# COURSE DATA

| Data Subject | |
|---|---|
| **Code** | 43299 |
| **Name** | Cosmology |
| **Cycle** | Master's degree |
| **ECTS Credits** | 6.0 |
| **Academic year** | 2022 - 2023 |

**Study (s)**

| Degree | Center | Acad. year | Period |
|---|---|---|---|
| 2150 - M.D. in Advanced Physics | Faculty of Physics | 1 | First term |

**Subject-matter**

| Degree | Subject-matter | Character |
|---|---|---|
| 2150 - M.D. in Advanced Physics | 3 - Advanced astrophysics | Optional |

**Coordination**

| Name | Department |
|---|---|
| | 16 - Astronomy and Astrophysics |
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# SUMMARY

Friedmann-Robertson-Walker (FRW) models. Inhomogeneities in the universe. Large-scale structure (observations). Statistical description of cosmic structure. The universe as a mixture of species interaction. The cosmological microwave background. Microwave background anisotropies

# PREVIOUS KNOWLEDGE

## Relationship to other subjects of the same degree

There are no specified enrollment restrictions with other subjects of the curriculum.

## Other requirements

# OUTCOMES

## 2150 - M.D. in Advanced Physics

- Students can apply the knowledge acquired and their ability to solve problems in new or unfamiliar environments within broader (or multidisciplinary) contexts related to their field of study.
- Students are able to integrate knowledge and handle the complexity of formulating judgments based on information that, while being incomplete or limited, includes reflection on social and ethical responsibilities linked to the application of their knowledge and judgments.
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- Comprender la fase terminal de las estrellas que conduce a la formación de objetos compactos (enanas blancas, estrellas de neutrones o agujeros negros) incluyendo el colapso estelar que precede a la formación de estos objetos, incluyendo también fenómenos como las supernovas y las erupciones de rayos gamma.

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## LEARNING OUTCOMES

At the end of the teaching-learning process the student will have learned to:

1. Select and correctly use various sources of information in both traditional and electronic format.
2. Know the basics of databases and bibliographic resources typica of the field: inspire, spiers, arXiv.
3. Properly handle and interpret qualitative and quantitative physical data, which validate the known theories in the field.
4. Analyze information from physical systems.
5. Prepare written documents and reports in an understandable and organized way. Document and illustrate such documents.
6. Articulate structured, consistent, oral speech, with a good diction and use of technical vocabulary.
7. Understand the arguments used in the field of Astronomy and Astrophysics.
8. Understanding the mathematical description of physical processes governing the formation and evolution of celestial objects at both stellar and cosmological scales.

Being able to develop and manage the mathematical techniques and skills for their application in simple cases of the Einstein equations of gravitation.

## DESCRIPTION OF CONTENTS

### 1. Friedmann-Robertson-Walker (FRW) Models

The cosmological principle, the Robertson-Walker metric and the background universe (FRW). Basic equations and free parameters in models including dark energy (cosmological constant or quintessence). The cosmological redshift z. Age of the Universe at redshift z. Cosmological distances

### 2. Inhomogeneities in the universe

Random fields in cosmology. Description of the density fluctuations.
Power spectrum. Gravitational instability. Dynamic structure formation.
Baryon acoustic oscillations. Evolució no lineal. Tècniques numèriques i universos virtuals.

### 3. The universe as a mixture of interacting species

The species filling the universe and their proportions in each cosmological period. Distribution functions in thermal equilibrium. The number density of photons and baryons. Liouville and Boltzmann equations in the FRW universe. Decoupling of species.

### 4. The cosmic microwave background (CMB)

Matter-radiation equilibrium for T >3500K: Black body spectrum. Recombination at T = 3500 K. Saha formula. The recombination studied with the Boltzmann equation: Residual ionization fraction. Matter-radiation decoupling. Silk damping. CMB evolution after decoupling (Liouville in FRW). Linear polarization of the CMB due to Thompson scattering during the recombination-decoupling process. Temperature constrast and angular correlations: deviations from gaussianity. Primordial contrasts at the decoupling epoch. Sachs-Wolfe, Doppler, and integrate Sachs-Wolfe contrasts. Non-gaussian effects: Rees-Sciama, lens, Sunyaev-Zeldovich, and Visniach. The angular power spectrum (Cl coefficients).

### 5. Observational Cosmology

Galaxies. The Local Group. Groups and clusters of galaxies. The macro-cosmic filaments walls and voids. Spectroscopic and photometric catalogs. Luminosity function. Peculiar velocities and virial theorem. X-ray emission: thermal bremsstrahlung. Estimates of mass and dark matter. Determination of cosmological parameters. Gravitational lenses: theory and observation.

### 6. Statistical  description of cosmic structure

Statistical description of cosmic structure. Distribution of galaxies and matter density field. Bias. Point processes.Counts per cell. Distribution function. Estimate of the correlation function. Effect of peculiar velocities. Real space and redshift space. Morphology and luminosity segregation. Cosmic evolution. Other descriptions of the macro cosmic fractal topological genus.

## WORKLOAD

| ACTIVITY | Hours | % To be attended |
|---|---|---|
| Theory classes | 39,00 | 100 |
| Other activities | 4,00 | 100 |
| Seminars | 3,00 | 100 |
| Preparing lectures | 52,00 | 0 |
| Preparation of practical classes and problem | 52,00 | 0 |
| **TOTAL** | **150,00** | |

## TEACHING METHODOLOGY

MD1 – Standard theory lecture.
MD3 – Problem solving.
MD4 – Problems.
MD5 – Seminars.
MD8 – Conferences of experts.

## EVALUATION

SE1 - Written exam on the theory and practical lectures: based on the results of learning and the specific objectives of each subject (100%).

## REFERENCES

### Basic

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