S t u d y p r o g r a m m e

Part A) of the study programme

L e a r n i n g o u t c o m e s

Faculty offering the field of study:	**Faculty of Physics, Astronomy and Informatics**
Field of study:	**Physics and Astronomy**
Level of study:	**Second-cycle studies**
Level of the Polish Qualifications Framework:	**Level 7**
Degree profile:	**Academically oriented**
Professional degree awarded to the graduate:	**magister**
Allocation of the field of study within academic or artistic discipline(s), to which learning outcomes for a given field of study refer:	**Disciplines:** **- Physical Sciences (60%)** **- Astronomy (40%)** **Major discipline: Physical Sciences**

Symbol	**Upon completion the graduate achieves the learning outcomes specified below:**
	KNOWLEDGE
K_W01	Has in-depth knowledge of advanced Mathematics and mathematical methods necessary for solving problems of Physics or Astronomy in the selected areas
K_W02	Knows advanced experimental, observational and numerical techniques which allow to plan a complex physical or astronomical experiment
K_W03	Knows the rules of the functioning of measuring systems and research equipment specific for the area of Physics or Astronomy, or knows advanced methods of theoretical, computational and mathematical Physics or Astronomy
K_W04	Knows the physical processes occurring in stars and galaxies, interstellar and extragalactic medium, has in-depth knowledge of the structure and evolutions of planetary systems, stars, galaxies, and the Universe
K_W05	Knows the processes occurring in atoms, molecules, optical phenomena and condensed matter
K_W06	Has knowledge of contemporary trends in the development of Physics and Astronomy
K_W07	Has basic knowledge of economic, legal, ethical and other conditions related to academic activity and teaching, knows the basic rules of copyrights.
	SKILLS
K_U01	Can apply a scientific method to problem-solving, conducting experiments, drawing conclusions and testing hypotheses
K_U02	Is capable of planning and conducting advanced experiments or observations as well as theoretical considerations in particular fields of Physics or Astronomy and their applications
K_U03	Can critically analyses measurements, observations or theoretical computations, along with evaluations of the results' accuracy
K_U04	Can use and modify available software for numerical modeling of astrophysical objects or physical phenomena
K_U05	Can find relevant information in specialist literature, both from databases and other sources; can recreate the reasoning or the course of an experiment described in literature, taking into account the assumptions and approximations made
K_U06	Can critically compare model data with experimental or observational data

K_U07	Can adapt knowledge and methodology of Physics and Astronomy as well as applied experimental and theoretical methods to the needs of related scientific disciplines
K_U08	Can see the connections between contemporary studies of the Universe and the development of Physics at the fundamental level
K_U09	Can present research findings (experimental, theoretical or numerical) in speech or writing
K_U10	Can efficiently communicate both with specialists and non-specialists in terms of topics relevant to the studied field of Physics or Astronomy
K_U11	Can work both independently and as a member of a team, also assuming the leading role; is aware of the responsibility for jointly-conducted tasks
K_U12	Can define the directions for further improvement of own skills and knowledge (including self-education) within the selected specialization and beyond it
K_U13	Has language skills in terms of fields of knowledge and disciplines of science relevant to the programme studied, in accordance with the requirements stipulated for the B2+ level of the Common European Framework of Reference
SOCIAL COMPETENCES	
K_K01	Knows the limitations of own knowledge and skills
K_K02	Appreciates the importance of knowledge in solving practical and cognitive problems, understands the need to question experts and authorities
K_K03	Knows and appreciates the importance of intellectual honesty in own actions and the actions of other persons; is aware of ethical problems in the context of research reliability (plagiarism or duplicate publication, data falsification)
K_K04	Understands the need to popularize the knowledge of Physics and Astronomy, including the most recent scientific and technological advances
K_K05	Can formulate opinions related to professional issues as well as opinions on certain topics of public interest such as global warming, renewable energy or atomic energy

Description of the process resulting in the achievement of learning outcomes

Part ***B) of the study programme***

Faculty offering the field of study:	Faculty of Physics, Astronomy and Informatics
Field of study:	Physics and Astronomy
Level of study:	second cycle
Level of the Polish Qualifications Framework:	level 7
Degree profile:	general academic
Allocation of the field of study within academic or artistic discipline(s), to which learning outcomes for a given field of study refer:	Disciplines: Physical sciences (60%), Astronomy (40%)**,** **Major discipline:** Physical sciences
Mode of study:	full-time programme
Number of semesters:	4
Number of ECTS required for the award of qualifications corresponding to the level:	120
Total number of teaching hours:	approx. 1170
Professional degree awarded to the graduate:	**magister (Master of Science)**
The relationship between the study programme and NCU mission and strategy:	II.1.4. Increase the use of activating, engaging and team-based methods of education. II.1.5. Implement modern educational methods, tools and technologies and improve and enrich the teaching infrastructure. II.2.1. Ensure linking the educational content with scientific activities.

Courses/course modules along with expected learning outcomes				
Course module	**Course**	**Expected learning outcomes**	**Forms and methods of teaching ensuring the achievement of learning outcomes**	**Methods of verifying and assessing expected learning outcomes achieved by the student**
Obligatory courses	• Classical and celestial mechanics • Stellar physics • Advanced mathematical methods • Electrodynamics and field theory • Atomic and molecular physics • General relativity • Quantum optics 1 • High-energy astrophysics • Condensed matter physics • Physics laboratory • Astrohydrodynamics • Large-scale Universe • From complex chemistry to new physics	**Knowledge** **Student:** • knows the basic Newtonian classical mechanics with the focus at the N-body problem and its variants (the planetary problem) • knows the kinematics and dynamics with application of the two-body problem in astrophysics (star-planet, binary stars, planet-moon configurations) • knows the basic theory of the restricted three body problem and its selected application in astrodynamics, galactic dynamics and planetary systems • knows elements of the dynamical systems theory • has advanced knowledge of physical processes which determine the stellar structure and govern the stellar evolution • knows main stellar types and groups, relates them with different lifetime phases • is familiar with contemporary problems of stellar studies • has knowledge of mathematical models used in theoretical physics	Expository teaching methods: - informative lecture - problem-based lecture - discussion Exploratory teaching methods: - classic problem-solving - experimental - laboratory - project work	Assessment methods: - written examination - oral examination - final knowledge test - activity in classes - activity in project work - reports from results of experiments

		• is familiar with selected mathematical methods related to tensor calculus, complex analysis and group theory, and their applications in physics, • has knowledge concerning the current trends in the development of mathematical and theoretical physics, • has extensive knowledge about electromagnetism and differential equations, which allows him to solve problems in electrostatics, magnetostatics, and electrodynamics, • possesses knowledge about the independent-particle approximation (Hartree-Fock method) and its properties • is familiar with importance of the electron correlation effects in providing an accurate description of atoms and molecules • is acquainted with the basic methods for electron correlation energy calculations like Moller-Plesset perturbation theory, configuration interaction and coupled-cluster methods in both single- and multi-reference versions, • has basic knowledge of general theory of relativity (GTR), • knows fundamental effects of GTR and basic cosmological models, • is familiar with gravitational waves, their characteristics and sources, • has in-depth knowledge of physics and mathematical methods necessary for solving problems in Quantum Optics, • knows advanced methods of theoretical Quantum Optics, • is familiar with the processes occurring in atoms, molecules and optical phenomena, • has knowledge of contemporary tendencies in the development of Quantum Optics and Atomic Physics, • knows experimental techniques which allows to plan physical and astronomical experiments,		

		• is familiar with functioning of measuring systems and research equipment specific for particular fields of physics and astrophysics, • knows the physical processes of how primordial perturbations grow gravitationally to form large-scale structure and galaxies, • has knowledge of the Lambda CDM model of cosmology and its observational strengths and weaknesses, • knows and understands the relation of free-licensing of software in relation to the intellectual obligations of scientific understanding, scientific reproducibility, intellectual freedom, universal dissemination of knowledge and non-discrimination in the sense of the International Union of Pure and Applied Physics (IUPAP), • knows basic physical processes that lead to the emission of astronomical objects, • understands how the emission of different astronomical objects is created, • has basic knowledge about acceleration of particles in astronomical objects, **Skills** **Student can:** • use parametrisation of the Keplerian orbits, various types of orbital elements, propagation of the initial condition • use construction of the kinematic merit function for astrophysical observations of binary systems (radial velocities, astrometry, eclipse timing) • use numerical integration of the equations of motion • deduce information on stars from spectroscopy • has basic skills in simulating stellar structure and evolution • is able to derive specific physical quantities using some mathematical models and scientific reasoning, • has skills to adapt knowledge and methodology of tensor calculus, complex analysis, group and representation theory to selected topics in physics,		

		• can model electromagnetic phenomena, • has the basic knowledge about problems related to solving the Schrodinger equation for atomic and molecular systems, • is able to make use of the variational principle to obtain optimal approximate solutions for quantum mechanical problems, can apply perturbation expansion to evaluate most important components of the wave function and the energy in the Schrodinger equation • is capable of presenting the Hartree-Fock equations and discuss different aspects of the method as a zeroth-order approximation • has basic skills in using the second-quantized form of the operators and knows how to apply many-body techniques to derive an explicit form of the equations • can demonstrate and analyze different ways of including the effect of electron correlation in description of atoms and molecules, can discuss assumptions underlying the approaches and their properties • can introduce and discuss multi-reference generalizations of the standard single-reference methods that are designed to describe quasi-degenerate and open-shell systems, • is skilled in tensor calculations, • is capable of solving Einstein equations for the simplest highly symmetric cases, • can explain the concept of black hole and the simplest cosmological models, • can apply the scientific method to problem-solving, drawing conclusions and testing hypothesis, • has the skill of performing theoretical considerations in Quantum Optics and Atomic Physics and their applications, • can conduct a critical analysis of observations or theoretical computations,		

		• can find relevant information in specialist literature, both from databases and other sources; can recreate the reasoning or the course of an experiment described in literature, taking into account the assumptions made and approximation, • can adapt knowledge, methodology and results of Quantum Optics to the needs of related scientific disciplines, • can efficiently communicate both with specialists and non-specialists in terms of the topics relevant to Quantum Optics and Atomic Physics, • can define the directions for further improvement of own skills and knowledge (including self-education) within the selected specialization and beyond, • can apply the scientific method to conducting experiments, drawing conclusions and testing hypothesis, • is capable of planning and conducting advanced experiments in particular fields of Physics, • can conduct a critical analysis of measurements, along with evaluation of the results' accuracy, • has the skill of critical comparison of model data with experimental data, • can use and modify the available free-licensed software for numerical modelling of large-scale physical properties of the Universe and of objects in the Universe, • can see how astronomical evidence suggesting the existence of dark matter and dark energy stimulates research in fundamental physics, • is able to explain various types of emission in astronomical objects, • can create a simple model to explain given type of emission, • is capable to extend his knowledge by reading professional astronomical articles **Social competences**		

		Student • understands the fundamental links between the mathematical theory and observations • understands the significance of the Copernicus revolution • is ready to study specialized subjects of astronomy • understands the significance of stellar science to all other areas of astronomy • understands the need for development of physics underlying the energy generation and transport in stars • is aware of numerous unsolved issues • knows the limitations of his own knowledge and skills related to mathematical methods and theoretical physics, • can formulate his own opinions related to some topics of modern physics, • understands the need for proper popularization of relativity concepts • appreciates the meaning of knowledge in solving practical problems, understands the need to question experts, • understands significance of astronomical observations as a natural replacements for some laboratory experiments, especially for those that are impossible to conduct in normal laboratories, • understands the need to popularize the knowledge of Astronomy,		
Elective course module I	• Quantum optics 2 • Quantum optics laboratory • Optoelectronics laboratory • Quantum information • Statistical physics • Biophysics	**Knowledge:** **Student:** • Has in-depth knowledge of advanced Mathematics and mathematical methods necessary for solving problems of Physics in the selected areas, • Knows advanced experimental or numerical techniques, which allow to plan a complex physical experiment, • Knows the rules of functioning of measuring systems and research equipment specific for the area of Physics	Expository teaching methods: - informative lecture - problem-based lecture - discussion Exploratory teaching methods: - classic problem-solving - experimental	Assessment methods: - written examination - oral examination - final knowledge test - activity in classes - activity in project work

	or other from a list published every year on a faculty webpage	• Knows advanced methods of theoretical, computational and mathematical Physics, • Knows the processes occurring in atoms, molecules, optical phenomena and condensed matter, Has knowledge of contemporary tendencies in the development of Physics. **Skills** **Student:** • Can apply the scientific method to problem-solving, conducting experiments, drawing conclusions and testing hypothesis, • Has the skill of planning and conducting advanced experiments or observations as well as theoretical considerations in particular fields of Physics and their applications, • an conduct a critical analysis of measurements or theoretical computations, along with evaluation of the results' accuracy, • Can use and modify the available software for numerical modeling of physical phenomena, • Can find relevant information in specialist literature, both from databases and other sources; can recreate the reasoning or the course of an experiment described in literature, taking into account the assumptions made and approximations, • Has the skill of critical comparison of model data with experimental data, • Can adapt knowledge and methodology of Physics as well as applied experimental and theoretical methods to the needs of related scientific disciplines, • Can present research findings (experimental, theoretical or numerical) in the written or oral form, • Can efficiently communicate both with specialists and non-specialists in terms of the topics relevant to the studied field of Physics, • Can work both independently and as a member of a team, also taking a leading role, is aware of the responsibility for jointly-conducted tasks,	- laboratory - project work	- reports from results of experiments

		• Can define the directions for further improvement of own skills and knowledge (including self-education) within the selected specialization and beyond it, • Has language skills in terms of fields of knowledge and disciplines of science relevant to the program studied, in accordance with the requirements set for the B2+ level of the Common European Framework of Reference. **Social competences** **Student:** • Knows the limitations of own knowledge and skills • Appreciates the meaning of knowledge in solving practical and cognitive problems, understands the need to question experts and authorities, • Knows and appreciates the importance of intellectual honesty in own and others' actions, is aware of ethical problems in the context of research reliability (plagiarism or duplicate publication, data falsification), • Understands the need to popularize the knowledge of Physics including the latest scientific and technological advances, • Can formulate opinions related to professional issues, as well as opinions on some topics of public interest, such as the global warming, renewable energy or atomic energy.		
Elective course module II	• Introduction to astrophysics • Galaxies: formation and evolution • Physics of planetary systems • Theoretical astrophysics laboratory • Astrochemistry and astrobiology	**Knowledge** **Student:** • Has in-depth knowledge of advanced Mathematics and mathematical methods necessary for solving problems of Astronomy in the selected areas, • Knows advanced observational and numerical techniques, which allow to plan a complex astronomical experiment, • Knows the rules of functioning of measuring systems and research equipment specific for the area of Astronomy, • Knows advanced methods of theoretical, computational Astronomy, • Knows the physical processes occurring in stars and galaxies, interstellar and extragalactic medium, has in-depth knowledge	Expository teaching methods: - informative lecture - problem-based lecture - discussion Exploratory teaching methods: - classic problem-solving - experimental - laboratory - project work	Assessment methods: - written examination - oral examination - final knowledge test - activity in classes - activity in project work - reports from results of experiments

	or other from a list published every year on a faculty webpage	of the structure and evolutions of planetary systems, stars, galaxies, and the Universe, • Has knowledge of contemporary tendencies in the development of Astronomy. **Skills** **Student:** • Can apply the scientific method to problem-solving, conducting experiments, drawing conclusions and testing hypothesis, • Has the skill of planning and conducting advanced observations as well as theoretical considerations in particular fields of Astronomy and their applications, • Can conduct a critical analysis of observations or theoretical computations, along with evaluation of the results' accuracy, • Can use and modify the available software for numerical modeling of astrophysical objects • Can find relevant information in specialist literature, both from databases and other sources; can recreate the reasoning or the course of an experiment described in literature, taking into account the assumptions made and approximations, • Has the skill of critical comparison of model data with experimental or observational data, • Can adapt knowledge and methodology of Astronomy as well as applied experimental and theoretical methods to the needs of related scientific disciplines, • Can see the connections between contemporary studies of the Universe and the development of Physics at the fundamental level, • Can present research findings (experimental, theoretical or numerical) in the written or oral form, • Can efficiently communicate both with specialists and non-specialists in terms of the topics relevant to the studied field of Astronomy, • Can work both independently and as a member of a team, also taking a leading role, is aware of the responsibility for jointly-conducted tasks,		

		• Can define the directions for further improvement of own skills and knowledge (including self-education) within the selected specialization and beyond it, • Has language skills in terms of fields of knowledge and disciplines of science relevant to the program studied, in accordance with the requirements set for the B2+ level of the Common European Framework of Reference. **Social competences** **Student:** • Knows the limitations of own knowledge and skills • Appreciates the meaning of knowledge in solving practical and cognitive problems, understands the need to question experts and authorities • Knows and appreciates the importance of intellectual honesty in own and others' actions, is aware of ethical problems in the context of research reliability (plagiarism or duplicate publication, data falsification) • Understands the need to popularize the knowledge of Astronomy, including the latest scientific and technological advances • Can formulate opinions related to professional issues, as well as opinions on some topics of public interest, such as the global warming, renewable energy or atomic energy.		
Astophysics laboratory (elective, 3 ECTS)	• Optical astrophysics laboratory, • Radioastronomy laboratory	**Knowledge** **Student:** • has in-depth knowledge of advanced Mathematics and mathematical methods necessary for solving problems of Physics or Astronomy in the selected areas, • Knows the rules of the functioning of measuring systems and research equipment specific for the area of Physics or Astronomy, or knows advanced methods of theoretical, computational and mathematical Physics or Astronomy, • Knows the physical processes occurring in stars and galaxies, interstellar and extragalactic medium, has in-depth	Observation/demonstration teaching methods: display Expository teaching methods: - description - discussion - informative (conventional) lecture - problem-based lecture - laboratory	- activity during class project, - written reports from class activities,

		knowledge of the structure and evolutions of planetary systems, stars, galaxies, and the Universe **Skills** **Student can:** • critically analyze measurements, observations or theoretical computations, along with evaluations of the results' accuracy • use and modify available software for numerical modeling of astrophysical objects or physical phenomena • present research findings (experimental, theoretical or numerical) in speech or writing • efficiently communicate both with specialists and non-specialists in terms of topics relevant to the studied field of Physics or Astronomy **Social competences** **Student:** • Knows the limitations of own knowledge and skills • Appreciates the importance of knowledge in solving practical and cognitive problems, understands the need to question experts and authorities		
University-wide courses	University-wide courses (from a list of courses)	**Knowledge** **Student:** • Has basic knowledge of economical, legal, ethical and other conditions related to scientific and didactic activity • Knows and understands the basic terms and rules of copyrights **Skills** **Student:** • Can adapt knowledge and methodology of Physics and Astronomy as well as applied experimental and theoretical methods to the needs of related scientific disciplines • Can define the directions for further improvement of own skills and knowledge (including self-education) within the selected specialization and beyond it	In agreement with subject description	In agreement with subject description

		• Has language skills in terms of fields of knowledge and disciplines of science relevant to the program studied, in accordance with the requirements set for the B2+ level of the Common European Framework of Reference **Social competences** **Student:** • Knows the limitations of own knowledge and skills • Can formulate opinions related to professional issues, as well as opinions on some topics of public interest, such as the global warming, renewable energy or atomic energy.		
Monographic lectures	Monographic lectures (from a list of courses)	**Knowledge** **Student:** • Knows the physical processes occurring in stars and galaxies, interstellar and extragalactic medium, has in-depth knowledge of the structure and evolutions of planetary systems, stars, galaxies, and the Universe • Knows the processes occurring in atoms, molecules, optical phenomena and condensed matter • Has knowledge of contemporary tendencies in the development of Physics and Astronomy **Skills** **Student:** • Can find relevant information in specialist literature, both from databases and other sources; can recreate the reasoning or the course of an experiment described in literature, taking into account the assumptions made and approximations • Has the skill of critical comparison of model data with experimental or observational data • Can see the connections between contemporary studies of the Universe and the development of Physics at the fundamental level **Social competences** **Student:** • Knows the limitations of own knowledge and skills	Expository teaching methods: - informative lecture - problem-based lecture - discussion	Assessment methods: - written examination - oral examination - final knowledge test

		• Appreciates the meaning of knowledge in solving practical and cognitive problems, understands the need to question experts and authorities • Understands the need to popularize the knowledge of Physics and Astronomy, including the latest scientific and technological advances • Can formulate opinions related to professional issues, as well as opinions on some topics of public interest, such as the global warming, renewable energy or atomic energy.		
Diploma project	• Diploma proseminar • Diploma seminar • Master thesis	**Knowledge** **Student:** • Has knowledge of contemporary tendencies in the development of Physics and Astronomy • Has basic knowledge of economical, legal, ethical and other conditions related to scientific and didactic activity • Knows and understands the basic terms and rules of copyrights **Skills** **Student:** • Can apply the scientific method to problem-solving, conducting experiments, drawing conclusions and testing hypothesis • Has the skill of planning and conducting advanced experiments or observations as well as theoretical considerations in particular fields of Physics or Astronomy and their applications • Can conduct a critical analysis of measurements, observations or theoretical computations, along with evaluation of the results' accuracy • Can use and modify the available software for numerical modeling of astrophysical objects or physical phenomena • Can find relevant information in specialist literature, both from databases and other sources; can recreate the reasoning or the course of an experiment described in literature, taking into account the assumptions made and approximations	Expository teaching methods: - informative lecture - problem-based lecture - discussion - presentation	Assessment methods: - written examination - oral examination - quality and correctness of presentation

		• Has the skill of critical comparison of model data with experimental or observational data • Can adapt knowledge and methodology of Physics and Astronomy as well as applied experimental and theoretical methods to the needs of related scientific disciplines • Can see the connections between contemporary studies of the Universe and the development of Physics at the fundamental level • Can present research findings (experimental, theoretical or numerical) in the written or oral form • Can efficiently communicate both with specialists and non-specialists in terms of the topics relevant to the studied field of Physics or Astronomy • Can define the directions for further improvement of own skills and knowledge (including self-education) within the selected specialization and beyond it • Has language skills in terms of fields of knowledge and disciplines of science relevant to the program studied, in accordance with the requirements set for the B2+ level of the Common European Framework of Reference **Social competences** **Student:** • Knows the limitations of own knowledge and skills • Appreciates the meaning of knowledge in solving practical and cognitive problems, understands the need to question experts and authorities • Knows and appreciates the importance of intellectual honesty in own and others’ actions, is aware of ethical problems in the context of research reliability (plagiarism or duplicate publication, data falsification) • Understands the need to popularize the knowledge of Physics and Astronomy, including the latest scientific and technological advances		

		• Can formulate opinions related to professional issues, as well as opinions on some topics of public interest, such as the global warming, renewable energy or atomic energy.		
Foreign language classes		Expected learning outcomes depend on the selection of the language by the student.	Forms and methods of teaching ensuring the achievement of learning outcomes depend on the selection of the language by the student	Methods of verifying and assessing expected learning outcomes achieved depend on the selection of the language by the student
Internships				
Duration of internships	**Not applicable**			
Form of internships				
Rules of internships				

Detailed allocation of ECTS credits

Academic or artistic disciplines, to which learning outcomes refer:

	Artistic or academic discipline	ECTS credits number	ECTS credits %
1.	Astronomy	48	40
2.	Physical sciences	72	60

Course modules	Course	No of ECTS credits	No of ECTS credits in the discipline: *(enter names of disciplines)*				No of ECTS credits for elective courses	No of ECTS credits obtained by the student in classes conducted with the direct contact with the teacher or tutor	No of ECTS credits obtained by the student as a result of: courses related to academic activity within a discipline or disciplines, to which the field of study is assigned / courses focused on training practical skills
			astronomy	Physical sciences	Other				
Obligatory courses	Classical and celestial mechanics	**5**	5					2,5	3
	Stellar physics	**5**	5					2,5	3
	Advanced mathematical methods	**6**		6				3	2
	Electrodynamics and field theory	**6**		6				3	2
	Atomic and molecular physics	**5**		5				2,5	2,5
	General relativity	**6**		6				3	2
	Quantum optics 1	**5**		5				2,5	3
	High-energy astrophysics	**3**	3					1,5	2
	Condensed matter physics	**3**		3				1,5	1,5
	Physics laboratory	**5**		5				3	2,5
	Astrohydrodynamics	**4**	4					2	2
	Large-scale Universe	**3**	3					1,5	1,5
	From complex chemistry to new physics	**4**		4				2	2
Summary for obligatory courses		**60**	20	40				30,5	29

Elective course module I	Quantum optics 2	**5**		5			5	2,5	4
	Quantum optics laboratory	**5**		5			5	3,5	4
	Optoelectronics laboratory	**5**		5			5	3,5	4
	Quantum information	**3**		3			3	1,5	2
	Statistical physics	**5**		5			5	2,5	2
	Biophysics	**5**		5			5	2,5	3
Elective course module II	Introduction to astrophysics[1]	**3**	3				3	1,5	1
	Galaxies: formation and evolution	**5**	5				5	2,5	2,5
	Physics of planetary systems	**5**	5				5	2,5	3
	Theoretical astrophysics laboratory 1	**3**	3				3	2	2
	Theoretical astrophysics laboratory 2	**3**	3				3	2	2
	Theoretical astrophysics laboratory 3	**3**	3				3	2	2
	Astrochemistry and astrobiology	**3**	3				3	1,5	1,5
Summary for elective course modules		**18**	0-18[2]	0-18[1]			18	11,5	10
Astrophysics laboratory (elective, 3 ECTS)	Optical astrophysics laboratory	**3**	3				3	2	2
	Radioastronomy laboratory	**3**	3				3	2	2
University-wide courses	University-wide courses (from a list of courses)	**9**			9		9	5	0
Monographic lectures	Monographic lectures (from a list of courses)	**6**	0-6[1]	0-6[1]			6	3	6
Diploma project and/or diploma examination	Diploma proseminar	**2**	0-2[1]	0-2[1]				1	2
	Diploma seminar	**2**	1	1				1	2
	Master thesis	**20**	10	10			20	6,5	20
	IN TOTAL:	**120** **100%**	**47** **39,2%**	**64** **53,3%**	**9** **7,5%**		**56** **46,7 %**	**60,5** **50,4%**	**71** **59,2%**

[1] Not for BSc in astronomy

[2] The score depends on a particular path of courses chosen.

Course module	**Course**	**Programme content**
Obligatory courses	Classical and celestial mechanics	The purpose of the lecture is to discuss basic issues of classical and celestial mechanics centered on the theory of two-body orbits, in the context of the N-body problem and its restricted variants (e.g., the restricted elliptic three-body problem). Modeling observations of binary stars and planetary systems is an important application in the field of astrophysics. Numerical techniques for solving equations of motion and qualitative analysis of simple models, such as the three-body perturbation problem, address basic concepts in dynamical systems theory. The material is intended to be understood by undergraduate students with an elementary background in differential calculus, linear and vector algebra and vector calculus.
	Stellar physics	The course covers numerous aspects related with the objects named "stars". Presented are the physical processes which determine stellar structure and govern stellar evolution. Students will be introduced into observational and theoretical methods of analyzing stars, and will know the recent results in this field.
	Advanced mathematical methods	Lecture and classes provide a review of some selected topics of tensor calculus, complex analysis and group theory along with a discussion of their applications in physics.
	Electrodynamics and field theory	Definitions of quantities describing electromagnetic fields and their sources. Maxwell's equations in integral and differential forms. Field discontinuities. Methods of solving Maxwell's equations. Relativistic formulation of electrodynamics. Spacetime models. Potential theory. Theory of radiation. Elements of classical field theory: Lagrangian and Hamiltonian formulation. Classical gauge theory: scalar electrodynamics and SU(2) Yang-Mills theory.
	Atomic and molecular physics	The lecture is devoted to extending knowledge of quantum mechanics of many-electron systems. It consists of issues related to the basics regarding the description of atomic and molecular systems.
	General relativity	The aim of the lectures is an introduction into general theory of relativity of Albert Einstein. The Einstein's equations are introduced and solved for the most interesting (although simplest) cases. These are a spherical symmetric field in vacuum, a homogeneous and isotropic universe and and some aspects of gravitational waves.
	Quantum optics 1	The aim of the course is to provide basic knowledge: - on issues of contemporary research in quantum optics and atomic optics, - on the fundamental laws of the quantum nature of radiation and their physical consequences as well as on the methods of their theoretical description , - on some specific phenomena in this field.
	High-energy astrophysics	This is a lecture about high energy astrophysics. During the lecture we describe astronomical instruments and measure techniques used in the high energy astrophysics and also sources and physical processes of the high energy emission.
	Condensed matter physics	The aim of the lecture is to familiarize students with semiconductors physics, doped semiconductors, semiconductor in the state of thermodynamic equilibrium, concentration of electric charge carriers, balance of carrier concentration, electric neutrality equation. Also presented will be issues of carrier transport in a semiconductor, charge carriers in an

		electric field, conduction, the Hall effect, non-equilibrium phenomena in a semiconductor, generation, recombination and trapping processes, diffusion, the principle of current flow, transport equations and the p-n junction. Simple diodes, photodiodes, solar cells, resistor, transistor and thermistor will be also discussed. Experimental methods for characterizing semiconductors will also be presented. The lecture is be a source of information about technology, which result in more and more modern semiconductor devices used in optoelectronics and photonics.
	Physics laboratory	Physics Laboratory is a laboratory where students make advanced experiments in Physics. Each experiment requires from student to: prepare theoretical background description, prepare experimental setup and make an experiment, analyze results and prepare a report in a form similar to scientific publication.
	Astrohydrodynamics	The aim of the lecture is to present bases of fluid dynamics and its application in description of astrophysical phenomena.
	Large-scale Universe	Large-scale astrophysical objects: galaxies, clusters of galaxies, voids, cosmic web, baryon acoustic oscillations; physical cosmology: hot big bang model, Lambda CDM model, general-relativistic models and their observational foundations, galaxy formation
	From complex chemistry to new physics	This lecture bridges the gap between the courses of quantum mechanics, quantum optics, spectroscopy, and computer science. We will first discuss the most important quantum chemistry methods which allow us to model ground- and excited-state molecular systems, that is, the Hartree-Fock theory and the Density Functional Theory. We will briefly discuss the wave function-based methods which take into account the correlated nature of electrons. Next, we will focus on studies of nuclear motion in molecules, and discuss vibrations, rotations of molecules, and collisions in simple systems. Finally, we will model the spectroscopic properties of several important molecules using quantum chemistry methods and computer programs.
Elective course module I	Quantum optics 2	The lecture is devoted to selected topics in quantum optics and information: techniques of single photon generation and implementations of quantum information processing protocols.
	Quantum optics laboratory	Quantum Optics Laboratory is a laboratory where students make advanced experiments in optics in quantum systems. Each experiment requires from student to: prepare theoretical background description, build experimental setup, develop necessary software and make an experiment, analyze results and prepare a report in a form similar to scientific publication.
	Optoelectronics laboratory	This lab course concerns principles and applications of optoelectronic devices, focusing on fundamental issues like generation, transition and detection of light.
	Quantum information	Sets of quantum and classical states, Qubits an d Bloch ball, Uncertainty relation, Maasen-Uffink formulation. Mutually unbiased bases. Quantum mechanics of composite and open quantum systems. Dilation theorems. Theory of quantum channels and generalized measurements. SIC POVMs. Optical systems in polarization domain. Non-cloning theorem, BB84 protocol. Space of hidden variables, Bell inequalities, non-signaling. Quantum teleportation, local filtering. Measures of entanglement , entanglement criteria. Shor Algorithm of factorization.
	Statistical physics	Classes and lectures provide a review of some selected topics of statistical physics, along with a discussion of basic mathematical tools such as probability theory, statistics and stochastic processes. A particular attention is paid to the

		role of statistical physics in thermodynamics of gaseous and magnetic systems and in quantum theory. Some examples of using this method in related sciences (astronomy, biophysics) are also presented.
	Biophysics	In this course specificity of biological living systems will be presented from the physical point of view. Unique features of biological matter will be outlined, with emphasis on chemical bonds that govern life – covalent bonds, H-bonds, VdW interactions. Special role of water will be stressed. A review of protein, membranes and DNA structures is a part of this course. Entropy and other thermodynamical functions will be discussed and linked with free energy changes in enzymatic reactions. Deeper understanding of transport processes and information flow in living systems will be presented. Passive and active transport together with ion channels is explained. Another topic is related to brain, action potential and synapses. Receptors and sensing will be discussed. Substantial part is devoted to oxygen transport processes and phenomenon of cooperativity. Some biophysical methods used in medicine will be presented – basics of pulsoxymetry, photodynamics therapy or dialysis.
	or other from a list published every year on a faculty webpage	Programme content depends on the selection of the lecture by the students.
Elective course module I	Introduction to astrophysics	This course is intended for students who lack a basic knowledge in astrophysics. The astronomical terminology will be introduced, and a review of astronomical objects and associated physical processes will be given. The lectures will be presented by several scientists specializing in different particular fields of research.
	Galaxies: formation and evolution	The aim of the lecture is to present basic knowledge of the structure, dynamics and evolution of galaxies.
	Physics of planetary systems	The lecture is devoted to presentation of current status of our knowledge concerning planets, and exoplanets in specifies. It will address detection methods and current results of planet searches first. Then basic concepts of formation processes as well as structure and evolution of planetary systems will be introduced. Finally the concept of habitability and study of exoplanetary atmospheres will be introduced.
	Theoretical astrophysics laboratory 1	Classes take the form of a computer lab and are devoted to numerical methods and specialized software that is applicable in modern theoretical astrophysics. The detailed scope of topics depends on the person conducting the classes and their research topics, which guarantees familiarizing the student with the current state of this field.
	Theoretical astrophysics laboratory 2	Classes take the form of a computer lab and are devoted to numerical methods and specialized software that is applicable in modern theoretical astrophysics. The detailed scope of topics depends on the person conducting the classes and their research topics, which guarantees familiarizing the student with the current state of this field.
	Theoretical astrophysics laboratory 3	The aim of the laboratory is to acquaint students with modern techniques of modeling of astrophysical phenomena by means of numerical simulation methods. Students perform and analyze a series of numerical experiments including: supernova explosions, accretion disks, astrophysical jets and selected hydrodynamical instabilities (gravitational instability, thermal instability, Kelvin-Helmholtz instability) of astrophysical relevance.

	Astrochemistry and astrobiology	Astrochemistry: The lectures are dedicated to the research of chemical processes in interstellar medium and physical and chemical evolution from single atoms to complex molecules. The newest discoveries in astrochemistry are summarized and discussed. Astrobiology: The course covers the basics of astrobiology from the formation of planetary systems to methods of signal detection from extraterrestrial civilizations. The series of lectures is based on the Drake's equation and discussion of its individual factors.
	or other from a list published every year on a faculty webpage	Programme content depends on the selection of the lecture by the students.
Astrophysics laboratory (elective, 3 ECTS)	Radio Astrophysics Laboratory	Lecture: Introduction to radio astronomy, radio emission processes, interferometric observation techniques, and research conducted at the IA UMK. Laboratory: Understanding the structure and operation of the radio telescope, as well as the basic methods of radioastronomical observations and the research topics conducted at UMK. The student acquires the skills to operate the 32m radio telescope and performs exercises involving basic measurements and observations of selected astronomical objects. The student summarizes the observation results in reports describing the course of the observations, the results, and their discussion.
	Optical astrophysics laboratory	The optical astrophysics laboratory aims to familiarize students with the achievements of observational astronomy, with an emphasis on topics pursued at the Institute of Astronomy of the Nicolaus Copernicus University (IA UMK), particularly in the optical domain. Student will become acquainted with available online databases and learn how to use them. They will also analyze simple observations. Basic software such as TOPCAT, AstroImageJ, and others will be used.
University-wide courses	University-wide courses (from a list of courses)	Programme content depends on the selection of the lecture by the students.
Monographic lectures	Monographic lectures (from a list of courses)	Programme content depends on the selection of the lecture by the students.
Diploma project	Diploma proseminar	The aim of course is: 1) to develop students' presentation skills in scientific and technical topics, including: a) selection of essential content of the presented subject, b) preparing a computer presentation, 2) preparation for substantive, public discussion on scientific and professional topics.
	Diploma seminar	The aim of the seminar is to develop the skills to clearly present results of one's own work or work published by other authors to a wider audience. To develop skills in discussion in scientific and technical topics.
	Master thesis	Preparation of a master's thesis under the supervision of a supervisor: -presentation of the substantive content of the project, results,

		- formulating conclusions from the theoretical, experimental, design and other performed tasks, in the form of a formal scientific text subject to peer-review. Development of skills in composition of a multi-chapter scientific manuscript, its editing, technical preparation of various forms of presentation of scientific content, experimental results and conclusions.
Foreign language classes		Programme content depends on the selection of language by the students.

This study programme is effective as of winter semester of the academic year 2025/2026.