1 Introduction

The goals of this lab are:

1. Determine whether there is any fixed-pattern noise in the bias frames
2. Determine the gain and the read noise of CCD1

Before beginning this lab, please study the handout “Introduction to IRAF.” If you have not already done so, follow the instructions in it for setting up IRAF in your astrol account. Then, try out the commands and examples in it.

The following instructions are meant to leave room for your own initiative. If they are unclear or too sketchy or if you get stuck at any point, don’t hesitate to ask for help.

2 Fixed-Pattern Noise

You’ll find ten bias frames in FITS format in my astrol account at the path:
/mnt/vol01/ndm/iraf/course/F2005/20050913/ Create a folder for them in your own iraf directory, and copy all of them to this folder with the Unix cp command or with the IRAF command copy /mnt/vol01/ndm/iraf/course/F2005/20050913/20050913.001.fits ./ and so forth.

The basic procedure will be to form the average bias frame, and then to compare the level of fluctuations in the individual frame with those in the average frame. The level of fluctuation will be measured by the standard deviation in the image. If there is no fixed-pattern noise, the fluctuations in the images should be independent of each other, and the standard deviation in the average image should be lower than that in the individual images by a factor equal to the square root of the number of frames being averaged:

$$\sigma_{\text{mean}} = \sigma_{\text{individual}} / \sqrt{n}.$$ 

On the other hand, if there is fixed-pattern noise, the standard deviation will decrease as the number of frames being averaged increases, but then it will level off as the remaining random fluctuations drop below the level of the fixed-pattern noise.

There are two sets of bias frames, one taken at the beginning of the night and one at the end. To see which images they are, consult the copy of that night’s log that is attached to this lab.

Before averaging all the bias frames together, make separate averages of the two groups of five and check that they have the same statistical properties; comment in your Results section (see below).

Check to see whether the edges of the images have spikes or other defects, using implot so that you can plot either rows or columns. To identify precisely which pixels are affected by the spike, you can zoom in on the end of a plot — plotting, for example, the first 100 pixels — with x 0 100. In order to obtain a realistic standard deviation, you’ll need to exclude any spikes by
forming an image section. For example, in an image called \texttt{bias.fits}, the region including columns 100 through 299 and all rows is denoted as \texttt{bias.fits[100:299,*]} ($x = 100$ to 299, all values of $y$).
To form an average image, use the task `imcombine`. In order to assess the noise in the image accurately, you should use no rejection. Its most important, non-self-evident, parameters are:

```
(combine= average) Type of combine operation
(reject = none) Type of rejection
```

To determine the mean and standard deviation of each frame or section thereof, use the task `imstat`:

```
imstat bias*.fits[a:b,c:d]
```

Discuss your results. As documentation, include plots taken from an individual frame and from the average. If you are unable to detect fixed-pattern noise, try to estimate how large an amplitude the fixed pattern would have to have in order to be detectable. Can you think of a more sensitive method, which might enable you to detect fixed-pattern noise at a lower level than the method suggested here?

3 Gain and Read Noise

In `/mnt/vol01/ndm/iraf/course/F2005/20050913` you'll find ten bias and ten flat frames from Sep. 13 (UT). Select six of each, create a folder for them in your account, and copy them to it. Check the flat frames for any cosmic rays and remove them using the task `lineclean` as demonstrated in class. Present before-and-after graphs to show the cosmic rays you removed.

Choose a pair of biases and a pair of flats. Survey one of the flats with `splot`, and find a rectangular region of the image, preferably including at least a few hundred pixels, where the signal is uniform to within about 10%. Define this region by means of an image section, and operate on the same region in all frames. Carry out addition and subtraction of these image sections with `imarith`, and find standard deviations with `imstat`. Use Howell’s formulas (p. 53) to calculate the gain and the readout noise of the CCD.

By way of error analysis, repeat the calculation with two additional pairs of flat frames (the bias frames probably don’t matter much), processed in the same way, and discuss the similarities and differences in the results.

4 Your Report

All students’ reports will be graded on clarity, on organization, and on English grammar, spelling, and usage, as well as on content. Please use a narrative format with complete sentences, and paragraph not an outline format. Students taking the class for Writing Across the Curriculum credit may be asked to revise the writeup. Their grade will depend on both the first version and the revised version. Your writeup should follow the usual outline of a technical paper:

**Introduction** Purpose and scope of the experiment

**Procedure** How you did the experiment, including the source of the data and including enough procedural detail so that the reader can repeat the experiment and replicate your findings. Printouts of spreadsheets showing calculations may be included.
**Results** What you found out. Include enough graphics so that the reader can appreciate your findings, and explain them clearly. Each graphic should have a number (Figure 1, 2, etc.) and a caption. Tables, if appropriate, should have a number, a title, and a caption if the table is complex.

**Conclusions** The importance of what you found out. Were the goals given in the introduction met? With hindsight, could the experimental design have been improved? What further research is needed?