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

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 ΛCDM 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
25.01.2022

Signature of lecturer:
Lecturer Nistor Nicolaevici
[redacted]

Signature of seminar instructor:
Lecturer Nistor Nicolaevici
[redacted]

Signature of the department director:
Associate Professor Marin Catalin
[redacted]