ASTR 4880/PHYS 5880 — Fall 2008 – Lab 1
Due: October 1, 2008

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 CCD3

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 *astro1* 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 Setting up your *astro1* account

Included with this writeup is a copy of the observing log for the night of 22 October 2007 (UT). The needed images for this exercise (for now, biases and "blue" flats only) can be found in FITS format in my *astro1* account at the path: `/mnt/vol01/ndm/iraf/course/F2008/20071022/` Create a folder for them in your own `iraf` directory, `cd` to that 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/F2008/20071022/*fits ./`

This document will be on line at the course web page in PDF format. It may be convenient to open the PDF on your local computer and cut and paste these commands to your command line.

3 Fixed-Pattern noise

The basic procedure will be to form the average bias frame, and then to compare the level of fluctuations in the individual frames 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:

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

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. We use the average in this case, rather than the median, even though we do have to rejec cosmic rays (see below) because the average is statistically better behaved than the median.

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.

Check to see whether the edges of the images have spikes or other defects. The best way to examine these images is to use *ds9* with the horizontal and vertical graph options open. Move the cursor around in the image to make a quick survey and zoom as needed. It's a good idea to exclude the very first and last pixels in an image or quadrant of an image, even if they are not spiky.

To study a partial image, create an *image section*, which may be copied to a new image. For example, a section including rows 1 though 200 and columns 100 through 400 im the image *bias1.fits* is specified as: `bias1.fits[1:100,100:400]` . The region including columns 100 through 299 and all rows is denoted as `bias1.fits[100:299,*]` ($x = 100$ to 299, all values of y). Since CCD3 images have four quadrants that are read out separately and may have different properties, **be sure to select only one of them (any one) for study.**

To form an average image, use the task `imcombine`. To determine the mean and standard deviation of each frame or section thereof, use the task `imstat`: `imstat bias*.fits[a:b,c:d]`

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).

In spite of having an exposure time of zero seconds, some of these biases appear to contain cosmic ray "hits." They are difficult to see in *ds9*. To see which images have them, you can:

- Inspect the maximum pixel value for each image with *imstat*
- Plot the histogram of pixel values for each image with *imhistogram*. In your report, show a histogram of at least one image section with and one without any cosmic rays.

Cosmic rays should not be included in the image statistics. The most convenient way to exclude them is to use rejection in both *imstat* and *imcombine*. Suggested parameters:

- *imstat*: `nclip  = 1`, `lsigma = 3.`, `usigma = 4.`
- *imcombine*: `reject = crreject`

Discuss your results. As documentation, include plots taken from an individual frame and from the average. In addition, be sure to show an example of cosmic ray rejection, which could be tabular output from *imstat* or image histograms.

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?

4 Gain and Read Noise

In `/mnt/vol01/ndm/iraf/course/F2008/` you'll find ten bias and ten "blue" flat frames (taken through blue filters) from 2007 October 22 (UT); the biases are the ones you used in section 3 of this lab. Select two biases and six flats, create a folder for them in your account, and copy them to it.

Choose a pair of biases and a pair of flats. (Based on your results from Section 3, would it be a good or a bad idea to combine frames from the beginning and the end of the night? Why?) Survey one of the flats with *splot*, and find a rectangular region of the image, within one quadrant and preferably including at least a few hundred pixels, where the signal is uniform to within about 10% (except for cosmic rays) and below 5000 ADU. Define this region by means of an image section, and operate on the same region in all frames. Check the region for any cosmic rays and remove them using the task `splot` as demonstrated in class. If you removed any cosmic rays, present before-and-after graphs to show them.

Use Howell's formulas (p. 73) to calculate the gain and the readout noise of the CCD. Carry out addition and subtraction of these image sections with `imarith`, and find standard deviations with `imstat`.

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.

5 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?