Task 1

Astronomical observations of CY Aquarius and other δ Scuti stars with the 70 cm telescope of the LSW

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Introduction

The typical duty cycle of an observational astronomer has 5 different phases. It starts I) with a scientific idea or question to be addressed and the successful application for telescope time, followed by II) the preparation and III) the execution of the observations. Once this is done, the scientific data set has IV) to be reduced and analyzed and V) the results be presented at astronomical conferences and finally published in a refereed astronomical journal. Normally an astronomer faces a number of those cycles in parallel, mostly somewhat out of phase with respect to each other.

While the topics a) and e) are ingredients to be learned and practiced during the course of a Phd, the remaining fundamental ones are well suited to be introduced during the astrolab. Thus you will get familiar in this task with:

1.1 Preparing astronomical observations

1.2 Carrying out astronomical observations

1.3 Data reduction and analysis

1.4 And as a concrete application: Investigating a deep field

To do so, you will learn the use of one popular astronomical software package and will also get a somewhat deeper understanding of the use and principles of modern charged coupled devices (CCDs). In practice, you will take time series data of a periodically variable star via relative photometry. This technique is relatively insensitive to ambient observing conditions. In addition, you will learn how this data set can be used for a completely different application.

1.1 Preparing astronomical observations

In order to use the telescope and its instrument (a CCD camera) you need to get familiar with its use. This will be done at the beginning of your observing session, where you will get an introduction by the assistant at the telescope itself.

For your project, you need to plan your observing session accordingly. Complementary to your astronomical data you also need to take several calibration images like biases, darks & flatfields because the astronomical data set is of little use otherwise. Why this is important will become clear to you later on.

To get ready "on sky" you need to find out a couple of things in advance as listed below. Assume the day when your observations are scheduled and the Landessternwarte Heidelberg as location. The coordinates for the Landessternwarte are: $8^o43'28''$ East, $49^o23'53''$ North. Use astronomical resources on the WEB, there is **no** need to do any calculus by hand.

- When does the sun set, when does it rise (in local time)?
- What is the meaning of civil twilight, nautical twilight and astronomical twilight?
- Flatfields are normally taken around the beginning of the nautical twilight in the evening and at the end in the morning. Astronomical observations can normally start after the end of the astronomical twilight in the evening and end after the start in the morning. At which times start the civil, nautical and astronomical twilights in the evening and morning?
- What is the meaning of sidereal time? What is the sidereal time at the end of the astronomical twilight in the evening? What does it mean in practice for an object with a right ascension equal to the sidereal time (in terms of observability)?
- The main target for the observing session will be a star of δ Scuti type. What is so special about these stars? Where are they located in the Hertzsprung-Russell diagram?
- Tab. 1 shows potential δ Scuti stars for your observing sessions. Not all of them are observable at the same time. Which one would you observe during your observing session and why? Hint: Consider the airmass of the target during your observing session. The airmass can be written as AM $\propto 1/cos(zenith\ distance)$. Why is it unfavorable to observe at higher airmasses (≥ 2)?

Target	RA (2000)	Dec (2000)	V [mag]	Period [min]	Amplitude [mag]
V460 And	$02^h34^m14.25^s$	42^o 14' 27.6"	13.5	108	0.60
GD 428	$03^h47^m19.88^s$	63^o 22' 42.1"	13.1	56	0.47
GSC 00191-01282	$07^h37^m58.43^s$	05^o 52' 27.9"	12.9	68	0.47
CY Aqr	$22^h37^m47.82^s$	01^o 32' 03.8"	11.0	88	0.71

Table 1: Sample of δ Scuti stars, which are the main targets for the observations.

- You need also to make sure that the target of your choice is not too close to the moon and that you should rather choose another one. What is the distance of the moon to the target of your choice in degrees during your observing session? Use the coordinates of the moon for 20h local time to check this.
- When you point to your target with the telescope you will first do an acquisition image to verify that you are on sky where you would like to be. For that you need a Finder Chart as is shown in Fig. 1 for CY Aquarius. Prepare a Finder Chart for the δ Scuti star of your choice.

Good resources for creating Finder Charts are the Sloan Digital Sky Survey (sdss.org) or the SIMBAD astronomical database (simbad.u-strasbg.fr/simbad/).

• Find out what relative (or differential) photometry means. Why is this technique so powerful in particular when observing from the Königstuhl?

• You may also observe a Messier or any other celestial object with different filters for fun and create a multi-color image for our own purposes. Select a nice deep-sky object observable either at the beginning of the night or about 4hrs after the end of the astronomical twilight (pls. do not select M27, M31 or M57 they have been observed many times already during the astro-lab). Recently, several trees have been cut here, ie you may observe objects down to -25deg declination at culmination! Take into account that we have not only broad-band filters (UBVRI) but also narrow-band filters (H_α, H_β, [O III]) at our disposal, the latter of which may be used for observations of gaseous nebulae. Recall that we have a large field of view of about 23' $\times$ 23'. Prepare also a Finder Chart and verify that the object is observable at air masses ≤ 2 and is at least 30deg off the moon. Choose the filters according to the physical nature (spectrum) of the object.

Once this is done and everything discussed with the assistant you may start with the observations.

1.2 Carrying out astronomical observations

Important: Make sure to take notes properly (logs can be found at the telescope). You need them later on for the data reduction and analysis.

• Opening dome, startup telescope and setup system.
• Check system by taking a bias frame (not saved).
• Take 10 bias frames first (binning = 2 for the entire observations).
• Once it is dark enough, 5 twilight flats in corresponding filters if you plan to observe a deep sky object, signal 10000 - 30000 ADU and 5 twilight flats in the V-filter (for relative photometry).
• Focusing telescope, determination offset telescope
• Start with the observations of the δ Scuti star. In order to have a sufficiently high signal-to-noise, exposure times should be in the range 30-90sec. Make sure that the target is at the center of the CCD and that a similarly bright star is on the frame (like the bright star $\sim$ 6' east of CY Aquarius, see Fig. 1) as it will be used for differential photometry. The peak intensities of the δ Scuti star and the reference star should be below 50000 ADU to be sure to work in the linear regime.
• The observations should go on for at least 2hrs to cover a full period of your main target.
• Do the observations of your Messier object.
• Shutdown telescope and closing dome.
• Once everything is done, start some darks using a script (made together with the assistant) with the different exposure times you have used for flatfields and your science exposures, 5 each. Once the script is started, it is time to rest.