SUBJECT TEACHING GUIDE

280 - THE DARK UNIVERSE

Master's Degree in Particle Physics and the Cosm

Academic year 2024-2025

1. IDENTIFYING DATA					
Degree	Master's Degree in Particle Physics and the Cosmos			Type and Year	Optional. Year 1
Faculty	Faculty of Sciences				
Discipline	PARTICLE PHYSICS AND ADVANCED COSMOLOGY				
Course unit title and code	280 - THE DARK UNIVERSE				
Number of ECTS credits allocated	6	Term		Semester based (2)	
Web					
Language of instruction	Spanish	English Friendly	No	Mode of delivery	Face-to-face

Department	INSTITUTO DE FISICA DE CANTABRIA
Name of lecturer	BRADLEY JAMES KAVANAGH
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Other lecturers	JOSE MARIA DIEGO RODRIGUEZ ROCIO VILAR CORTABITARTE IGOR GARCIA IRASTORZA

3.1 LEARNING OUTCOMES

- Understand the meaning of the Dark Universe
- Understand the Dark Universe from different points of view: astrophysics, cosmology and particle physics
- Identify the current evidence for Dark Matter and Dark Energy
- Know the properties of Dark Matter and Dark Energy, and their possible interpretations
- Know the ongoing theoretical and experimental efforts to understand the Dark Universe , including:
  - ? Identifying a range of possible candidates for Dark Matter
  - ? Knowing the state-of-the-art of Dark Matter searches (direct, indirect and collider searches)
  - ? Identifying possible explanations for Dark Energy
  - ? Knowing the current state-of-the-art in constraining the properties of Dark Energy
- Be familiar with alternatives to Dark Matter and Dark Energy

4. OBJECTIVES

- Introduction to Dark Matter (DM) and Dark Energy (DE)
- The Lambda-Cold Dark Matter “Concordance Model” of Cosmology
- Observational evidence for DM (Big Bang Nucleosynthesis, Cosmic Microwave Background, Galaxy Clusters, Galaxy Rotation Curves)
- DM Candidates (including WIMPs, Axions, MACHOs, hidden sectors,..)
- Production of DM in the Early Universe (Freeze-out, Freeze-in)
- DM detection (direct, indirect, colliders)
- Alternative models to DM, such as Modified Newtonian Dynamics (MOND)
- Observational evidence for the accelerated expansion of the universe (DE)
- The cosmological constant problem
- DE and alternatives: cosmological constant, modified gravity, quintessence, dark fluid
- Prospects for constraining the properties of DE with future cosmological surveys and telescopes

6. SUBJECT PROGRAM

CONTENTS	
1	Classes and practicals on Dark Matter (DM) and Dark Energy (DE)
2	Oral Presentation
3	Tutorials
4	Individual work - problems and written reports

7. ASSESSMENT METHODS AND CRITERIA

Description	Type	Final Eval.	Reassessn	%
Written tasks and reports	Work	Yes	No	45,00
Oral Presentation	Oral Exam	Yes	Yes	45,00
Attendance and participation to the in-person activities	Others	No	Yes	10,00
TOTAL				100,00

Observations

Evaluation will be based on written tasks and reports (approx 45%), a final oral presentation (approx 45%), and attendance and participation to the in-person activities (approx 10%). Depending on health restrictions, it may be necessary to re-weight the different aspects of the evaluation.

Observations for part-time students

Evaluation will be based on written tasks and reports (approx 45%), a final oral presentation (approx 45%), and attendance and participation to the in-person activities (approx 10%). Depending on health restrictions, it may be necessary to re-weight the different aspects of the evaluation.

8. BIBLIOGRAPHY AND TEACHING MATERIALS

BASIC

“The Early Universe”, E. Kolb & M. Turner (1990) [https://ui.adsabs.harvard.edu/abs/1990eaun.book.....K/abstract]

“Particle Dark Matter: Evidence, Candidates and Constraints”, G. Bertone, D. Hooper & J. Silk (2004) [https://arxiv.org/abs/hep-ph/0404175]

“Particle Dark Matter: Observations, Models and Searches”, edited by G. Bertone, Cambridge University Press (2010) [https://doi.org/10.1017/CBO9780511770739]

“Lectures on Dark Matter Physics”, M. Lisanti (2016) [https://arxiv.org/abs/1603.03797]

“Yet Another Introduction to Dark Matter”, M. Bauer & T. Plehn (2017) [https://arxiv.org/abs/1705.01987]

“Lectures on Dark Energy and Cosmic Acceleration”, J. Frieman (2009) [https://arxiv.org/abs/0904.1832]

Dark matter direct-detection experiments", Teresa Marrodan Undagoitia, Ludwig Rauch, (2015), [https://arxiv.org/abs/1509.08767]

Dark Matter at Colliders: Dark Matter LHC Forum [https://lpcc.web.cern.ch/content/dark-matter-wg-documents]

“The Cosmological Constant and Dark Energy”, J. Peebles & B. Ratra (2002) [https://arxiv.org/abs/astro-ph/0207347]

“Dark energy two decades after: Observables, probes, consistency tests”, D. Huterer & D. Shafer (2018) [https://arxiv.org/abs/1709.01091]

“CMB Tutorials”, Wayne Hu [http://background.uchicago.edu]