magnetic fields)

4. Multi-messenger astronomy, fundamental physics aspects

Evidence for dark matter. Direct and indirect dark matter searches, possible candidates and signatures.
Current limits from multi-messenger astronomy.

Tests of Lorentz invariance with multi-messenger observations.

Search for axion-like particles through cosmic- and gamma-ray propagation anomalies.

Learning activities and methodology

Title	Hours	ECTS	Learning outcomes
Homework: study, check of the lecture notes and slides	65	2.6	
Lectures	45	1.8	
Oral presentation on a topic, based on a paper and associated references	35	1.4	

Theory lectures.

Classwork and homework.

Annotation: within the schedule set by the centre or degree programme, 15 minutes of one class will be reserved for students to evaluate their lecturers and their courses or modules through questionnaires.

Assessment

Continuous assessment activities

Title	Weight	Hours	ECTS	Learning outcomes
Attendance and active participation to the lectures	10%	0	0	CA14, KA22, SA51, SA52, SA53, SA54
Oral presentation of a research topic	45%	1	0.04	CA14, KA22, SA51, SA52, SA53, SA54, SA55
Final exam	45%	4	0.16	CA14, KA22, SA51, SA52, SA53, SA54

Attendance to the lectures and active participation (e.g., asking questions) will be tracked

One final exam covering all the topics will be done (with a tentative duration of 2.5 hours).

Individual work on a research topic, based on a paper provided by the teachers and on the associated references found by the student, is required. A written report and its oral presentation, followed by a discussion with the panel (teachers of the master), should be done.

In case of failure, there will be the opportunity to pass the course with a new exam and / or the defense of a

new essay; the threshold score to have the opportunity to recover is 3/10.

This subject/module does not foresee the single assessment system.

Model 2 - Restricted Use: For this subject, the use of Artificial Intelligence (AI) technologies is permitted exclusively in support tasks, such as bibliographic or information searches, text correction or translations and creation of illustrations for the presentation. The student must clearly identify which parts have been generated with this technology, specify the tools used and include a critical reflection on how these have influenced the process and the final result of the activity. The lack of transparency of the use of AI in this assessable activity will be considered a lack of academic honesty and may lead to a partial or total penalty in the grade of the activity, or greater sanctions in serious cases.

Bibliography

- Radiation Detection and Measurement, Glenn F. Knoll, Wiley, NJ, USA (2000)
- Exploring the X-ray Universe, Philip A. Charles, Frederick D. Seward, Cambridge University Press, Cambridge, UK (1995)
- Radiative Processes in Astrophysics, Rybicki, G. B. and Lightman, A. P., Wiley-VCH Verlag GmbH, Weinheim, Germany (1985)
- Very high energy cosmic gamma radiation : a crucial window on the extreme Universe, F. A. Aharonian, River Edge, NJ: World Scientific Publishing (2004)
- Accretion power in Astrophysics", J. Frank, A. King, D. Raine, Cambridge University Press (3rd Edition, 2002)
- High Energy Astrophysics", M.S. Longair, Cambridge University Press (2011) (also available as EBOOK)

Software

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Course groups and languages

The information provided is provisional until November 30. After this date, you will be able to consult the language of each group through this [link](#). To access the information, you will need to enter the course CODE

Type of teaching	Group	Language	Semester	Shift
(TE) Theory (master)	1	English	second semester	morning-mixed