UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

COURSE SYLLABUS

Stellar Astrophysics

2526-1-F5803Q002

Aims

Stellar astrophysics is the branch of astronomy that focuses on understanding stars, their formation, structure, evolution, and eventual fate. It helps us learn how stars are born from clouds of gas and dust, how they produce energy through nuclear fusion, how they shine and change over time, and how they die - like becoming white dwarfs, neutron stars, or black holes. Stellar astrophysics is for understanding the fundamental building blocks of galaxies and of the universe as a whole.

The acquisition of knowledge, comprehension and competence in this field is guided by the Dublin Descriptors:

Knowledge and understanding (DdD1)

- knowledge and comprehension through modelling of stellar equilibria given a microphysical state of matter;
- knowledge and comprehension of the role of radiation and nuclear reactions in stars;
- knowledge and comprehension of stellar stability and gravitational collapse;
- knowledge and comprehension of star formation in its foundations.

Applying knowledge and understanding (DdD2)

- ability to use astrophysical observations to construct models and to test and constrain stellar properties using classical and quantum mechanics;
- ability to analytically derive stellar properties from birth to death using basic principles, and to acquire the competencies necessary to apply stellar physics in the context of galaxy formation and evolution;
- students will use their computers to create key diagrams illustrating the evolution of stars.

Making judgements (DdD3)

- analysis of open problem and development of critical understanding.

Communication skills (DdD4)

- students will be invited to present and summarize key concepts of stellar astrophysics to their peers. Additionally, the examination topic supports the development of communication skills with both depth and rigor.

Contents

Key areas of study within stellar astrophysics include:

Stellar Structure: studying the internal layers of stars and the role of gravity, thermodynamics, quantum mechanics and radiation in shaping their equilibrium properties.

Stellar Evolution: understanding how stars change over time and evolve into their eventual fate, such as becoming white dwarfs, neutron stars, or black holes; exploring the origin of the chemical elements and metal enrichment.

Star's Formation: investigating how interstellar gas clouds cool down, collapse and fragment into stellar clusters; the role of metallicity in shaping the stellar initial mass function.

Stars in binary systems: investigating stellar evolution when stars pair in binaries.and their detectability as electromagnetic and gravitational wave sources.

Detailed program

I. BASIC CONCEPT

- Hertzprung-Russell Diagram
- Stellar equilibria and stability, virial theorem, stellar timescales
- Light from stars: black body radiation, opacity and radiative/convective transport
- Classical and quantum gases
- Nuclear reactions: Gamov’s energy, synthesis of the heavy elements
- Stability

II. STARS ON THE MAIN SEQUENCE

- Scaling relations
- The Initial Mass Function (IMF)
- Maximum and Minimum mass of stars and mass funciton

III. STELLAR EVOLUTION

- The role of gravity and microphysics in driving stellar evolution
- Degenerate stars: the Chandrasekhar Mass limit
- Evolving stars in the Hertzprung-Russell diagam
- Red giants, Horizonthal Branch, AGB
- Advanced reading in stellar evolution (*)
- Supernovae (*)
- Stellar Feedback (*)
- Gravitational collapse: neutrino emission and deleptonisation (*)
- White dwarfs, neutron stars and black holes - mass function
- Cooling of white dwrafs (*)

- Stellar evolution in binary systems (*)

IV. STAR FORMATION

- Gas cooling
- Star formation: Jean’s Mass, protostars and the Hayashi track
- Population III stars (*)
- Planet formation (*)

The asterisk indicates advanced topics that students choose to explore the material in greater depth. These can serve as potential themes for the topic selected by the student during the oral examination.

Prerequisites

Undergraduate Degree in Physics or Astronomy.

In more detail, knowledge is requested in:

Calculus
Classical Mechanics
Electromagnetism
Structure of matter
Quantum Mechanics

Teaching form

Total hours in teaching delivery mode 60 - CFU 8
42 hours of frontal lectures, mostly at the blackboard, occasionally with the support of slides (6 CFU)
16 hours of supporting activities and exercises (2 CFU)

No synchronous remote teaching activity is planned for this class.
Lectures are in English.

Recorded lectures from previous years are available for students who may be unable to attend classes in person.

Textbook and teaching resource

Supporting materials will be uploaded to the e?learning platform throughout the course. Below is an (incomplete) list of useful books and references, which will be updated regularly.

Books:

Notebook, "Stellar Astrophyiscs" by Chiesa under the supervison of Colpi

Prialnik, “Stellar structure and evolution” - the reference book

Phillips, “The Physics of Stars” - ample description of nuclear reactions in stars and basic description of stellar equilibria

Kippenhahn and Weigert, “Stellar structure and evolution” - key text for understanding stellar evolution and star's formation - advanced text

Stahler and Palla, “The formation of stars” - advanced text

Armitage, "Astrophysics of planet formation" - reference book

Shapiro and Teukolsky, “Black holes, white dwrafs and neutron stars” - the classic text on compact objects

Selected reviews and selected papers provided during the lectures.
Recorded classes.

Semester

First semester

Assessment method

The final exam is an oral assessment (viva) covering all topics discussed in class. There are no intermediate (midterm) exams.

The exam is divided into three parts:

General Knowledge

- assessment of the student’s knowledge on the foundational principles of stellar astrophysics

Ability of understanding

- evaluation of the student’s understanding of the physical processes underlying stellar astrophysics, described with detail and rigor.

Student topic

- presentation of a topic chosen by the student, preferably delivered as a computer?based presentation (e.g. slide deck), or alternatively on a written paper note (10 minutes).

Evaluation is based on three equally important criteria:

1. **Depth of Understanding**
   ? Demonstrate a comprehensive grasp of the subject matter.
   ? Show ability to connect concepts and apply knowledge in context.

2. **Analytical Thinking**
   ? Successfully perform analytical derivations where appropriate.
   ? Pose relevant, thoughtful, and probing questions.

? Engage critically with the material.

3. **Clarity and Conciseness of Presentation**
   ? Present ideas in a clear and logically structured manner.
   ? Use precise language and appropriate visual aids (when applicable).

Office hours

Upon appointment via email

Sustainable Development Goals

QUALITY EDUCATION