SYLLABUS

1. **Information about the study programme**

1.1 Institution of higher education	West University of Timișoara
1.2 Faculty	Physics
1.3 Department of	Physics
1.4 Field of study	Physics
1.5 Study cycle	Master
1.6 Study programme / Qualification	**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. **Information about the subject/discipline**

2.1 Name	Stellar Astrophysics						
2.2 Course coordinator	Victor E. AMBRUȘ						
2.3 Seminar coordinator	Victor E. AMBRUȘ						
2.4 Year of study	II	**2.5 Semester**	I	**2.6 Type of assessment**	E	**2.7 Type of discipline**	DS/DO/AP 2303

3. **Total estimated time (hours of teaching per semester)**

3.1 Number of hours per week	**4**	**3.2 course**	**2**	**3.3 seminars/labs**	**2**
3.4 Total hours in the curriculum	**56**	**3.5 course**	**28**	**3.6 seminars/labs**	**28**
Distribution of time:					**hours**
Study based on Instructions, course materials, bibliography and notes					**56**
Additional documentation library, specialized electronic platforms / field					**17**
Training seminars / laboratories, homework, essays, portfolios and essays					**28**
Tutoring					**14**
Examinations					**4**
Other activities					

3.7 Total hours of individual study	**119**
3.8 Total hours per semester	**175**
3.9 Number of credits	**7**

4. **Prerequisites (where applicable)**

4.1 of curriculum	• Standard model (AP 1201); • Quantum Fields (AP 1204);
4.2 of 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. **Conditions (where applicable)**

5.1 for the course	-
5.2 **for the seminar**	-

6. **Discipline objectives – learning outcomes**

Knowledge	• The correct identification and use of the main laws and principles of physics relevant to this course in 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
Skills	• Solving physics problems 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
Responsibility 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.

7. **Contents**

7.1. 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. Nucleoynthesis 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. Compact stars (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).		

7.2. Seminar/laboratory	**Teaching methods**	**Observations**
Chap.1. Stellar formation (2 hours) • Barometric formula. • Gravitational collapse of interstellar clouds.	Problem solving at the blackboard and in the notebooks.	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.		
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. Compact stars (8 hours) • M-V relation for light white dwarves. • Chandrasekhar limit for heavy white dwarves. • Constant density model for general relativistic stars. • Causality limit for 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 7.1. Course.		

8. **Corroboration of the course contents with the epistemic expectations of the community representative, professional associations and representative employers of the programme itself**

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. **Evaluation**

Type of activity	**9.1 Evaluation criteria**	**9.2 Evaluation methods**	**9.3 Percentage of the final mark**
9.4 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%**
9.5 Seminar	For 50% marks: fundamental notions from this domain. For 100% marks: advanced notions from this domain.	3. Written evaluation: Problem solving.	**33%**
9.6 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.			

Date: [redacted]der: Signature of Tutorial leader:

16.09.2023 Lect. Dr. Victor E. Ambruș Lect. Dr. Victor E. Ambruș

HEAD OF THE DEPARTMENT:

Prof. Dr. habil. Cătălin MARIN

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