SEMESTER LEARNING ACTIVITY PLANS (SLAP)
SEMESTER EVEN 2022/2023

Cosmology

MFF5982 / 3 Credits

Lecturer Coordinator:

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UNIVERSITAS GADJAH MADA
FACULTY OF MATHEMATICS AND NATURAL SCIENCE
2022

	Universitas Gadjah Mada Faculty of Mathematics and Natural Science Physics Department / Study Program Master Physics Semester Even 2022/2023

SEMESTER LEARNING ACTIVITY PLANS (SLAP)

Code	Course Name	Credits (credits)	Semester	Status	Prerequisite
MFF5982	*Cosmology*	*3*	*Even*	*Elective*	*None*

Short Description	Cosmology course is Elective course 3 credits (Theory) in the 2022 Curriculum Master Physics Study Program, Faculty of Mathematics and Natural Science UGM. The syllabus of this course is as follows: 1. Introduction, Observation of cosmological fundamentals, General relativity as fundamentals of cosmology. 2. TRU mathematical devices: Covariance principle, tensor, metric, covariant derivative, Einstein tensor, energy-momentum tensor, geodesic equation, Einstein equation, some examples of Einstein equation solutions. 3. Cosmic dynamics: cosmological principles, Robertson Walker's metric, proper distance, Friedmann's equations, fluids and acceleration equations, state equations, cosmological constants. 4. Single component universe: Universe only with curvature component, the spatially flat universe, the universe with a material component, the universe with radiation component, the universe with a lambda component. 5. Multiple-component universe: matter-curvature, matter-lambda, matter-curvature-lambda, radiation-matter, benchmark model. 6. Cosmological parameters: two numbers, luminosity distance, angular-diameter distance, standard candle-Hubble parameter-acceleration. 7. Dark matter: visible matter, dark matter in galaxies and galaxy clusters, candidate of dark matter. 8. Dark Energy: indirect detection of dark energy, an alternative to dark energy. 9. Cosmic microwave Background radiation: CMB observation, recombination, and decoupling, recombination physics, temperature fluctuations. 10. Early universe: thermodynamic equilibrium, entropy, Boltzmann equation, Saha equation, out-off equilibrium, thermal history of the universe. 11. Big Bang Nucleosynthesis: Nuclear Statistical equilibrium, initial conditions, light element production, primordial abundance: predictions and observations. 12. Inflation: flatness problem, the horizon problem, inflation solution, inflation as a scalar field, density perturbations and relic gravitation, specific models. 13. Structure Formation: evolution of density inhomogeneity, spectrum of density perturbations, two stories: hot and cold dark matter, probing the primeval spectrum, the omega problem. The courses are held in class for 14 weeks, each week's session last for 3 x 50 minutes. Four weeks of course period is used for Midterm Exam and Final Exam, each held for two weeks as scheduled. Student evaluation for course assessments is performed summative and formative. The summative evaluation is implemented as written exams, both Midterm and Final Exam, which take a maximum of 120 minutes. The formative evaluation is implemented as individual assignments for each student in the form of completing an assignment individually. Monitoring is carried out by observing student activities during the course, such as attendance, Q&A and discussion about the material presented, and student performance in completing individual assignments.

Program Learning Outcomes (PLO) Imposed on the Course	PLO 3	Mastering further knowledge of classical and modern physics theory, and its relationship with other disciplines, and has mastered an advanced field of physics specialization that allows him to keep up with the latest international research developments.
	PLO 4	Mastering various mathematical disciplines related to an advanced field of physics, and able to develop physical models using various mathematical and computational tools with an inter or multidisciplinary approach to solving problems related to an advanced field of physics.
	PLO 6	Able to apply knowledge to analyze, synthesize, formulate problems and solve problems comprehensively in one of advanced field of physics, through experimental or theoretical research, then be able to classify and draw conclusions about their findings for the development of science and technology.
Course Outcomes (CO)	**Upon completion of this course, students should be able to:**	
	CO1	Understand the definition of introduction, fundamental observations of cosmology; General relativity as the basis of cosmology (TRU mathematical tools: Covariance Principle, tensor, metric, covariance derivative, Einstein tensor, momentum-energy tensor, geodesic equations, Einstein equations, some examples of solving Einstein equations); Cosmic dynamics (cosmological principles, Robertson Walker metrics, proper distance, Friedmann equations, fluid and acceleration equations, equations of state, cosmological constants).
	CO2	Understand the single component universe (Evolution of energy density, universe only with curvature component, spatially flat universe, universe with material component, universe with radiation component, universe with lambda component); Multiple-component universe (curvature-matter, lambda-matter, lambda-curvature-matter, matter-radiation, benchmark model); Measuring cosmological parameters (two numbers, luminosity distance, angular-diameter distance, standard candle-Hubble parameter-acceleration).
	CO3	Understand the Dark matter (visible matter, dark matter in galaxies and galaxy clusters, candidate of dark matter); Dark Energy (dark energy indirect detection, dark energy alternative); Cosmic microwave Background radiation (CMB observations, recombination, and decoupling, recombination physics, temperature fluctuations).
	CO4	Understand the Early universe (thermodynamic equilibrium, entropy, Boltzmann equation, Saha equation); Early Universe (out-off equilibrium, thermal history of the universe)); Big Bang Nucleosynthesis (Nuclear Statistical equilibrium, initial conditions, light element production, primordial abundance: prediction and observation).
	CO5	Understand the Inflation (flatness problem, horizon problem, inflation solution, inflation as a scalar field, density perturbations and relic gravity, specific models); Structural formation (evolution of density inhomogeneity, the spectrum of density perturbations, two stories: hot and cold dark matter, probing the primeval spectrum, the omega problem).
	CO6	
	CO7	
	CO8	

The Correlation of CO to Learning Materials and Methods, and Time Allocation		Learning Materials	Learning Methods	Time Allocation
	CO1	Introduction, Cosmological fundamental observations.	Lecture, discussion	3 x 50 minutes
	CO1	General relativity as a fundamental of cosmology (TRU mathematical tools: Principle of Covariance, tensor, metric, covariant derivative, Einstein's tensor, energy-momentum tensor, geodesic equation, Einstein's equation, some examples of solutions to Einstein's equations).	Lecture, discussion	3 x 50 minutes
	CO1	Cosmic dynamics (cosmological principles, Robertson Walker metrics, proper distance, Friedmann equations, fluid and acceleration equations, equations of state, cosmological constants).	Lecture, discussion	3 x 50 minutes
	CO2	Single component universe (Evolution of energy density, universe with only curvature component, spatially flat universe, universe with material component, universe with radiation component, universe with lambda component).	Lecture, discussion	3 x 50 minutes
	CO2	Multiple-component universe (curvature-matter, lambda-matter, lambda-curvature-matter, matter-radiation, benchmark model).	Lecture, discussion	3 x 50 minutes
	CO2	Measures cosmological parameters (two numbers, luminosity distance, angular-diameter distance, standard candle-Hubble parameter-acceleration).	Lecture, discussion	3 x 50 minutes
	CO2	Dark matter (visible matter, dark matter in galaxies and galaxy clusters, candidate for dark matter).	Lecture, discussion	3 x 50 minutes
	CO3	Dark Energy (indirect detection of dark energy, alternatives to dark energy).	Lecture, discussion	3 x 50 minutes
	CO3	Cosmic microwave Background radiation (CMB observations, recombination and decoupling, physics of recombination, temperature fluctuations).	Lecture, discussion	3 x 50 minutes
	CO3	Early universe (thermodynamic equilibrium, entropy, Boltzmann equation, Saha equation).	Lecture, discussion	3 x 50 minutes

	CO4	Early Universe (out-off equilibrium, thermal history of the universe).	Lecture, discussion	3 x 50 minutes
	CO4	Big Bang Nucleossynthesis (Nuclear Statistical equilibrium, initial conditions, light element production, primodial abundance: prediction and observation).	Lecture, discussion	3 x 50 minutes
	CO4	Inflation (flatness problem, horizon problem, inflation solution, inflation as a scalar field, density perturbations and relic gravity, specific models).	Lecture, discussion	3 x 50 minutes
	CO4	Structural formation (evolution of density inhomogeneity, spectrum of density perturbations, two stories: hot and cold dark matter, probing the primeval spectrum, the omega problem).	Lecture, discussion	3 x 50 minutes
	Final Exam/ Project Task Results/ Case Analysis Results			
Learning Methods	Lecture, discussion			
Student Learning Experience	Learn to analyze and review: Introduction, Cosmological fundamental observations., General relativity as a fundamental of cosmology (TRU mathematical tools: Principle of Covariance, tensor, metric, covariant derivative, Einstein's tensor, energy-momentum tensor, geodesic equation, Einstein's equation, some examples of solutions to Einstein's equations)., Cosmic dynamics (cosmological principles, Robertson Walker metrics, proper distance, Friedmann equations, fluid and acceleration equations, equations of state, cosmological constants)., Single component universe (Evolution of energy density, universe with only curvature component, spatially flat universe, universe with material component, universe with radiation component, universe with lambda component)., Multiple-component universe (curvature-matter, lambda-matter, lambda-curvature-matter, matter-radiation, benchmark model)., Measures cosmological parameters (two numbers, luminosity distance, angular-diameter distance, standard candle-Hubble parameter-acceleration)., Dark matter (visible matter, dark matter in galaxies and galaxy clusters, candidate for dark matter)., Dark Energy (indirect detection of dark energy, alternatives to dark energy)., Cosmic microwave Background radiation (CMB observations, recombination and decoupling, physics of recombination, temperature fluctuations)., Early universe (thermodynamic equilibrium, entropy, Boltzmann equation, Saha equation)., Early Universe (out-off equilibrium, thermal history of the universe)., Big Bang Nucleossynthesis (Nuclear Statistical equilibrium, initial conditions, light element production, primodial abundance: prediction and observation)., Inflation (flatness problem, horizon problem, inflation solution, inflation as a scalar field, density perturbations and relic gravity, specific models)., Structural formation (evolution of density inhomogeneity, spectrum of density perturbations, two stories: hot and cold dark matter, probing the primeval spectrum, the omega problem)..			
Access to Learning Media/ LMS and Offline and Online Percentage	Sync (google meet), Asynchronous (google classroom, video)			
Assessment Methods and Synchronization with CO				

Assessment Methods	Assessment Percentage	Criteria/Indicators	CO1	CO2	CO3	CO4

Participatory Activity*						
Project Results/ Case Study Results/ PBL Results*						
Cognitive						
Assignment	30%		7,5%	7,5%	7,5%	7,5%
Quiz						
Midterm Exam	35%		17,5%	17,5%		
Final Exam	35%				17,5%	17,5%

*) can also be obtained from the Midterm or Final Exam as the result of participatory activities or project/ case study results. According to IKU 7, the percentage of project results/ case study/ PBL results is at least 50%.

References

Main references:

1. Kolb, E.W & Turner, M.S., The Early universe, 1989, Addison-Wesley Publishing Company.
2. Ryden, B. Introduction of Cosmology, 2016, Department of Astronomy, The Ohio State University.
3. Raine, D.J & Thomas, E.G, An Introduction To The Science Of Cosmology, 2001, IOP Publishing.
4. Scott Dodelson, Modern Cosmology, 2003, Academic Press.
5. Cheng T., 2005, Relativity, Gravitation, and Cosmology. A basic introduction, Oxford University Press, Oxford.

Lecturers (*Team Teaching*)

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Authorization	**Date of Drafting**	**Lecturer Coordinator**	**Head of Curriculum Committee**	**Head of Study Program**
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