COURSE DATA

Data Subject	
Code	43296
Name	Stellar astrophysics
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
ALOY TORAS, MIGUEL ANGEL	16 - Astronomy and Astrophysics

SUMMARY

Basic concepts of stellar physics. Late stages of estellar evolution and evolution after the Main Sequence. White Dwarfs. Neutron Stars. Black hole astrophysics. Supernovae and core collapse. Progenitors of gamma-ray bursts. Accretion in Astrophysics.

PREVIOUS KNOWLEDGE

Relationship to other subjects of the same degree

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

Other requirements

Students should have completed a course equivalent to Astrophysics corresponding to the third year of a physics degree and have taken as optional course Relativity and Cosmology in the last year of a degree in physics. In any case, if these subjects have not been taken, the student should possess the following previous knowledge:

1. Rudiments of mathematical analysis and physics of fluids.
2. Basic stellar evolution.
3. Lagrangian and Hamiltonian mechanics.
4. Special and General Relativity.
5. Ele

OUTCOMES

2150 - M.D. in Advanced Physics

- Students should apply acquired knowledge to solve problems in unfamiliar contexts within their field of study, including multidisciplinary scenarios.
- Students should be able to integrate knowledge and address the complexity of making informed judgments based on incomplete or limited information, including reflections on the social and ethical responsibilities associated with the application of their knowledge and judgments.
- Students should communicate conclusions and underlying knowledge clearly and unambiguously to both specialized and non-specialized audiences.
- Students should demonstrate self-directed learning skills for continued academic growth.
- Students should possess and understand foundational knowledge that enables original thinking and research in the field.
- Ser capaces de obtener y de seleccionar la información y las fuentes relevantes para la resolución de problemas, elaboración de estrategias y asesoramiento a clientes.
- Ser capaz de gestionar información de distintas fuentes bibliográficas especializadas utilizando principalmente bases de datos y publicaciones internacionales en lengua inglesa.
- Saber organizarse para planificar y desarrollar el trabajo dentro de un equipo con eficacia y eficiencia.
- Ostentar la preparación para tomar decisiones correctas en la elección de tareas y en su ordenación temporal en su labor investigadora y/o profesional.
- Poseer la capacidad para el desarrollo de una aptitud crítica ante el aprendizaje que le lleve a plantearse nuevos problemas desde perspectivas no convencionales.

- Estar en disposición para seguir los estudios de doctorado y la realización de un proyecto de tesis doctoral.

- Comprender de una forma sistemática el campo de estudio de la Física y el dominio de las habilidades y métodos de investigación relacionados con dicho campo.
- Concebir, diseñar, poner en práctica y adoptar un proceso sustancial de investigación con seriedad académica.
- Realizar un análisis crítico, evaluación y síntesis de ideas nuevas y complejas en el área de la Física.
- Analizar una situación compleja extrayendo cuales son las cantidades físicas relevantes y ser capaz de reducirla a un modelo parametrizado.
- Evaluar la validez de un modelo o teoría propuesto por otros miembros de la comunidad científica.
- Saber modelizar matemáticamente los problemas físicos sencillos nuevos, conectados con problemas conocidos. Ser capaz de expresar en términos matemáticos nuevas ideas.
- Elaborar una memoria clara y concisa de los resultados de su trabajo y de las conclusiones obtenidas en el área de la Física.
- Exponer y defender públicamente el desarrollo, resultados y conclusiones de su trabajo en el área de la Física.
- Comprender los fundamentos teóricos de la física estelar y cómo se forman y evolucionan las estrellas a partir de aplicación de las leyes de la física.
- 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.

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: NASA-ADS, 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.
9. 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. Introduction and basic concepts

Apparent luminosities and magnitudes. Stellar masses and radii. Mass-Luminosity relation. Stellar temperatures. Spectral types. Herzsprung-Russell diagrams. Stellar populations. The Sun: fundamental magnitudes. Equations of stellar structure. Virial Theorem.

2. Summary of stellar evolution

We will sum up the most representative evolutionary tracks of stars according to their masses. Four separated paradigmatic evolution tracks will be considered: low-mass stars, intermediate-mass stars, massive stars, and supermassive stars.

3. White Dwarfs.

Equations of estate. Structure and stability. Cooling. White dwarfs in binary systems: thermonuclear supernovae.

4. Neutron stars.

Equations of state. Structure and stability. Pulsars. Magnetospheres of neutron stars. Proto-neutron stars. Cooling. Neutron stars in binary systems.

5. Supernovae and stellar collapse

Observational properties of supernova explosions. Relation between stellar collapse and hydrodynamic supernovae. Physics of the collapse. Bound phase. Post-bounce phase. Key aspects for the shock survival after the core bounce. Delayed mechanism. Convection and rotation as
elements that help to explode a supernova. The role of the magnetic field in the supernova explosion mechanism.

6. Stellar nucleosynthesis.

It will be shown how stars have been involved in the synthesis of most of the chemical elements we know, except for the primordial elements.

7. Black holes

Solutions of the Einstein equations of black hole type: Schwarzschild and Kerr. Dynamics of test particles around black holes. Spectrum of masses. Observational evicences of the existence of black holes.

8. Accretion in astrophysics

We introduce a key concept in astrophysics: the accretion as a result of angular momentum transport. In this first lecture on accretion we will introduce accretion basics like the Roche potential. We will consider the case of accretion in binary systems and discuss in depth the case of geometrically thin accretion disks. The basic model of Shakura-Sunyaev disk will be introduced. The physical properties of accretion disks will be considered, and the different accretion flows are classified according to their properties.

We shall give the student a broad view of the astrophysical scenarios in which accretion is the key element for converting gravitational energy into other types of energy that lead to a multitude of observed phenomenologies. We shall develop the concepts needed to understand the processes of stationary accretion, emphasizing cases in which the central object (accretor) is a compact object (typically a black hole). Not only that, but we will consider the most relevant mechanisms for extracting energy from accretion processes, in particular the Blandford-Znajek mechanism.

WORKLOAD

ACTIVITY	Hours	% To be attended
Theory classes	39,00	100
Other activities	4,00	100
Seminars	3,00	100
Attendance at events and external activities	3,00	0
Development of group work	15,00	0
Development of individual work	10,00	0
Study and independent work	20,00	0
Readings supplementary material	10,00	0
Preparation of evaluation activities	10,00	0
Preparing lectures	15,00	0
Preparation of practical classes and problem	20,00	0
Resolution of case studies	6,00	0
TOTAL	**155,00**	

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.
SE3 - Continuous evaluation of students in the classes of theory and practice: participatory assistance and exercises in the classroom.
SE5 - Evaluation of non-presential activities related to theory and practical lectures: reports (and problems) zsubmitted.
SE7 - Oral presentation and exhibition of works in the classroom.

REFERENCES

Basic

- Referencia b1: Kippenhahn, R. Weigert, H., Stellar Structure and Evolution. Second Edition, Springer-Verlag, Berlin (1991)
- Referencia b2: Karttunen et al., Fundamental Astronomy. Fifth Edition., Springer-Verlag, Berlin (2007)
- Referencia b3: Janka, H.-T., Conditions for shock revival by neutrino heating in core-collapse supernovae, A&A, 368, 527 (2001)
- Referencia b4: Filippenko, A., Optical spectra of Supernovae, ARAA, 35, 309 (1997)
- Referencia b5: Vedrenne, G. & Atteia, J.L., Gamma-Ray Bursts: The brightest explosions in the Universe. Springer; Praxis Publishing Ltd, Chichester, UK (2009)
- Referencia b6: Shapiro, S.L., Teukolsky, S.A., Black Holes, White Dwarfs and Neutron Stars. John Wiley and Sons, Nueva York (1983)
- Referencia b7: M. Camenzind, Compact Objects in Astrophysics:White Dwarfs, Neutron Stars and Black Holes, Springer-Verlag, Berlin (2005)
- Referencia b8: Frank, J., King, A. Raine, D., Accretion Power in Astrophysics. Second Edition, Cambridge University Press, Cambridge (1992)

Additional

- Referencia c1: Arnett, D., Supernovae and Nucleosynthesis. Princeton University Press (1996)
- Referencia c2: Clayton D.D., Principles of Stellar Evolution and Nucleosynthesis. Chicago University Press (1983)
- Referencia c3: G.S. Bisnovatyi-Kogan, Stellar Physics II, Springer-Verlag Berlín (2001)
- Referencia c4: T. Padmanabhan, Theoretical Astrophysics (vol. I: Astrophysical Processes; vol. II: Stars and Stellar Systems) Cambridge University Press (2001)
- Referencia c5: LeVeque, R.J., Mihalas, E., Dorfi, E.A., Müller, E. Computational Methods for Astrophysical Fluid Flow: Saas-Fee Advanced Course 27. Lecture Notes 1997. Swiss Society for Astrophysics and Astronomy (Saas-Fee Advanced Courses) Springer, 1998
- Referencia c6: Piran, T., The physics of gamma-ray bursts, Reviews of Modern Physics, 76, 1143 (2005)
- Referencia c7: N.K. Glendenning, Compact Stars: Nuclear Physics, Particle Physics, and General Relativity, Second Edition, Springer-Verlag, Berlin (2000)
- Referencia c8: Mészáros, P., High-Energy Radiation from Magnetized Neutron Stars. The University of Chicago Press (1992)
- Referencia c9: Boettcher, M., Harris, D.E., Krawczynski, H., Relativistic Jets from Active Galactic Nuclei, Wiley-VCH, Weinheim (2012)
- Referencia c10: C.W. Misner, K.S.Thorne, J.A.Wheeler, Gravitation. W.H. Freeman and Co., San Francisco, CA (1973)