



### COURSE UNIT (MODULE) DESCRIPTION

Course unit (module) title	Code
<b>Evolution of Stars</b>	<b>FF37056_4_50412_20241</b>

Lecturer(s)	Department(s) where the course unit (module) is delivered
<b>Coordinator:</b> dr. Carlos Viscasillas Vázquez <b>Others:</b>	Faculty of Physics, Institute of Theoretical Physics and Astronomy. Saulėtekio al. 3, 10257 Vilnius

Study cycle	Type of the course unit (module)
Master	Optative

Mode of delivery	Semester or period when the course unit (module) is delivered	Language(s) of instruction
Auditory teaching and practical	Autumn Semester	English, Lithuanian

Requisites	
<b>Co-requisites (if relevant):</b> Introductory courses in classical physics and calculus.	<b>Additional requirements (if any):</b> Astronomy course (desirable)

Number of ECTS credits allocated	Student's workload (total)	Contact hours	Individual work
5	140	64	76

Purpose of the course unit (module)
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The purpose of this course is to provide a comprehensive and specialized understanding of stellar evolution theory for stars of various masses. Through this course, students will gain insights into how the fundamental physical properties of stars evolve over time, how these changes are connected to their nuclear processes, and the nature of the final stages and remnants of stellar life. The course aims to bridge theoretical knowledge with practical application using advanced tools, equipping students with the skills to analyze and interpret stellar evolution from both a theoretical and observational perspective.

Learning outcomes of the course unit (module)	Teaching and learning methods	Assessment method
Formulate the basic laws of physics, nuclear processes, and equations-of-state to describe stellar interiors and structure.	Lectures, in-class work and discussions, problem-solving (individual/group), self-learning.	Homework, participation, presentations, exam during the examination period.
Identify the evolutionary stage of a star based on its observational characteristics, e.g., using the Hertzsprung-Russell diagram to classify stars.	<i>Ibidem.</i>	<i>Ibidem.</i>
Describe the key phases of stellar evolution and the resulting end products as a function of the star's initial mass.	<i>Ibidem.</i>	<i>Ibidem.</i>
Answer both quantitative and qualitative questions regarding the evolutionary path of stars throughout their life-cycle.	<i>Ibidem.</i>	<i>Ibidem.</i>
Learn to use tools to analyze the impact of initial stellar masses on their evolution and final stages. Specifically, run and interpret the outputs from the state-of-the-art open-access MESA stellar evolution code to compute stellar models and analyze the interior of stars.	Practical lessons, projects.	Tasks, reports, participation, presentations.

Content: breakdown of the topics	Contact hours						Individual work: time and assignments		Assignments
	Lectures	Tutorials	Seminars	Workshops	Laboratory work	E. mokymas(is)	Contact hours (total)	Individual work	
1. Stellar Properties.	4						4	6	Homework, recommended literature reading, self-study, participation, presentations.
2. Fundamentals of Stellar Structure.	4						4	6	<i>Ibidem.</i>
3. Star Formation and Early Evolution.	4						4	6	<i>Ibidem.</i>
4. Main Sequence Stars or Core-Hydrogen Burning Phase.	4				8		12	12	Homework, recommended literature reading, self-study, participation, presentations, simulations with MESA, reports.
5. Post-Main Sequence Stars. Late Stages of Stellar Evolution.	4				8		12	12	
6. Evolution of Low- and Intermediate-Mass Stars.	4				8		12	14	
7. Evolution of Massive Stars.	4				8		12	14	
8. Evolution of Binary Star Systems.	4						4	6	
<b>Total</b>	<b>32</b>				<b>32</b>		<b>64</b>	<b>76</b>	

Assessment strategy	Weight, %	Deadline	Assessment criteria
<b>Exam</b>	60%	2-26 January 2024	The examination consists of a series of questions designed to verify that the student has a clear understanding of the main concepts related to the structure and evolution of both low and high-mass stars.
<b>Projects with MESA</b>	30%	Lecture period	Written report and oral presentations on the results of the simulations with MESA and their interpretation within the framework of the subject.
<b>Attendance and participation in classes</b>	10%	Lecture period	Consistent and proactive participation in lectures and class activities, offering valuable information and asking relevant questions. Demonstrate strong engagement with peers, contributing positively to group activities and fostering mutual development. Show significant improvement in knowledge, preparation, and collaboration throughout the semester.

Author	Year	Title	Publishing house	Access online or in VU library
<b>Required reading</b>				
Prialnik, Dina.	2009	<i>An Introduction to the Theory of Stellar Structure and Evolution.</i>	Cambridge University Press.	Yes
Salaris, Maurizio; Cassisi, Santi.	2005	<i>Evolution of Stars and Stellar Populations.</i>	Wiley	Yes

<b>Recommended reading</b>				
Lamers, Henny J. G. L. M.; Levesque, Emily M.	2017	<i>Understanding Stellar Evolution.</i>	IOP	
Kippenhahn, Rudolf; Weigert, Alfred; Weiss, Achim.	2012	<i>Stellar Structure and Evolution.</i>	Springer	
Bisnovatyi-Kogan, Gennady S.	2011	<i>Stellar Physics 2: Stellar Evolution and Stability.</i>	Springer	
Ryan, Sean G.; Norton, Andrew J.	2010	<i>Stellar Evolution and Nucleosynthesis.</i>	Cambridge University Press	
Maeder, André.	2009	<i>Formation and Evolution of Rotating Stars.</i>	Springer	
De Boer, Klaas; Seggewiss, Wilhelm.	2008	<i>Stars and Stellar Evolution.</i>	EDP	
Hansen, Carl J.; Kawaler, Steven D.; Trimble, Virginia.	2005	<i>Stellar Interiors: Physical Principles, Structure, and Evolution.</i>	Springer	
Clayton, Donald D.	1968 (1984)	<i>Principles of Stellar Evolution and Nucleosynthesis.</i>	McGraw-Hill	
Schwarzschild, Martin.	1958 (2015)	<i>Structure and Evolution of Stars.</i>	Princeton Legacy Library	
Chandrasekhar, S.	1939 (2010)	<i>An Introduction to the Study of Stellar Structure.</i>	Dover	