Astrolab organized by the Landessternwarte Heidelberg - what you need to know

Jochen Heidt, January 2025

Overview astrolab

The astrolab is offered twice a year. It will always be held during 2 weeks mid-February/early-March and end-September/early-October and can be attended by Bachelor-, Master- and PhD-students. The Bachelor- and Master-students take part for one week, the PhD-students for two weeks. It runs daily from 8.45h until 16.45h with a lunch break from 12.15h to 13.00h and is held at the "Ostinstitut" and the "Nordinstitut" of the Landessternwarte. Since the Landessternwarte does not have a canteen (and since we are not allowed to use the canteen at MPIA) the students need to take care of food by their own. A kitchen for preparing food is available in the "Ostinstitut".

The Landessternwarte can either reached by car or by public transport. For the latter line 30 starting from the stop Peterskirche (direction Bismarckplatz) at 8.32h and exit at stop Sternwarte at about 8.42h to come to the Landessternwarte is recommended. Transport down is at 16.50h from the Sternwarte with 17.01h being at the stop Peterskirche (direction Karlstorbahnhof). You can also come up by car. In that case, please leave your car just in front of the entrance to the Landessternwarte on the right hand side. There is ample space to park your car. Once you are at the entrance of the Landessternwarte you will see signs directing you to the "Ostinstitut" where we will start on the first day.

After the welcome at the beginning of the astrolab held in the "Ostinstitut", the students will start with their first task which has been assigned in advance based on their preferences. The students always work in groups of two. The group assignment is made before the astrolab starts. The scripts and any accompanying material for the tasks is available online and/or will be available on site. For each of the tasks a tutor will guide the students. He will give an introduction and hands out any further material required. Then the students are expected to work by their own through the task. The tutor is always available in case of questions or remarks, however. Once the students have successfully gone through the task they will discuss it with the tutor. Then the next task will be assigned again according to their preferences. Typically the students need about one full day or a bit more to go through an entire task. There is no preparation at home or homework afterwards required.

The main aim of the astrolab is to introduce the students to various astronomical tools an astronomer uses as part of his job. However, it is also of our interest to attract the students to the field of astronomy. This is only possible, if the students enjoy what they are doing. Thus, no grades are given. There is also no limit of how many tasks the students need to pass to have successfully attended the astrolab. It is more important that they work carefully. Typically the students are able to go through about 2-4 tasks per week. All what they do, is done up at the Königstuhl.

As part of the task 1, observations are carried out with the 70cm telescope at the Landessternwarte. During the astrolab in September/October, the observations are carried out during that week(s), since the weather is normally pretty good. On the contrary, this does not work during the astrolab in February as only a few nights are normally clear if at all. Thus the observations are carried out during the preceeding lecture term, typically between end of October until Christmas (to be extended if required). The procedure of how this is done in practice will always be presented at the beginning of the lecture *Introduction to Astronomy & Astrophysics I*. Alternatively, the procedure is described at the astrolab WEB.

In the following the content and aim of the tasks, which are offered during the astrolab is described. Altogether, 10 tasks are available, which cover a wide range of astronomical applications. They range from extrasolar planets to Pulsars and QSO, observations of the sun or of variable stars during the night with the telescope up to the design of optical elements frequently used in astronomy.

In addition, we will comment on a few things the students need to do in advance for the preparation of the astrolab.

Bring your own laptop, you will need it. If you do not have one, please let me know in advance. We have a few spare laptops at the Landessternwarte, which you can use during the astrolab.

Before the astrolab starts

To have a start into each of the weeks with a minimum of hickups and subsequently a smooth astrolab, we require some action from your side in advance. We need to a) create groups of two students for the astrolab; b) we need to know which tasks you prefereably would like to work at; c) we need to assign the first task of the week for each group in advance; d) and need to know if you are interested in observations with the 70cm telescope during the astrolab.
There are some restrictions from our side as for the selection of the tasks:
• PhD and master students can do all tasks.
• Tasks 9 and 10 can only be done by Bachelor students who have attended the lecture "Introduction to Astronomy and Astrophysics II" as these tasks are dominated by extragalactic astronomy. This condition may not be fulfilled for most of you this time.
• We would like to make sure that everybody has learned the principles of data reduction for at least either photometry (Task 1) or spectroscopy (Task 11). Each group should do one of those two tasks.

Thus please go to
`https://docs.google.com/spreadsheets/d/1fn3jPtrdDmG5L1eWO5iAxxyySJx6x851k51bnxFjIrg/edit?gid=0#gid=0`
and provide the following information:

PhD-students:
• Your name
• Your preference for Task 1 or 11 by just marking one of them
• Select four of your favorite tasks among 2, 3, 7, 8, 9 and 10 by just marking them.
• Your partner if you have already one, and if not whether it should preferably be female, male or whether it doesn't matter.

Master-students:
• Your name
• Your preference for Task 1 or 11 by just marking on of them
• Select three of your favorite tasks among 2, 3, 7, 8, 9 and 10 by just marking them.
• Your partner if you have already one, and if not whether it should preferably be female, male or whether it doesn't matter.

Bachelor-students:
• Your name
• Your preference for Task 1 or 11 by just marking on of them
• Select three of your favorite tasks among 2, 3, 7, 8, 9 and 10 by just marking them. **Recall** that tasks 9 and 10 can be done only by students who have attended the "Introduction to Astronomy and Astrophysics II". This may be the case for only some of you this time.
• Your partner if you have already one, and if not whether it should preferably be female, male or whether it doesn't matter.

If you would like to go for an observing session with the 70cm telescope, please go to:

https://docs.google.com/spreadsheets/d/1aS7nlJ4LsbAtdIVuzH9dFRlJk6x-iSstC1RGHdpgDZ4/edit?gid=0#gid=0

in case you take part in the astrolab during the 1st week from February 17 - 21 or to

https://docs.google.com/spreadsheets/d/1uGnNw1otxY4mHwfcnToCnn9Kspp5-0GWjSeO2l3JgBc/edit?gid=0#gid=0

in case you take part in the astrolab during the 2nd week from February 24 - 28.

and indicate your availability for the observations. We will offer observations every evening, Mo-Fr. during two slots with 4 students each. The first slot runs from 17.45 - 21.15h and the second slot runs from 21.30 - 23.15h (or 00.15h you need to talk to the tutor at the telescope). Please indicate your availability only for the week(s) where you are in the astrolab. The details (logistics etc.) for each evening will be discussed on a daily basis during the astrolab. Depending on the interest we may assign one or more slots to each of you. We may suffer from a bad weather period, so it is unpredictable to which amount observations can be carried out. Note that participation on an observing session is *not* required for a successfull participation at the astrolab.

Please provide the required information for your preferred tasks, partner and potential observations with the 70cm telescope by

Thursday, February 13 23.59h

at the latest. Its contents can not be changed afterwards. In case of any questions mail me at jheidt@lsw.uni-heidelberg.de. Please do not use the google spread-sheet for spamming. Based on the input, the groups will be formed and for each group the task for the first day of the astrolab be assigned. This information will be made available by **Friday, February 14 18h** at

https://www.lsw.uni-heidelberg.de/users/jheidt/praktikum/astrolab_material.html .

There you will also find the scripts and other material for each of the tasks, the names and e-mail addresses of the tutors for each of the tasks.

For tasks 1 and 11 you need to use a special software to go through these tasks. We have prepared laptops which you will use while working on these tasks.

When assigning the tasks during the astrolab, we will try to follow your preferences. However, as we normally can hold a maximum of 4-5 groups per task only, this may not always be possible.

Not all of you are from the faculty for physics and astronomy. If you are from a different faculty, please let me know and provide details about the faculty, your module, on whether your participation must be graded and where the confirmation of participation and grades if necessary should be mailed to. In case you have an exam or other activities preventing you to attend the astrolab during one of the days, please let me know too. Again, please give me this information until the astrolab starts.

Astro-lab, ZAH, Landessternwarte Heidelberg, Ostinstitut

PhD students: Feb 17 - 28 2025

Bachelor/Master students Feb 17 - 21 2025
Bachelor/Master students Feb 24 - 28 2025

Organizer: J. Heidt (JH)

Tutors: Nina Mackensen (NM), Florian Rothmaier (FR), Walter Seifert (WS), NN (NN) and Julian Stürmer (JS)

Tutor at 70cm telescope: Natscha Sattler, Jochen Heidt

Tasks, tutors and notes

1. **Photometry with the 70cm telescope (WS)**
2. **Virtual Observatory tools (NM)**
3. **Differential solar rotation (NN)**
4. **HST + optical design software - (not offered this semester)**
5. **Observations with a solar telescope - complementary! (WS)**
6. **Extrasolar planets - (not offered this semester)**
7. **Crab nebula (NM)**
8. **Rotation of the Milky Way (FR)**
9. **Extragalactic Astronomy (NN)**
10. **Cosmology (FR)**
11. **Introduction to spectroscopy (JS)**

Download of scripts and electronic material for tasks:

directly:

https://www.lsw.uni-heidelberg.de/users/jheidt/praktikum/astrolab_material.html

or via:
⇒ Hompepage LSW: https://www.lsw.uni-heidelberg.de
⇒ Lectures and seminars / Kolloquien und Lehrveranstaltungen
⇒ Astro-lab

E-mail addresses:

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Introduction to task 1: Photometric observations with the 70cm telescope.

In practical astronomy two basic observing techniques are used - photometry and spectroscopy. In may cases photometry alone is already sufficient to answer specific scientific questions. On the other hand can photometry just be a preparatory tool for follow-up spectroscopy, e.g. by selecting candidates of interest based on deep and wide photometric surveys.

In the task **Photometric observations with the 70cm telescope** one gets familiar with the basics of photometric observations, ie an entire observing cycle will be carried out. This includes the preparation of the observations, carrying out the observations by themself as well as the data reduction and analysis of the images. For the preparation of the observations all basics like observability of the target(s), calibration measurements required and design of an observing night, all of which are necessary for an successful observing run, are obtained. During the observations themself the use of a telescope and the technique of photometric observations by observations of a variable star are learned. For the data reduction and analysis of the images one gets familiar with a classical software package frequently used in astronomy.

The aim of this task is to introduce to a fundamental tool in observational astronomy and is thus offered for Bachelor-, Master- and PhD-students.

Landessternwarte, Ostinstitut. Tutor: Walter Seifert

Observations with the 70cm telescope:

Landessternwarte, 70cm telescope. Tutors: Natascha Sattler, Jochen Heidt

Introduction to task 2: Virtual observatory

In order to use a telescope or a satellite for his science, the astronomer must first apply for observing time by submitting an observing proposal. Once successful he either takes the data by himself and/or the data are taken for him. These data normally become public after one year (to make most use of the expensive telescope/satellite time). In addition, huge wide-field sky surveys like the *Sloan Digital Sky Survey* take data of millions of galactic and extragalactic sources. These huge amount of data can directly be used for scientific applications like the large-scale structure of the Universe or the pre-selection of rare objects like very high-redshift galaxies or extremely cool stars.

In order to allow everybody in a convenient way to extract the data of his interest, which may cover the entire wavelength range from Radio up to gamma-rays, the *Virtual Observatory* (VO) was founded. The German node of the international VO is dubbed GAVO (German astrophysical VIRTUAL observatory) and is based at the Astronomisches Recheninstitut in Heidelberg. The VO is already an important tool in observational astronomy and is expected to become one of *the* standards in the nearby future.

In the task **Virtual observatory** one gets familiar with its tools and how to apply them. As a starter one goes guided through a specific application by extracting an exotic object out of a huge database. Than another scientific question has to be solved by applying what just was learned. This task is somewhat dynamic. If interested (and indeed some groups have already done this during the astrolab) scientific questions of own interest can be tackled.

The aim of this task is to introduce to the fundamental tool of the VO and is thus offered for Bachelor-, Master- and PhD-students.

Landessternwarte, Ostinstitut. Tutor: Nina Mackensen

Introduction to task 3: Differential solar rotation

When you look at the Sun during day it looks like a pretty boring astronomical object, shining constantly at more or less the same brightness. Thats not true. The Sun is in fact a very energetic and active star, famous for its violent corona with its prominences, its sunspots and the solar wind causing the beautiful aurorae.

In this task you will determine the solar rotation at different latitudes using the change of the position of sunspots as a function of time. This differential solar rotation of the sun is one of the great mysteries in solar research - and not understood yet. You will measure the differential solar rotation using data from the Solar & Heliospheric Observatory SOHO, an observatory launched in 1995 to explore the sun and still delivering exciting data.

The aim of this task is to introduce to the use of archives - this time the one provided by the European Space Agency (ESA) - and to show how easy fundamental numbers can be retrieved using those data available for everybody. This task is fairly short and not too difficult and thus best suited for Bachelor students, but offered for everybody.

Landessternwarte, Ostinstitut. Tutor: NN

Introduction to task 4: Optical design

In order to built an optical system using lenses or mirrors, quite a few restrictions like aberration and the way to correct for it need to be considered. For example, during the first years of its operation, the Hubble space telescope suffered from spherical aberration, an optical distortion caused by an incorrectly shaped mirror. This was corrected by means of a system named COSTAR. In principle, Hubble got glasses (but in fact mirrors instead of lenses were used).

The task **Optical design** gives an introduction of how optical systems can be designed. Particular importance is devoted to ray-tracing, which calculates the path of light along an optical system. To do so, an optical design software named *OSLO* is used. With the software an own optical system is designed. It is also worked out, why Hubble initially delivered a poor image quality and how this was corrected.

This task rests on basics introduced in e.g. the lecture "Observational Methods" and is thus offered for Master- and PhD-students only.

Not offered this semester

Observations with a solar telescope

The Landessternwarte recently received a solar telescope which can be used for public outreach to observe solar prominences, sunspots etc. If the weather is good, the students may enjoy themselves by using them to observe the Sun. This is not a task but an add-on to all the other activities we have during the week.

Landessternwarte, Ostinstitut (outdoors). Tutor: Walter Seifert

Introduction to task 6: Extrasolar planets

The search for and characterization of extrasolar planets is currently one of the hottest topics in astrophysics. At present (July 2013) about 900 extrasolar planets are known, at least 130 stars harbor more than one planet. It is only a question of time until the first extrasolar planet in a habitable zone (in an orbit around a star where life is potentially possible) will be detected and its atmosphere be spectroscopically characterized.

The task **Extrasolar planets** gives an introduction into the various methods to indirectly and directly detect such objects. In a case study (setting the Solar system at 20pc distance) the strengths and weaknesses of the two most successful methods to detect extrasolar planets - the transit and radial velocity method - will be investigated. It will be demonstrated that an extrasolar planet can, in principle, be detected even with a 70cm telescope but also that it is extremely difficult (and technically challenging) to detect earthlike planets.

This task rests on basics introduced in the e.g. the lecture “Observational Methods” and is thus offered for Master- and PhD-students only.

Not offered this semester

Introduction to task 7: The Crab nebula

Pulsars are exotic objects. They are rotating neutron stars, which emit a beam of electromagnetic radiation covering the entire wavelength regime, from Radio- up to gamma-rays. In the case of the binary Pulsar PSR B1913+16, Hulse & Tayler (Nobel price physics 1993) were able to indirectly detect gravitational waves - a requirement of the theory of general relativity.

In the task **Crab nebula** some of the basic properties of Pulsars using the Crab nebula - a supernova remnant dated 1054 - as prime example will be discussed. In the first part, some properties like the kinematic age and distance of the Crab nebula as well as periods and dispersion of some Pulsars need to be determined. In the second part, some properties of the radiation emitted by the Crab nebula - Synchrotron and inverse Compton radiation - will in detail be considered. Using data from various observatories a broad-band spectrum from Radio- up to TeV energies will be constructed and some of its characteristics discussed.

This task gives an introduction to one of the most important radiation processes in the Universe and is thus offered for Bachelor-, Master- and PhD-students. These processes are also important for the monsters of the Universe, the so-called super-massive black holes. The construction and interpretation of broad-band spectra as done here is one of *the* tools for astronomers to derive properties of extremely compact objects.

Landessternwarte, Ostinstitut, Tutor: Nina Mackensen

Introduction to task 8: Rotation of the Milky Way

As any other galaxy, the Milky Way rotates, without any doubt. However, it does not rotate as expected as a rigid body which is thought to be one of the consequences of the presence of Dark Matter. Its rotation curve is of fundamental nature as it is an ingredient for dynamical models for it and allows also to determine is absolute mass.

In the task **Rotation of the Milky Way** one method to determine the rotation curve of the Milky Way will be explored. By using 21cm radio data of HI clouds and applying the tangent method the rotation curve will be derived and some of its aspects be discussed.

This task is fundamental for the understanding of our Milky Way and galaxies in general and thus offered for Bachelor-, Master- and PhD-students.

Landessternwarte, Ostinstitut. Tutor: Florian Rothmaier

Introduction to task 9: Extragalactic astronomy

Our view on how galaxies form and evolve has changed dramatically with the *Hubble Deep Field*. It was 1996 the deepest image of a small region on the sky ever taken. It has shown that galaxies in the past (look-back time approx. 10 billion years) had a substantially different morphological appearance than the galaxies today. At the same time, QSO were detected at largest redshifts (look-back time approx. 13 billion years) using the *Sloan Digital Sky Survey* giving evidence that supermassive black holes are an important ingredient in galaxy formation and evolution.

The task **Extragalactic astronomy** is divided in three parts. In part one, about 80 galaxies in the Virgo cluster are morphologically classified by eye and using this information some properties of the Virgo cluster as well as galaxy transformation mechanisms will be derived. The comparison of the morphological properties of galaxies in the Virgo cluster to the one of field galaxies and galaxies in the Local Group can be interpreted in terms of luminosity functions. The comparison to the Hubble Deep Field allows further to develop evolutionary models for galaxies. Armed with hat knowledge the *Galaxy Zoo* project will be introduced and actively be participated in part two. The Galaxy Zoo project is an international collaboration of about 20000 volunteers, who classify by eye millions of galaxies morphologically (better than a software can do!). Using this enormous amount of information statistical tests can be used to probe models of galaxy formation. Finally, in part three, an introduction to the world of QSO is offered. This includes determination of a redshift of a QSO using emission lines, estimate of luminosities and comparison to inactive galaxies, interpretation of broad-band spectra, luminosity function and its Malmquist Bias within as well as apparent superluminal motion.

The aim of this task is to introduce to some fundamental properties of galaxies and QSO and is offered for Master- and PhD-students. It can also be done by Bachelor-students provided that they have attended the lecture "Introduction into astronomy & astrophysics I **and** II".

Landessternwarte, Ostinstitut. Tutor: NN

Introduction to task 10: Cosmology

Cosmology is the study of the origins and eventual fate of the Universe. In recent years, this branch has received particular attention due to the detection of the expanded acceleration of the Universe by Perlmutter, Schmitt and Riess (Nobel price 2011) using observations of supernovae.

The task **Cosmology** gives a basic introduction to this field. Particular emphasis is given to the three fundamental parameters of Cosmology, namely the Hubble constant H_0, the density parameter Ω_M and the dark energy parameter Ω_Λ. As *the* tool to determine these parameters (or at least to set restrictions to them), supernovae type I as standard candles or the period-luminosity relation of Cepheids are introduced. Measurements for these are than used to get a handle on these parameters. Finally, the fundamental plane of Cosmology is introduced and various cosmological models as well as their restrictions thereof based on supernovae, galaxy cluster and cosmic microwave background measurements be discussed.

The aim of this task is to give a broader insight into Cosmology and is offered for Master- and PhD-students. It can also be done by Bachelor-students provided that they have attended the lecture “Introduction into astronomy & astrophysics I **and** II”.

Landessternwarte, Ostinstitut. Tutor: Florian Rothmaier

Introduction to task 11: Introduction to spectroscopy - where I am?

In practical astronomy two basic observing techniques are used - photometry and spectroscopy. In may cases photometry alone is already sufficient to answer specific scientific questions. On the other hand can photometry just be a preparatory tool for follow-up spectroscopy, e.g. by selecting candidates of interest based on deep and wide photometric surveys. Spectroscopy is in many cases the only way to fully uncover the nature of an astronomical object.

In the task **Introduction to spectroscopy - where I am?** one gets familiar with the basics of the data reduction of spectroscopic data. Contrary to photometry, this is a little bit more complex as the data have not only be corrected for detector artefacts, but also 1-dimensional spectra be extracted from 2-dimensional images which need to be set to to a wavelength scale and flux-calibrated as function of wavelength. This will be done with the help of a classical software package frequently used in astronomy.

But this is only one part of the story. To make this task a little bit more exciting and a little bit more tough, the students will receive a spectroscopic data set of an object unkown to them. It will be their pleasure to find out what this for an object is, ie to classify it. It can be either a main-sequence star, a peculiar star, a galaxy, or an active galaxy/QSO. Thus, they will also become an introduction into the world of stellar spectral types and (active) galaxy identifications.

The aim of this task is to introduce to a fundamental tool in observational astronomy and is thus offered for Bachelor-, Master- and PhD-students.

Landessternwarte, Ostinstitut. Tutor: Julian Stürmer