AY 105 Lab Experiment #6: CCD Characteristics II: The Revenge

In this lab, you'll continue investigating the properties of CCDs that you started in Experiment #2. You'll measure CCD characteristics and amplifier properties such as the read noise (e^-), gain (e^-/ADU), and dark current.

Startup. The CCD detector used in this lab is cooled by a thermoelectric cooler (TEC), which takes about 5 minutes to cool the CCD to a stable equilibrium. Thus the first thing you should do is to start up the CCD software and make sure the CCD is cooling.

On the PC, start the"pictor" program. The program will start and display some menu items at the top.

Check to see that the Pictor camera itself has the power cable connected, and that the transformer is plugged in. You should see some digits displayed on the LEDs on the back of the camera. To initialize the camera operation, pull down the Connection menu and select Connect. If the menu only displays Disconnect, choose that, then pull down the menu again and select connect. You should see a message saying that it is talking to the camera; if not, check the serial cable connection (the thin black cable with an RJ connector on the end) between the PC and the CCD camera and try again. Then, set an initial temperature of $-10°$ C by pulling down the Camera menu and selecting Set Temperature. Enter -10 into the display and make sure the Max Cooling box is unchecked.

At any time, near the bottom right-hand corner of the screen the software displays a number like "-10.22 75 % ". This is a reading of the CCD temperature in °C and the percentage of the total available cooling power that is being applied to the CCD. After you set a new temperature, you'll see these numbers change a lot, and you may notice that the approach to the set temperature is underdamped. It oscillates about the set temperature for a while before settling down, and takes about 5 minutes to fully settle.

Configuration. CCD detectors are very sensitive to light. To achieve accurate and reproducible results, a change is required in the experimental methods generally used thus far, where optics and detectors were used in the open. To reduce as much as possible the stray light reaching the CCD, in this lab the detector is located on top and at the far right end of a (more or less) light-tight enclosure. Look inside at the layout of the optics inside this "black box"; sketch this in your lab notebook, and ask the instructor or TA to explain anything about it you don't understand. You may remove the red screws on the top and lift the handle to reveal the diffuser / filter / test pattern location inside the enclosure. Check to make sure that the test pattern is in the final slot (extreme right). Replace the cover and tighten the red screws with your fingers.

Also note the configuration of the cables—the serial and power cables to the CCD camera as described above.

You will note that we use a special high-end light source for our setup - a flashlight with black tape over it and a small hole punched in.

Method. In this lab you'll use the windows PC to initiate CCD exposures from 5 seconds to several minutes of integration time, read out the serial CCD data and display it, and save the "good" exposures in FITS format for analysis during the second lab period. The exposure time (and some other parameters that are not critical for this lab) can be set by clicking on the icon that resembles four horizontal lines (next to the text display at the top that normally reads "Default"). As discussed in class #2 this CCD does not have a shutter, but instead operates in "frame-transfer" mode, taking about 4 ms to transfer. However, due to a settling time of the bias after the software clears the chip, you should not use exposure times shorter than 5 seconds.

Exposures are started by clicking on the button at the top of the screen that looks like a camera. Try it. Subwindows will pop up that display the status of the exposure and the readout, and at the end the image will be displayed on the screen with an automatic stretch. There are also items in other menus that talk about taking darks, biases, etc. DO NOT use these, as they have the problem of taking exposures that are too short. In addition, you do not want the software to automatically subtract these correction frames from your image, which would make a proper analysis impossible. The program saves each image in an internal temporary file. If you want to save an image for later transfer, click the left mouse button on the image to select it, then pull down the File / Save menu item. Images saved in FITS format have a ".fts" extension. Also, note that the PC software displays the image such that the amplifier is in the upper left-hand corner, but later when you display the image in IRAF it will be flipped top to bottom from what the PC shows, placing the amplifier in the lower left-hand corner of the display.

Required Exposures.

The first exposures you obtain are images of the test target with between 2500 and 3000 ADU ("analog-to-digital units", also called DN, for "digital numbers") above the bias level. Among other things, this will tell you whether everything is working inside the enclosure. With the lamp off, you can take a (minimum) 5-second exposure to determine roughly the bias level. Before you obtain your final frame, you may need to take some short exposures to adjust the focus of the Nikon camera lens. You can access the lens by removing the four red screws on the front cover; rotate the lens only a small amount from its original position (shouldn't be far off, depending on how well the previous group did). Replace the cover each time before taking another exposure. Once you have an exposure time that gives you the proper signal level, take another at

1/5 of this exposure time, and a third at 1/25 of this. These data will be used during the data analysis phase to see how linear the response of the CCD detector is (i.e., counts in DN should be a perfectly linear function of exposure time in seconds).

Next take several 5-second dark exposures (with the lamp off), which we will use as our bias frames. Then, take two dark exposures at each of the exposure times used for the test target–these will make up your dark exposures.

Now remove the test pattern from inside the enclosure, turn on the lamp, and take several well-exposed "flat field" exposures using just the opal glass diffuser. Use the same exposure times as your well-exposed images from before. These images reveal the pixel-to-pixel variation in the gain of the CCD to uniform illumination.

The final CCD characteristic to be investigated is the dark current itself, which is an exponential function of temperature and also varies significantly from pixel to pixel. This is caused by thermally-generated electrons that collect during your integration time. Individual pixels with much higher dark current than surrounding pixels are called "hot pixels." Take one exposure at your middle exposure time from above, and record the temperature of the CCD at the beginning and end (of course, these frames are all taken with the light off.) Then take a 5-minute exposure at this temperature. Next, adjust the temperature to 5 degrees warmer, and wait for the regulation cycle to settle. Take the same pair of exposures as before, and repeat this operation to get readings at -15, -10, -5, and warmer if you can. You may need to shorten the exposure times at the highest temperatures to avoid saturating the detector. From the pairs of exposures, you should be able to determine the rate of dark current generation, and for one temperature (the one you took your bias frames) whether the dark current is generated at a constant rate. You should determine an average rate for pixels excluding the very hot pixels.

Note that the short exposure time will allow you to track any changes in the bias with temperature, and thus give you a good estimate of the true amount of dark current generated.

Data Analysis. You should use the second lab session to reduce your data. You can copy the data from the PC using "SSH Secure File Transfer" (see the instructor or TA if you have questions on how to use the software) over to kronos or another cluster machine, and use IRAF to perform your reduction.