Universitat Autònoma de Barcelona

2023/2024

Neutron Stars, Black Holes and Gravitational Waves

Code: 44084
ECTS Credits: 6

Degree	Type	Year	Semester
4313861 High Energy Physics, Astrophysics and Cosmology	OT	0	2

Contact

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Teaching groups languages

You can check it through this link. To consult the language you will need to enter the CODE of the subject. Please note that this information is provisional until 30 November 2023.

Teachers

Miquel Nofrarias Serra

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Laura Tolos

Francesco Coti Zelati

Diego Blas Temiño

Prerequisites

Basics of Astronomy and Physics is required. It is advised (but not strictly needed) to have followed the course of Observational Techniques. The course of High-Energy Astrophysics is complementary to this course in some specific topics.

Objectives and Contextualisation

Neutron Stars and Black Holes are the extreme leftovers of the explosion of very massive stars. They challenge fundamental aspects of nuclear physics, plasma physics, general relativity, and represent the sources of all detected Gravitational Waves so far, when they are in a binary system and collide. The course is intended to:

- provide a basic and broad view of the observations and theoretical understanding of Neutron Stars and Black Holes, focusing on their known Galactic population
- give a self-contained introduction to physics of Gravitational Waves, explaining the current state of detections of compact object mergers, and the beginning of the multi-messenger astronomy era

- provide an interconnected view of open questions about compact objects, related to the fundamental physics uncertainties and to the observational biases that shape the phenomenology of the detected population

Competences

- Formulate and tackle problems, both open and more defined, identifying the most relevant principles and using approaches where necessary to reach a solution, which should be presented with an explanation of the suppositions and approaches.
- Understand the bases of advanced topics selected at the frontier of high energy physics, astrophysics and cosmology and apply them consistently.

Learning Outcomes

1. Recognise the kind of source that emits radiation in different bands, and know how to estimate the kind of gravitational waves expected from different systems of neutron stars and black holes.
2. Understand the physical processes responsible for the multi-band emission of neutron stars of different classes, and black holes of various masses.

Content

- Introduction and observational overview of compact objects in connection with high-energy astronomy
- Neutron star physics: equation of state
- Neutron star physics: transport properties
- Neutron star physics: spin-down of pulsars
- Neutron star physics: observed emission at different wavelengths and associated physical mechanisms
- Modeling of the observed population of isolated neutron stars: long-term evolution of magnetic and thermal properties
- Elements of Special and General Relativity as well as tensor calculus
- Black holes: basic theory
- Gravitational waves: basic theory
- Gravitational waves: post-Newtonian approximation and quantitative study of GW sources
- Gravitational waves: observational review
- Binary neutron stars mergers and the new era of the multi-messenger astronomy

Methodology

Theory lectures, with small exercises in class. Assignment of homework, based on the content seen in class.

Annotation: Within the schedule set by the centre or degree programme, 15 minutes of one class will be reserved for students to evaluate their lecturers and their courses or modules through questionnaires.

Activities

Title	Hours	ECTS	Learning Outcomes
Type: Directed			

Lectures	45	1.8	2
Type: Autonomous			
Study of the theoretical and observational concepts	70	2.8	2

Assessment

The evaluation will be composed of:

- 50% the average mark of the different assignments given during the course (indicatively one exercise per teacher)
- 50% one final written exam, with different questions covering the main different topics. There will be a resit exam in case of not reaching the minimum total mark of the course.

This subject does not foresee the single assessment system.

Assessment Activities

Title	Weighting	Hours	ECTS	Learning Outcomes
Homework for different topics	50%	33	1.32	2, 1
Written exam (two chances)	50%	2	0.08	2, 1

Bibliography

S. L. Shapiro & S. A. Teukolsky "*Black Holes, White Dwarfs, and Neutron Stars: The Physics of Compact Objects*", Wiley Ed., 1983
P. Haensel, A.Y. Potekhin & D.G. Yakovlev "*Neutron Stars 1 - Equation of State and Structure*", Astrophysics and Space Sciences Library, Springer, 2006
"*The Physics and Astrophysics of Neutron Stars*", Astrophysics and Space Sciences Library, Springer, (Editors: L. Rezzolla, P. Pizzocchero, D. I. Jones, N. Rea, I. Vidaña), 2018
"*Astrophysical Black Holes*", Astrophysics and Space Sciences Library, Springer (Editors: Haardt, Gorini, Moschella, Treves, Colpi), 2016
S. Weinberg, "*Gravitation and Cosmology: Principles and Applications of the General Theory of Relativity*", Wiley Ed., 1972
W. Misner, K. S. Thorne, J. A. Wheeler, "*Gravitation*", W. H. Freeman and Company, 1973
M. Shibata, *"100 Years of General Relativity: Volume 1 - Numerical Relativity"*, World Scientific, 2015
"*Gravitational Wave Astrophysics*", Astrophysics and Space Sciences Library, Springer (Editor: Sopuerta), 2016

Software

None