UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

COURSE SYLLABUS

Modern Cosmology and Galaxy Formation

2425-1-F5802Q022

Aims

Gain foundational knowledge and a comprehensive understanding of major topics in Modern Cosmology and Galaxy Formation in the early Universe. Establish a strong Master-level basis for engaging with current theoretical research and observational efforts in the field. Enhance practical research skills, including the ability to formulate meaningful questions and hypotheses, and develop effective strategies for testing them.

Contents

The field of galaxy formation, a rapidly growing area of study, sits at the crossroads of astronomy, particle physics, and cosmology. This course integrates diverse topics from these disciplines, which collectively underpin our understanding of how cosmic structures form and evolve. Key subjects include the evolution of the Universe and its particle and radiation content, the statistical properties of large-scale cosmic structures, the linear and nonlinear growth of dark matter halos, the interplay of processes affecting the gaseous and dark matter components of galaxies and clusters, and the thermodynamics and chemistry of cosmic baryons. By balancing observational and theoretical perspectives, the course offers astrophysics students a comprehensive introduction to the science behind galaxy formation and evolution. Furthermore, new ground- and space-based instruments and facilities set to emerge over the next decade promise transformative insights into primeval galaxies, the timeline and photon budget of reionization, and the physics and fine-grained properties of the gas within the "cosmic web."

Detailed program

Smooth Homogeneous Universes
Surface Brightness and Extragalactic Background Light
Cosmic Dynamics

Observational Tools in Cosmology
Distances and Horizons in Cosmology
Thermal History and Recombination
Collisional Boltzmann Equation and Relic Abundance
Dark Matter
MACHOs and WIMPs
N-Body Simulations
Gaussian Random Fields and Correlation Function
Gravitational Instability
Jeans Mass and Baryomic Acoustic Oscillations
Non-Linear Evolution and the Formation of Dark Matter Halos
Properties and Abundance of Dark Matter Halos
End of the Dark Ages
21-cm Cosmology
Kompaneets Equation and Sunyaev-Zeldovich Effect
Cosmic Star Formation History
Cosmic Reionization of Hydrogen and Helium
Early Results from the James Webb Space Telescope

Prerequisites

Mathematics and Physics for students of the bachelor's degree. Basic knowledge of electromagnetism, gravitation, relativity, particle and atomic physics, statistical physics and thermodynamics. It is useful (but not required, as the course is largely self-contained) to take this class after the first-semester courses of the Astrophysics and Space Physics Master.

Teaching form

The lectures (6 CFU, 42 contact hours) will be held in English. During the lectures, the instructor will propose questions and problems (not graded) to be solved in groups, in order to encourage students to actively participate in class. All materials will be made available online, but attendance and active participation are integral parts of the teaching-learning process.

Textbook and teaching resource

There is no official textbook for this course. However, you will find most of the topics we cover in these books:

Peebles, Peebles Principles of Physical Cosmology. ISBN: 0691019339
Longair, Galaxy Formation. ISBN: 978-3-540-73477-2
Mo, van den Bosch, & White, Galaxy Formation and Evolution. ISBN: 9780511727726
Padmanabhan, Theoretical Astrophysics Volume III. ISBN:0521566304

The instructors notes will be made available on the e-learning page of the course.

Semester

Second Semester.

Assessment method

The final exam will take the form of an oral discussion focused on the concepts and practices covered in the course. It will last approximately 40 minutes and consists of two parts. In the first part, the candidate will deliver a 20 minute presentation on a selected topic related to cosmology or galaxy formation, agreed upon in advance with the instructor. The presentation will involve the use of the blackboard. The second part will include questions and discussions designed to assess the students' qualitative and quantitative understanding of the key concepts taught in the course and their ability to perform analytical derivations.

The oral exam will be conducted in English.

Office hours

By appointment (via email).

Sustainable Development Goals