Modern Astrophysics - astro850

Module No.	**astro850**
Category	Elective
Credit Points (CP)	
Semester	8.

Module: Modern Astrophysics

Module Elements:

Nr	Course	Course No.	CP	Type	Teaching hours	Semester
1	Stellar and Solar Coronae	astro851	4	Lect. + ex.	2+1	ST
2	Gravitational Lensing	astro852	4	Lect. + ex.	2+1	ST
3	The Physics of Dense Stellar Systems as the Building Blocks of Galaxies	astro8531	6	Lect. + ex.	3+2	WT
4	Numerical Dynamics	astro854	4	Lect. + ex.	2+1	ST
5	Quasars and Microquasars	astro856	3	Lecture	2	WT
6	Star Formation	astro857	4	Lect. + ex.	2+1	WT
7	Nucleosynthesis	astro858	6	Lect. + ex.	3+1	ST
8	The cosmic history of the intergalactic medium	astro859	4	Lect. + ex.	2+1	WT
9	Binary Stars	astro8501	4	Lect. + ex.	2+1	ST
10	Physics of Supernovae and Gamma-Ray Bursts	astro8502	4	Lect. + ex.	2+1	WT
11	Radio and X-Ray Observations of Dark Matter and Dark Energy	astro8503	4	Lect. + ex.	2+1	WT
12	Lecture on Advanced Topics in Modern Astrophysics	astro8504	4	Lect. + ex.	2+1	WT/ST
13	Astrophysics II (MA)	Astrophysics II	8	Lect. + ex.	4+1	WT
14	Star Formation (MA)	Star Formation	3	Lect. + ex.	2	WT
15	Galaxy Dynamics (MA)	Galaxy Dynamics	4	Lect. + ex.	2+1	WT

Requirements:

Preparation:

Adequate preparation in the M.Sc. in Astrophysics programme

Choice of classes to be made with mentor

Content: This module contains a number of lectures on various astrophysical phenomena, from stars to the largescale structure of the universe

Aims/Skills: The student shall acquire deeper knowledge of a variety of astrophysical phenomena, from stars through large-scale structure to cosmological aspects. The physical mechanisms and mathematical tools required to understand these phenomena shall be conveyed, complementing what is being treated in the compulsory astrophysics courses

Form of Testing and Examination: If the lecture is offered with exercises: requirements for the sub-module examination (written or oral examination): successful work with exercises

Length of Module: 1 semester

Maximum Number of Participants: ca. 100

Registration Procedure: s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Note: The students must obtain 18 CP in all out of the modules astro830, -840, -850.

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Stellar and Solar Coronae - astro851

Course	**Stellar and Solar Coronae**
Course No.	astro851

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	ST

Requirements:

Preparation:

Form of Testing and Examination: Requirements for the examination (written or oral): successful work with the exercises

Length of Course: 1 semester

Aims of the Course: The student shall gain thorough knowledge of activity phenomena exhibited by the sun and other stars

Contents of the Course: Sunspots and solar corona; Solar cycle; The Dynamo theory; Emission mechanism; Coronal loops; Magnetic reconnection; Flares; Magnetic stellar activity; Mapping star-spots: Doppler imaging; Radio coronae

Recommended Literature: Literature references will be provided during the course

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Gravitational Lensing - astro852

Course	**Gravitational Lensing**
Course No.	astro852

Category	**Type**	**Language**	**Teaching hours**	**CP**	**Semester**
Elective	Lecture with exercises	English	2+1	4	ST

Requirements:

Preparation:

Form of Testing and Examination: Requirements for the examination (written or oral): successful work with the exercises

Length of Course: 1 semester

Aims of the Course: After learning the basics of gravitational lensing followed by the main applications of strong and weak lensing, the students will acquire knowledge about the theoretical and observational tools and methods, as well as about the current state of the art in lensing research. Strong emphasis lies on weak lensing as a primary tool to study the properties of the dark-matter distribution and the equation of state of dark energy

Contents of the Course:

The detection of the deflection of light in a gravitational field was not only one of the crucial tests of Einstein's Theory of General Relativity, but has become in the past two decades a highly valuable tool for astronomers and cosmologists. It is ideally suited for studying the mass distribution of distant objects, search for compact objects as a potential constituent of the Galactic dark matter, provide powerful (and cheap) 'natural telescopes' to take a deeper look into the distant Universe, to measure the mass

distribution in clusters and on larger spatial scales, and to study the relation between luminous and dark matter in the Universe. Principles and methods are described in detail and the applications will be presented

Recommended Literature:

P. Schneider, C. Kochanek, J. Wambsganss; Gravitational Lensing: Strong, Weak and Micro: Saas-Fee Advanced Course 33. Swiss Society f Astrophysics and Astronomy (Springer, Heidelberg 2006)

P. Schneider, J. Ehlers, E. F. Falco; Gravitational Lenses (Springer, Heidelberg 1992)

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The Physics of Dense Stellar Systems as the Building Blocks of Galaxies - astro8531

Course	**The Physics of Dense Stellar Systems as the Building Blocks of Galaxies**
Course No.	astro8531

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	6	WT

Requirements:

Preparation: Participation in the lecture course and in the exercise classes and reading

Form of Testing and Examination: A final two hour written exam on the contents of the course

Length of Course: 1 semester

Aims of the Course: The students are taught the fundamentals of collisional stellar dynamics and of the emergence of stellar populations from galactic building blocks

Contents of the Course:

Fundamentals of stellar dynamics: distribution functions, generating functions, collisionless Boltzmann equation, Jeans equations, Fokker-Planck equation, dynamical states, collisional dynamics and relaxation, formal differentiation between star clusters and galaxies, mass segregation, evaporation, ejection, star-cluster evolution, the form, variation and origin of the stellar initial mass function, stellar populations, their evolution and their properties, binary stars as energy sinks and sources, the distribution functions of binary stars and the evolution of these distribution functions, star-cluster birth, violent relaxation, birth of dwarf galaxies.

The lecture course covers a broad range of topics related to the emergence of stellar populations from their molecular cloud cores. It provides a Bonn-unique synthesis on the one hand side between observationally and theoretically derived distribution functions, which describe stellar populations, and on the other hand side the temporal evolution of these distribution functions, such that a comprehensive mathematical formulation of stellar populations in galaxies becomes possible with this knowledge.

Recommended Literature:

Lecture notes

Galactic Dynamics by J.Binney and S.Tremaine (1987, Princeton University Press)

Dynamics and Evolution of Galactic Nuclei by D.Merritt (2013, Princeton University Press)

Dynamical Evolution of Globular Clusters by Lyman Spitzer, Jr. (1987, Princeton University Press)

The Gravitational Million-Body Problem by Douglas Heggie and Piet Hut (2003, Cambridge University Press)

Gravitational N-body Simulations: Tools and Algorithms by Sverre Aarseth (2003, Cambridge University Press)

Initial Conditions for Star Clusters by Pavel Kroupa (2008, Lecture Notes in Physics, Springer)

The stellar and sub-stellar IMF of simple and composite populations by Pavel Kroupa (2013, Stars and Stellar Systems Vol.5, Springer)

The universality hypothesis: binary and stellar populations in star clusters and galaxies by Pavel Kroupa (2011, IAUS 270, p.141)

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Numerical Dynamics - astro854

Course	**Numerical Dynamics**
Course No.	astro854

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	ST

Requirements:

Preparation:

Form of Testing and Examination: Requirements for the examination (written): successful work with exercises and programming tasks

Length of Course: 1 semester

Aims of the Course: The students will have to familiarize themselves with the various numerical recipes to solve the coupled 2nd-order differential equations as well as with the limitations of these methods

Contents of the Course: The two-body problem and its analytical solution. Ordered dynamics: integration of planetary motion, solar system, extra-solar planets. Collisional dynamics: integration of stellar orbits in star clusters, star-cluster evolution. Collisionless dynamics: integration of stellar orbits in galaxies, cosmological aspects

Recommended Literature:

Write-up of the class;

S. J. Aarseth; Gravitational N-body simulations: Tools and Algorithms (Cambridge University Press, 2003)

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Quasars and Microquasars - astro856

Course	**Quasars and Microquasars**
Course No.	astro856

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	2	3	WT

Requirements:

Preparation:

Form of Testing and Examination: Written or oral examination

Length of Course: 1 semester

Aims of the Course: The phenomenon of quasars and their energy production shall be studied from the smallest (stellar binaries) to the largest (active galactic nuclei) scales

Contents of the Course: Microquasars and Quasars; X-ray binaries; Accretion; Neutron stars; Black holes; X-ray observations; Spectral states; Radio observations; Doppler boosting; Energy losses; Magneto-hydrodynamic production of jets; Gamma-ray observations; Review of Microquasars; Quasi periodic oscillations (QPO)

Recommended Literature: Literature references will be provided during the course

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Star Formation - astro857

Course	**Star Formation**
Course No.	astro857

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	WT

Requirements:

Preparation:

Form of Testing and Examination: Written or oral examination

Length of Course: 1 semester

Aims of the Course: An introduction to basic concepts, modern theories, and the current observational basis of star formation.

Contents of the Course: The structure and evolution of the interstellar medium in relation to Star Formation: molecular excitation, interstellar chemistry; the star formation process: conditions, cloud collapse, protostellar evolution; low mass vs. massive star formation; related phenomena: jets and outflows, protostellar disks, shocks, photodissociation regions; the initial mass function, global star formation, starbursts, the star formation history of the Universe, the very first stars.

Recommended Literature:

Stahler, Palla: The Formation of Stars (Wiley-VCH, 2004)

Additional literature will be given during the course

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Nucleosynthesis - astro858

Course	**Nucleosynthesis**
Course No.	astro858

Category	**Type**	**Language**	**Teaching hours**	**CP**	**Semester**
Elective	Lecture with exercises	English	3+1	6	ST

Requirements:

Preparation: Introduction to Astronomy, Stars and Stellar Evolution

Form of Testing and Examination: Written or oral examination

Length of Course: 1 semester

Aims of the Course: Obtain an overview of the different nucleosynthesis processes in the universe, an understanding of how they work, and where they work.

Contents of the Course:

Basic: Thermonuclear reactions

Big Bang nucleosynthesis

Overview of stellar evolution

Hydrostatic Nucleosynthesis I: Hydrogen burning

Hydrostatic Nucleosynthesis II: Helium burning and beyond

Hydrostatic Nucleosynthesis III: The s-process

Hydrostatic Nucleosynthesis IV: s-process components

Explosive Nucleosynthesis I: Core-collapse supernovae

Explosive Nucleosynthesis II: r-process and p-process

Explosive Nucleosynthesis III: Thermonuclear supernovae

Cosmic ray nucleosynthesis

Chemical Evolution of galaxies

Recommended Literature:

Lecture script

C.E.Rolfs, W.S.Rodney: Cauldrons in the Cosmos (ISBN 0-226-45033-3), not compulsary

D.D. Clayton: Physics of Stellar Evolution and Nucleosynthesis (ISBN 0-226-10953-4), not compulsary

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The cosmic history of the intergalactic medium - astro859

Course	**The cosmic history of the intergalactic medium**
Course No.	astro859

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	WT

Requirements:

Preparation: Basic atomic physics (hydrogen atom) and basic thermodynamics. No previous knowledge of astrophysics is required.

Form of Testing and Examination: Written or oral examination

Length of Course: 1 semester

Aims of the Course: The aim of this course is to familiarize students with the physics of the intergalactic medium (the material that pervades the vast regions between galaxies) and with its significance for cosmology and the astrophysics of galaxies. Thanks to progress in observations, theoretical modeling, and computational power, our knowledge in this field is growing rapidly. The main questions driving current research will be discussed and new results introduced as they occur.

Contents of the Course:

Basic: Transport of continuum and line radiation, photo-ionizations and radiative recombinations, the cooling function, the expanding universe.

Advanced: Cosmic recombination, the dark ages, hydrogen and helium reionization, 21cm-probes of the dark ages and reionization, quasar absorption systems, the UV background, the warm-hot intergalactic medium, intracluster gas, Lyman-alpha fluorescence.

Recommended Literature: The study of the intergalactic medium is a young subject. No textbook exists for this topic. Lecture notes will be distributed.

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Binary Stars - astro8501

Course	**Binary Stars**
Course No.	astro8501

Category	**Type**	**Language**	**Teaching hours**	**CP**	**Semester**
Elective	Lecture with exercises	English	2+1	4	ST

Requirements:

Preparation: Introductory astronomy and cosmology lectures, stars and stellar evolution

Form of Testing and Examination: Written or oral examination, successful exercise work

Length of Course: 1 semester

Aims of the Course: The course will provide the necessary understanding of the basic physics of binary stars, in particular orbits, mass-transfer, chemistry and the importance of binary stars and populations of binaries to modern astrophysics.

Contents of the Course: Most stars are not alone, they orbit a companion in a binary star system. This course will address the evolution of such binary stars and their impact on the Universe. It will start by considering orbital dynamics and observations of binaries, followed by stellar interaction in the form of mass transfer by Roche-lobe overflow and wind mass transfer. The effect of duplicity on chemistry, rotation rates and orbital parameters will be studied with the emphasis on uniquely binary-star phenomena such as type Ia supernovae, thermonuclear novae and gamma-ray bursts. It will conclude with quantitative studies of populations of binary stars.

Recommended Literature:

An Introduction to Close Binary Stars - Hildtich - Cambridge University Press ISBN 0-421-79800-0

Interacting Binary Stars - Pringle and Wade - CUP (Out of print but you can find cheap second-hand copies on www.amazon.com) ISBN 0-521-26608-4

Evolutionary Processes in Binary and Multiple Stars - Eggleton - CUP ISBN 0-521-85557-8

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Physics of Supernovae and Gamma-Ray Bursts - astro8502

Course	**Physics of Supernovae and Gamma-Ray Bursts**
Course No.	astro8502

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	WT

Requirements:

Preparation: Introductory astronomy and cosmology lectures

Form of Testing and Examination: Written or oral examination, successful exercise work

Length of Course: 1 semester

Aims of the Course: The student will learn basic physics on supernova and gamma-ray burst, and will have an overview on their applications to various fields of astrophysics.

Contents of the Course:

Basic physics on stellar hydrodynamics, radiation processes, and stellar death.

Type Ia supernova: observations and theory. Application to cosmology

Core collapse supernova: observations and theory

Gamma-ray bursts: observations and theory.

Implications for massive star population and star-formation history

Supernova nucleosynthesis and chemical evolution of galaxies

Explosions of the first generations of stars

Some related issues: supernova remnants, neutrinos, shock break-out, etc.

Recommended Literature: Lecture notes with key references for each topic will be provided.

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Radio and X-Ray Observations of Dark Matter and Dark Energy - astro8503

Course	**Radio and X-Ray Observations of Dark Matter and Dark Energy**
Course No.	astro8503

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	WT

Requirements:

Preparation: Introductory astronomy and cosmology lectures

Form of Testing and Examination: Written or oral examination, successful exercise work

Length of Course: 1 semester

Aims of the Course: The student will learn how the phenomena of dark matter and dark energy are explored using radio and X-ray observations, from the largest down to galaxy scales.

Contents of the Course: Introduction into the evolution of the Universe and the theoretical background of dark matter and dark energy tests, dark matter associated with galaxies, dark matter associated with galaxy clusters and superclusters, the cosmic microwave background (CMB), epoch of re-ionization, low-frequency radio astronomy, high-z supernovae, cosmic infrared background (CIB), precise distance measurements at cosmological distances, observational evidence for hierarchical structure formation, MOND vs. dark matter cosmology.

Recommended Literature: Lecture notes will be provided

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Lecture on Advanced Topics in Modern Astrophysics - astro8504

Course	**Lecture on Advanced Topics in Modern Astrophysics**
Course No.	astro8504

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	WT/ST

Requirements:

Preparation: Theoretical courses at the Bachelor degree level

Form of Testing and Examination: Requirements for the examination (written or oral): successful work with the exercises

Length of Course: 1 semester

Aims of the Course: This course is to allow the students to have deeper insight into a specialised subject of astrophysics that is not covered in the astrophysics curriculum otherwise. The content of the course depends on the lecturer's expertise and may vary from time to time.

Contents of the Course: See detailed announcements ("kommentiertes Vorlesungsverzeichnis")

Recommended Literature:

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Astrophysics II (MA) - Astrophysics II

Course	**Astrophysics II (MA)**
Course No.	Astrophysics II

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	4+1	8	WT

Requirements:

Preparation: Astrophysics I

Form of Testing and Examination: written test

Length of Course: 1 semester

Aims of the Course: The student will gain the ability to apply fundamental concepts of physics to describe astrophysical phenomena and will obtain an overview of the experimental foundations of our knowledge about the cosmos. The courses will enable him to understand the fundamental principles of the universe and its history. The courses also give an introduction to topics of active research in astrophysics and thus prepares the students towards their own research activity within the master thesis.

Contents of the Course:

Based on the introductory course ‘Astrophysics I’ in the Bachelor program this course deepens the understanding in selected topical areas of relevance. These are:

Interstellar medium: molecular clouds, HII regions, photon dominated regions, shock waves, radiation processes, radiative transfer, astrochemistry

Star formation (low mass and high mass), planetary system formation

Galaxies: galactic structure, morphology, dynamics, chemical evolution, nuclei of active galaxies

Large scale structure of the universe: intergalactic distance ladder, galaxy clusters, dark matter, gravitational lenses, experimental cosmology

Recommended Literature:

Binney and Merryfield, Galactic Astronomy (Princeton University Press)

Binney and Tremaine, Galactic Dynamics (Princeton University Press)

Carroll and Ostlie, An Introduction to Modern Astrophysics (Addison-Wesley)

Schneider, Einfhrung in die extragalaktische Astronomie & Kosmologie (Springer, Berlin)

Shu, The Physics of Astrophysics I & II (University Science Books, Mill Valley)

Tielens, The Physics and Chemistry of the Interstellar Medium (Cambridge University Press)

Unsöld and Baschek, Der neue Kosmos (Springer, Berlin)

Weigert and Wendker, Astronomie und Astrophysik (VCH Verlag)

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Star Formation (MA) - Star Formation

Course	**Star Formation (MA)**
Course No.	Star Formation

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2	3	WT

Requirements:

Preparation: Astrophysics I (Astrophysics II recommended)

Form of Testing and Examination: Oral examination

Length of Course: 1 semester

Aims of the Course: Understanding of fundamental concepts of star formation in a variety of environments.

Contents of the Course:

The lecture introduces the basic aspects of Star Formation:

Physical Processes in the ISM, Interstellar Chemistry, ISM and Molecular Clouds, Equilibrium Configurations and Collapse, Protostars, Formation of High Mass Stars, Jets, Outflows, Disks, Pre-main sequence stars, Initial Mass Function, Structure of the Galaxy, Starburst Galaxies, Star Formation in the early Universe

Recommended Literature:

Palla and Stahler, Formation of Stars (Wiley)

Carroll and Ostlie, An Introduction to Modern Astrophysics (Addison-Wesley)

Shu, The Physics of Astrophysics I & II (University Science Books, Mill Valley)

Tielens, The Physics and Chemistry of the Interstellar Medium (Cambridge University Press)

Spitzer, Physical Processes in the Interstellar Medium (Wiley)

Unsöld and Baschek, Der neue Kosmos (Springer, Berlin)

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Galaxy Dynamics (MA) - Galaxy Dynamics

Course	**Galaxy Dynamics (MA)**
Course No.	Galaxy Dynamics

Category	**Type**	**Language**	**Teaching hours**	**CP**	**Semester**
Elective	Lecture with exercises	English	2+1	4	WT

Requirements:

Preparation: Astrophysics I (Astrophysics II recommended)

Form of Testing and Examination: Oral examination

Length of Course: 1 semester

Aims of the Course: Understanding of fundamental concepts of stellar and galaxy dynamics.

Contents of the Course: The lecture introduces to basic aspects of stellar and galaxy dynamics: Multiple stellar systems, dynamics of open and compact stellar clusters, elliptical, disk and barred spiral galaxies, gas kinematics, galaxy evolution in galaxy clusters, gravitational friction, violent relaxation, the Hubble fork, galaxy collisions and mergers, cosmological evolution of stellar systems.

Recommended Literature:

Binney and Merryfield, Galactic Astronomy (Princeton University Press)

Binney and Tremaine, Galactic Dynamics (Princeton University Press)

Carroll and Ostlie, An Introduction to Modern Astrophysics (Addison-Wesley)

Schneider, Einführung in die extragalaktische Astronomie & Kosmologie (Springer, Berlin)

Weigert and Wendker, Astronomie und Astrophysik (VCH Verlag)

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