UNIVERSITÀ DEGLI STUDI DI PALERMO

DEPARTMENT	Fisica e Chimica - Emilio Segrè
ACADEMIC YEAR	2022/2023
MASTER'S DEGREE (MSC)	PHYSICS
SUBJECT	ASTROPHYSICS - LABORATORY
TYPE OF EDUCATIONAL ACTIVITY	C
AMBIT	20901-Attività formative affini o integrative
CODE	21961
SCIENTIFIC SECTOR(S)	FIS/05
HEAD PROFESSOR(S)	BARBERA MARCO Professore Associato Univ. di PALERMO
OTHER PROFESSOR(S)	
CREDITS	6
INDIVIDUAL STUDY (Hrs)	78
COURSE ACTIVITY (Hrs)	72
PROPAEDEUTICAL SUBJECTS	
MUTUALIZATION	
YEAR	2
TERM (SEMESTER)	1° semester
ATTENDANCE	Mandatory
EVALUATION	Out of 30
TEACHER OFFICE HOURS	**BARBERA MARCO** Tuesday 15:30 17:30 Laboratorio XACT dell'INAF-OAPA in via G.F. Ingrassia 31 Thursday 15:30 17:30 Laboratorio XACT dell'INAF-OAPA in via G.F. Ingrassia 31

DOCENTE: Prof. MARCO BARBERA

PREREQUISITES	- Basic knowledge of the laws of classical physics, and in particular: electromagnetism, geometrical optics, kinetic theory of gases. - Radiation interaction processes with matter. - Standard Methods for the analysis and processing of data and the errors associated with them.
LEARNING OUTCOMES	Knowledge and understanding Acquisition of fundamental knowledge on the instruments used for the detection of electromagnetic radiation in Astronomy, and particularly in the band of X-rays. Knowledge of the main technical characteristics of certain instruments in use or under development (optics and detectors) and ability to identify weakenes and strengths of these tools for their scientific application in Astronomy. Applying knowledge and understanding Ability to apply the acquired knowledge to design and carry out a program of astronomical observations, for example in the visible band, or a program of laboratory measurements within a development and calibration activity of X-ray instrumentation. Making judgments Ability to contribute, within a program of experimental measurements, to set-up the experimental apparatus, define the measurement procedure, choose the algorithms for the analysis and data processing. Ability to interpret the measurement results and the associated experimental uncertainty. Communication skills Ability to present with clarity and expertise, both in writing and orally, the results of a measurement program. Ability to synthesize in the exposure and skills in the use of graphical tools for the presentation of scientific work products. Learning skills Capacity to study from text books, scientific publications and technical reports in the field of observational Astronomy and in particular on instrumentation for the detection of X-rays. Ability to successfully attend seminars and specialist conferences in the field.
ASSESSMENT METHODS	The final assessment is based on the evaluation of a report on the activities carried out by the student in the laboratory and on an oral exam. The lab report usually contains a description of: the objectives of the experience, the experimental set-up used, the experiments carried out and the methodology used to analyze the data and short discussion of the results. The experiments and the related reports are carried out in groups of two-three students, in such a way as to combine the ability to work independently with the ability to confront in a group. The preparation of the reports has the aim to stimulate the student to describe a work activity with the ability of synthesis, clarity, and appropriate scientific terminology. The oral test consists of an examination-interview in which the candidate is invited to present and defend his lab report. During this discussion, taking a cue from the report, but not only, the candidate is asked to expand on the topics that were covered during the course. This test allows to evaluate not only the candidate’s knowledge and his ability to apply it, but also his technical language skills and ability to present a topic in a clear and concise way. The final assessment will be made on the basis of the following level of performances: a) Basic knowledge of the experimental techniques, sufficient degree of awareness and autonomy in defense of the activities carried out in the laboratory and described in the report (18-22); b) good knowledge of the experimental techniques, fair degree of awareness and autonomy in defense of the activities carried out in the laboratory and described in the report (23-26); c) detailed knowledge of the experimental techniques and capability to put them in a context, good degree of awareness and autonomy in defense of the activities carried out in the laboratory and described in the report (27-30 laude);
EDUCATIONAL OBJECTIVES	The course “Laboratory Astrophysics” provides an introduction to the main electromagnetic radiation detection techniques used in High Energy Astrophysics, and a discussion of the main parameters that characterize the performance of such instrumentation (effective area, the field of view, angular resolution , energy resolution, temporal resolution). The observational techniques used in High Energy Astrophysics are then addressed in more detail describing the characteristics of certain types of equipment in use or under development for future space missions. Finally, some basic concepts are presented on vacuum technologies used for the development and calibration of instrumentation for high energy astrophysics. The laboratory activities are divided into two modules. The first one consists of carrying out an observational program of optical astronomy using a telescope

	equipped with a CCD camera belonging to INAF-OAPA in the Norman Palace (also venue of DiFC). In the second module, students will acquire the ability to use in the laboratory equipment for the characterization of optical components studied in the context of astronomy projects from space. The experience will include the preparation of the experimental apparatus, the acquisition of measurements and data analysis and will be carried out at the XACT laboratory of INAF-OAPA.
TEACHING METHODS	The course takes place in the first semester of the second year of the master's degree in Physics. The teaching activity consists of lectures (3 credits) and laboratory experiments (3 credits). The former aim at providing basic concepts on the main techniques used in Astronomy to detect electromagnetic radiation, in particular in the field of high energies, and on some aspects related to the need to use such instrumentaion from Space. The latter are intended to allow the students to carry out a program of observations with an optical telescope, and also to use laboratory instrumentation for the characterisation of optical components for space astronomy missions.
SUGGESTED BIBLIOGRAPHY	Gli argomenti del corso sono trattati in alcuni capitoli dei seguenti testi e in ulteriore materiale bibliografico che saranno suggeriti via via dal docente. The topics of the course are dealt within some chapters of the following texts, and in further bibliographical material that will be gradually suggested by the teacher. Basic textbooks H. Bradt, 'Astronomy Methods - A Physical Approach to Astronomical Observations', 2004, Cambridge University Press., ISBN 052136440X C. R. Kitchin, 'Astrophysical Techniques' – 4th edition, 2003, Institute of Physics Publishing, Bristol and Philadelphia, ISBN 9780750309462 In-depth textbooks A.G. Michette and C.J. Buckley, ‘X-Ray Science and Technology’, 1993, Institute of Physics Publishing, Bristol, UK, ISBN 10: 075030233X G.W. Fraser, ‘X-ray Detectors in Astronomy’, 1989, Cambridge University Press., ISBN 9780521106030 N. Harris, ‘Modern Vacuum Practise’, 1989, McGraw-Hill Book Company.

SYLLABUS

Hrs	Frontal teaching
2	- Observational Astronomy: cosmic rays, electromagnetic radiation, gravitational waves. - Atmospheric absorption of E.M. radiation - Main characteristics of an E.M. radiation detector (Quantum efficiency, spectral resolution, temporal resolution, spatial resolution, polarization). - Main features of a telescope (effective area, angular resolution).
2	- Recalls on the main processes of radiation interaction with matter in the X-rays. - The Photoelectric Absorption. - The mass attenuation coefficient of a monatomic substance and a chemical compound. - Absorption fine structures.
2	- Laboratory X-ray sources. - Electron impact X-ray source. Emission line and continuum.
2	- X-ray monochromators. - Fraunhofer diffraction from a grating, the Chandra LETG. - Bragg diffraction in crystals or multilayers. - X-ray monochromator schemes: Bragg-Bragg channel cut, Laue-Bragg, Bragg-Bragg fixed output. - The solution chosen at the XACT facility.
6	- X-ray detectors. - The gas and gas scintillating proportional counters. - The micro-channel plate. - The solid state detectors. - The microcalorimeters.
4	- X-ray optics. - Operating principles: Total reflection, Bragg and Laue diffraction, coded masks. - Geometries: Kirkpatrick-Baez, Wolter, double cone, spiral, Lobster eye. - Technologies: polishing, replication, thin sheets, Si micropores, plastic foils, active optics.
2	- Spacecraft: balloons, rockets, satellites. - Launchers. - Satellites and characteristics of the different orbits. - Measurement of time, attitude control, tracking.
2	- Introduction to some high energy Astrophysics missions currently operating or under design and development. The Athena mission of the European Space Agency and the italian contribution to the hardware development. The filters of the WFI and X-IFU detectors.
2	Vacuum technologies. Viscous and molecular flow. Pumping speed, throughput, conductance. Main gas contributions in high and ultra high vacuum systems. Vacuum pumps, pressure gauges, leak detectors, quadrupole probe.

Hrs	Workshops
24	1. Laboratory of Optical Astronomy Carrying out a program of photometric observations using the Celestron C14 telescope at INAF-OAPA. Study of variable stars with the differential photometry technique. 1.1 Introduction. - Differential and absolute photometry. Operation and calibration of an optical CCD. The Celestron C14 at INAF-OAPA. 1.2 Selection of the science targets and reference sources. Finding sources in catalogs and check observability of selected sources (e.g. magnitude of variability amplitude, observing site, date of observation, etc.). 1.3 Determination of exposure time based on the properties of the selected sources and instrumental characteristics; 1.4 Carry out the instrument calibration program and observation of the selected targets; 1.5 Data analysis and comparison with data published in the literature.
24	2. Laboratory of X-ray Astronomy Participation in an experimental program at the XACT laboratory of INAF-OAPA. 2.1 Introduction. - The XACT laboratory and its main components: electron impact X-ray source, vacuum system, X-ray detectors, control and operation of these instruments. 2.2 Analysis of the experimental apparatus and definition of the measurement technique to use based on the physical quanity to be calibrated (transmission of materials, detection efficiency, energy resolution, imaging capability and effective area of X-ray optics, etc.); 2.3 Carry out the measurement program; 2.4 Data analysis and interpretation of the results.