

Astro 103/104 lab Name: \_\_\_\_\_ Date: \_\_\_/\_\_\_/200\_ Sec. \_\_\_

## Advanced Image Processing

This laboratory introduces students to techniques that they need to use in the image processing part of their semester project. A word of caution: in a real-life project the skills learned here must be used intelligently (change what needs to be changed), and it should not be followed blindly and without thinking.

Steps (1-a) through (2-c) of this lab needs Windows personal computers with CCDOPS installed (free software), and Step (2-b) needs CCDSOFT; (3-a) though (4b) can be done on either Windows or Mac, and requires Adobe Photoshop.

It is necessary that students attempting this lab *have done and remember* the Introductory Image Processing Laboratory. If considerable time has passed since doing the introductory lab, additional review will be required.

### Exercise 1: Preparation.

It is necessary to re-read, the day *before* lab time, Sections 1, 2 and 5 of the booklet entitled “Image taking with a CCD camera”.

Your work will be complex enough, so you will need to organize your work neatly on the computer. Please **follow the steps and conventions** below to avoid confusion. Be especially adamant in using the folder locations and names as suggested; otherwise it will be impossible to locate your work (and you may receive no credit at all). Disorganized work invariably leads to confusion and as a consequence you will be unable to finish this lab in the available two hours.

On the computers in the lab, you must be running Windows. 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 *AstroLabs/Advanced 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 *last* names (call it something like *DoeAndDoe*), and copy the *01Originals*, *07Emergency*, *Darks* and *Flats* folders into it by CTRL-dragging. You’ll be working on this copy, which makes sure that you do not destroy the originals.

The first several steps in image processing, called Steps (1) here, are fairly standard, essential the same for any type of astronomical imaging. These steps are done on all images taken with the *same* filter (red, green, blue, or any other); these images are all combined into one image. This way, the result is *one image* with each filter (i.e. each color). These steps are best done with software specialized for astronomical image processing, such as CCDOPS and CCDSSOFT. These and the further steps are, in this order:

- (1-a) Dark subtraction
- (1-b) Flat fielding
- (1-c) Removal of blooming streaks
- (1-d) Hot and cold pixel removal
- (1-e) Median filtering
- (1-f) Assessing the quality of each image and dropping the bad ones
- (2-a) Aligning multiple images
- (2-b) Combining
- (2-c) Removing image gradient
- (3-a) Converting to Photoshop, cutting the background, color composition
- (3-b) Balancing the colors
- (3-c) Contrast adjustment
- (4-a) Resizing, cropping and converting to .png format
- (4-b) Uploading your files.

### Exercise 1: Single image reduction

Perform steps (1-a) through (1-g) on each image separately. You should already know how to do these steps; however here are a few pointers to speed up this process.

Start CCDOPS on the computer by clicking its icon  on the taskbar. Recall that whenever you want to open a file in CCDOPS, drag the file icon(s) onto the CCDOPS panel and *never double-click on the file icon!*

Open each dark frame, and fill in the table to make it easy to select which one(s) to use.

Name	Exposure time	Temperature

**(1a)** Make a copy of your *01Originals* folder by control-dragging and dropping its icon; rename the copy *02DarkSubtracted*. Dark subtract each image in it, and re-save each resulting image.

**(1b)** Next, open each frame in the *Flats* folder. Some of the flat frames are damaged, over-exposed (use the crosshair: pixel readings over 40,000 is too much) or under-exposed (pixel readings under 10,000 is too little in a flat frame). Which ones will you use?

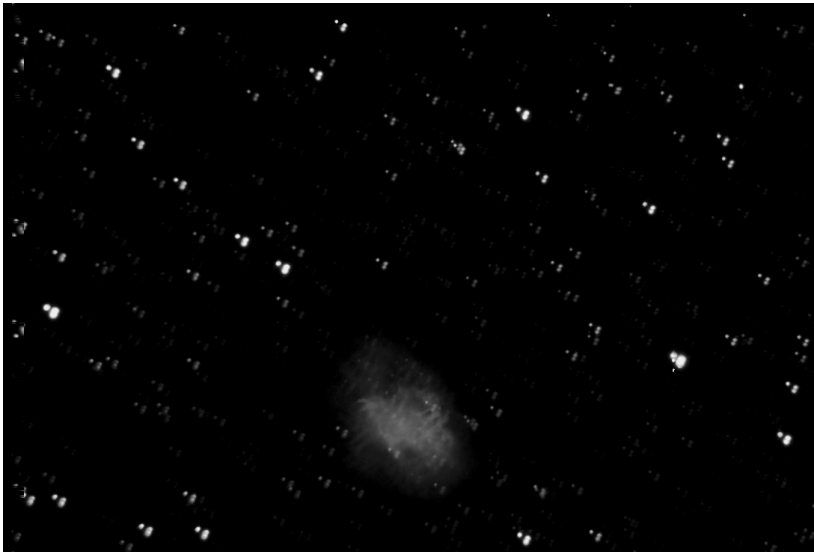
Red	Green	Blue

Again, make a copy of your *02DarkSubtracted* folder by control-dragging and dropping its icon; rename the copy *03FlatFielded*. Flat field each image in it, and re-save each resulting image.

**(1c-1d-1e)** Next, make a copy of *03FlatFielded* and rename it *04PixelsFixed*. Then, you'll make some 'filtering' on each image. The necessary utilities are located under UTILITIES→FILTER UTILITIES. First, use the FIX BLOOMING STREAKS filter (this will affect only very bright stars and may not do an obvious change on each image; do it anyway), then use the KILL WARM PIXELS (strong) filter, then the REMOVE COLD PIXELS (medium) filter, and use the MEDIAN FILTER and save. Observe the change each time, pressing the AUTO button on the CONTRAST panel. Finally, check DISPLAY→MODIFICATIONS that it shows the above operations in the right order and each operation only once; otherwise you have made a mistake.



### Exercise 2: Combination of multiple images

**(2-a)** When you have more than one image taken with the same color filter, you have to align the images, otherwise each star will 'become a double' when the images are combined. Unless the camera has been turned between taking the images, this alignment involves only shifting the images, and that can be most effectively done with CCDSOFT. Follow the procedure exactly, because an ineffective organization of your work will make our job extremely tedious.



**Figure 1:**

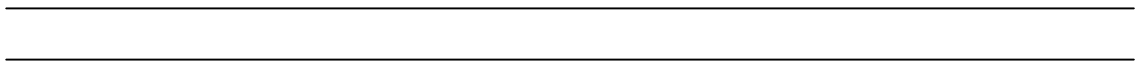
**Bad alignment results in multiple pictures of each star.**

Make a copy of your *04PixelsFixed* folder by control-dragging and dropping its icon; rename the copy *05Aligned*. Start CCDSOFT by clicking on its icon  in the taskbar; its panel opens. Now, open the *05Aligned* folder, select all the files in it, and drag-and-drop them onto the CCDSOFT panel. Select the align tool  and mark the same star on each image by clicking on it. This star must be reasonably bright, but *should not be clipped* in its center (i.e. not too bright), otherwise the software will not find its centroid correctly. Once you have marked one star on each image, perform the alignment by IMAGE→ALIGN→ALIGN CENTROIDS. Now you have the images all aligned. The easy way to save them now is ALIGN→CLOSE ALL and answer *yes* to save each file.

Notice that, instead of the procedure here, you could have aligned the images in the *04PixelsFixed* folder directly, but saving them under a new name in a new folder would have been a very tedious job.

**(2-b)** The next job is to combine the images taken with the same color filter. The following comments are in order:

- (i) These images are all in black-and-white, so combining images with different filters would be wrong: it would mean losing the color altogether.
- (ii) The simplest way to combine the images would be to co-add them in CCDOPS. However, doing that would lead to clipping the bright stars. Think this over and explain why with an example of pixel numbers:



Use CCDOPS's AVERAGE IMAGES utility to perform the averaging. Do not use any offsets. Note that when you have finished selecting all the files that are to be averaged, you'll need to hit CANCEL; this will *not* cancel the averaging but rather perform it. (You may want to show your images in *1:1 magnification* and with *Auto-contrast*.) Save the images in the *06Combined* folder as *M1\_Blue.fit*, *M1\_Green.fit*, and *M1\_Red.fit*.

**(2-c)** A careful examination of these three images reveals a *gradient* in each of your three images; it is especially bad in the green image. A gradient is the result of an uneven illumination of the background sky by streetlights: this is why it is strongest in green. Open your three images and *enhance the contrast* in each by setting the RANGE parameter to, say, 50; adjust the BLACK point so that the background is grey (neither black nor white). Now the gradient is obvious in each image.

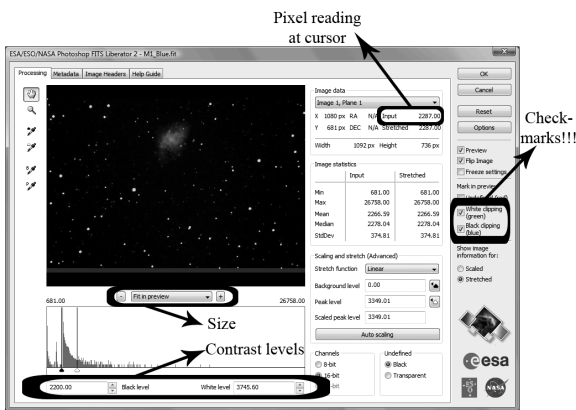
You'll find the REMOVE GRADIENT tool under UTILITIES→PIXEL UTILITIES. Before using it close your images (don't save), make a copy of your *06Combined* folder by control-dragging; rename the copy *07GradientRemoved*. Open the three files in it with CCDOPS, and start the REMOVE GRADIENT tool. You'll also need the crosshair. Select three points close to three corners of the image, making sure that each of these points is *pure background* not part of a nebula, nor a star. Use the crosshair to make sure of that. Now, perform the gradient removal, and check your work: set the RANGE parameter to about 50, and again adjust the black point. If you are not satisfied with the result, you can UNDO the operation, and select different points. You may need a few tries to get it right. When done, hit AUTO-contrast and save the three files.

### Exercise 3: Background cutting, color composition, balance, and image size

This part of the laboratory is where you learn the most important, and new, skills in image processing. Pay particularly careful attention to this part.

There may be students who have not managed to prepare a good quality set of three images in their *07GradientRemoved* folder, or ran out of time. To make sure everyone has a shot at Exercise 3, we made a *07\_Emergency* folder with the three images already prepared. Compare your images in your *07GradientRemoved* folder to these. In case your images are bad, or you ran out of time, use the *07\_Emergency* version instead. (This will result in loss of credit; but it is still better than not do Exercise 3 at all.)

**(3-a) Convert to Photoshop, cut background, compose colors.** Open your three images in Adobe Photoshop. (Right click on the file icon, use *Open With*, and chose Photoshop.) Normally Photoshop cannot open *.fits* files, but we have installed a plugin, written by the Space Telescope Institute, called FITS LIBERATOR 2.3, which converts files from *.fits* format to Photoshop's *.psd* format.



We also use Liberator to cut the background on each image. Please make sure that, on the Liberator panel, *White clipping (green)* and *Black clipping (blue)* are checked. You will see all pixels that your black-point and white-point settings cut away, in obvious blue or green. Walk around with the cursor and observe the *Input* number change. This background is mainly due to streetlights, and has to be removed. You must set the black level to a number that only leaves a few blue (black-clipped) pixels. (Use 100% size.) Set the white point at 40,000 plus your black point, and click OK.

You will notice that the background is quite uneven. This is because we are taking our images on campus, and streetlights shine unevenly into the telescope. In good quality astrophotography, which is possible only in complete darkness, the background should be (almost) completely flat. This makes it hard to pick the correct background cut. As a hint, a good background cut on the *07\_Emergency/ M1\_Green.fit* version image is 2890.

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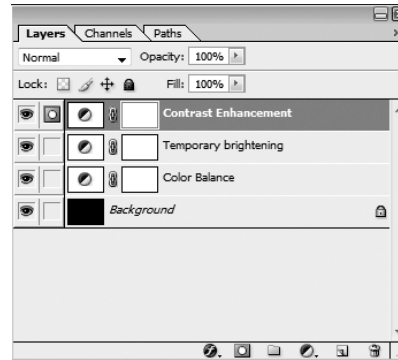
Name	Black point	White point
<i>M1_Blue.fit</i>		



Open all three of your images. Record the black and white points you used. Do not worry that the image is very dark and the nebula vanished; it is in fact there, only invisible with the current contrast settings.

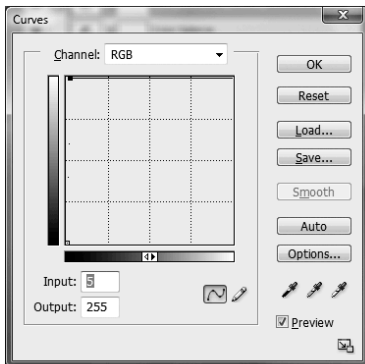
Now you merge the channels to form an RGB colored image. Bring up the CHANNELS palette (use WINDOW→CHANNEL if needed) and click MERGE CHANNEL. (It is hidden behind the double arrow on the CHANNELS palette, see the picture.) Select RGB and match the filenames. When prompted, do not save the *fits* files, but save (use SAVE AS) the resulting color image as *CrabYourNames01.psd* in Photoshop format in a new folder *08\_Color*. Make sure you navigate to *your own folder and do not save into somebody else's area!*

**(3-b) Balance the colors.** Make sure 100% size. (The size is in the bottom left Photohshop window; click it to change.) the LAYERS palette and insert three curves LAYER→NEW ADJUSTMENT LAYER→CURVES for *Color balance*, *Temporary brightening*, *Enhancement*, in this order, but do not the curves as yet. The LAYERS palette should picture indicates.

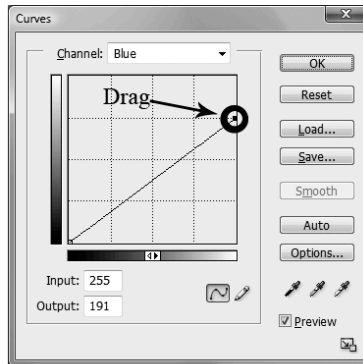


your image is corner of the Click F7 to show layer. Use this, name them *Contrast* actually modify look like the

Select the *Temporary brightening* layer, and brighten up the image using



The curve to modify the *Temporary brightening* layer.



The curve to modify the *Color balance* layer.

LAYER→CHANGE LAYER CONTENT→CURVES; use an RGB curve as indicated on the picture. This enhances the dim pixels, but clips bright ones. You'll notice that color has not been fully balanced. It is impossible to predict, due to changes in atmospheric extinction, which color needs to be enhanced or suppressed. Next, select the *Color balance* layer, and change all the three of red, green, and blue curves as indicated. Doing so will

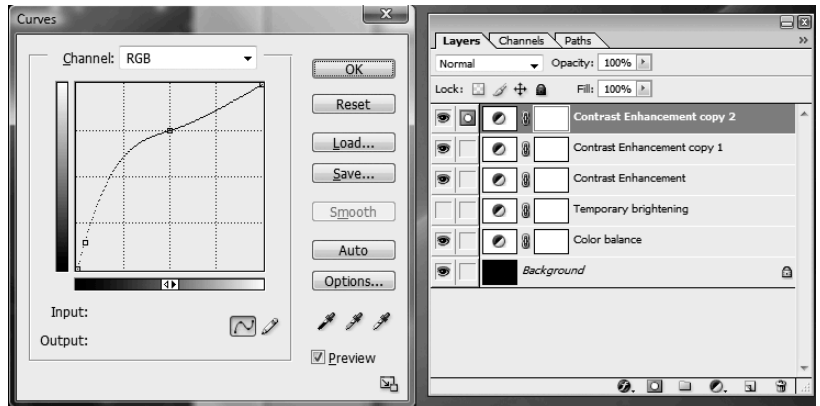
allow you to suppress or enhance each color without causing additional clipping. Save your image, using FILE→SAVE AS, under the name *CrabYourNames02.psd*.

Now you are ready to balance the colors. Modify the *Color balance* layer again, and *drag up and down* the dots at the right end of the red, green, and blue curves. (We circled this dot on the picture of the blue channel.) Make sure the input is always at 255; the output will be changing. Your aim is to make the average star white with a hint of orange on the image. Note that the center of bright stars is always white, but this is not real: it is only the result of clipping. Make sure that the average *dim star* becomes white with a hint of orange color. When you are satisfied with the color of your stars, save the image as *CrabYourNames03.psd*.

**(3-c) Adjust the contrast.** In order to enhance the nebula we must enhance the dim pixels on the image. You have probably noticed already that it is impossible to enhance the contrast without clipping the middle of the bright stars. On your image right now, the nebula is bright, but the center of most stars has lost its true color and became pure white. This is an artifact of the curve on the *Temporary brightening* layer.

The problem is that on the *Temporary brightening* layer we used only linear scaling (a *straight* ‘curve’). This was necessary; nonlinear scaling would have hopelessly confused the colors. Now, we can address this problem and add nonlinear scaling. It must be applied after colors have been balanced: the *Contrast Enhancement*, layer that does it must be above the *Color balance* layer.

So now, switch off the *Temporary brightening* layer (click on the ‘eye’ on the LAYERS palette). The image becomes very dark. Now modify the *Contrast Enhancement* layer, do not touch the individual color channels, work only on the RGB. Your mileage may vary, but in one trial we found the best result with a curve in the picture, but we have duplicated the curve layer twice. This procedure may involve some trial and error.




Once you are satisfied, save the image as *CrabYourNames04.psd*.

#### Exercise 4: The final touches

By now you should have a decent-looking color image. However, it is not ready for publication yet. For one, look at the size of your image file; its size is \_\_\_\_\_ Mbytes. This is too big to send in an email or put on the internet. Look at your image carefully now. You see that the image is blurred, and stars blobs that are much larger than one or two pixels in size. It makes sense to resize the image, make it smaller. At the same time, the edges of the image are bad due to the alignment process. To see this, make the *Temporary brightening* layer visible again.

##### (4-a) Crop, resize and re-format.

To remedy both of these issues, use the CROP utility (click the  button on the toolbar). Type *800 px* and *500 px* into the width and height boxes – that will be the size of your resized and cropped image. Now, drag a rectangle across your picture, but be sure to leave out the bad edges. Try, as much as possible, to center the nebula so you get a pleasing picture. Click the checkmark to accept the crop, then make the *Temporary brightening* layer invisible. Save your file as *CrabYourNames05.psd*. Now, the file size became \_\_\_\_\_ Mbytes.

If you wish, you may use the CLONE STAMP utility () on the *Background* layer to doctor out minor smudges from the picture.

This file is in Photoshop format (*.psd*), and most computers (and printers) cannot directly print it. The standard picture format on the internet, as well as the format for insertion into a Microsoft Word document, is 24-bit *.png*. (The primitive and lossy *.jpg* is used only when quality is not an issue.) You can convert your file into a *.png* file using FILE→SAVE FOR THE WEB. Be sure to select the PNG-24 format, and check that you are saving in your own folder.

**(4-b) Upload your files.** Your instructor will grade work the you place on the **server**, not on the individual computers. Click on the SERVER icon on the desktop and navigate to *StudentsWorkArea*, and the proper semester's folder inside it. Drag the whole folder named with your last names (like *DoeAndDoe*, remember?) into the server folder so it gets copied. Your instructor will be looking especially at the three files in the *07GradientRemoved* folder, and the files *08Color/CrabYourNames05.psd*, *08Color/CrabYourNames05.png*.

Look at the solution file in the *AstroLab/Advanced Image Processing Lab* folder.

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