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EUROPEAN UNIVERSITY FOR CUSTOMISED EDUCATION

STUDY GUIDE

NUCLEAR ASTROPHYSICS

Organised by

[Università di Catania]

1. IDENTIFYING DATA.	
· **Course Name.**	*Nuclear Astrophysics (1015752)*
· **Coordinating University.**	*Università di Catania*
· **Partner Universities Involved.**	---
· **Course Field(s).**	*Astrophysics, astronomy, nuclear physics*
· **Related Study Programme.**	*International Master of Science in Physics (Msc in Physics), LM17*
· **ISCED Code.**	*0533 Physics*
· **SDG.**	*SDG Goal 4: Inclusive and equitable quality education* *SDG Goal 7: Affordable and clean energy* *SDG Goal 9: Industry, innovation and infrastructure*
· **Study Level.**	*The course is part of the International Master of Science in Physics (Msc in Physics, LM17) program*

· **Number of ECTS credits allocated.**	*6*
· **Mode of Delivery.**	*Online (intended for EUNICE)*
· **Language of Instruction.**	*English*
· **Course Dates.**	*from 03/03/2025 to 14/06/2025*
· **Schedule of the course.**	*Second semester*
· **Key Words.**	*Stars, stellar evolution, energy generation, stellar nucleosynthesis, primordial nucleosynthesis, nuclear reactions, nuclear reaction mechanisms, cross sections, indirect methods, experimental nuclear physics*
· **Catchy Phrase.**	*The cosmos is within us. We are made of star-stuff. (Carl Sagan)*

· **Prerequisites and co-requisites.**	*Elements of stellar physics - stellar evolution - nuclear processes in stellar evolutions - elements of nuclear physics - nuclear models - nuclear reactions - energy balance - cross section - main characteristics of charged particle detectors*
· **Number of EUNICE students that can attend the Course.**	*unrestricted number*
· **Course inscription procedure(s).**	*EUNICE website*

2. CONTACT DETAILS.	
· **Department.**	*Dipartimento di Fisica e Astronomia "E. Majorana", Univ. di*

	Catania
· Name of Lecturer.	*Livio Lamia*
· E-mail.	*livio.lamia@dfa.unict.it*
· Other Lecturers.	-----

3. COURSE CONTENT.

1. Introduction to the Nuclear Astrophysics
Primordial nucleosynthesis. Formation of stars. Physical basis of stellar evolution. State equation and energy production. Stellar equilibrium equations. Stellar evolution. Quiescent combustion. Explosive scenarios. Stellar nucleosynthesis: combustion of hydrogen, combustion of helium. Processes r and s

2. Thermonuclear reactions
Definitions: Cross section, reaction rate, mean life.

3. Reaction rates in stars
Non-resonant reactions induced by neutrons, non-resonant reactions induced by charged particles. Resonant reactions

4. Measurements of cross sections at energies of astrophysical interest
Direct measurements, Limit of direct measurements. Electronic screening in the laboratory and in the stars. Indirect methods, Theoretical recalls: Direct-type reaction mechanisms. Indirect measures: ANC, Coulomb dissociation, Trojan Horse Method, R-matrix, Inverse reactions. Reactions with radioactive beams.

5. Techniques and experimental setups in Nuclear Astrophysics

4. LEARNING OUTCOMES.

The course aims to provide students with a sufficiently broad picture of the combination and synergy of skills oftwo of the most fascinating fields of scientific research: Astrophysics and Nuclear Physics. After a discussion of peculiar aspects of the two research fields, experimental techniques and theoretical approaches, that have led to important results in Nuclear Astrophysics, will be presented. The course also aims to enhance:

Knowledge and understanding.

Critical understanding of the most advanced experimental procedures and techniques in Nuclear Physics needed for applications in the stellar environments.

Remarkable expertise with the scientific method, understanding of nature, and of the research in NuclearAstrophysics.

Applying knowledge and understanding

Ability to identify the essential elements of a phenomenon, also in terms of order of magnitude and

level of approximation necessary, for applications in Astrophysics.

Ability to use analogy as a tool to apply known solutions to new problems (problem solving).

Ability to plan and apply experimental and theoretical procedures to new measurements, or to improve existing results.

Making judgements

Ability to convey own interpretations of physical phenomena, when discussing within a research team.

Communication skills.

Ability to discuss about advanced physical concepts, both in Italian and in English.

Learning skills.

Ability to acquire adequate tools for the continuous update of one's knowledge. Ability to exploit databases and bibliographical and scientific resources to extract information and suggestions to better frame and develop one's study and research activity. Ability to acquire, through individual study, knowledge in new scientific fields.

5. OBJECTIVES.

The course aims at providing the following objectives:
- to apply fundamental laws in physics to problems related with stellar physics and nuclear physics;
- to apply the knowledge of nuclear physics concepts within stellar evolution and nucleosynthesis of the elements in the cosmos;
- to apply fundamental laws for deriving physical quantities of interest in nuclear physics, such as binding energy and q-value;
- to apply the acquired skills for evaluating astrophysically relevant energy ranges in nuclear astrophysics, cross sections and reactions rates for nuclear reactions;
- to apply basic knowledges for the application of indirect methods in experimental nuclear astrophysics

6. COURSE ORGANISATION.

UNITS

1.	*Nuclear processes involved in stellar evolution*
2.	*Nucleosynthesis in the Cosmos*
3.	*Nuclear structure and binding energy*
4.	*Nuclear reactions: q-value, cross sections and reactions rates*
5.	*Difficulties in experimental nuclear astrophysics: indirect methods*

LEARNING RESOURCES AND TOOLS.

Lectures will be delivered by using slides prepared by the teacher.
PLANNED LEARNING ACTIVITIES AND TEACHING METHODS.
Learning activities are in the form of lectures on the different topics. Seminars could be also delivered.

7. ASSESSMENT METHODS, CRITERIA AND PERIOD.

At the end of the course, an oral exam is foreseen.

OBSERVATIONS.

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8. BIBLIOGRAPHY AND TEACHING MATERIALS.

1. Nuclear Physics of Stars, C. Iliadis, Wiley
2. Cauldrons in the Cosmos, C. Rolfs, The Univ. Of Chicago Press
3. Nuclear and Particle Physics, W.S.C. Williams, Clarendon Press
4. Introductory Nuclear Physics, K. S. Krane, Wiley & Sons. Inc.