Astronomy 361 CCD Laboratory

Winter 2004 — 2004 Mar 3
Due Wed Mar 10 — Prof. Monnier

100 total points

1 Goal

In this lab, you will obtain data that will allow you to characterize the CCD camera used at the Angell Hall Observatory. Your main goal is to use the mean-variance method to determine the electronic gain (e-/ADU) and detector readnoise (e-).

2 Data Collection Procedures

2.1 Setting up (15 minutes)

Follow separate instructions on how to start the camera. Be sure to turn on the chiller. Also, turn on the lamp to be used later so that it warms up (temperature stabilizes).

Spend the first 10-15 minutes familiarizing yourself with the software interface. Experiment with taking data using different filters, different integration times, and specifying subarrays. Learn how to use the software tools in order to see the distribution of pixel values. Note how the cursor position and pixel values are always shown at the bottom-left on the screen. Know the difference between the different image types: LIGHT/DARK/BIAS

Before starting actual data collection in the next section, be sure to setup the following camera parameters:

a. Binning 1×1

b. Turn Subarray Readout on: Left: 256 Right: 256 Width: 256 Height 256. Note that this is easy to reset when clicking on the windows, so be aware.

c. Reduction: None

d. Johnson V filter

e. Temperature -5 deg C

2.2 Mean-Variance Method (45 minutes)

In order to speed up data taking, you only need to collect data from a subarray of the CCD (this was set up above). In this experiment, we will be collecting 3 CCD frames (or subarrays) at many different integration times. The observed noise (variance) will increase as the mean number of counts increases, and we can determine the electronics gain (e-/ADU) and the read-noise (e-) by analyzing this behavior.

a. First, take a bias frame with zero integration time (ideally, you would take many bias frames and later average together to from a less-noisy "master" bias frame).

b. Set the integration time to 30 seconds.

c. Illuminate the CCD as uniformly as you can (this is a little tricky because there is no flat-field screen in dome). Point telescope to dome slit (SLEW WEST) – keep cover on. Clamp portable light to dome edge and indirectly illuminate the telescope aperture.

d. Adjust light so that the CCD is not saturating, and record a very high signal-to-noise level image (mean counts $\sim$30000 ADU; the saturation level is 65536). This is essentially the same as taking a flat field, although our lighting method is not ideal. If you get strange results, the flip-mirror (for the eyepiece) might be in the wrong position.

e. Record 3 frames at this light level.

f. Be sure to record all needed observing details for use in your lab report (you will need to turn in your data logs with your report). You can use the empty table on the last page of this handout.

g. Now collect data with different count levels. This is probably most easily done by adjusting the integration time. Make sure you collect data for range of times corresponding to totally dark to nearly saturating the detector (at least 5 different times, spanning from 0 seconds to 30 seconds).

2.3 Transfering Data

When you are finished, Prof. Monnier will transfer data from the observing computer to both the windows machines and the astronomy department anonymous ftp site in case you want to access the data from a unix machine (ftp.astro.lsa.umich.edu/pub/get/monnier/).

3 Instructions for Lab Report

While data collection is done as a group, each student will individually analyze the data and submit an independent lab report. As with working on homework, you should feel free to discuss your work with your fellow students but the lab report you turn in must be your own, written in your own words, displaying your own effort, and reflecting your own understanding.

3.1 General

Each lab report should contain the following information.

- Brief description of experimental goal (a few sentences)
- Brief description of experimental setup (1-2 paragraphs)
- Description of data analysis method. Describe and explain the reasoning behind each step you took to analyze the raw data (using IDL or equivalent). Include a table with the analyzed ("reduced") data in summary form. Do not forget to include an error analysis (all measurements have uncertainties and it is critical to estimate these).
- Plot data in meaningful way (see below for details).
- Interpret your results. Include discussion of errors and ways to improve experiment.
- Conclude with a one-paragraph summary of the result at the end
- Appendix. Attach the data logs you took during the experiment. Also, attach a printout of computer programs/scripts you wrote to analyze the data.

3.2 Specific Instructions for the Mean-Variance Method

When you take 3 frames at a constant light level, you will get three values for each pixel. For these 3 values, you can calculate the mean and variance. By plotting the variance vs. the mean counts (bias-corrected) for a varietly of light levels, one can fit a straight line to the data using built-in IDL routines for least-squares fitting (e.g., LINFIT). Interpret the values of the slope and the y-intercept in terms of the noise properties of the CCD (gain and read-noise). Please explain your method mathematically based on the statistics of Poisson fluctuations. Be sure in your summary paragraph to report the readnoise in units of photo-electrons (e-) and the gain in units of (e- / ADU).

3.3 Analysis Hints (IDL)

One can load in the bias and image frames using readfits(), as we did in the IDL Tutorial. After loading in the bias frame [`IDL> bias = float(readfits('file1'))`] and the exposed image file

[IDL> image = float(readfits('file2'))], you can create the bias-corrected frame by simply doing array subtraction [IDL> newimage = image-bias]. You can look at histogram of values using plothist procedure. You can also use the mean(), median(), and stdev() functions to calculate common statistics of the pixel values. The median is often better to use since there are occasional 'hot' pixels that can strongly bias the mean if not careful.

For creating the mean-variance plot, each long-exposure image can be bias-corrected and the median can be measured as explained above. However, measuring the variance is not as easy. Here is one method that I might use (feel free to develop your own method):

a. Load into memory the three bias-corrected long-exposure image associated with a given light level. e.g.
```
IDL> image1 = float(readfits('image1')-readfits('bias'))
IDL> image2 = float(readfits('image2')-readfits('bias'))
IDL> image3 = float(readfits('image3')-readfits('bias'))
```

b. Form an average image.
```
IDL> image123=(image1+image2+image3)/3.
```
You might want to inspect the image using one of the IDL image display routines (e.g., imcont] to makes sure everything looks ok!

c. Now you can subtract this mean image from the individual images in order to estimate the variance.
```
IDL> var1=(stdev(image1-image123))^2
IDL> var2=(stdev(image2-image123))^2
IDL> var3=(stdev(image3-image123))^2
```

d. With three measurements of the variance you can easily include error bars in your analysis.

The preceding analysis can be repeated for each illumination level (would be good to use an IDL script in order to avoid typing this in every time). This procedure should result in a variance and mean-level estimate for each illumination level to be included in the final plot.

Date: Name: Group Members:

Table 1: Observing Log (CCD Experiment)

Time	T_{int} (s)	File Number(s)	Data Description (LIGHT/DARK/BIAS)	Comments