Module No.: astro840
Credit Points (CP):
Category: Elective
Semester: 1.-2.

Fachgruppe Physik und Astronomie Universität Bonn

Module: Elective Advanced Lectures: 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 for Participation:

Form of Examination:
written examination

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

Course achievement/Criteria for awarding cp's:
see with the course

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 astro840 and astro850.

Modules:

astro840 **Elective Advanced Lectures: Observational Astronomy**
astro850 **Elective Advanced Lectures: Modern Astrophysics**

Course: universitätbonn Research Project

Course No.: astro831

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

Requirements for Participation:
Students are asked to contact one of the BCGS lecturers prior to the start of their project. Lecturers provide help if needed to find a suitable research group and topic. Not all groups may have projects 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.

registration by written application to the examination office (see homepage)

Module: Elective Advanced Lectures: Observational Astronomy

Module No.: astro840

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 for Participation:

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)

Module: Elective Advanced Lectures: Observational Astronomy

Module No.: astro840

Course: universitätbonn Submillimeter Astronomy

Course No.: astro842

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

Requirements for Participation:

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

Module: Elective Advanced Lectures: Observational Astronomy

Module No.: astro840

Course: Astronomical Interferometry and Digital Image Processing

Course No.: astro843

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

Requirements for Participation:

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

Module: Elective Advanced Lectures: Observational Astronomy

Module No.: astro840

Course: universitätbonn Observational Cosmology

Course No.: astro845

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

Requirements for Participation:

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

Module: Elective Advanced Lectures: Observational Astronomy

Module No.: astro840

Course: Wave Optics and Astronomical Applications

Course No.: astro846

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

Requirements for Participation:

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)

Module: Elective Advanced Lectures: Observational Astronomy

Module No.: astro840

Course: universitätbonn Optical Observations

Course No.: astro847

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

Requirements for Participation:

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

Module: Elective Advanced Lectures: Observational Astronomy

Module No.: astro840

Course: Galactic and Intergalactic Magnetic Fields

universitätbonn

Course No.: astro848

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

Requirements for Participation:

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)

Module: Elective Advanced Lectures: Observational Astronomy

Module No.: astro840

Course: 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 for Participation:

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

Module: Elective Advanced Lectures: Observational Astronomy

Module No.: astro840

Course: Introduction to Hydro- and Magnetohydrodynamics

Course No.: astro8401

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

Requirements for Participation:

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

Module: Elective Advanced Lectures: Observational Astronomy

Module No.: astro840

Course: X-Ray Astronomy

Course No.: astro8402

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

Requirements for Participation:

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

Module: Elective Advanced Lectures: Observational Astronomy

Module No.: astro840

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 for Participation:

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

Module: Elective Advanced Lectures: Observational Astronomy

Module No.: astro840

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 for Participation:

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

Module: Elective Advanced Lectures: Observational Astronomy

Module No.: astro840

Course: The Cosmic Microwave Background

Course No.: astro8405

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

Requirements for Participation:
Some basic knowledge of electrodynamics and thermal physics, and some experience with Python programming. No prior course-work on cosmology is necessary.

Preparation:

Form of Testing and Examination:
Weekly exercise classes, after successful evaluation of which a final oral exam at the end of the semester

Length of Course:
1 semester

Aims of the Course:
This course intends to give the students a modern and up-to-date introduction to the science and experimental techniques relating to the Cosmic Microwave Background (CMB). No prior knowledge of cosmology is assumed; rather, the course introduces the necessary concepts in the class, and partly depends on the mandatory cosmology course that is taught in parallel. The aim is to make the students interested in the vast field of CMB research, which continues to be one of the richest source of information about our Universe.

Contents of the Course:
Roughly 14 lectures, covering the four main topics of (i) CMB thermal spectrum, (ii) CMB temperature anisotropies and their cosmological significance, (iii) CMB polarization and the search for primordial gravitational waves, and (iv) CMB foregrounds and component separation techniques. There will be weekly exercise classes, some of which involve simple programming and plotting.

Recommended Literature:
Appropriate references are provided during the lectures.

Module: Elective Advanced Lectures: Observational Astronomy

Module No.: astro840

Course: Active Galactic Nuclei (OA)

Course No.:

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

Requirements for Participation:

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)

Module: Elective Advanced Lectures: Observational Astronomy

Module No.: astro840

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 for Participation:

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

Module: Elective Advanced Lectures: Observational Astronomy

Module No.: astro840

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 for Participation:

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