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Date _____

Lab Partner(s) _____

Project Score

TRI-COLOR IMAGING

From: *Imaging the Universe - A Laboratory Manual for Introductory Astronomy*, R. Mutel et. al.

PROJECT LEVEL: Introductory

PROJECT GOALS: The student will learn how to use an image processing program to combine filtered monochrome images in order to make a true-color image. Topics discussed are synchrotron radiation, chromatic filters (C,R,B,V), and spectral line emission

IMAGE DIRECTORY/LIST: proj-05_Tri_Color: chapel-[rgb].jpg, crab-[rgb].fts, m27-[rgb].fts

1 INTRODUCTION

This laboratory exercise demonstrates how color images are produced not only in astronomical imaging, but in everyday applications such as television. You will use filtered **MONOCHROME** CCD images of the **CRAB NEBULA** (M1), the **DUMBBELL NEBULA** (M27), and a building on campus to make true-color images from grey-scale filtered images.

1.1 USING FILTERS

To most people, color images are the most interesting to look at, but at the low-light levels prevalent to most visual astronomy, images seem to be grayscale because the light levels are not high enough to stimulate the cones in the human eye. The cones are responsible for color vision, while the rods are responsible for monochromatic, but are sensitive to lower light levels. Varying wavelengths of light will stimulate the cones in different combinations to produce the color vision we are used to. CCD cameras do not have the same limitations that the human eye has, however, and are able to “see” colored light at levels that a human cannot. However, the images taken, even without a **FILTER**, contain only shades of gray. How can astronomers produce such stunning astronomical images as appear in magazines and other journals? Filters exist that can be put in between the camera and the telescope that enable images to be taken that will only allow light of a certain range of colors through. These filters range from the infrared to the ultraviolet, although the visually colored filters are the most important for making color images. The filters most used for color processing are the red, blue, and visual (green) filters while the clear filter image is used for more advanced image processing. These filters are used because they correspond exactly to the cones that process color in the human eye. A fine example of combining R, G,

and B filtered images to produce a true color picture of an astronomical object (the Crab supernova remnant discussed below) is shown in the figure on page 5.

This sort of processing is used by most people every day, without even knowing it. It is known as **RGB PROCESSING**. Every television set reproduces an image using signals sent with data using red (R), green (G), and blue (B) filters, and translates it into a working image on your screen. Color cameras also process images like this, reading what color levels are present in what you are imaging and translating it onto the film or CCD. A more advanced form of processing is known as LRGB, where the L stands for luminance. This is a better processing method in that it can correct for the brightness of objects that can be lost when images are taken through the colored filters.

2 CREATING TRUE-COLOR IMAGES

1.2 THE DANFORTH CHAPEL

Run MaxIm. Open the tricolor directory and load the chapel images **chapel.jpg**, **chapel-r.jpg**, **chapel-b.jpg**, and **chapel-g.jpg**. These images were taken across Hubbard Park from the Danforth Chapel near the IMU on campus in June 2001.

Look at the unfiltered image first (chapel.jpg). This is a color image of the building. This is what you would see if you looked at the building under most conditions (with some variation due to time of day, etc.) We will try to reproduce this image using the filtered images of the building.

Move the three filtered image windows so that you can see all three at once as best you can. Note how the different filters highlight different areas of each image, even though the images are not obviously different other than apparent amount of detail shown. Note the differences you see in the images (e.g. the blue sky is quite dark in the R image).

QUESTION 1:

Describe the differences in the three filtered images. Where is the R filter image brightest? Where is the G filter brightest? Where is the B filter brightest? Is this what you expect?

You can use these separate red, green, and blue images to make a true color image. Select one of the filtered images, and **click on Color and then Combine Color** from the menu at the top. A new

window will open displaying a list of 3 or 4 images, a preview box, and a ratio box. Above the image list is a selection called Conversion Type. Make sure RGB is selected from these selections. On the image list, make sure the correct images correspond to the correct colors (chapel-r to red, etc.).

Set the ratios to 1:1:1 for now, and hit the preview button. In the small window you will see a preview of the image that will be produced after combining the colors. Even though the preview does not quite look like the original (unfiltered) image, click OK. Note how the image is similar to the original, but there are some differences. Discard the image you just produced and repeat the above step.

QUESTION 2:

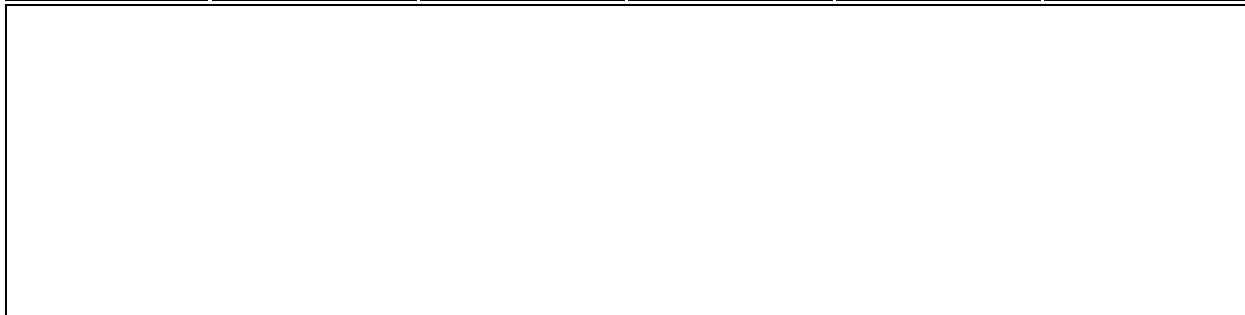
Make another color image with the three chapel images, but this time change your mixing ratios. How does this affect the resulting image?



QUESTION 3:

What mixing ratio gives you the best match to the original image? (Hint: a ratio of 1:2:3 is the same as a ratio of 2:4:6. If you are trying to change the overall brightness and contrast of the image, try using the Screen Stretch tool.) How close did you come? Note that you will not be able to reproduce the original image exactly. Describe any differences between your image and the original in the space provided.

R		G		B	
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1.3 THE CRAB SUPERNOVA REMNANT (M1)

Open the images **crab-r.fts**, **crab-g.fts**, and **crab-b.fts**. These images were taken of the “Crab” supernova remnant (Messier catalog number 1, M1) using red, green, and blue filters. You may get a warning about “negative pixel values,” but do not worry about this, it does not affect the image.

Move the image windows so that all three images are visible at the same time. You will need to adjust the image in order to bring out the maximum amount of detail. This is known as adjusting the histogram. Using the Screen Stretch window, move the red and green arrows underneath the graph to adjust the background (or black) with the red arrow and the brightness (white) with the green. Adjust each of the three images in this fashion.

Notice that the images are obviously different from each other.

The red image shows a fair amount of filamentary structure produced by hydrogen gas glowing most intensely at 656.3 nm (the red Balmer H α line). This is an emission line that we already have observed in the lab.

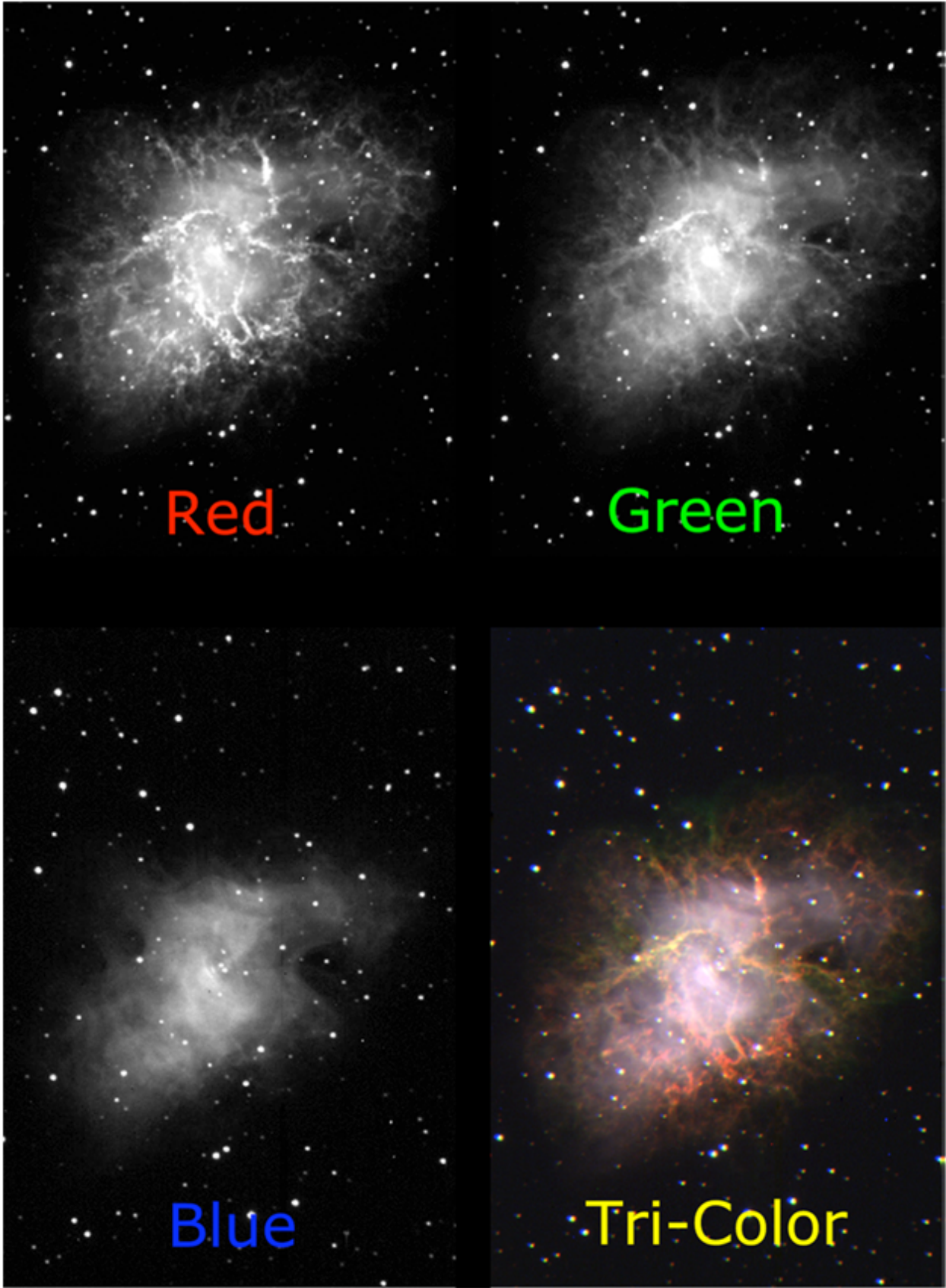
The more diffuse emission seen in the blue image results from electrons spiraling around magnetic field lines at very high speeds, and is called synchrotron radiation.

The green (visible) image contains both synchrotron radiation and the Balmer H β line.

QUESTION 4:

What type of object would you find at the center of the Crab nebula? Can you observe this type of object with an optical telescope? If not, what type of telescope might you use to observe this object?

You can use the separate red, green, and blue images to make a true color image, as we have done with the chapel images. Select Color and Combine Color again. Make sure that the image names are in the correct places in the window that opens up. Use the ratios and preview again to examine your image. You should see a beautiful image of the Crab with the red hydrogen filaments extending slightly beyond the hazy white-blue glow of the synchrotron radiation nebula. If you do not see this, adjust the ratios until you are close. Use the series of images on the next page as a reference.



QUESTION 5:

What mixing ratio gives you the best match to the original image? How close did you come? Describe any differences between your image and the original in the space provided.

R		G		B	

Since the Crab Nebula is believed to be the remnant from a supernova recorded by Chinese astronomers in 1054 A.D., we can use its present size and the present year to determine the expansion speed of the nebula. To do this, measure the average radius of the Crab Nebula in pixels. **The pixels in the image have an angular size of 1.2 arcseconds. Convert the radius to arcseconds, and then to a.u. and km using the small angle formula. The nebula is about 2000 pc away.** (You might need to consult the instructions for the Image Analysis Lab for some help with this.)

QUESTION 6:

Estimate the radius of the Crab Nebula. Calculate the radius in pixels using the distance formula. **Take at least 2 more measurements of radius, choosing different locations along the nebula edge.** Use your three measurements to find the average radius of M1 in pixels.

	Center Coordinate	Edge Coordinate	Radius
Measurement 1			
Measurement 2			
Measurement 3			
		Average (pixels)	

QUESTION 7:

Convert the average radius in pixels to a linear distance using the Scale Factor of the M1 image and the given distance. Express your answer in kilometers. Assuming that the remnant's expansion speed has been constant since the explosion (since there is no accelerating force acting on it), calculate the expansion speed of the material in km/s by dividing the radius of the nebula in km by the age in seconds.

M1 radius (pc)	
M1 radius (km)	
Age of M1 (years)	
Age of M1 (s)	
Expansion Speed (km/s)	

1.4 M27 (THE DUMBBELL NEBULA)

The Dumbbell Nebula is a famous example of a planetary nebula. These beautiful objects result from a dying star which is expelling large amounts of gas. The nebula is caused by glowing gas that surrounds the core of a highly evolved star. The gas is glowing because the star is emitting intense ultraviolet radiation, exciting the atoms in the gas to glow. The greenish center of the nebula is radiation primarily from oxygen and nitrogen, while the red glow near the outer boundary is due to hydrogen (H α line).

Open the images **m27-c.fts**, **m27-g.fts**, **m27-g.fts**, **m27-r.fts**.

QUESTION 8:

What type of object is expected to be at the center of a planetary nebula like M27? Can you detect this type of object using an optical telescope? How else might you detect this type of object?

In addition to the RGB images, you now have a clear filter image of the planetary nebula. We will now be combining images in a somewhat more advanced way, using **LRGB COMBINATION**. What the clear filter image will do is add brightness which can be lost in the other images to the color image. Start the color combination in the same fashion that we have been doing so far.

Start with the standard RGB image processing that we have been doing, and form your image. Leave this image open, but move it to the side if necessary. Now, click on one of the filtered images and repeat the above step. Instead of selecting RGB in the color combine window, you now need to select LRGB from the Conversion Types. This will open up one more position in your image selection list, but this selection will be blank. Click on the arrow on the box labeled Luminance, and select the m27-c image for your luminance. There is no ratio for luminance like there is for each color, but there is a “weight,” a value representing how strongly it will affect the combined image. Try 100% at first, but vary with the weight for best results.

QUESTION 9:

What differences are visible between the RGB and LRGB images?

QUESTION 10:

What mixing ratio gives you the best match to the original image? Compare your color image of M27 with the web image at <http://antwarp.gsfc.nasa.gov/apod/ap981009.html>. Describe any differences between your image and the original in the space provided.

R		G		B	