

# Image Analysis V9

There are a number of ways to analyze your images. The purpose of this exercise is to explore these techniques. Details of calibration and sources of noise can be found in Chapter 6 of Introduction to Astronomical Image Processing for Windows. Everything we will be working with here will not change the actual distribution of pixel values in your images. The next handout will work with processes that do change the pixel distribution.

1. Set up a page in your journal labeled Image Analysis.
  - a. If you are in the computer room at MCAO, images we have taken during class or images from previous observing session can be found in a directory named "classdata". Select a directory containing objects we have observed in class. If it has been cloudy, select an object from any directory in "classdata".
  - b. If you are working at home, download images from the class website. Remember: Use 7-Zip to extract the images from the zip (or tar) file.
  - c. Label a page in your journal "Image Analysis of \_\_\_\_\_" with the name of the object you have chosen. Note the date, time, and CCD temperature of one of the raw object images. This information can be found in the FITS header (under Edit→Fits Header).
2. **CALIBRATION SETUP:** Calibrating images (or any type of measurement) is the process of removing unwanted signals from the observations. For CCD images, we will want to remove the bias signal, remove the thermal noise, and remove any nonuniformities in pixel response. This is done by subtracting the master bias, subtracting the master thermal, and dividing by the master flat (using the appropriate filter). Luckily, we don't have to do this manually. To prepare to calibrate your images, set up the calibration tool (under Calibrate→Setup).
  - a. Change the setting from Basic to Advanced.
  - b. There are 4 tabs in the Calibration Setup window, labeled Bias, Dark, Flat, and Defect. Click the "Bias" tab and select "Use Bias Frame" in the Bias window. Select your bias frames (be sure to use the ones from the proper night. Windows sometimes goes off to random directories). Leave "average" as the default, then click "Process bias frame". This will create an average of your selected bias images, and store it in a buffer.
  - c. Now click the "Dark" tab at the top of the Setup window. Select your dark frames (again be careful of the directories) and make sure you turn on "Automatic Dark Matching". This will scale your dark image to the exposure time of your object images. Process the dark frames.
  - d. Now click the "Flats" tab.
    - i. First, decide which filter you will be using (b, v, r, and nf). Open the flats from that filter using File- → Open. Inspect the flat images and make a note of those that include bright streaks. You will want to exclude these from your final flat image.

- ii. Back in the Calibration Setup window, select your flat images. If you are using an object with images from multiple filters (b, v, r, and nf) choose only the flats from a single filter. Exclude the flat images with bright streaks that you noted. Make a note of the filter you choose. You will need that information for selecting your object images later. In the “Flats” window, leave the defaults as they are (you do not need to subtract flat-dark) and process the flat image.
  - e. If the images you are using are recent, they were taken with either the Alta or the Aspen camera. Neither camera has large defects, so you are finished setting up the calibration tool. If you are using very old images from the older CCD (Ap7p), you will need to account for a defect. Click the “Defect” tab and “Select Defect Map”. Browse for the file defect1.fts.
  - f. Move the Calibration Setup window off to the side of the AIP4Win window.
3. **CALIBRATING SCIENCE IMAGES** involves removing the bias, thermal, and other sources of noise from each raw image. Luckily we do not need to do this manually.
- a. Click “Multi-Image”, then “Autoprocess”, then “Deep Sky”.
  - b. Click on “Select Images” to choose your science images. Be aware that you must choose images that were taken with the same filter as the flat images you selected in the Calibration tool.
  - c. Once you have selected your images, make sure you check the “calibrate image” box. Make sure you check this box every time you load new images.
  - d. Click the “alignment” tab. Each raw image is a little different because no telescope tracks perfectly. The Alignment function allows you to select a star(s) on a single image as an alignment star(s). As the program goes through each raw image, it will identify this star and shift all the images such that they all line up.
    - i. Select one of your images as the master image (click the arrow to the right of the “Select master frame” window and a list of your raw object images will appear).
    - ii. Select 1 star alignment (if the image is not from the 24 inch telescope, consult with me about what to do).
    - iii. Click on a star in the master frame (use a fairly isolated star not too close to the edge, and not too bright or too dim). Return to the Alignment window and click “star 1”. The circle around the star you selected should turn yellow. The computer will then look for that star in each image, and shift the image accordingly so everything lines up in the final product.
    - iv. Another nice feature is the “Skip frames with elongated stars” button. The program tells you the elongation of your alignment star. Elongation is a measure of how round the star is. 0 is perfectly round, and 1 is a line (not round at all). Change the

elongation limit to a value about twice that given for your alignment star. The program will then monitor the shape of your alignment star (measure pixel width in x and y directions). Any image that exceeds the elongation limit will be skipped.

- v. If your images are recent (after 2022) you will want to change the mode from automatic to manual. The telescope has been jumping around by small amounts in Right Ascension. Images taken during a “jump” contain stars that are either doubled or streaked. Manual mode will allow you to evaluate each image as it is calibrated and skip it if necessary. You may also need to reselect the alignment stars.
- vi. Click “OK” and the program will produce a calibrated averaged image of your object.
- vii. Include a screenshot of your calibrated and stacked image.

#### 4. Working with your Calibrated and Stacked Image

- a. Make sure your calibrated and stacked image is the active window. On the Display Control window, click the tab labeled “Imager”. Unfortunately, neither the Aspen or the Alta cameras are included in the list, so select “unknown”. The relevant information for both the Aspen and the Alta is gain = 1.1, noise=6, and the pixels are 13 microns by 13 microns in size. If the image was taken with the SBig CCD, the pixels are 9 microns by 9 microns, the noise is 15, and the gain is 1. If the image was taken with the Ap7p, the gain is 5, the noise is 10, and the pixels are 24 microns by 24 microns. Click “Set Imager Parameters” to copy the parameters to your image.
- b. The most basic information in any image is the pixel values (PV) of each pixel in the array. This is the number of electrons (or counts) contained in each pixel. The computer interprets these numbers as a shade of gray, and that array produces the visible image. To read the pixel value of a pixel, simply move the cursor to the pixel of interest. The x and y value of each pixel and its pixel value (PV) will appear in the Display Control Window.
- c. Let’s look at the statistics of the entire image. Click on the Measure -> Statistics button. A window appears that gives basic information on your image, including the total number of pixels, the x and y dimension. It gives you statistics for the entire image, and for the central 95% of the image. This allows you to determine if the image is uniform over the entire field.
  - i. Record the image name (give it a sensible name) and the minimum and maximum for the whole image (you can include a screen shot of the Statistics window).
  - ii. The minimum value defines the bottom of the range of pixel values. In a raw image, this should be the bias+thermal noise+background sky (consult your results from the Basic Use of AIP handout for bias+thermal noise). In a calibrated image, it

- should just be the background sky. A minimum of zero is an indicator that something has gone wrong in the calibration.
- iii. The maximum is the top of the range of pixel values found in the image. If the difference between the max and min values is small, the image is very flat, and is probably underexposed. If the maximum is close to the maximum possible value (around 65500), some stars are saturated.
  - iv. What are your maximum and minimum values for your image?
    1. What do your min and max values say about your image?
- d. Record the mean and standard deviation for the central 95% of the image. This information lets you determine whether the image is technically sound (ie nothing wrong with your image).
- i. An image that is M pixels wide by P pixels high will contain a total of MxP pixels. The mean is simply the sum of all the pixel values divided by MxP. This value is usually somewhat greater than the sky background because every pixel is included.
  - ii. The standard deviation is a measure of the distribution of the pixel values from the mean pixel value for the image.
    1. How does your standard deviation compare to your mean value?
    2. Do you think your image has a large deviation?
5. **Record the pixel values for various parts of the image.** Click on Measure→ Star Image Tool. The Star Image Tool window will appear. This tool will measure the statistics of the pixels enclosed in an aperture defining the star and an annulus surrounding the star that defines the local sky. The default is a circle with an inner width of 6 pixels and in outer annulus between 9 and 15 pixels.
- a. Choose 2 bright stars and 2 fainter stars in the image. Place the cursor on the center of each star and left click.
  - b. Set up a table as shown below in your journal. Record the information from the Star Image Tool in the table in the in your journal. (FWHM is “the full width at half maximum brightness” in pixels):

Object	Xc, Yc	FWHM	Peak Pixel Value	Star-Sky	Sky	Width (pixels)	Elongation
Star 1	135, 210	2.2	500	57800	6700	15	0.05
Star 2	245, 90	2.3	700	2600	6700	13	0.01

- c. Click on the “Shape” tab. You will see a graph plotting the PV (red points) versus distance (in pixels, the blue boxes represent pixels) from the center of the star. How wide (in pixels) is the star’s image? Record this information in your table.
- d. Record the elongation (roundness) of the star images. This is the difference between the star’s radius in the x/y axes as well as along the diagonal direction. Small values indicate round stars, larger values (closer to 1) indicate elongated stars. Is your star round?

- e. Click on stars of similar brightness in the corners of the image. What happens to the elongation of the star? What do you think is causing this?
- f. Stars come in all brightnesses. What do you think should happen to the radii of stars as they increase in brightness?
  - i. What do your measurements say actually does happen?
- g. What happens to the sky values as the stars get brighter? What do you think should happen?
- h. Looking at your numbers for Star-Sky and Sky, what is the ratio of star to sky for each star  $((\text{Star-Sky})/\text{Sky})$ ? This is a rough estimate of the signal to noise ratio. If this ratio is above 4, there is a 99.9% chance that the star is real, and not some random fluctuation in the background noise.

#### 6. **Image Histogram.**

- a. Click on the Measure -> Histogram button. A histogram is an inventory of pixel values found in an image. It plots the pixel values on the x axis and the number of pixels with each pixel value on the y axis (this is usually logarithmic). The distribution of pixel values reveals a great deal about any image. One way to think about it is that the darker parts of the image is represented on the left of the graph, and the brighter parts on the right. There is a lot of information in this histogram.
- b. Include a screen shot of your histogram in your report.
- c. Move the cursor through the histogram to answer the next questions.
- d. What is the pixel value of the highest peak in your histogram?
  - i. How many pixels have this value?
  - ii. What do you think this represents in your image?
- e. Change the scale to 0 and 65535.
  - i. How would you identify saturated stars in an image?
  - ii. Are there any saturated stars in this image?
- f. Based on the above, describe what you think the the histogram says about this image.
- g. Open one of the raw science images and repeat the histogram measurement. How does this histogram differ from the histogram of your calibrated image?
- h. Create a histogram of your average bias frame.
  - i. You can create the average bias frame by clicking on Multi-Image- → Average Combine- → Files and then selecting your bias frame.
  - ii. Once you have your averaged bias, click on Measure- → Histogram. Makes sure your average bias is the active image.
  - iii. What is bias?
  - iv. Given this definition, what do you think the distribution of pixels should look like?
  - v. Does your histogram agree with this?
  - vi. Include a labeled screen shot of your bias frame and its histogram.
- i. Create a histogram of your master dark frame.

- i. You can create the average dark frame by clicking on Multi-Image- → Average Combine- → Files and then selecting your dark frame.
      - ii. What is dark (or thermal) noise?
      - iii. Given this definition, what should the distribution of pixel values look like?
      - iv. Does your histogram agree with this?
      - v. What do you think the few outlying pixels are?
      - vi. Include a labeled screen shot of your dark frame and its histogram.
    - j. Create a histogram of your average flat frame.
      - i. You can create the average flat frame by clicking on Multi-Image- → Average Combine- → Files and then selecting your flat frame (one filter only).
      - ii. In one sentence, describe the procedure for creating a flat field image.
      - iii. What is the purpose of a flat field?
      - iv. Given this definition, what should the distribution of pixel values look like?
      - v. Does your histogram agree with this?
      - vi. Include a screen shot of your flat and its histogram
7. The dynamic range of an astronomical image is sometimes very large (there are very faint things and very bright thing in the same image). The Profile tool examines slices of the image, sometimes revealing stars and structure that are not readily apparent in the image itself.
- a. Go back to your calibrated image. Click on the Measure -> Profile Tool. Click on your calibrated image, hold the mouse button down, move the mouse across the image, and then release the mouse button. A plot of the relative pixel values across the line you selected will appear in the Profile tool window. This plot line represents that slice through the image. In general, stars are represented by narrow peaks, and objects such as galaxies and nebula are more extended and can show detailed structure. You can change the scale by switching between “Black/White” (which uses 0 and 65535 to determine the scale) and “Auto Min/Max” which uses the min and max values to determine the scale.
  - b. Experiment with 5 different slices. For each slice record the following:
    - i. How do stars appear in the Profile tool?
    - ii. Do you see any detailed structure from any nebula or galaxies?
    - iii. If your image contains an object such as a nebula or a galaxy, draw lines at different locations and describe the structure you find.
  - c. Include a screen shot of your image and profile for an interesting location.
8. Go back to your calibrated image. Click on the Measure -> Distance Tool. You can use this to measure the separation (in pixels, microns, and arc seconds)

between objects in your image. The focal length of the telescope is 4200 mm. Click “New Stars”.

- a. Click on a star near the center of your image, then click “set” star 1 for star 1. Repeat a nearby star for star two. Record your results in your journal.
- b. Repeat for a star near the left and right edges of the image. What is the field of view of the image (in pixels and arc seconds)? Arc seconds are a fraction of a degree (1 degree = 60 minutes = 3600 arcseconds)

Object	Dist. Pixels	Dist Microns	Dist Arcsec	PA
Star 1 x,y				
Star 2, x,y				