v. 9, Aug. 14, 09

Astro 103/104 lab **Name: ____________** **Date:** ___/__/200_ **Sec.** __

Image Processing

(Note: Do not use the steps in this lab to process your images later in the semester. Instead, follow Chapter 7 of the booklet.)

This is a rainy-day laboratory, which can be done independently of any future image taking. The resulting color images are pretty enough, and the concepts learned in the process are interesting and useful by themselves. They are also relevant to regular digital photography.

The lab needs Windows personal computers with CCDOPS (v. 5.41B6 or later) installed. Two students may work together on one computer. In case it is done as a take-home lab, students may install CCDOPS on their own computer (note that the drivers need not be installed). The program is included in the CD with the lab materials, and it can be installed for free.

Exercise 1: Preparation.

A day ***before*** lab time, read Sections 1, 2 and 5 of the booklet entitled "Image taking with a CCD camera" ***Be prepared*** to answer a few of the review questions in 5-10 minutes as a ***test in the beginning of the laboratory***. If you have any trouble understanding any of these questions, be sure to seek help ***before*** lab time.

You will need to organize your work neatly on the computer. Please **follow the steps and conventions** below to avoid confusion with other people's work.

On the computers in the lab, you must be running Windows XP. If the computer is running as a Mac, restart it while holding down the *Option* key until you are given a choice to start it up as Windows. Log in as *Student*. (After finishing, restart the computer in Mac!)

The materials for the lab are in the AstroLab/Image Processing Lab folder on the desktop. However, make sure you do not make any changes there! Instead, open TemporaryStudentWork and make a new folder inside it with your names (call it something like *JohnDoeAndJaneDoe*), and copy the *RawImages* folder into it by CTRL-dragging. You'll be working on this copy, which makes sure that you do not destroy the originals.

If you are doing this lab on another Windows computer, you might need to install CCDops from the CD (the installer is called *InstOps.exe*), and copy the folder *RawImages* from the CD.

Exercise 2: Understand parameters and the crosshair

Start CCDOPS on the computer by clicking its icon on the taskbar. (The icon looks like a CCD camera with a little red cross.) Whenever you want to open a file in CCDOPS, use File➔Open and *never double-click on the file icon!* There are many programs that can edit pictures and the computer may well open your pictures with the wrong program.

Open the file called *ContrastExcercise.fit*. As you open an image in CCDOPS, you will first see a list of the parameters of the image. Click in the middle of the panel to see the image. You can always look at these parameters again, by choosing Display➔Parameters (try it out now!) Also, look at Display➔Modifications. You'll see what was done to the image previously. This image has been modified by: ____________(*fill in*).

Now bring up the crosshair by choosing Display➔Crosshair. Set the contrast at black point ("BACK") *400*, range *100* (that gives you a *white point = black point + range = 500*). The image is all white now, because almost all the pixels are brighter than *500* (check this fact by clicking at a few points in the image and reading off the pixel "Value" from the crosshair tab ("XHAIR"). A few readings are: ___,___,___,___. Are they over 500?________

Bring up the black point by keeping down the up arrow on the CONTRAST tab, all the way to about *800*. You will see, at each stage, that the outer regions of the nebula become dark (the pixel values in these regions become smaller than your black point), while the middle of the Orion Nebula is still all white (the pixel values there are still larger than your white point). Verify, by clicking at a few points and reading the pixel values from the crosshair, that the pixel values on the dark parts are smaller than your black point; on the white parts they are larger. Readings in the dark parts: ___,___,___; are these numbers less than the black point?________ Readings in the white parts: ___,___,___; are these numbers more than the white point?________

This situation is called CLIPPING. The all-white pixels are white-clipped; the all-black pixels are black-clipped. In both cases, no detail whatsoever can be made out. The correct way to present an image is to avoid clipping, and have (preferably) all pixel values fit in the range between the black point and the white point, when they will be in various shades of grey. This is achieved by raising the RANGE value. Try now range values *1000*, *3000* and *10000*. Each setting will show best a different part of the nebula. Do you see that there is a lot more on the image that the computer monitor can show? It takes some sophisticated doctoring (with Photoshop) to present all parts of a dynamic image at the same time.

Now explain, in a few words, what you learned from the above exercise. Include the meaning of *black point*, *white point*, *clipping*. Be specific.

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Now set the black point to *400* and the range to *400* again. You will observe that there is noise in the background. Click on this noisy part of the image, and read off the background haze ("AVGVAL") and the noise from the crosshair tab ("XHAIR"). Move the cursor around, click in a few places, and pick a characteristic value: *background* = _______, *noise* = _______. This background value is above your *black point* (>400), so it is not completely black, but it is much lower than your *white point* (<<800), so it is dark gray.

Now raise the *black point*. When the *black point* is equal to the background, the haze starts to vanish. However, as you continue raising the *black point*, you'll see that some of the nebula gets eaten away. You need a compromise where the background is invisible, but very little of the nebula is gone. Find this compromise: *black point*=_________.

You see that much of the nebula is all white. Move the cursor inside the nebula, and click in a few places. The VALUE of the pixels you click on varies, but all the pixels look the same white. All the pixel values are more than the *white point* (which is around *1000* now), so you have all the nebula clipped. In order to see it all, start raising the RANGE now. As the *white point* raises, more and more of the nebula changes from all white to various shades of gray, and the details become visible. However, the Orion Nebula has such a huge dynamic range that by the time you raise the white point enough to remove all the clipping, the faint part of the glow becomes all but invisible. In fact, the computer screen is not *deep* enough to adequately show this nebula. Only sophisticated image processing software, such as Photoshop, can make all its the parts visible at the same time. We must, for now, be satisfied with a compromise that keeps most of the faint glow but leaves only the middle of the image clipped. The best compromise you could find was RANGE=__________ and *black point* = _______, i.e. *white point* = ___________.

Make sure now that you understand all this: now you know how to read the value of any pixel on an image (use the crosshair, click, read VALUE), you know that *white point* = *black point* + RANGE, you know that a pixel whose VALUE is less than the *black point* looks black (it is *cut*), a pixel whose VALUE is more than the *white point* looks white (it is *clipped*), and a pixel whose VALUE is between the *black point* and the *white point* look some shade of gray (it is *visible*).

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The basic steps of image processing are (it this order!): dark subtraction, flat fielding, removal of damaged pixels (hot or cold), alignment, combining of images with the same color, sharpening and/or blurring, color composition and scaling. We'll learn about some of these steps now. We will go through the processing of a set of images that were taken with the fit camera on a 12-inch Meade telescope.

Exercise 3: Dark subtraction

In the *RawImages* folder you will find a set of raw images taken with red, blue or green filters. Open all the six light images, one by one, in CCDOPS, and note the exposure time, image size, and CCD temperature of each one. Do the same with the two dark frames found in the same folder.

Filename	Filter	Exposure	Size	Temperature
________.fit	red	____ sec	___ x ___	____ ^{0}C
________.fit	green	____ sec	___ x ___	____ ^{0}C
________.fit	blue	____ sec	___ x ___	____ ^{0}C
________.fit	blue	____ sec	___ x ___	____ ^{0}C
________.fit	blue	____ sec	___ x ___	____ ^{0}C
________.fit	blue	____ sec	___ x ___	____ ^{0}C
________.fit	(dark frame)	____ sec	___ x ___	____ ^{0}C
________.fit	(dark frame)	____ sec	___ x ___	____ ^{0}C
________.fit	(dark frame)	____ sec	___ x ___	____ ^{0}C
________.fit	(dark frame)	____ sec	___ x ___	____ ^{0}C

Notice how noisy the images are. Notice also that the noise pattern on the light images tends to follow the noise pattern on the dark frames. Consequently, if you subtract *(light image) - (dark frame) = (resulting image),* much of the noise will be canceled. Do this with each image: click on one of the images to select it, choose Utility➔Dark Subtract, and choose the appropriate dark frame's name. You must use a dark frame with the same exposure time, size and temperature as your light image (when asked, use the STANDARD method). Much of the noise vanishes, but the object is still invisible because the black and white points are not optimized. Change the contrast settings to make the image look best. (A good way to start is to click on the AUTO button on the CONTRAST panel.) Save your image with a letter D added to its name (CrabBlue1.fit□CrabBlue1D.fit, for example). *Make sure* *you save into your own folder!* Did your images get much better? Subtract the appropriate dark from all the six of your images, and then look at Display➔Modifications for a double check. Close the files; you should now possess six ***D.fit files.

To see what happens if you subtract a dark with the wrong exposure or temperature, try it once, but *do not save* your resulting image. Describe what happened: *I subtracted from the light image called _________ (t=______sec) a dark frame with the wrong t=______sec. I found that* ____.
Close all files again.

Exercise 4: Flat fielding

The second step in image processing will be flat fielding. Notice the dust shadows and the uneven illumination on your images. Now open the three flat frames, which are images of the daylight clear sky. Notice that the dirt and the unevenness follow the same pattern on the light frames and on the flat frames. Consequently, if you divide, pixel by pixel, *(light image) / (dark frame) = (resulting image),* much of the unevenness will be canceled. Do this with each image: open each ***D.fit file, choose Utility➔Flat Field, choose the appropriate flat frame's name. You must use a flat frame taken with the same color filter, but you do not need the same temperature or exposure time. (There can be dust particles on the color filters; this is the reason why you need to use a flat taken in the same color.) Check the Modifications tab: flat fielding has now been added to the list.

Change the contrast settings to make the image look best. Save your image with a letter F added to its name (as in CrabBlue1D.fit➔CrabBlue1DF.fit). *Make sure you save into your own folder!* Did your images get better?

Exercise 5: Hot and cool pixel removal

Out of the 300,000 detectors (one for each pixel), some are always defective. These pixels will be very bright ("*hot*"), or very dark ("*cold*"). It is simple to remove these defects with software. Use Utility➔Filter Utilities➔Kill Warm Pixels (and also Remove Cool Pixels).You'll need to set the strength of the filter. Because only trial and error tells you the correct strength, you'll need to try all three. Each time, try and do not save but reopen the original image, until you are sure which strength you want to choose. When you are sure, save your image with a letter K added to its name (for example, save it as CrabBlue1DF.fit➔CrabBlue1DFK.fit). *Make sure you save into your own folder!* Did the noise get significantly reduced? Now close all your images.

Exercise 6: Combining images

At this point a few more advanced steps are usually done that we ignore in this laboratory. The images need to be aligned (aligning is awkward in CCDOPS, it is much easier in CCDSOFT); then sharpening may be applied to reduce the size of the stars (a piece of software called CCDSHARP can be used for that). The raw images we use have actually been aligned already. Keep in mind that when it comes to your semester project, and you want an impressive picture to reward your efforts, you will have to include these steps.

You want to co-add all images taken with the same color filter. For example, four blue images with $t = 15\ min$ each, when co-added together, will result in a blue image as good as one with $t = 60\ min$. The only reason they were taken in pieces is that without a very expensive mount it is almost impossible to guide for more than a quarter of an hour at a time. Of course you do *not* want to co-add images taken in different colors, because then you would lose all your color information.

The co-adding procedure is very simple. Open the first image to co-add, and choose Utility➔Co-Add, and choose the second image. You can co-add more images in the same way (you can ignore the offset and pedestal facility, just set all numbers to zero). You may only need to keep adjusting the contrast each time. Do ***not*** save the result without changing the name!

Co-add the four blue images now. Do you see that the noise in the images is significantly reduced now? Save your result as ***BlueDF.fit. What modifications are indicated in this image now? ____

Exercise 7: Color composition with CCDOPS and saving in tiff.

Finally you have three images, one each in red, green, and blue. These will be combined into one color image. CCDOPS includes a simple color composition facility. It is not very sophisticated, but it is good enough to roughly understand the essentials. In the semester project, you will use Photoshop CS for more professional results.

In order to have the color image right, first you have to adjust the contrast settings of each of the three component images. Do this *very carefully*, and make sure your *black point* is just high enough to remove all background but leave the object's faintest parts still visible. The range should be low enough to keep all the tiny details visible, while high enough to avoid clipping of even the bright parts of the object. You may need a few adjustments to have both settings as good as possible. You want an image with as much detail visible as possible. At this point save the images with the adjusted contrast settings, and fill out the table.

I found that the following settings produced the prettiest component images:

Filename	Filter	Black point	Range
________.fit	red		
________.fit	green		
________.fit	blue		

Now you are ready for color composition. Choose Utility➔RGB Combine, and set the name of your three images. Use the default settings first. If you were careful enough with the range settings in the components, you should have a decent color picture.

You may tweak your picture a bit by changing the "FACTORS" a little. Simply try what works best for you. However, if your images miss significant detail, either because they are too dark or too bright, or you have significant background haze, you'll have to go back to the previous step and set the contrast in each component again. Save and close them, and do the color composition again.

When you feel you are satisfied with your image, save it as "***.tif" (take care of the extension!), in TIF format. This is a lossless image format, and all picture viewer programs will understand it. Send a copy to your own email address, or you may ask your instructor to have it printed out for you. Compare it to the image called "Solution.tif".

Make sure to restart the computers so they automatically return to Mac.