Anexa Nr. 2

Subject content

1. Program information

1.1. University	West University of Timişoara
1.2. Faculty	Physics
1.3. Departament	Physics
1.4. Study direction	Physics
1.5. Study cycle	Master
1.6. Study program*	**Astrophysics, Elementary Particles and Computational Physics** / conform COR: fizician (211101); profesor în învăţământul gimnazial (232201 - în condiţiile legii); asistent de cercetare (248102); referent de specialitate în învăţământ (235204); analist (213101; analist financiar (241493).

2. Subject matter information

2.1. Subject matter	Stellar Astrophysics						
2.2. Subject teacher	Victor E. AMBRUȘ						
2.3. Subject applications teacher	Victor E. AMBRUȘ						
2.4. Study year	II	2.5. Semester	I	2.6. Assesment type	**E**	2.7. Subject type	**Ob - AP 2302**

3. Study time distribution

3.1. Nr. of hours / week	4	In which: 3.2 course	2	3.3. Problem class	2
3.4. Total hours in educational plan	56	In which: 3.5 course	28	3.6. Problem class	28

Time distribution*	**hrs**
Study after lecture notes, bibliography or notes	56
Additional documentation in the library, electronic specialty platforms/ field	28
Seminar/ laboratory preparations, homework, portfolio and essays	28
Tuturing	16
Exams	16
Other activities....	

3.7. Total number of personal study hours	144
3.8. Total number of hours in semester	200
3.9. Number of credits	8

4. Preconditions

4.1. Curriculum	Introduction in astronomy (AP1204); Standard model (AP 1201); Fizica atomului şi moleculei (FF2301) Electricitate şi magnetism (FF1201); Termodinamică şi fizică statistică (FF3501); Matematică II (Ecuaţiile diferenţiale ale fizicii matematice) (FF1203).
4.2. Skills	General skills: ability to assimilate fundamental knowledge; correct usage of physics-specific terminology; ability to work individually and as part of a team; Professional skills: the correct identification and usage of the main laws and principles of physics; ability to solve physics-specific problems.

5. Course objectives – expected results achieved by attending and graduating this course

Knowledge	The correct identification and usage of the main laws and principles of physics relevant to this course în a given context Energy production, radiative transfer and strucutre of Sun-like stars Structure of degenerate stars: white dwarves Nuclear equation of state and neutron stars: M-R diagram
Abilities	Solving physics problems in given conditions, using analytical and numerical methods Identify fusion processes relevant for stellar energy production Radiative transfer and opacity inside stellar atmospheres Polytropic stars and white dwarf physics Solving the Tolman-Oppenheimer-Volkoff equation for stellar structure in general relativity Nuclear Field Theory models for dense nuclear matter and neutron star physics
Responsability and autonomy	Acquaintance with modern directions related to stellar astrophysics Understanding the physics behind stellar structure and evolution Learning about modern space missions such as NICER, aiming to measure simultaneously neutron star masses and radii.

6. Table of contents

6.1. Course	Teaching methods	Observations
Chap.1. Stellar formation (2 hours) Gravitational collapse. The Virial theorem. The Jeans Criterion.	Interactive lecturing at the blackboard or using the beamer.	[1] Chap. 2; [2] Chap. 12; [3] Chap. 10.
Chap.2. Nucleosynthesis and Stellar Evolution (4 hours) The Hertzsprung-Russell diagram. Evolutionary track of stars on the H-R diagram. Nuclear fusion processes in the star interior. Heavy element nucleosynthesis. Novae, Supernovae and stellar remnants.		[1] Chap. 1.7, 6; [2] Chap. 13, 15, 16; [3] Chap. 8.10-8.17.
Chap. 3. Radiative transfer (10 hours) Electromagnetic radiation Blackbody radiation. Boltzmann and Saha equations. Radiative transfer equation Opacity of spectral lines. Rosseland opacity Gray atmosphere. Spectral line formation.		[1] Chap. 1.2, 1.3, 1.5, 3, 4; [2] Chap. 5, 9.1, 9.5; [3] Chap. 4.16; 5.5, 5.7-5.10; 6.13-6.24; 7, 8.7, 8.8.
Chap. 4. Internal structure of stars (4 hours) Mixing length theory Integrating stellar structure equations		[1] Chap. 5; [2] Chap. 9, 10, 11;
Chap. 5. Polytropic models (8 hours) Lane-Emden equation Tolman-Oppenheimer-Volkoff equation Equation of state of dense nuclear matter β-equilibrium in neutron stars		[1] Chap. 5.4; [2] Chap. 16; [4] Chap. 4, 5; [5] Chap. 5, 7.

Bibliography

1. Francis LeBlanc, An introduction to stellar astrophysics (Wiley, 2010). ISBN: 978-0-470-69956-0
2. Bradley W. Carroll, Dale A. Ostlie, An introduction to modern astrophysics (San Francisco, Pearson Addison-Wesley, 2007). ISBN: 978-0-321-44284-0.
3. Martin Harwitt, Astrophysical concepts (Springer, 2006). ISBN: 978-0-387-32943-7.
4. Norman K. Glendenning, Compact stars: Nuclear physics, particle physics, and general relativity (Springer, New York, USA, 1997).
5. Jürgen Schaffner-Bielich, Compact star physics (Cambridge University Press, 2020).

6.2. Seminar/laboratory	Teaching methods	Observations
Chap.1. Stellar formation (2 hours) Barometric formula. Gravitational collapse of interstellar clouds.	Problem solving at the blackboard	The bibliographic references follow those from the course.

Chap.2. Nucleoynthesis and Stellar Evolution (4 hours) Spectral classes. Timescales for the various stages of stellar evolution. Nuclear reactions in stellar interiors.	and in the notebooks.	
Chap. 3. Radiative transfer (10 hours) Poynting-Robertson effect Motion in charged Fermi acceleration Boltzmann equation and excited atoms distribution Saha equation and ionization fractions Monochromatic and Eddington fluxes. Opacity and optical depth. Lorentz profile of the spectral lines. Equivalent width.		
Chap. 4. Internal structure of stars (4 hours) Equations of stellar structure Numerical integration of a stellar model (application)		
Chap. 5. Polytropic models (8 hours) M-V relation for light white dwarves. Chandrasekhar limit for heavy white dwarves. Constant density model for general relativistic stars. Causality limit of neutron star masses. Walecka σ-ω model for nuclear matter Isospin symmetry and ρ mesons npeμ model and β-equilibrium Neutron star mass-radius curve and comparison to experimental measurements		
Bibliography See 6.1. Course.		

7. Matching course contents with expectations of representatives of the academic community, of professional associations and of representative employers of the study programme domain

Knowing and understanding the specific phenomena studied in this course, formation and development of practical abilities to correctly and completely interpret results, practice of the teamwork spirit and of the ability to organise and investigate, nurturing a scientific environment based on values, professional ethics and quality. The course covers modern aspects of the physics of stars ranging from our Sun to extremely compact objects such as neutron stars. Graduates will have knowledge relevant to modern research fields and on-going experiments such as Super-Kamiokande for neutrino detection, NICER for neutron star mass and radius measurement, or CBM experiment at GSI for probing the nuclear equation of state at neutron star densities.

9. Assessment

Activity type	Assessment criteria	Assessment methods	Percent în final

			mark
9.1. Course	For 50% marks: fundamental notions from this field. For 100% marks: advanced notions from this field.	1. Written evaluation: questions with multiple-choice answers. 2. Oral examination: a) elementary topics; b) advanced topics.	**34%+33%**
9.2 Seminar/laboratory	For 50% marks: fundamental notions from this domain. For 100% marks: advanced notions from this domain.	3. Written evaluation: Problem solving.	**33%**
10.6. Minimum performance standards			
50% marks for multiple-choice answer test; 50% marks for problem test; Oral examination on elementary topics. Alternatively: 50% marks for multiple-choice answer test; Written project on one of the course themes.			

Minimum attendance: according to the applicable WUT regulations (course 50%; seminar 70%).
Final mark: 34% multiple-choice test, 33% written exam, 33% oral examination. Bonus points awarded for good attendance and for timely homework submission.

Date: Signature of Course leader: Signature of Tutorial leader:

16.09.2022 [redacted]bruș L[redacted]ruș

Signature of Head of Department:

Conf. Dr. habil. Cătălin MARIN