Homework 5

Due Date/Time: Beginning of class (7 pm), Wednesday, October 9th 2019

Problems

1. (Adapted from Chromey 8.6):
   Construction of a monolithic 8192 x 8192 pixel CCD array is technologically possible. How long would it take to read this array through a *single* amplifier at a pixel frequency of 25 kHz? Now, assume that the charge transfer efficiency (CTE) is 0.99 (99%). How much charge will our hypothetical detector lose from the last pixel in an array of this size?

2. From Chromey: 9.5 ("On a 20-second exposure, a star with magnitude *B* = 15…")

Investigating and Understanding Calibration Frames

The Amherst data we worked with in Lab 5 are located at the following Google Drive link: https://drive.google.com/drive/folders/1jQFkkWjcLKNSK-MQLfeXeKF5bdnudxCL?usp=sharing (also accessible at https://tinyurl.com/337-lab5-data)

In this homework, you will download the calibration data and use DS9 to do some investigative analysis of the images. Recall from last week's lab that the FITS headers provide valuable information, and you can adjust the scale properties to bring out various features in the images. Additional DS9 techniques you will need are described below.

Measuring pixel properties:
For a region: In DS9, you can use regions to measure pixel properties within a FITS image. In the top menu, go to "Region" -> "Shape" -> "Box" to create a region and double-click within it. This will bring up a new window that provides the coordinates and size of the region, as well as some analysis utilities. In the menu of this new window, click "Analysis" -> "Statistics". This will open another window summarizing the pixel properties of the region you created (e.g., number of pixels within the box, average/median/min/max values of those pixels, etc).

For a cut across the image: Another useful region tool to analyze an image is under "Region" -> "Shape" -> "Projection". This allows you to draw a line of any length across an image and produces a plot of the pixel values at every point along that line. For example, try drawing a projection across a single star in the Amherst image of the M13 from last week to see how the values increase and decrease across the PSF of the star.

Blink two images to compare them:
It is possible to open two (or more) images simultaneously in DS9 and go back and forth to compare them quickly. To do this, click the “Frame” button above the image, then click “New”. A blank window will appear, and you can now open another FITS file by clicking the “File” and “Open” buttons. *Make sure you align the frames first by clicking “Frame” (in the menu, not button) -> “Match” -> “Frame” -> “Image”.* To go back and forth, you can hit the “tab” key, or to do it automatically, click the “Frame” button then “Blink”. Click “Single” to stop. (You can also see two or more images simultaneously by clicking “Tile”.)

1) **Bias Frame - Taken with closed shutter.**
    a) How long was the exposure time for this image?
    b) Why are the pixel values not all the same?
    c) What is the range of pixel values? Describe quantitatively using the DS9 analysis utilities described above.
    d) How uniform are the values? Use the projection tool in DS9 to measure the values across the image in different directions. Are there any gradients in pixel value?
    e) How many photons should have hit the detector? Where is the signal coming from?

2) **Dark Frames - Taken with closed shutter.**
    a) How long was the exposure time for these images?
    b) What are the typical pixel values? How do they compare with the bias frame values?
    c) How uniform are the values? Use the projection tool in DS9 to measure the values across the image in different directions. Are there any gradients in pixel value?
    d) Do you notice any unusual or different regions of the image? E.g., any “hot spots”? What do you think these are?
    e) Are the same features present in every frame? (Try matching and blinking the frames to look for similarities/differences.)
    f) How many photons should have hit the detector? Where is the signal coming from? What might be the source of any appearing/disappearing signals?

3) **Flatfield (“flat”) Frame - Taken with open shutter.**
    a) How long was the exposure time for this image?
    b) In what filter was this image taken?
    c) What features are evident in the image? Describe them qualitatively.

d) By mousing over or drawing regions in the image, what are the quantitative properties of the features in part (c)?
e) How uniform are the values? Use the projection tool in DS9 to measure the values across the image in different directions. Are there any gradients in pixel value?
f) What are the typical pixel values in the flat frames? How do they compare with the biases and darks?
g) What are we measuring with the flat images, and how might we use these calibration frames?
h) How many photons should have hit the detector? Where is the signal coming from? (The Amherst flatfields are taken using “twilight flats”.)

Pre-Lab Reading and Questions for Week 6

Reading

Please read the following sections in Chromey:

- 9.1 (*Arrays*)
- 9.2 (*Digital image manipulation)*
- 9.3 (*Preprocessing array data: bias, linearity, dark, flat, and fringe*)

Questions

You will use the reading for this week to help make sense of the calibration data you analyzed in the last lab and previous part of this homework.

1. What is the purpose of taking bias frames?
2. What is the purpose of taking dark frames?
3. What is the purpose of taking flat frames?
4. Briefly describe the different methods to obtain flat frames. What are the pros/cons of the different approaches?
5. How might a science frame contain contributions from each of the different kinds of calibration frames we took?
6. At a level understandable to a peer, write down your own step-by-step “recipe” to taking biases, darks, and flat frames and then applying them to calibrate your science data.