Astronomical Image Processing for Windows V6

Basic Use of the Program

What exactly is a CCD and how do we use the images we get from one? A CCD is basically a digital camera, but it is a little more sensitive (and more expensive) than the digital cameras you can buy at Walmart. All digital cameras work on the same principle: they contain a piece of silicon and the associated electronics that can transform photon energy into electrons (a voltage) which are then amplified by the electronics and read out to a computer. The piece of silicon is called a chip and is divided into pixels. Light falling on each pixel is converted into an electronic signal. This signal is typically expressed as "counts" or "ADU". ADU stands for analog to digital unit. An astronomical CCD outputs the resulting image in FITS format. The nice thing about digital cameras is that their images can be manipulated by any number of image processing programs.

Which brings us to AIP4WIN V2. The program is installed on most of the computers in the computer room at the observatory. It is not installed on computers at the University, since the publisher does not sell a site license. This program also only runs under Windows. There is no version for Mac, but it may under Wine.

The purpose of this exercise is to perform basic manipulation of images to get a feel for the program. After opening AIPWINV2, click "FILE", then "Open Image". A menu will appear. If you are using a computer in the computer room at MCAO, images we have taken during class or images from other times are found in a directory named "classdata". Usually this directory will be found on the C drive. If it is not there, look for an E drive and search there. If you are using your own computer, you will have to download images from the class website (www.physics.udel.edu/~jlp/classweb2/) Observations are grouped by date. Choose a date we have observed during class, or some similar directory.

Each set of observations contain calibration images as well as science images. The calibration frames are biases, darks, and flats. Each image will include a keyword in their name. For example, a dark image will be called mcao20171116darkr0007.fits. "mcao" gives the observatory name, 20171116 is the date, and "dark" says what kind of image it is. The next letter indicates the filter, but THIS IS NOT IMPORTANT for biases or darks, as the shutter is closed at all times. The last numbers are sequential. There should be 10 to 20 bias frames, 10 dark frames, and 20 flat frames for each filter. Flat images are images taken of a supposed uniform light source. They are named "mcao20171116flatr0005.fits", for example. Flat images are taken with filters. The letter after "flat" in their file names will be either "v", "b", ‘r", or "nf". It is very important to work with flats and science images taken with the same filter. This will be discussed in detail as the class proceeds.

Start by opening the bias files. A bias image should look uniform, with perhaps some wavy patterns. Look at the bias images to make sure they look similar. Close any images that are different, and note their filenames in your observing journal.
Click on one of the bias images (this will make it your "active" window) and click "Measure"→"Statistics". A window will pop up with statistical information about the image. Record the minimum, maximum, mean, standard deviation.

Now we want to combine the images to create an average, or "master" bias. Click "Multi-Image" on the top bar of AIPV2. Click "Image Math". A menu appears that says "Create an image consisting of…" For A=, click on the arrow on the right and a list of files will appear. Click on your bias file #1. This selects that file as the first file to use. If you click on the second arrow from the top, a list of operations will appear. Select Average, since we want to average 2 images. Now click on the third arrow and select your #2 bias frame. If everything looks okay, click "Perform Math Operation". A new image will appear that is the average of the two original files. Click on "Measure", "Statistics" and "Image". Record the min, max, mean, and standard deviation for this image in your journal.

1) How does the standard deviation compare to your measurement for a single image?
2) How would you expect the standard deviation to behave when averaging multiple images?

Now, we could repeat this averaging routine by hand with all the biases, but there is an easier way. Click "Multi-Image" then "Average Combine", then "Images". A menu will appear listing the available images. Select the original single bias frames. Make sure you do not include the image you created above. When you have your images selected, click "Ok". A new image will appear that is the average of all your single bias images.

1) How does the appearance of this image compare with your single images?
2) Click "Measure", "Statistics" and "Image". Record min, max, mean and standard deviation for this image in your journal. How does the standard deviation compare to your measurement for a single image?
3) How does the standard deviation compare to your measurement for your average of two images?
4) Why?

Repeat the above for the dark frames. To avoid confusion, you may want to close the original single bias frames. Keep your master bias open but do NOT include it in your averaged darks. Record your answers/observations in your journal.

1) How does the mean value for the "master" dark compare with the mean value for the "master" bias? Consider what you know about bias and dark images, and present a theory to explain the differences.

Now, subtract the "master" bias from the "master" dark. To do this, click "Multi-Image",

"Image Math". Select the master dark as frame A, select "minus" as your operation, and then the master bias as frame B. What you have left is just the "thermal noise" of the CCD. This image is called the "master thermal" image.

1) Click "Measure", "Statistics" and "Image". Record the information about this image in your journal.
2) How does the mean value for this image compare with the mean value for the master bias and the master dark?
3) What is thermal noise? How does this agree with your theory presented above?

You can close all the single biases and single dark frames to avoid confusion. Open a single flat image.

1) Click "Measure", "Statistics" and "Image". Record the information about this image in your journal.
2) How does the appearance of this image compare with the biases and the darks?
3) How does the mean value compare the mean of the biases and the darks?
4) Create a "master" flat by averaging all of the individual images for the same filter. (should be 15-20 individual images). It is very important that you use only those flats taking with the SAME FILTER.
5) Click "Measure", "Statistics" and "Image". Record the information about this average flat in your journal.
6) What is the mean for your flat image?
7) The CCD has 16 bit electronics, which means the voltages from each pixel can be converted to maximum value of 65536 (2^{16}). The CCD is not sensitive to increased brightness beyond that limit. Flat images should be exposed long enough to have a signal about half this value. Does the mean for your single flat meet this requirement?
8) How do the master flat's statistics compare with the statistics for the master dark and master bias images?
9) Now, subtract the master bias and the thermal frame from the master flat.
10) Click "Measure", "Statistics" and "Image". Record the information about this image in your journal. How do the statistics compare with the statistics of the original master flat?

Now you should have a better feel for AIP4WIN. You have begun to work with the bias, dark, and flat images. Bias images are images with zero exposure time so no light hits the chip. CCDs are adjusted to give a nonzero output even when no light hits the chip. Bias images record this "bias level" as well as random noise contributions from the electronics. Dark images are images with a non-zero exposure time, but the shutter remains closed so no light actually hits the detector. Dark frames have two components: the zero-point bias level and a thermal noise signal. The thermal signal accumulates at a rate that depends on the temperature of the detector. Thermal signal should grow linearly with exposure time. The last calibration image is a flat frame, and it is the only calibration frame where the camera shutter is actually opened. Flat images map the relationship between the intensity of the light and the response of each pixel on the detector. We are ready to move on to some actual images analysis!