

COURSE SHEET

1. Information on the study programme

1.1. Higher education institution	West University of Timisoara
1.2. Faculty	Physics
1.3. Department	Physics
1.4. Study cycle	Master
1.5. Study programme / Qualification	Astrophysics, elementary particles and computational physics / according to COR: Physicist (211101); Research assistant in physics (248102); Teacher (232201); Education reviewer (235204)

2. Information on the course

2.1. Course title		Introduction to Gravitation and Cosmology - AP1202					
2.2. Lecture instructor		Nistor Nicolaevici					
2.3. Seminar / laboratory instructor		Nistor Nicolaevici					
2.4. Study year	I	2.5. Semester	II	2.6.Examination type	End paper	2.7. Course type	Optional

3. Estimated study time (number of hours per semester)

3.1. Attendance hours per week	3	out of which: 2 lecture	1 seminar	
3.2. Attendance hours per semester	42	out of which: 28 lecture	14 seminar	
3.3 Distribution of the allocated amount of time				hours
Study of literature, course handbooks and personal notes				60
Supplementary documentation at library or using electronic repositories				15
Preparing for homework				15
Exams				6
Tutoring				4
3.4. Total number of hours per semester	100			
3.5. Number of credits (ECTS)	6			

4. Prerequisites

Curriculum	Analytical mechanics; Electrodynamics; Statistical Physics
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5. Course objectives

- to provide a mathematical introduction to Einstein's General Relativity, with an emphasize on cosmology
- to present a number representative results of the General Relativistic theory, such as the classical tests of the theory, black hole space-times, and cosmological models
- to present the key concepts of modern cosmology in the context of the inflationary Big Bang theory, along with recent observational results

6. Content

	Teaching methods	References
1. Historical introduction. Review of Special Relativity. Gravity as a manifestation of the geometry of space-time - intuitive exposition	PowerPoint presentations	[1] Chap. 1 [2] Chaps. 1, 2 [3] Chap. 1
2. Mathematical description of curved spaces. Manifolds. Vectors and tensors. Metric. Covariant derivative. Curvature. Geodesics		[1] Chaps. 2 – 4 [2] Secs. 4.1 - 4.9, Chap. 6
3. Principles of equivalence. Description of space-time in General Relativity. Extension of special relativistic equations to curved space-times. The Einstein equations. The weak field limit, The cosmological constant		[1] Chaps. 7, 8 [2] Chap. 7.1 [3] Chap. 3
4. The Schwarzschild metric. Experimental tests of general relativity. Gravitational redshift. Precession of planetary orbits. Deflection of light. Radar echoes		[1] Chap. 9 [2] Chaps. 8, 9 [3] Secs. 6.1 - 6.3
5. Schwarzschild black holes. Gravitational collapse and black hole formation. Singularities of the metric. Eddington-Finkelstein coordinates. The Kruskal extension. Observational evidence for black holes		[1] Chap. 11 [2] Chaps. 11.9 [3] Chap. 6.4
6. Brief history of cosmological ideas. Fundamental observations. Large scale structures. Homogeneity and isotropy of the Universe. Cosmological redshift and Hubble's law		[2] Chap. 14.1 [3] Chap. 7.1 [4] Chaps. 1, 2
7. Homogenous and isotropic space-times. The Friedman-Robertson-Walker metric. Cosmic scale factor, the Hubble and deceleration		[1] Chap. 14 [2] Sec. 14.2 [4] Chap. 4

parameters. Geometry of the FRW universes		[5] Chap. 3
8. Measures of distances. The luminosity and angular diameter distances. The redshift-distance relation. Apparent magnitude, absolute magnitude, distance modulus. The Cosmic Ladder		[1] Chap. 14.10 [2] Secs. 14.4 - 14.6 [5] Secs. 7.2, 7.3
9. The cosmological fluid. The Friedmann equations. Cosmological density parameters. Evolution of the scale factor. Big Bang models. The age of the universe. Analytical models		[1] Chap. 15 [3] Secs. 8.1, 8.2 [4] Chap. 5 [5] Chap. 6
10. Dark matter. Matter distribution in the universe. Galaxy rotation curves. Galaxy cluster composition. Influence on the formation of structures. Dark matter searches		[3] Sec. 7.1.4 [4] Chap. 9 [5] Chap. 8
11. The Cosmic Microwave Background. Blackbody spectrum of the CMB. The Hot Big Bang Model. The barion to photon ratio. Recombination and decoupling. Temperature fluctuations in CMB		[3] Sec. 8.5 [4] Chap. 10 [5] Chap. 9
12. Primordial nucleosynthesis. Thermal history of the early universe. Proton-neutron interactions. Deuterium and Helium synthesis. The deuterium bottleneck. Barion-antibarion asymmetry		[2] Secs. 15.6, 15.7 [3] Sec. 8.4 [4] Chap. 12 [5] Chap. 10
13. Inflation and the very early universe. The flatness and horizon problems. The inflationary scenario. The solution to the problems. Inflation and particle physics		[3] Secs. 9.1, 9.2 [4] Chap. 13 [5] Chap. 11
14. Measuring the cosmological parameters. Standard candles, the supernova data and the accelerating universe. CMB anisotropy and evidence for a flat universe. The concordant Λ CDM model		[3] Secs. 9.3-9.5 [4] Chap. 15 [5] Secs. 7.4, 7.5

7. Recommended literature

[1] M. P. Hobson, G. Efstathiou and A. N. Lasenby, *General Relativity: An Introduction for Physicists* (Cambridge, 2006)

[2] S. Weinberg, *Gravitation and Cosmology* (Wiley, 1972)

[3] T. P. Cheng, *Relativity, Gravitation and Cosmology* (Oxford, 2005)

[4] A. Liddle, *An Introduction to Modern Cosmology* (Wiley, 2003)

[5] B. Ryden, *Introduction to Cosmology* (Addison-Wesley, 2002)

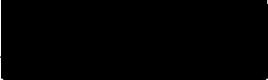
8. Evaluation

Activity	Weight in the final mark
Lectures (regular attendance)	20%
Homework	30%
End paper	50%
Minimum mark for passing	6

Date of completion
25.01.2023

Signature of lecturer:
Lecturer Nistor Nicolaevici

Signature of seminar instructor:
Lecturer Nistor Nicolaevici


Signature of the department director:
Associate Professor Marin Catalin