**Department of Physics and Astronomy**
**University of Iowa**
**29:137 Astronomical Laboratory**
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**Lab 1: Properties of CCD Cameras**

# 1 Introduction

Charge-coupled devices (CCDs) are the basic instruments used in astronomy for the detection of photons in the ultraviolet, visible, and infrared parts of the spectrum. They are also used in x-ray astronomy in conjunction with devices that convert x-rays to visible photons. The purpose of this lab exercise is to work with a CCD camera and learn about its operating characteristics. It is worth reading about the fundamentals of CCDs from the internet, or in a book which discusses them. I recommend the discussion in the book *Astrophysical Techniques* by C.R. Kitchen.

The device which will be used in this lab is an ST-402XME camera made by the Santa Barbara Instrumentation group. The experiment this week will be carried out in the laboratory. *Before class, familiarize yourself with the manual on this instrument*. The manual can be found at (www.sbig.com/sbwhtmls/online.htm), and is also on the course web page under "Textbooks". Be sure and read the description of the KAF-0402 chip which is the basis of this camera. This, plus technical aspects of the camera which you should read are included on the SBIG home page. Go to URL (www.sbig.com) and click on "Products". That will bring you to an online page called "Online Product Catalog". Click on the left menu bar under "Products", and choose the ST-402ME camera description. It will bring up a page full of technical information on the camera. Check out the description of the chip itself, and notice the plot of the "quantum efficiency" as a function of wavelength. Pay attention to concepts such as the "well capacity" of the device (saturation charge in the semiconductor, which directly relates to the maximum number of photons which are accumulated), the number of pixels, and the physical size of the pixels.

The software which controls the camera and downloads data from the processor in the camera is called CCDOPS. This software package is running on the computers in Room 655, but each working team will need it installed on at least one laptop computer for next week's lab, when we use the camera with a telescope for astronomical observations and measurements. CCDOPS permits a fair amount of image analysis. Download and look over the CCDOPS manual; you will need it to control and analyse data from the camera. However, we will also use Maxim DL, which is a more versatile image analysis program.

For this lab, every student needs to fill out a worksheet and submit it. When you are told to do something, briefly write what was done or give the number of the task from this writeup, and put a checkmark. When measurements or plots are needed, supply those. You may fill out the worksheet on a separate sheet of paper, or submit a copy of your workbook entries. A full lab report will not be required for this project.

# 2 Equipment to be used

The following are the pieces of equipment that you will use in this project. We have equipment for two setups.

- An optical bench
- An SBIG ST-402XME camera, with power adaptor and USB cable.
- A computer running the CCDOPS software package and Maxim DL for image analysis
- A special light source with test pattern
- 3 neutral density filters to cut down the brightness of the test pattern. Astronomical CCD cameras are sensitive
- A lens to focus the test pattern on the CCD chip
- Wooden blocks to properly adjust the height of the camera
- Clamp to secure the camera to the optical bench

## 3 Setting up the Camera

Here is what you need to do to set up the equipment. There are measurements you need to do in the process. The measurements must be written down.

1. Connect the camera to the computer, and establish communication between them. Connect power to the camera, and run the USB cable from the camera to one of the *back USB ports* of the computer. Bring up CCDOPS on the computer.

2. You now need to have the computer and the camera talk to each other. You do this by clicking on the “camera” button in the menu bar of CCDOPS, then click on “Establish COM link”. The camera should make a number of clicking sounds and flash a red pilot light to show its contentment if the link is successful.

3. One of the first things you should do is to have the pleasure of seeing the CCD chip itself. This will also be your first interaction with CCDOPS. On the icon toolbar (see p33 in manual), click “GRAB”, which controls taking an image. The GRAB function is described on p34 of the CCDOPS manual. Set the exposure time to several seconds, then click “OK”. This will open the shudder. You can look into the camera (use a red flashlight in the darkened room) and see the rectangular device, several millimeters on a side. That is the chip we are using. Make a checkmark in your worksheet if you were thoroughly gratified to see the chip.

4. Set up the light box with test pattern and the lens on the optical bench. Both of these should be on movable pedestals that fit on the optical bench. The lens will be used to focus the image of the test pattern on the CCD.

5. Measure the focal length of the lens. This will be used later in Section 4. Write the value down in your notebook and worksheet.

6. Move the lens a distance from the camera such that the focal point will fall approximately on the CCD chip. When that is the case, the CCD functions as a camera.

7. Tape about 3 neutral-density filters over the pattern on the light box, to cut down its intensity to a range which is matched to camera. Also, tape or cover up any places where light is coming through from the light box.

Make a sketch of the apparatus as you have set it up, including dimensions. In view of the sensitivity of the camera, for the measurements and tests to be made in the rest of the project, the room must be made completely dark. This is done by covering the windows with opaque paper.

# 4 Focusing the Pattern

We now need to focus the test pattern on the CCD chip. In this exercise, we are using the small lens as our telescope. We will use the FOCUS capability in CCDOPS.

1. Click FOCUS on the icon toolbar in CCDOPS. The description of the FOCUS operation is described on pp39-45 of the CCDOPS manual. The main control you have is the exposure time. Make this short, say a second or two. Click “OK”, and the camera keeps taking images. Watch the images on the screen while moving the lens back and forth on the optical bench. Keep doing this until you have the sharpest possible image. Then screw the lens down on the optical bench. Measure the distance from the lens to the front face of the camera, and write it down for future reference.

# 5 Taking Images

You are now ready to use the ST-402XME to take images, in this case of the test pattern on the light box.

1. Take exposures with a number of exposure times, just to experiment and get a feeling for the sensitivity of this instrument and its operating characteristics. Use the image processing tools in CCDOPS to experiment a little. For instance, use the CONSTRAST window which will appear when you take an image. Activate and de-activate the “Smooth” box, and note the results.

2. Determine the exposure time for which brightest pixels saturate, i.e. the charge accumulated in a well levels off at a constant value. For the operator of the camera, this corresponds to the raw image value when saturation occurs. Record this value.

3. Take 10 images with exposure time ranging from the shortest possible with the ST-402XME (0.040 sec) to 1.50 times the saturation time. *Save them to a folder for your working team.* You will analyse them with Maxim DL in the next section.

# 6 Image Analysis with Maxim

In this section we will use the program Maxim DL to read in and analyse the images you took. You will also use Maxim in the analysis section (next).

1. Look at your images from part 5.3 in Maxim DL. Pick one with an exposure time such that no part of the image is saturated, but there is enough signal to clearly show all of the detail of the test pattern. Print it out and put it in your notebook. You should also submit it with your worksheet.

2. Pick a distinctive feature on the testpattern, and identify it on the copy mentioned immediately above. For that point on the image, make a plot of the signal (raw image value) as a function of exposure time. Identify the clearly linear portion. For what values of the CCD charge would your measurement begin to be significantly in error, i.e. the charge not simply proportional to the integrated flux of light?

3. Determine the **image scale** for this CCD and this setup. That is, what is the number of minutes of arc per pixel. Compare your result with the formula on p31 of the CCDOPS manual. Comment on the degree of agreement or disagreement. Describe how you independently determine the angle corresponding to features on the test pattern. Write all of this down.

4. Pick three "features" on the image of the test pattern. Clearly indicate what they are on the hardcopy of the image. Use Maxim DL to measure

the *relative* intensities of these features. Write these down in your notebook and worksheet.

5. As time permits, explore other features of the camera, such as use of the internal filter wheel.