Department of Physics and Astronomy
University of Iowa
29:137 Astronomical Laboratory
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Lab 2: Imagery and Photometry with a CCD Camera

1 Introduction

In this lab, we will use the ST-402XME CCD camera to make astronomical observations and measurements. The camera will be attached to a Celestron 8 telescope and used to make images, and measure magnitudes. The exercise will consist of three parts. First, the system will be set up in the lab and made to work. In this part, we will take a thrilling image of the inside of the aperture lid of the C8. In the second part of the project, we will take the equipment to the roof and take data. We will take an image of the globular cluster M13, and measure the magnitudes of stars in the constellation of Lyra. The third part of the project will consist of data analysis in the lab with the program Maxim DL. The goal will be to obtain measurements of stellar magnitudes for stars in Lyra and M13.

2 Equipment to be Used

- Celestron 8 telescope with finder telescope.
- Adapter, C8 → ST-402XME camera
- ST-402XME camera, power cable, and USB cable
- Labtop computer running CCDOPS software
- Work stations in Room 655 running Maxim DL

3 System Setup in the Lab

The reason for this section is that it is easier to set up a telescope in a room with the lights on than at night on the roof of Van Allen Hall, or at a remote observing station. This is a chance to make sure you have all the necessary pieces, that they fit, and that you have the necessary software. Follow these procedures.

1. Begin by making sure the finder scope on the C8 is aligned. This is crucially important, otherwise you will not be able to find the celestial objects we need to measure. Take the C8 and its tripod to the roof. Set up the telescope with the finder in place, and a low power eyepiece in the main telescope. Point through the C8 to an object which is easy to find on the horizon, such as a building beyond the airport. Then look through the finder scope. For the telescope to be aligned, the target object should be right on the crosshairs. It won't be. Use the small screw adjustments at the base of the finder scope to adjust the direction of the finder until the target object is right on the crosshairs.

   Check the alignment by looking at a couple of other objects. Choose the object, and move the telescope so that the target is right on the crosshairs of the finder. It should be in the middle of the main telescope field as well. If it is not, continue the adjustments. With the finder scope aligned, you can point at an object with the finder (easy) and be assured it is in the main field of view.

   When it is aligned, disassemble the telescope and bring it back downstairs. Be sure not to bump the finder or otherwise ruin the alignment. You can remove the eyepiece and diagonal; you will not use them again.

2. In the lab room, mount the C8 on its tripod.

3. Connect the adapter for the ST-402XME camera to the C8, and screw the camera onto the adapter.

4. Download the CCDOPS software from the SBIG site
   (http://www.sbig.com/sbwhtmls/softpage.htm)
   onto a laptop computer that can be taken to the roof or remote observing site. Go to the "software downloads" section of the web page and download CCDOPS version 5 for Windows machines, or the appropriate version for Macs. Each working team should have at least one laptop with CCDOPS installed. If no one in the working team has a laptop, talk to the instructor.

5. Connect the USB cable to the camera, then connect the power cable to the camera. **This is a good time to review the instructions on p76 of the CCDOPS manual, giving the right order for powering up and powering down the camera**.

6. Bring up CCDOPS, connect to the camera, and listen to the contented clicking sounds that indicate the camera is working.

7. Make sure the aperture lid is on the C8. Then use the GRAB option to take a picture of short duration. Make sure the camera takes the image, which is obviously blank.

8. Find a map of the constellation of Lyra, either in published star charts (preferably with leather binding and an artist's drawings of the mythological figures together with the stars in the constellations), or with a program like *Starry Night Pro*. Be sure you have a chart showing you the principal stars in Lyra.

9. If you are not already familiar with its location in the sky, find the globular star cluster M13 in Hercules, using star charts or *Starry Night Pro*.

10. That completes the setup in the lab. Power down the camera by choosing CAMERA from the menu bar and choosing SHUTDOWN. Then disconnect the power cable.

4 Setting up the System for Astronomical Observations

This section of the lab will be done during a nighttime session. Follow these steps.

1. Disassemble the C8 and the camera assembly and carry it to the roof and reassemble. Be sure not to bump the finder scope.

2. Bring to the roof additional equipment you need, such as power strips and the computers for instrument control and data processing. Bringing some chairs will minimize human suffering.

3. With the computers running, connect the USB cable to the ST-402XME, followed by the power cable. Bring up CCDOPS on the control and processor computer.

4. The main task to be accomplished before making observations is to focus the camera. First, point the telescope at a bright star like Vega or Altair and have the telescope track.

5. Check the section on p39 on "Rough Focusing". We follow the same procedures as we did in the lab on focusing. Run the camera in focus mode on the bright star while you adjust the focus knob of the telescope. Continue the focus until the star image is as close to pointlike as possible. The camera is now ready for measurements.

5 Measuring Stellar Magnitudes

The model we use for the response of the camera to a star is as follows. Let Q be the charge on a pixel of the CCD. Then

$$Q = AFt \tag{1}$$

where F is the flux of radiation from the star (Watts/m^2), t is the time of integration or exposure, and A is the coefficient describing the instrumental response. Given fluxes F_1 and F_2 from two stars, the difference in their magnitudes is then

$$m_1 - m_2 = 2.50 \log \left(\frac{F_2}{F_1} \right) \tag{2}$$

So if we have observations of two stars, characterized by measureables Q_1 and t_1 and Q_2 and t_2, respectively, the difference in magnitudes is

$$m_1 - m_2 = 2.50 \log \left(\frac{Q_2 t_1}{Q_1 t_2} \right) \tag{3}$$

Obviously, the camera must be unsaturated for these equations to be valid. In addition, there is a noise floor that must be corrected for. Even in the total absence of light, the pixels will develop a charge. This must be corrected for. In standard operation, the camera takes a dark frame and subtracts it. However, at least as a check that this has been done properly, you need to measure the background far from any star and determine the background that needs to be subtracted from the raw measurement to yield a value of Q that is used in the above formula.

The star Vega is a fundamental standard with B and V magnitudes of 0.03, and a U magnitude of 0.02. If you have forgotten about U, B, and V magnitudes, review your General Astronomy textbook, or ask the instructor. In this exercise, we will make measurements with no filter, and equate our magnitudes to the V magnitude.

1. Take several exposures of Vega. Make sure you have several images in which the image is not saturated.

2. Move the telescope to each of the stars ϵ, ξ, δ, β, and γ in Lyra. Take a couple of frames of each star, making sure that none of the stars of interest are saturated.

3. Keep an eye on the focus. If the focus looks like it is drifting, you will have to go up and repeat step # 1 before proceeding again to step # 2.

6 Images of M13

In this part of the exercise, you will take images of the magnificent globular star cluster in Hercules, M13. Find M13 and take a few images of it, with different exposure times. If there is some other non-stellar object that you would like to observe instead of M13, discuss it with the instructor.

When you are done, go through the shutdown procedure described above. Disassemble all of the equipment and carry it down to the lab. Leave the ST-402XME cameras on the lab tables, and set up the Celestrons again. Make sure all dust caps are on the Celestrons.

7 Data Analysis and Report

Download all image files from the control and analysis computer to the workstations in room 655 that have Maxim DL. Your report, consisting of worksheets, should contain the following raw data and analysis. Be sure your report includes the tables and figures indicated.

1. Give a table (Table 1) with your photometry data for Vega and the other stars, giving Q and t for the various exposures. Clearly describe how you corrected for (or checked) for the dark count background.

2. Use equation (3) to calculate the V magnitudes of the following stars, $\epsilon_1, \epsilon_2, \xi_1, \xi_2, \delta_1, \delta_2, \beta, \nu_1, \nu_2,$ andγ Lyrae. Present your results in tabular form (Table 2).

3. Describe how you estimate the errors on your magnitudes. Calculate those out for all of your stars, and include them in another column in Table 2.

4. Find independent estimates of the magnitudes of as many of these stars as you can. Describe the source of your information. Give these values in another column of Table 2, and make a plot showing your value of the magnitudes versus the independent values. Did you do a good job, or do you feel ashamed of yourself?

5. Select your best image of M13 and include it in your report. Identify some faint stars, near the limit of what you can see, which appear to be part of the cluster. Measure their magnitudes.

6. Find the distance to M13. Give your source; Wikipedia is not an acceptable source for information of this sort. Using this distance, and assuming no extinction correction, calculate the absolute visual magnitudes of these faint cluster members. How do they compare with the Sun?