….Introduction to modern cosmology….
- COURSE SYLLABUS

NATIONAL CENTRE FOR NUCLEAR RESEARCH ŚWIERK

1.	**Course title:** *Introduction to modern cosmology*	
2.	**Lecturer:** *Marek Biesiada, Pawel Bielewicz, Katarzyna Malek (NCBJ)*	
3.	**Field, type and level of studies, year of study:** *astrophysics, doctoral studies, all years of study*	
4.	**Course character:** *monographic lecture*	
5.	**Teaching method:** *on-site*	
6.	**Language:**	*English*
7.	**Course type and number of hours:** *Lecture , 15 lectures*	
8.	**Estimated load of student's independent work:**	-
9.	**Total workload and number of ECTS points:**	*3 ECTS*
10.	**Short description and main focus of the course:** *In the series of lectures the following topics will be covered:* *I. Introduction to modern cosmology (7 lectures) MB* • *Overview of modern cosmology from historical perspective: topics covered by 2 lectures* ◦ *cosmological paradoxes in Newtonian physics* ◦ *theoretical and observational pillars of modern cosmology* ◦ *expansion of the Universe* ◦ *Big Bang Nucleosynthesis* ◦ *Cosmic Microwave Background and earlier relics* ◦ *Dark Matter problem: evidences and candidates* ◦ *accelerated expansion of the Universe: Dark Energy - LambdaCDM concordance model* • *Theoretical pillar of cosmology: topics covered by 2 lectures* ◦ *General Relativity in a nutshell* ◦ *homogeneous and isotropic expanding Universe: Friedmann-Lemaitre-Robertson-Walker metric* ◦ *redshift and distances in cosmology; redshift drift: Loeb-Sandage test* ◦ *Friedmann equations* ◦ *cosmological horizons* ◦ *brief overview of inflation*	

	• *Modern cosmological probes and tests: topic covered by 2 lectures*
	  ◦ *determination of cosmological parameters*
	  ◦ *idea of cosmological tests: Hubble diagram, Alcock-Paczynski test*
	  ◦ *measuring distances at cosmological scales: standard candles: SN Ia, gamma ray bursts, tip of the red giant branch; standard rulers: statistical (BAO) and individual (compact radio sources, water masers); Tully-Fisher and Faber-Jackson relations; surface brightness fluctuations*
	  ◦ *cosmic chronometers: differential ages of passively evolving galaxies*
	  ◦ *gravitational lensing: basic notions, time delays, strong lensing + stellar kinematics*
	  ◦ *galaxy clusters*
	• *Gravitational waves and cosmology (1 lecture)*
	  ◦ *introduction to gravitational wave astrophysics*
	  ◦ *primordial gravitational waves: mechanism of generation, properties and expected level*
	  ◦ *stochastic background of gravitational waves: Pulsar Timing Arrays*
	  ◦ *coalescing compact binary systems: standard sirens*
	  ◦ *current vision of using gravitational wave signals as cosmological probes*
	
	II. Cosmic Microwave Background (6h) PB
	• *Physics of the Cosmic Microwave Background*
	• *Primary and secondary CMB anisotropies*
	• *CMB angular power spectrum*
	• *Relation with cosmological parameters and analysis of data*
	• *Status of CMB observations and future experiments*
	
	III. Galaxy surveys (2h) KM
	• *photometric and spectroscopic surveys,*
	• *redshift and stellar mass estimations*	

11.	**References:** • *Steven Weinberg "Cosmology" (2008 edition)* • *Scott Dodelson "Modern Cosmology"* • *Malcolm S. Longair "Galaxy Formation"* • *M.P. Hobson, G. Efstathiou and A.N. Lasenby "General Relativity: An Introduction for Physicists"* • *George F.R. Ellis, Roy Maartens, Malcolm A.H. MacCallum, "Relativistic Cosmology"* • *Massimo Meneghetti "Introduction to Gravitational Lensing: With Python Examples"*	
12.	**Prerequisites:** *It is assumed: the knowledge of classical mechanics, thermodynamics; knowledge of the basics of the General Relativity is not necessary, though it would be an advantage.*	
13.	**Educational outcomes:** ***Knowledge:*** *After completing the course, the student:* 1. *Knows the basics of the standard cosmological model;* 2. *Has proper understanding of the expansion of the universe, cosmological redshift, cosmological horizons* 3. *Is familiar with modern cosmological probes and tests* 4. *Understands relevance of gravitational waves in cosmology*	**PQF level 8 codes:** *P8S_WG*

	5. *Is familiar with CMB physics and methods of data analysis;* 6. *Knows the most important observational CMB data supporting the standard cosmological model and current challenges in CMB observations;* 7. *Is familliar with the estimation of photometrioc and spectroscopic redshifts, as well as stellar masses*	
	Practical Skills: *After completing the course, the student:* 1. *Can apply knowledge of core concepts in physics and astrophysics to understand cosmology.* 2. *Can understand and critically assess papers on broad topics of modern cosmology;* 3. *Is able to interpret the publications of CMB experiments;* 4. *Is able to perform a basic CMB data analysis and understands computational methods and tools used in the analysis;*	*P8S_UW*
	Social Skills: *Students understand the importance of cosmology in a broad astrophysical and social context and are able to discuss cosmological topics with experts, colleagues and laymen. Students are able to critically evaluate arguments presented in scientific and popular science discussions and articles.*	*P8S_KK*
14.	**Evaluation of the educational outcomes:** *oral exam*	
15.	**Criteria to complete the course:** *attendance, grade of at least 3 on the oral exam*	
16.	**Contact with the lecturer:** *By email: Marek Biesiada marek.biesiada@ncbj.gov.pl Paweł Bielewicz pawel.bielewicz@ncbj.gov.pl Katarzyna Małek katarzyna.malek@ncbj.gov.pl*	