Module-Handbook
Master in Astrophysics
PO von 2006

SS 2024

July 2023

We don’t offer each of these modules regularly.

For any update please see:

https://www.physik-astro.uni-bonn.de/de/studium/

lehrveranstaltungen/termine-und-lehrveranstaltungen

Master in Astrophysics, University of Bonn

1^{st} Term

physics600	physics605	astro810	astro830
Base Module: Laboratory Course	**Base Module: Theoretical Physics**	**Compulsory Astrophysics I**	**Elective Advanced Lectures**
7 CP	7 CP	12 CP	(a)

2^{nd} Term

astro820	astro840	astro850	astro890
Compulsory Astrophysics II	**Observational Astronomy**	**Modern Astrophysics**	**Seminar**
12 CP	(a)		4 CP

3^{rd} Term

astro940	astro950
Scientific Exploration of Master Thesis Topic	**Methods and Project Planning**
15 CP	15 CP

4^{th} Term

astro960
Master Thesis
30 CP

Note: The students must achieve the indicated number of CP (Credit Points)
(a): In the modules 830, 840, 850 at least 18 CP altogether must be achieved.

Abbreviations:

CP	Credit Points (*Leistungspunkte*)
ex.	exercises
hrs	hours
lab.	laboratory
Ma-PO	"Master-Prüfungsordnung" (Examination Regulations (Master Course))
n.a.	not applicable
ST	Summer Term
TH	Teaching Hours
WT	Winter Term

On proposal of the board of examination, the Dean may agree to further compulsory selectable (sub-) modules. The office of the board of examination will announce these compulsory selectable (sub-) modules agreed upon, electronically or by public notice, in due time before the beginning of the semester.

Note about programme language:
The M.Sc. in Astrophysics programme is a programme in English language. At the discretion of the lecturer and the class German language may be used as the teaching language as well. Furthermore non-German speaking students are expected to learn German language on their own accord during the course of this programme.

Note to the points "Requirements" and "Preparation":
The point "Requirements" contains courses that have to be passed in order for the students to be able to participate in the module.
The point "Preparation" contains other courses whose content helps significantly towards the understanding of this course.

Note about module (submodule) examinations:
The details about the submodule examination will be announced by the lecturer before the start of the lecture
Please find updated versions of the module-handbook at http://www.physik-astro.uni-bonn.de

Table of Contents: M.Sc. in Astrophysics (PO von 2006)

Module No.: physics600
Credit Points (CP): 7
Category: Required
Semester: 7.

Fachgruppe
Physik und Astronomie
Universität Bonn

Module: Base Module Laboratory Course

Requirements:

Preparation:

Content:
Every student has to complete this Laboratory Course. The course consists of advanced experiments introducing into important subfields of contemporary experimental physics and astrophysics. The lab-course is accompanied by a seminar.

Aims/Skills:
The students shall gain insight in the conceptual and complex properties of relevant contemporary experiments. The students gain experience in setting up an experiment, data logging and data analysis. They experience the intricacies of forefront experimental research

Form of Testing and Examination:
Before carrying out an experiment, the students shall demonstrate to have acquired the necessary preparatory knowledge. Experiments are selected from the catalogue of laboratory set-ups offered.
Cumulative lab-units of >= 9 are required.
Requirements for the submodule examination (written report for every laboratory): successful completion of the experiment and initial oral questioning

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

Module No.: physics605
Credit Points (CP): 7
Category: Required
Semester: 7.

Fachgruppe
Physik und Astronomie
Universität Bonn

Module: Base Module Theoretical Physics

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
1.	Advanced Quantum Theory	physics606	7	Lect. + ex.	210 hrs	WT
2.	Advanced Theoretical Physics	physics607	7	Lect. + ex.	210 hrs	WT

Requirements:

Preparation:

Content:
The course provides fundamental knowledge needed for theoretical lectures in the Master course

Aims/Skills:
The M.Sc. Physics programme includes one obligatory module for all students. It includes a theoretical unit to extend the B.Sc. in Physics knowledge

Form of Testing and Examination:
Requirements for the module examination (written 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: When the student has (upon admission) demonstrated satisfactory knowledge of Advanced Quantum Theory already, the class Advanced Theoretical Physics may be taken instead

Module: Base Module Theoretical Physics

Module No.: physics605

Course: Advanced Quantum Theory

Course No.: physics606

Category	Type	Language	Teaching hours	CP	Semester
Required	Lecture with exercises	English	3+2	7	WT

Requirements:

Preparation:
Theoretical courses at the Bachelor degree level

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

Length of Course:
1 semester

Aims of the Course:
Ability to solve problems in relativistic quantum mechanics, scattering theory and many-particle theory

Contents of the Course:
Born approximation, partial waves, resonances
advanced scattering theory: S-matrix, Lippman-Schwinger equation
relativistic wave equations: Klein-Gordon equation, Dirac equation
representations of the Lorentz group
many body theory
second quantization
basics of quantum field theory
path integral formalism
Greens functions, propagator theory

Recommended Literature:
L. D. Landau, E.M. Lifschitz; Course of Theoretical Physics Vol.3 Quantum Mechanics (Butterworth-Heinemann 1997)
J. J. Sakurai, Modern Quantum Mechanics (Addison-Wesley 1995)
F. Schwabl, Advanced Quantum Mechanics. (Springer, Heidelberg 3rd Ed. 2005)

Module: Base Module Theoretical Physics

Module No.: physics605

Course: Advanced Theoretical Physics

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Course No.: physics607

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	WT

Requirements:

Preparation:
3-year theoretical physics course with extended interest in theoretical physics and mathematics

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

Length of Course:
1 semester

Aims of the Course:
Introduction to modern methods and developments in Theoretical Physics in regard to current research

Contents of the Course:
Selected Topics in Modern Theoretical Physics for example:
Anomalies
Solitons and Instantons
Quantum Fluids
Bosonization
Renormalization Group
Bethe Ansatz
Elementary Supersymmetry
Gauge Theories and Differential Forms
Applications of Group Theory

Recommended Literature:
M. Nakahara; Geometry, Topology and Physics (Institute of Physics Publishing, London 2nd Ed. 2003)
R. Rajaraman; Solitons and Instantons, An Introduction to Solitons and Instantons in Quantum Field Theory (North Holland Personal Library, Amsterdam 3rd reprint 2003)
A. M. Tsvelik; Quantum Field Theory in Condensed Matter Physics (Cambridge University Press 2nd Ed. 2003)
A. Zee; Quantum Field Theory in a Nutshell (Princeton University Press 2003)

Module No.: astro810
Credit Points (CP): 12
Category: Required
Semester: 7.

Fachgruppe
Physik und Astronomie
Universität Bonn

Module: Compulsory Astrophysics I

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
1.	Stars and Stellar Evolution or specific: Stellar Structure and Evolution	astro811	6	Lect. + ex.	180 hrs	WT
2.	Cosmology	astro812	6	Lect. + ex.	180 hrs	WT

Requirements:

Preparation:

Content:
The module represents the fundamentals of the phases of stars and stellar evolution and the knowledge about our cosmological model

Aims/Skills:
The student shall acquire deeper understanding of the workings of stars and their evolution, in particular of important transitory phases of evolution, and shall be able to understand the origin of stars related with the location of their parameters in the HRD.
The student shall acquire deep understanding of the foundation of our world models and of their consequences, with special emphasis on the formation of structures in the universe and its physical and observational consequences

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

Module: Compulsory Astrophysics I

Module No.: astro810

Course: Stars and Stellar Evolution or specific: Stellar Structure and Evolution

Course No.: astro811

Category	Type	Language	Teaching hours	CP	Semester
Required	Lecture with exercises	English	3+1	6	WT

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:
Students will acquire sufficient knowledge to understand stars and their evolution. Study of radiation transport, energy production, nucleosynthesis and the various end phases of stellar evolution shall lead to appreciation for the effects these processes have on the structure and evolution of galaxies and of the universe

Contents of the Course:
Historical introduction, measuring quantities, the HRD. Continuum and line radiation (emission and absorption) and effects on the stellar spectral energy distribution. Basic equations of stellar structure. Nuclear fusion. Making stellar models. Star formation and protostars. Brown Dwarfs. Evolution from the main-sequence state to the red giant phase. Evolution of lower mass stars: the RG, AGB, HB, OH/IR, pAGB, WD phases. Stellar pulsation. Evolution of higher mass stars: supergiants, mass loss, Wolf-Rayet stars, P-Cyg stars. Degenerate stars: White Dwarfs, Neutron Stars, Black Holes. Supernovae and their mechanisms. Binary stars and their diverse evolution (massive X-ray binaries, low-mass X-ray binaries, Cataclysmic variables, etc.). Luminosity and mass functions, isochrones. Stars and their influence on evolution in the universe

Recommended Literature:
Lecture notes on "Stars and Stellar Evolution" (de Boer & Seggewiss)

Module: Compulsory Astrophysics I

Module No.: astro810

Course: universitätbonn Cosmology

Course No.: astro812

Category	Type	Language	Teaching hours	CP	Semester
Required	Lecture with exercises	English	3+1	6	WT

Requirements:

Preparation:
Introductory astronomy

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 acquire deep understanding of the foundation of our world models and of their consequences, with special emphasis on the formation of structures in the universe and its physical and observational consequences. The lecture shall enable the student to read and understand original literature in astrophysical cosmology, but also to see the direct connection between the fundamental problems in cosmology and particle physics, such as the nature of dark matter and dark energy

Contents of the Course:
Kinematics and dynamics of cosmic expansion, introduction to General relativity, Friedmann equations and classification of world models, flatness and horizon problem; thermal history of the big bang, decoupling, WIMPS, nucleosynthesis, recombination and the CMB; gravitational light deflection, principles and applications of strong and weak gravitational lensing; structure formation in the Universe, perturbation theory, structure growth and transfer function, power spectrum of cosmic fluctuations, spherical collapse model, Press-Schechter theory and generalizations, cosmological simulations, cosmic velocity fields; principles of inflation; lensing by the large-scale structure, cosmic shear; anisotropies of the CMB, determination of cosmological parameters

Recommended Literature:
J. A. Peacock; Cosmological Physics (Cambridge University Press 1998)
P. J. E. Peebles; Principles of Physical Cosmology (Princeton University Press 1993)
Handout of the Transparencies

Module No.: astro820
Credit Points (CP): 12
Category: Required
Semester: 8.

Fachgruppe
Physik und Astronomie
Universität Bonn

Module: Compulsory Astrophysics II

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
1.	Astrophysics of Galaxies	astro821	6	Lect. + ex.	180 hrs	ST
2.	Physics of the Interstellar Medium	astro822	6	Lect. + ex.	180 hrs	ST

Requirements:

Preparation:

Content:
This module presents both, theoretical aspects, as well as the detailed properties of the major building blocks of cosmic structure, viz. galaxies. The fundamentals of the physics of the interstellar medium are conveyed, along with the tools used to study its properties

Aims/Skills:
The student shall acquire knowledge about the properties of galaxies, including their formation and their evolution, based on knowledge of the constituent matter (stars, gas, dark matter). The fundamentals of stellar dynamics are also conveyed. Physical processes relevant for the study of the interstellar medium have to be understood including the basic methods of measurements and their interpretation of the fundamental phases of the ISM

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

Module: Compulsory Astrophysics II

Module No.: astro820

Course: Astrophysics of Galaxies

Course No.: astro821

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

Requirements:

Preparation:
Introductory astronomy as well as a good understanding of stars and their evolution as well as of the interstellar medium

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

Length of Course:
1 semester

Aims of the Course:
The student shall acquire deep knowledge of the structure of the Milky Way and of other galaxies including their evolution.
This must enable them to understand and evaluate new publications in the field. It should provide the student a quick entry into the research phase of the study programme

Contents of the Course:
Review of stars and stellar evolution, review of the interstellar medium. Solar neighbourhood: observables, differential galactic rotation, Hyades, Goulds Belt, Local Bubble. The Galaxy: size, dynamics of objects, rotation curve, disk and z-distribution. Stellar dynamics: Boltzmann, Jeans drift, Schwarzschild ellipsoid, scale length and height, density wave, mass distribution, age of populations, dark matter concept, evolution. Satellites: the Magellanic Clouds, their structure and evolution, Magellanic Stream, Dwarf spheroidals, Local Group galaxies. Star clusters: stellar dynamics, binary and multiple stars, energy exchange, star-cluster birth and death, origin of galactic field population. Active galactic nuclei: observables, jets, accretion, black holes. Structure and shape of spirals and ellipticals, surface brightness, globular cluster systems. Galaxy clusters: distances, statistics, luminosity function, X-ray halos, virial theorem. Galaxy evolution: chemical enrichment, galactic winds, infall, observables. Galaxy collisions: relaxation, mergers, birth of dwarf galaxies

Recommended Literature:
J. Binney; B. Merrifield; Galactic Astronomy (Princeton University Press 1998)
J. Binney, S. Tremaine; Galactic Dynamics (Princeton University Press 1988)
L. S. Sparke; J. S. Gallagher; Galaxies in the Universe (Cambridge University Press, 2000)
Write-up of the class

Module: Compulsory Astrophysics II

Module No.: astro820

Course: Physics of the Interstellar Medium

Course No.: astro822

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

Requirements:

Preparation:
Introductory astronomy

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 acquire a good understanding of the physics and of the phases of the ISM. The importance for star formation and the effects on the structure and evolution of galaxies is discussed.

Contents of the Course:
Constitutens of the interstellar medium, physical processes, radiative transfer, recombination, HI 21cm line, absorption lines, Stroemgren spheres, HII regions, interstellar dust, molecular gas and clouds, shocks, photodissociation regions, energy balances, the multi-phase ISM, gravitational stability and star formation.

Recommended Literature:
B. Draine; The Physics of the Interstellar and Intergalactic Medium (Princeton Univ. Press 2010)
J. Lequeux; The Interstellar Medium (Springer 2005)

Module No.: astro830
Credit Points (CP):
Category: Elective
Semester: 7.

Fachgruppe
Physik und Astronomie
Universität Bonn

Module: Elective Advanced Lectures

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
Observational Astronomy						
1.	Selected 84* courses from catalogue	astro84*	3-6	see catalogue	90-180 hrs	WT/ST
Modern Astrophysics						
1.	Selected 85* courses from catalogue	astro85*	3-6	see catalogue	90-180 hrs	WT/ST
Research Internship						
1.	Internships in the Research Groups	astro831	4	internship		WT/ST
Cologne Courses						
1.	Astrophysics Courses from Cologne	see catalogue	3-8	see catalogue	90-240 hrs	WT/ST
1.	Also possible classes from M.Sc. in Physics					

Requirements:

Preparation:

Content:
This module comprises a catalogue of special topics in theoretical and observational astrophysics, which supplements the compulsory courses such as to provide the students with a thorough understanding of modern astrophysics

Aims/Skills:
The student has the opportunity to gain insight into specialized fields of modern theoretical and observational astrophysics, in addition to the compulsory courses, by selecting one such course out of the catalogue offered

Form of Testing and Examination:
If the lecture is offered with exercises: requirements for the 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

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

Module: Elective Advanced Lectures

Module No.: astro830

Course: Internships in the Research Groups

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Course No.: astro831

Category	Type	Language	Teaching hours	CP	Semester
Elective	Research Internship	English		4	WT/ST

Requirements:
Students are asked to contact one of the BCGS lecturers prior to the start of their internship. Lecturers provide help if needed to find a suitable research group and topic. Not all groups may have internships available at all times, thus participation may be limited.

Preparation:
A specialization lecture from the research field in question or equivalent preparation.

Form of Testing and Examination:
A written report or, alternatively, a presentation in a meeting of the research group.

Length of Course:
4-6 weeks

Aims of the Course:
Students conduct their own small research project as a part-time member of one of the research groups in Bonn. The students learn methods of scientific research and apply them to their project.

Contents of the Course:
One of the following possible items:
- setting up a small experiment,
- analyzing data from an existing experiment,
- simulating experimental situations,
- numerical or analytical calculations in a theory group.

Recommended Literature:
provided by the supervisor within the research group.

Module No.: astro840
Credit Points (CP):
Category: Elective
Semester: 8.

Fachgruppe Physik und Astronomie Universität Bonn

Module: Observational Astronomy

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
1.	Selected 84* courses from catalogue	astro84*	3-6	see catalogue	90-120 hrs	WT/ST
2.	Astrophysics Courses from Cologne marked "OA"	see catalogue	4	see catalogue	120 hrs	WT/ST
3.	Also possible classes from M.Sc. in Physics					

Requirements:

Preparation:

Content:
This module covers all observational tools used in modern astronomy, over a wide range of the electromagnetic spectrum

Aims/Skills:
Observational astronomy shall be conveyed to the students by teaching the fundamentals of observational astronomical tools, along with relevant applications. These tools cover essentially the entire electro-magnetic spectrum, from radio wavelengths through X-ray energies. They naturally also encompass a wide range of astrophysical phenomena, including condensed matter (stars, neutron stars), the interstellar and intergalactic medium, galaxies and active galactic nuclei, and clusters of galaxies. Emphasis is also on observational cosmology

Form of Testing and Examination:
If the lecture is offered with exercises: requirements for the submodule 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

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

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

Fachgruppe Physik und Astronomie Universität Bonn

Module: Modern Astrophysics

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
1.	Selected 85* courses from catalogue	astro85*	3-6	see catalogue	90-180 hrs	WT/ST
2.	Astrophysics Courses from Cologne marked "MA"	see catalogue	3-8	see catalogue	90-240 hrs	WT/ST
3.	Also possible classes from M.Sc. in Physics					

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 submodule 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

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

Module No.: astro890
Credit Points (CP): 4
Category: Elective
Semester: 8.

Fachgruppe
Physik und Astronomie
Universität Bonn

Module: Seminar

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
1.	Seminar on Cosmology	astro891	4	seminar	120 hrs	WT/ST
2.	Seminar on Radio Astronomy	astro892	4	seminar	120 hrs	WT/ST
3.	Seminar on Stellar Systems: "Star Clusters and Dwarf Galaxies"	astro893	4	seminar	120 hrs	WT/ST
4.	Specialized Seminars	astro894	4	seminar	120 hrs	WT/ST

Requirements:

Preparation:

Content:
Modern developments in astrophysics are discussed using recent literature

Aims/Skills:
These seminars will introduce the student for the first time into professional research in astrophysics. Active participation will furnish the student with the skill to read and present modern research topics

Form of Testing and Examination:
Talk

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

Module: Seminar

Module No.: astro890

Course: Seminar on Cosmology

Course No.: astro891

Category	Type	Language	Teaching hours	CP	Semester
Elective	Seminar	English	2	4	WT/ST

Requirements:

Preparation:
astro812 (Cosmology)

Form of Testing and Examination:
Talk

Length of Course:
1 semester

Aims of the Course:
The students will be introduced to the newest state of knowledge in cosmology. They will familiarize themselves with open questions and acquire knowledge on the newest methods in research

Contents of the Course:
The newest literature (in particular using papers from the astro-ph preprint server) relevant to the research on cosmology will be presented in short talks and will be reviewed

Recommended Literature:

Module: Seminar

Module No.: astro890

Course: Seminar on Radio Astronomy

Course No.: astro892

Category	Type	Language	Teaching hours	CP	Semester
Elective	Seminar	English	2	4	WT/ST

Requirements:

Preparation:
astro841 (Radio Astronomy: Tools, Applications, Impacts)

Form of Testing and Examination:
Talk

Length of Course:
1 semester

Aims of the Course:
The participating students will learn in depth how the radio-astronomical tools can be utilized in practice to scrutinize a wide range of astrophysical phenomena. Technically, this will cover the whole radioastronomical band, from meter-wavelengths to the sub-mm regime

Contents of the Course:
The students will give oral presentations on a selected subject from the recent literature (refereed journals and proceedings). These will cover both, scientific advancements made with radio-astronomical techniques as well as technical developments. The presentations will be prepared by the students with support by the supervisor(s)

Recommended Literature:

Module: Seminar

Module No.: astro890

Course: Seminar on Stellar Systems: "Star Clusters and Dwarf Galaxies"

Course No.: astro893

Category	Type	Language	Teaching hours	CP	Semester
Elective	Seminar	English	2	4	WT/ST

Requirements:

Preparation:
astro811 (Stars and Stellar Evolution), astro821 (Astrophysics of Galaxies)

Form of Testing and Examination:
Talk

Length of Course:
1 semester

Aims of the Course:
The students will be introduced to the newest state of knowledge in the field of Star Clusters. They will familiarize themselves with open questions and acquire knowledge on the newest methods in research

Contents of the Course:
The newest literature (in particular using papers from the astro-ph preprint server) relevant to the research on stellar populations, star clusters and dwarf galaxies will be presented in short talks and discussed

Recommended Literature:

Module: Seminar

Module No.: astro890

Course: Specialized Seminars

Course No.: astro894

Category	Type	Language	Teaching hours	CP	Semester
Elective	Seminar	English	2	4	WT/ST

Requirements:

Preparation:
Good results in the first Semester of the M.Sc. in Astrophysics programme

Form of Testing and Examination:
Talk

Length of Course:
1 semester

Aims of the Course:
Students will gain insight in special fields and their most recent developments. Knowledge about the newest methods and newest results will be acquired

Contents of the Course:
The newest literature from preprints, reviews and other up-to-date material on specialised topics, chosen based on the most recent developments in special areas of astrophysics, will be presented in short talks and discussed. The main theme will vary from semester to semester

Recommended Literature:

Module No.: astro940
Credit Points (CP): 15
Category: Required
Semester: 9.

Fachgruppe Physik und Astronomie Universität Bonn

Module: Scientific Exploration of the Master Thesis Topic

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
1.	Scientific Exploration of the Master Thesis Topic	astro941	15		450 hrs	WT

Requirements:
Successful completion of 40 credit points from the first year of the Master phase, including the base modules physics600 and physics605 and the compulsory modules astro810 and astro820

Preparation:

Content:
Under guidance of the supervisor of the Master Thesis topic, the student shall explore the science field, read the relevant recent literature, and perhaps participate in further specialised classes and in seminars. The student shall write an essay about the acquired knowledge, which may serve as the introduction part of the Master Thesis

Aims/Skills:
The student shall demonstrate to have understood the scientific question to be studied in the Master Thesis

Form of Testing and Examination:
Essay

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

Module No.: astro950
Credit Points (CP): 15
Category: Required
Semester: 9.

Fachgruppe
Physik und Astronomie
Universität Bonn

Module: Methods and Project Planning

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
1.	Methods and Project Planning	astro951	15		450 hrs	WT/ST

Requirements:
Successful completion of 40 credit points from the first year of the M.Sc. phase, including the base modules physics600 and physics605 and the compulsory modules astro810 and astro820

Preparation:

Content:
Under guidance of the supervisor of the planned Master Thesis topic, the student shall acquire knowledge about the methods required to carry out the Master Thesis project. This may include the participation in specialised seminars or specialised classes for the Master programme. The student shall plan the steps needed to successfully complete the Master Thesis

Aims/Skills:
The student shall demonstrate to have understood the methods to be used in the Master Thesis research. The project plan has to be presented

Form of Testing and Examination:
Short proposal for Master Thesis

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

Module No.: astro960
Credit Points (CP): 30
Category: Required
Semester: 10.

Fachgruppe
Physik und Astronomie
Universität Bonn

Module: Master Thesis

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
1.	Master Thesis	astro960	30	Thesis	900 hrs	WT/ST

Requirements:
Successful completion of the preparatory phase for the Master Thesis (astro940 and astro950)

Preparation:

Content:
Under guidance of the supervisor of the Master Thesis topic, the student shall carry out the research of the Master Thesis project

Aims/Skills:
The student shall identify and work out the science question to be tackled in the Master Thesis

Form of Testing and Examination:
Master Thesis and oral presentation

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

Catalogue of 84* and 85* courses

Modules:

astro830 **Elective Advanced Lectures**
astro840 **Observational Astronomy**

Course: Radio Astronomy: Tools, Applications, Impacts

Course No.: astro841

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

Requirements:

Preparation:
Good knowledge of electrodynamics, atomic physics, and astronomy

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:
An introduction to modern radio astronomy, its history, methods, and research potentials is given. The goals are to equip the student with the background and know-how to analyze and interpret data from modern single-dish and interferometer radio telescopes, and to enable them to motivate and write radioastronomical observing proposals. Aperture synthesis techniques are explained at some depth. The lecture is furnished with numerous examples demonstrating the versatility and power of radioastronomical tools

Contents of the Course:
Radiation: processes, propagation; Signal detection; Radio telescopes: properties, types; Receivers: heterodyne, bolometers; Backends: continuum, spectroscopy, pulsars; Interferometers: Fourier optics, aperture synthesis; imaging; Future: APEX, ALMA, LOFAR.

Recommended Literature:
B. F. Burke; F. Graham-Smith, An Introduction to Radio Astronomy (Cambridge University Press 2002)
T. L. Wilson; C. Rohlfs; Tools of Radio Astronomy (Springer, Heidelberg 4. rev. und erw. Ed. 2006)
J. D. Kraus; Radio Astronomy (Cygnus-Quasar Books, Durham 2. Aufl. 1986)
R.A. Perley; F. R. Schwab, A.H. Bridle; Synthesis Imaging in Radio Astronomy, 3rd NRAO Summer School 1988 (Astronomical Society of the Pacific Conference Series, 1989)
A. R. Thompson, J. M. Moran, G.W. Swenson, Interferometry and Synthesis in Radio Astronomy (Wiley & Sons, Weinheim 2. Aufl. 2001)
Lecture Notes (U. Klein)

Modules:

astro830 **Elective Advanced Lectures**
astro840 **Observational Astronomy**

Course: Submillimeter Astronomy

Course No.: astro842

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

Requirements:

Preparation:
Basic astronomy knowledge

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:
Students with B.Sc. in Physics will be introduced to astronomy in the submillimeter wavelength range, one of the last spectral regions to be explored with new high-altitude ground-based or airborne telescopes, and from space

Contents of the Course:
The basic concepts of emission/excitation mechanisms from interstellar dust and molecules are discussed as well as the properties of the observed objects: the dense interstellar medium, star forming regions, circumstellar environments. Star formation near and far is a central focus of submillimeter astronomy and will thus be introduced in depth. Telescopes, instrumentation, and observational techniques will be described in the course

Recommended Literature:
Contemporary review articles

Modules:

astro830 **Elective Advanced Lectures**
astro840 **Observational Astronomy**

Course: universitätbonn Astronomical Interferometry and Digital Image Processing

Course No.: astro843

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:
Students learn the basics required to carry out research projects in the field of wave optics and astronomical infrared interferometry

Contents of the Course:
Statistical optics; Wave optics; image detectors; resolution enhancement by digital deconvolution; interferometric imaging methods in optical astronomy; Theory of photon noise; iterative image reconstruction methods; astronomical applications

Recommended Literature:
J. W. Goodman; Introduction to Fourier Optics (Roberts & Company Publishers 3. Aufl. 2004)
Lecture Notes

Modules:

astro830 **Elective Advanced Lectures**
astro840 **Observational Astronomy**

Course: universitätbonn Observational Cosmology

Course No.: astro845

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:
Students with B.Sc. in Physics will be introduced to past and current experiments in cosmology, with some bias toward radio- and submillimeter astronomy

Contents of the Course:
Brief history of cosmology and its initial discoveries: cosmic expansion, cosmic microwave background. Overview of modern cosmological experiments, their major aims and technology. Aims: constraints on Big Bang and dark energy, CMB power spectrum and polarization, Sunyaev-Zeldovich effect, Supernova Ia distance measures, structure /cluster /galaxy formation, epoch of reionization, high-redshift galaxies and quasars. Experiments: APEX, LOFAR, Planck, Herschel, ALMA, SKA. Techniques: bolometer, HEMT

Recommended Literature:
B. F. Burke; F. Graham-Smith, An Introduction to Radio Astronomy (Cambridge University Press 2002)
J. A. Peacock; Cosmological Physics (Cambridge University Press 1998)
Contemporary Review Articles

Modules:

astro830 **Elective Advanced Lectures**
astro840 **Observational Astronomy**

Course: Wave Optics and Astronomical Applications

Course No.: astro846

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

Requirements:

Preparation:

Form of Testing and Examination:
Written or oral examination

Length of Course:
1 semester

Aims of the Course:
Acquire the fundamentals necessary to carry out research projects in the field of wave optics and astronomical infrared interferometry

Contents of the Course:
Fundamentals of wave optics; Fourier mathematics; digital image processing; Michelson interferometry; speckle interferometry; speckle holography; Knox-Thompson method; bispectrum-speckle interferometry; interferometric spectroscopy; infrared-long-baseline interferometry; optical phase-closure method; infrared interferometry of young stars and stars in late evolutionary stages and in nuclei of galaxies

Recommended Literature:
Lecture Notes
J. W. Goodman; Introduction to Fourier Optics (Roberts & Company Publishers 3rd edition, 2004)

Modules:

astro830 **Elective Advanced Lectures**
astro840 **Observational Astronomy**

Course: universitätbonn Optical Observations

Course No.: astro847

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

Requirements:

Preparation:
Astronomy introduction classes

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

Length of Course:
1 semester

Aims of the Course:
The students should get familiar with major aspects of optical astronomical observations, data reduction, and image analysis.

Contents of the Course:
Optical CCD and near infrared imaging, data reduction, catalogue handling, astrometry, coordinate systems, photometry, spectroscopy, photometric redshifts, basic weak lensing data analysis, current surveys, how to write observing proposals.
Practical experience is gained by obtaining and analysing multi-filter CCD imaging observations using the 50cm telescope on the AIfA rooftop, as well as the analysis of professional data from the archive.

Recommended Literature:
Provided upon registration

Modules:

astro830 **Elective Advanced Lectures**
astro840 **Observational Astronomy**

Course: Galactic and Intergalactic Magnetic Fields

Course No.: astro848

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

Requirements:

Preparation:
Good knowledge of electrodynamics and astronomy

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

Length of Course:
1 semester

Aims of the Course:
The students shall become familiar with relativistic plasmas in astrophysics. They shall comprehend the origin and significance of magnetic fields in diffuse astrophysical media. The potential role of magnetic fields in the evolution of the universe will be discussed. The detection and quantitative measurements of magnetic fields in the ISM and IGM shall be conveyed, along with a description of the current and future observational facilities.

Contents of the Course:
Introduction: magnetism, physical quantities, history, observational evidence; radiation processes: radiation transport, free-free radiation, synchrotron radiation, inverse-Compton radiation, propagation effects; diagnostics: optical polarisation, synchrotron radiation, Faraday rotation, Zeeman effect; radio continuum observations: total and polarised intensity, rotation measure, RM synthesis, telescopes; Milky Way: diffuse ISM, molecular clouds and star-forming regions, supernova remnants, diffusive shock acceleration, cosmic rays, origin and maintenance of magnetic fields, galactic dynamo; external galaxies: spiral galaxies, dwarf irregular galaxies, elliptical galaxies, origin of magnetic fields; active galactic nuclei: radio galaxies, quasars, Seyfert galaxies, origin of magnetic fields; intergalactic magnetic fields: clusters of galaxies, radio halos, radio relics, mini-halos, magnetisation of the IGM, cosmological shocks; cosmological magnetic fields

Recommended Literature:
M.S. Longair: High Energy Astrophysics, Vol. 1+2 (Cambridge University Press, 2008)
S. Rosswog, M. Brüggen: Introduction to High-Energy Astrophysics (Cambr. Univ. Press 2009)
L. Spitzer: Physics of Fully Ionized Gases (Dover Publications , 2006)
Lecture Notes (U. Klein)

Modules:

astro830 **Elective Advanced Lectures**
astro840 **Observational Astronomy**

Course: universitätbonn Multiwavelength Observations of Galaxy Clusters

Course No.: astro849

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

Requirements:

Preparation:
Introductory Astronomy lectures

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

Length of Course:
1 semester

Aims of the Course:
To introduce the students into the largest clearly defined structures in the Universe, clusters of galaxies. In modern astronomy, it has been realized that a full understanding of objects cannot be achieved by looking at just one waveband. Different phenomena become apparent only in certain wavebands, e.g., the most massive visible component of galaxy clusters - the intracluster gas - cannot be detected with optical telescopes. Moreover, some phenomena, e.g., radio outbursts from supermassive black holes, influence others like the X-ray emission from the intracluster gas. In this course, the students will acquire a synoptic, mulitwavelength view of galaxy groups and galaxy clusters.

Contents of the Course:
The lecture covers galaxy cluster observations from all wavebands, radio through gamma-ray, and provides a comprehensive overview of the physical mechanisms at work. Specifically, the following topics will be covered: galaxies and their evolution, physics and chemistry of the hot intracluster gas, relativistic gas, and active supermassive black holes; cluster weighing methods, Sunyaev-Zeldovich effect, gravitational lensing, radio halos and relics, and the most energetic events in the Universe since the big bang: cluster mergers.

Recommended Literature:
Lecture script and references therein

Modules:

astro830 **Elective Advanced Lectures**
astro840 **Observational Astronomy**

Course: universitätbonn Introduction to Hydro- and Magnetohydrodynamics

Course No.: astro8401

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

Requirements:

Preparation:
Revision of vectors and vector calculus, electromagnetism, basic thermodynamics

Form of Testing and Examination:
Written or oral examination

Length of Course:
1 semester

Aims of the Course:
The students will become familiar with the basic laws of hydrodynamics and magnetohydrodynamics and will understand their universal applicability and importance in many varied contexts. As well as learning about the basic phenomena such as waves and compressible flow, several particular contexts (mainly in astrophysics and atmospheric physics) will be examined in detail using analytical tools which the students will then learn to apply in other, new situations and contexts. By doing this the students will develop abilities to tackle and interpret any hydrodynamical phenomenon they encounter.

Contents of the Course:
The fluid approximation, Euler equations, ideal fluids, viscous fluids, diffusion of heat, sound waves, hydrostatics, flow around an object, the Bernoulli equation, the Reynolds number and other dimensionless parameters used to describe a flow, compressible and incompressible flow, supersonic and subsonic flow, shock waves (with example: supernovae), surface gravity waves, internal gravity waves, waves in a rotating body of fluid (example: earth's atmosphere), stability analysis (examples: convection, salt fingers in ocean), the magnetohydrodynamics equations, Alfven waves, flux conservation, flux freezing, magnetic pressure and tension, force-free fields, reconnection (with example: solar corona), angular momentum transport and the magneto-rotational instability (example: astrophysical discs).

Recommended Literature:
E.Landau & E.Lifshitz, Fluid mechanics (Pergamon Press 1987)
S.Shore; Astrophysical hydrodynamics: an introduction (Wiley-VCH, 2007)
Lecture notes at http://www.astro.uni-bonn.de/~jonathan/misc/astroMHDnotes.pdf

Modules:

astro830 **Elective Advanced Lectures**
astro840 **Observational Astronomy**

Course: X-Ray Astronomy

Course No.: astro8402

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

Requirements:

Preparation:
Introductory astronomy lectures

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

Length of Course:
1 semester

Aims of the Course:
The student shall be familiarized with X-ray observations as a powerful tool to study almost all astrophysical objects in ways not possible in other wavebands.

Contents of the Course:
History, space-based instruments, radiation processes, solar system objects, isolated compact objects, binaries with compact objects, supernova remnants, interstellar medium, Galactic center, normal galaxies, galaxy clusters, superclusters, intergalactic medium, active galactic nuclei.

Recommended Literature:
Lecture notes will be provided

Modules:

astro830 **Elective Advanced Lectures**
astro840 **Observational Astronomy**

Course: Hydrodynamics and astrophysical magnetohydrodynamics

Course No.: astro8403

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

Requirements:

Preparation:
Revision of elementary thermodynamics, vector calculus and electromagnetism. Please note that although this course is designed mainly with astrophysics in mind, no knowledge of astrophysics is assumed. Students of other branches of physics are welcome.

Form of Testing and Examination:
Exercises throughout the semester, and an oral examination at the end of the course.

Length of Course:
1 semester

Aims of the Course:
Almost the entire universe is fluid and so an understanding of many phenomena is impossible without a proper grasp of fluid dynamics. This course introduces the field, drawing on examples from astrophysics as well as atmospheric physics to illustrate the principles. The aim is for the students to develop an intuitive understanding of underlying principles. Roughly the last quarter of the course is an introduction to magnetohydrodynamics; here the emphasis is on astrophysical applications (rather than laboratory/plasma physics).

Contents of the Course:
The fluid approximation, Euler equations, ideal fluids, viscous fluids, diffusion of heat, sound waves, hydrostatics, flow around a solid body, the Bernoulli equation, the Reynolds number and other dimensionless parameters used to describe a flow, compressible and incompressible flow, supersonic and subsonic flow, shocks (with example: supernovae), surface & internal gravity waves, vortices and vorticity, waves in a rotating body of fluid (example: earth's atmosphere), stability analysis (examples: convection, shear instability), the magnetohydrodynamics equations, Alfven waves, flux conservation, flux freezing, magnetic pressure and tension, force-free fields, reconnection (with example: solar corona), angular momentum transport and the magneto-rotational instability (example: astrophysical discs).

Recommended Literature:
E.Landau & E.Lifshitz, "Fluid mechanics" Pergamon Press 1987
S.Shore, "Astrophysical hydrodynamics: an introduction", Wiley-VCH 2007
A. Choudhuri, "The physics of fluids and plasmas", Cambridge 1998
Lecture notes at http://www.astro.uni-bonn.de/~jonathan/misc/Hydro_astroMHD.pdf

Modules:

astro830 **Elective Advanced Lectures**
astro840 **Observational Astronomy**

Course: Radiointerferometry: Methods and Science

Course No.: astro8404

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

Requirements:

Preparation:
Einführung in die Radioastronomie (astro123), Radio Astronomy (astro841)

Form of Testing and Examination:
Requirements for the examination (written or oral): Successful participation in the exercise sessions

Length of Course:
1 semester

Aims of the Course:
Basics of radiointerferometric observations and techniques; review of science highlights; use of common data analysis packages.

Contents of the Course:
Principles of interferometry, aperture synthesis, calibration, continuum and spectral line imaging, zero spacing, VLBI, use of AIPS and CASA, ALMA and VLA proposal writing, LOFAR and SKA, science highlights.

Recommended Literature:
"Synthesis Imaging in Radio Astronomy II" (ASP Conference Series, V. 180, 1998), Editors: Taylor, Carilli, Perley
Interferometry and Synthesis in Radio Astronomy (Wiley 2001), by Thompson, Moran, Swenson

On-line material

Modules:

astro830 **Elective Advanced Lectures**
astro850 **Modern Astrophysics**

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

Modules:

astro830 **Elective Advanced Lectures**
astro850 **Modern Astrophysics**

Course: universitätbonn 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)

Modules:

astro830 **Elective Advanced Lectures**
astro850 **Modern Astrophysics**

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)

Modules:

astro830 **Elective Advanced Lectures**
astro850 **Modern Astrophysics**

Course: universitätbonn 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)

Modules:

astro830 **Elective Advanced Lectures**
astro850 **Modern Astrophysics**

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

Modules:

astro830 **Elective Advanced Lectures**
astro850 **Modern Astrophysics**

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

Modules:

astro830 **Elective Advanced Lectures**
astro850 **Modern Astrophysics**

Course: universitätbonn 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

Modules:

astro830 **Elective Advanced Lectures**
astro850 **Modern Astrophysics**

Course: The cosmic history of the intergalactic medium

universitätbonn

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.

Modules:

astro830 **Elective Advanced Lectures**
astro850 **Modern Astrophysics**

Course: universitätbonn 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

Modules:

astro830 **Elective Advanced Lectures**
astro850 **Modern Astrophysics**

Course: Physics of Supernovae and Gamma-Ray Bursts

universitätbonn

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.

Modules:

astro830 **Elective Advanced Lectures**
astro850 **Modern Astrophysics**

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

Modules:

astro830 **Elective Advanced Lectures**
astro850 **Modern Astrophysics**

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:

Cologne Courses in Astrophysics

Modules:

astro830 **Elective Advanced Lectures**
astro850 **Modern Astrophysics**

Course: Astrophysics II (MA)

Course No.:

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)

Modules:

astro830 **Elective Advanced Lectures**
astro850 **Modern Astrophysics**

Course: Star Formation (MA)

Course No.:

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)

Modules:

astro830 **Elective Advanced Lectures**
astro850 **Modern Astrophysics**

Course: Galaxy Dynamics (MA)

Course No.:

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)

Modules:

astro830 **Elective Advanced Lectures**
astro840 **Observational Astronomy**

Course: Active Galactic Nuclei (OA)

Course No.:

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

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 and physical radiation mechanisms for active galactic nuclei Like Seyfert-galaxies, QSOs, quasars, and violently variable objects.

Contents of the Course:
The lecture introduces to basic aspects of active galactic nuclei:
Types of sources HII-galaxies, LINERs, Seyfert I, Seyfert II, QSO I , QSO II, BLLac /OVV-sources
Structure of an active nucleus: Broad line region (BLR), Narrow line region (NLR) and extended narrow line region (ionization cone).
Forbidden and permitted line transitions as density and temperature probes
Continuum emission processes: free-free and synchrotron radiation
Radio galaxies, jets and lobes as well as super luminal motion in jets.

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)
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)

Modules:

astro830 **Elective Advanced Lectures**
astro840 **Observational Astronomy**

Course: Methods of Experimental Astrophysics (OA)

Course No.:

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

Requirements:

Preparation:
Elementary Physics (Bachelor level); Astrophysics I (and II)

Form of Testing and Examination:
Exercise and written test; or oral examination

Length of Course:
1 semester

Aims of the Course:
Gain insight into which type of instrumentation, based on which principles, is employed for particular astronomical and astrophysical applications; and learn about their practical and fundamental limitations in resolution and sensitivity

Contents of the Course:
- detection of radiation: direct and coherent detection
- Signal/Noise ratio: fundamental and practical limits
- principles of optical instruments: imaging
- principles of optical instruments: spectroscopy
- radio receivers: Local Oscillator, Mixer and Backend-Spectrometers
- calibration: theory and measurement startegies

Recommended Literature:
Rieke: Detection of Light
Kraus: Radioastronomy
Bracewell: The Fourier Transform and its Applications

Modules:

astro830 **Elective Advanced Lectures**
astro840 **Observational Astronomy**

Course: The Fourier-Transform and its Applications (OA)

Course No.:

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

Requirements:

Preparation:
Elementary Physics (Bachelor level); Elementary QM

Form of Testing and Examination:
Exercise and written test; or oral examination

Length of Course:
1 semester

Aims of the Course:
Strengthen insight into how the mathematical principles of Fourier Theory as a common principle affect many areas of physics (optics: diffraction/interference; QM: Heisenberg principle; statistics of noise and drifts; data acquisition: sampling) and other applications (data compression, signal processing).

Contents of the Course:
- introduction to the principles of Fourier Transform mathematics
- Delta-function and more general distributions
- diffraction optics and interferometry
- uncertainty principle in QM as application of FT
- theory of noise, drifts and their statistics
- intro to wavelet analysis and data compression

Recommended Literature:
Bracewell: The Fourier Transform and its Applications