

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



## 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.

**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:**

## 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:****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:****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 AlfA 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:**

## 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, multiwavelength 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:**

## 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, Alfvén 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, Alfvén 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](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**  
 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 Merrifield, 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 strategies

**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