Report on the lab-test images of the NIR camera

The images obtained using the NIR Camera in laboratory conditions are analysed. The data acquisition modes used are the single frame (SF) and double correlated sampling (DCS). SF mode is the reset-integrate-read mode of reading out the array, whereas DCS is the reset-read-integrate-read mode of readout. The gain, dark current and read noise of the data acquisition are estimated in the SF and DCS modes. A summary of these estimation is presented below.

1 General sensitivity

The array is seen to have lesser sensitivity for the first 50 or so columns. This is seen in both SF and DCS mode. When one image is subtracted from a similar image, the resultant image does not show this problem. In the DCS mode, there is a gradation in the count level along the column, such that the count level at X=512 is 25% less than the count level at X=0. On the other hand, in long exposure darks, a reverse trend is seen. The count at X=512 is about $\sim$ 20% more than that at X=0. A segregation low sensitivity pixels are seen at two places. One cluster is located at X=350;Y=140 and another cluster of pixels at X=150;Y=260.

2 Characterisation using the SF mode images

2.1 Gain

The gain is estimated by measuring the shot noise as a function of detector signal at high photon flux levels where the photon shot noise dominates the detector readout noise. Totally 26 images and 13 difference images were used for this analysis. The $\sigma^2/2.0$ of the difference image is plotted versus the detector signal. This plot is shown in figure 1. The system gain is the inverse of the slope of the fit. The slope is found to be 0.184$\pm$0.007 which results in a gain of 5.4$\pm$0.2 e^-/ADU. It can be seen from the figure 1 that the last two points deviate from the rest of the points. If these two points are excluded, then fitting only the rest 11 points give a slope of 0.182$\pm$0.007. This is shown in figure 2. The resultant gain is 5.5$\pm$0.2 e^-/ADU.

A few words on caution to be observed here. To estimate the standard deviation on the difference image or to estimate the mean count on the original frame, care should be taken to avoid hot pixels as well as pixels with low sensitivity. A sub array of pixels is chosen within the frame, where no hot pixels are located and a mean value is estimated. It is noticed that the pixels with lower sensitivity give rise to larger noise than what is otherwise seen and hence the two cluster of low sensitivity pixels are avoided here. Therefore, an array of

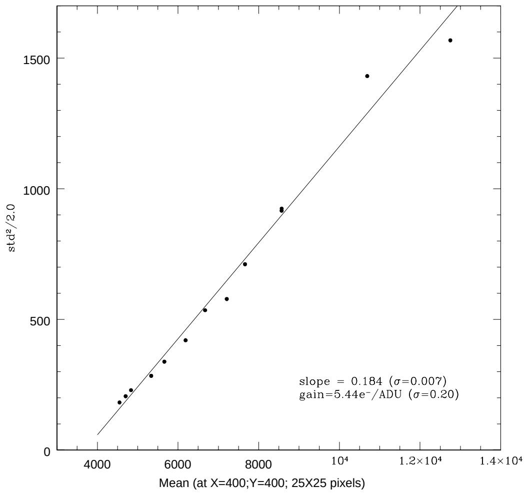

Figure 1: The $\sigma^2/2.0$ is plotted versus the counts. The slope of the fit is the inverse of the system gain. All the 13 points are shown here.

25X25 pixels near X=400 and Y=400 is used to estimate the mean counts and standard deviation.

2.2 Dark current and Bias counts

The long exposure dark frames can be used to estimate the dark current. The exposure time is plotted versus the mean counts. The slope of this plot gives the dark current in terms of count/sec. This is multiplied by the value of gain to obtain the value in term of electrons per second. The plot is shown in figure 3, and the values obtained are also indicated. Therefore the dark current is found to be 3.43±0.03 ADU/sec, or 18.9±0.2e^-/sec.

The plot shown in figure 3 also indicates that the system is still in the linear range of response at a count level of $\sim$ 13,000. A few more deeper exposure frames will be required to estimate the linear response range for the system. The y-intercept of the plot indicates then count level for an integration time equal to zero. This is nothing but the bias level, and this turns out to be 4500 counts.

2.3 Read Noise

The read noise of the system is estimated from the frames with shortest integration time. A pair of frames are then use to create a difference frame by subtracting one from the other. The standard deviation of such a difference

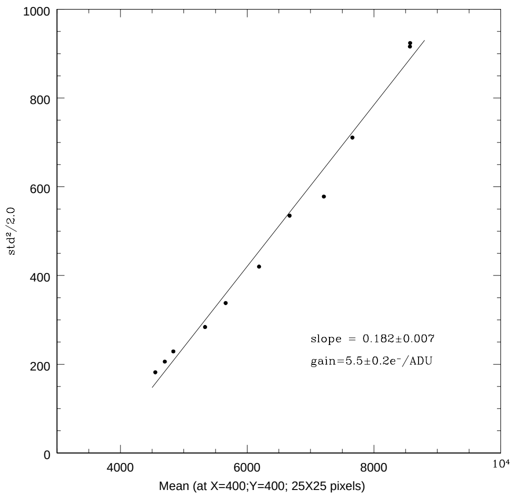

Figure 2: The $\sigma^2/2.0$ is plotted versus the counts. The slope of the fit is the inverse of the system gain. Only 11 points are shown here.

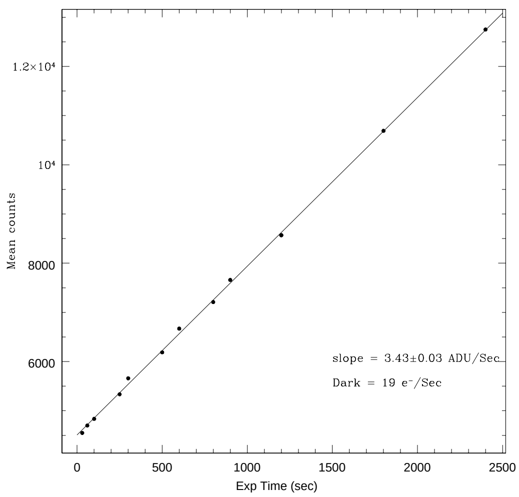

Figure 3: The count versus the integration time is shown here. This plot is used to estimate the dark current and the bias count.

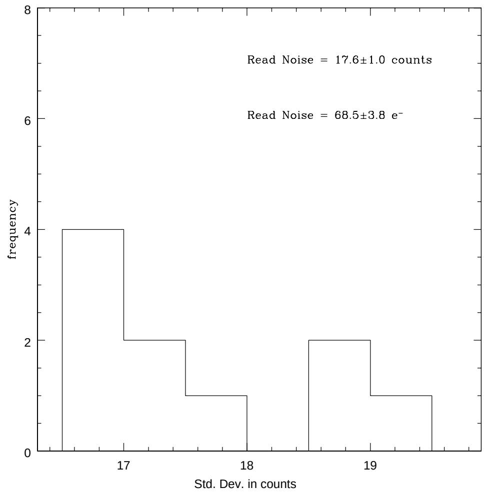

Figure 4: The frequency distribution of the standard deviation is shown here, for the SF mode. The read noise is estimated from the mean of this distribution.

frame is estimated and divided by $\sqrt{2}.0$ to obtain the read noise in counts, which when multiplied by the gain given it in term of electrons. In this mode, 5 images are used to create 10 difference images. The frequency distribution of the std. dev is shown in figure 4.

The mean value of the distribution is 17.6±1.0 counts, which is equivalent to 17.6*5.5 = 68.5±3.8 electrons. This is a very high value for read noise.

3 Characterisation using DCS mode

3.1 Gain

The method used to estimate gain is identical to the one used in the SF mode. Using 18 images, 9 difference images were created and all the 9 data points were used to estimate the gain. The plot of mean count versus $\sigma^2/2.0$ is shown in figure 5.

It can be seen that the least-square fit to the data points is excellent. The slope is estimated to be 0.161±0.002, and the value of gain, which is the inverse of the slope is 6.21±0.08 electrons/ADU. The same precautions as indicated in the SF mode is observed here also.

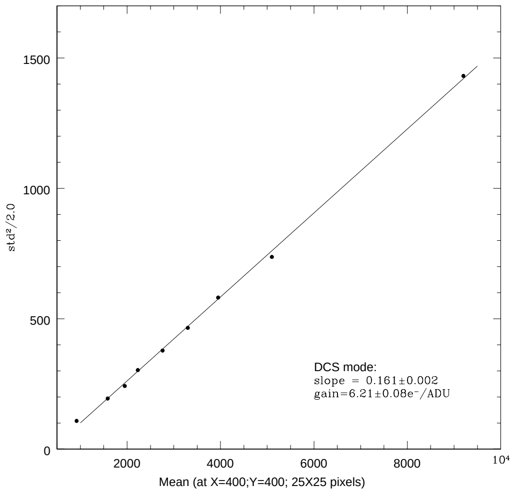

Figure 5: The $\sigma^2/2.0$ is plotted versus the counts. The slope of the fit is the inverse of the system gain. All the 9 points are shown here.

3.2 Dark current and Bias count

The integration time is plotted against the mean counts as shown in figure 6, is used to estimate the dark current, which is the slope of the straight line fit to the plot. It is found to be 3.64±0.06 counts, which is same as 22.6±0.4 electrons/sec. The bias level is found to be 580 counts.

3.3 Read Noise

The read noise is estimated using the images with shortest integration time. These are the images with 0.8 sec integration time. From 6 images, 15 difference frames were made. The standard deviation of the counts is seen to deviate quite a bit ($\sim 2\sigma$) in the case of one frame. Hence 14 estimates were used and the frequency distribution is shown in figure 7. The mean of this distribution is found to be 8.0±1.0 counts. Therefore the read noise is (8.0*6.21)/1.414, which is 35.1±4.4 electrons.

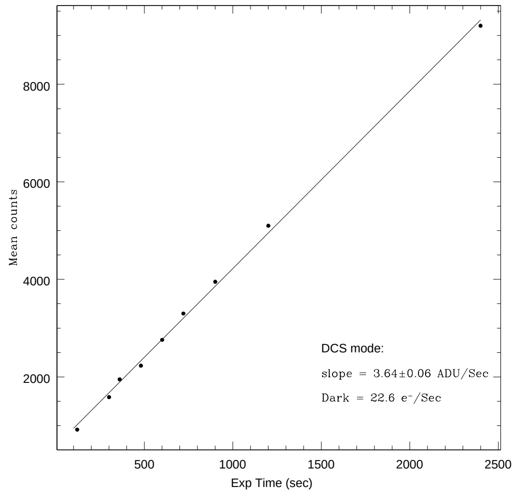

Figure 6: The count versus the integration time is shown here. This plot is used to estimate the dark current and the bias count.

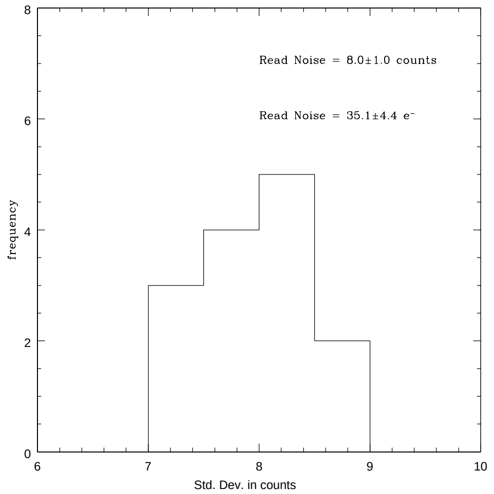

Figure 7: The frequency distribution of the standard deviation is shown here, for the SF mode. The read noise is estimated from the mean of this distribution.

4 Summary

The characteristics of the NIR camera and the data acquisition system can be summarised as follows:

Gain	5.5±0.2 e^-/ADU (SF)
	6.21±0.8 e^-/ADU (DCS)
Dark Current	18.9±0.2 e^-/sec(SF)
	22.6±0.4 e^-/sec(DCS)
Read Noise	68.5±3.8 e^- (SF)
	35.1±4.4 e^- (DCS)
Bias counts	4500 counts (SF)
	580 counts (DCS)