Lab 2
Characteristics of a CCD
ASTR 250

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1 Objective

To investigate the precision of measurements made with a Charge Coupled Device (CCD).

2 Introduction

A CCD is essentially a grid of easily ionizable material. When photons strike the device electrons are freed and collected into buckets spatially corresponding to each pixel. The buckets are read and amplified by the device to convert the analogue signal to digital. CCDs are not perfect and are subject to quantum inefficiencies. In general the noise for a CCD tends to follow a Poisson distribution, but other factors may change this. Other sources of noise include Cosmic rays which will instantly saturate single pixels. Bias noise comes from the unique zero point for each pixel, and it must be subtracted from all science images. Small pixel to pixel efficiency differentials can be corrected for by taking flat field images. Dark current comes from the thermal ionization of electrons. Thus is is vital that the CCD is kept cold. Read noise is introduced by the analog to digital conversion.

3 Equipment

CCD camera system STAR 1 on the Climenhaga 0.5 meter telescope.
IRAF data analysis program.

4 Procedure

4.1 Part 1

First remove the telescope covers, set the gain to 4, and ensure all computers and monitors are on a functioning correctly.

4.1.1 Bias Frame

The filter was changed to DC and a 0 second exposure was taken.

4.1.2 Dark Frame

A 100 second exposure was then taken with the same filter settings.

4.1.3 Dome Flats

The filter was then set to CC and the dome was illuminated with a lamp. A 0.1 seconds exposure was taken. The exposure time was then doubled repeatedly until the final exposure time was 51.2 seconds.

4.2 Part 2

The files were downloaded to the local computer after they had be preprocessed.

4.2.1 Processing the images

In IRAF the ccdproc library was setup as described in the lab manual[1] then run to remove the bias and flat fields.

4.2.2 Finding the Mean and Standard Deviation of Counts

In IRAF the imstat library was used to find the mean and standard deviation of a 20x20pixel^2 region of the image. The results were then recorded into Table 2.1.

4.2.3 Testing the Linearity of the CCD

A file was created with two columns. The first for counts and the seconds for exposure time. Next the IRAF task graph was used to plot the data using the setup detailed in the lab manual[1]. The resulting log-log plot was then printed.

4.2.4 Examining the Noise

After creating a file containing the standard deviation and mean values for counts an awk scripts was used to convert the ADUs to electrons. A gain of 15 was used. Next the IRAF task graph was used to plot the log of the signal against the log of the error. The resulting plot was then printed after updating it's labels and title.

4.2.5 Examining the Relative Noise

Next another plot was created of log(N/S) against log(N). An awk script was used to generate the N/S value.

4.2.6 Theoretical Noise

Equation 2.4 was used to find the theoretical noise values.

4.2.7 Verifying the Gain of the Detector

Another graph was made plotting N_{ADU} against σ^2_{ADU}.

5 Data and Calculations

See attached data page and graph.

6 Discussion

6.1 Questions

6.1.1 Finding the Mean and Standard Deviation of Counts

The results are lower than what would be expected using a Poisson distribution.

6.1.2 Testing the Linearity of the CCD

The results are linear. At higher signal levels the slope will flatten out as the CCD saturates, and at low signal the slop will also flatten due to the bias dominating the signal.

6.1.3 Examining the Noise

A gain of 15 is used. The plot generated shows that the noise appears to be linear with signal. This is odd because Poisson noise should follow the square root of signal. This indicates other noise is present. This makes sense when looking at equation 2.4 because readout noise is linear with time. To estimate the read noise the higher noise/signal values are chosen from the graph to compute it. This is done because the signal term will become negligible and the noise will be essentially equal to the total noise at these values.

6.1.4 Examining the Relative Noise

This plot shows how the signal normalized error changes as signal increases. It shows a slight downwards trend. A signal of approximately 15000 photons is needed to get a S/N of 100. According to this Graph 1.3 a S/N corresponds to 1000 counts in ADU at a gain of 15. This means that approximately 15000 photons are needed.

7 Conclusion

The various relationships between sources of noise on CCD detectors were investigated after taking and processing images. The linear response as well as saturation points of the CCD was plotted.

8 References

1. Department of Physics and Astronomy, Astronomy 250 Lab Manual, pp. 11 to 23. (University of Victoria: Victoria, BC). July 2011.