

Name		
Partner(s)		
Date		
Grade		
Category	Max Points	Points Received
On Time	5	
Printed Copy	5	
Lab Work	90	
Total	100	

Tricolor Imaging

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.

Background and Theory

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 the next page.

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. Procedure

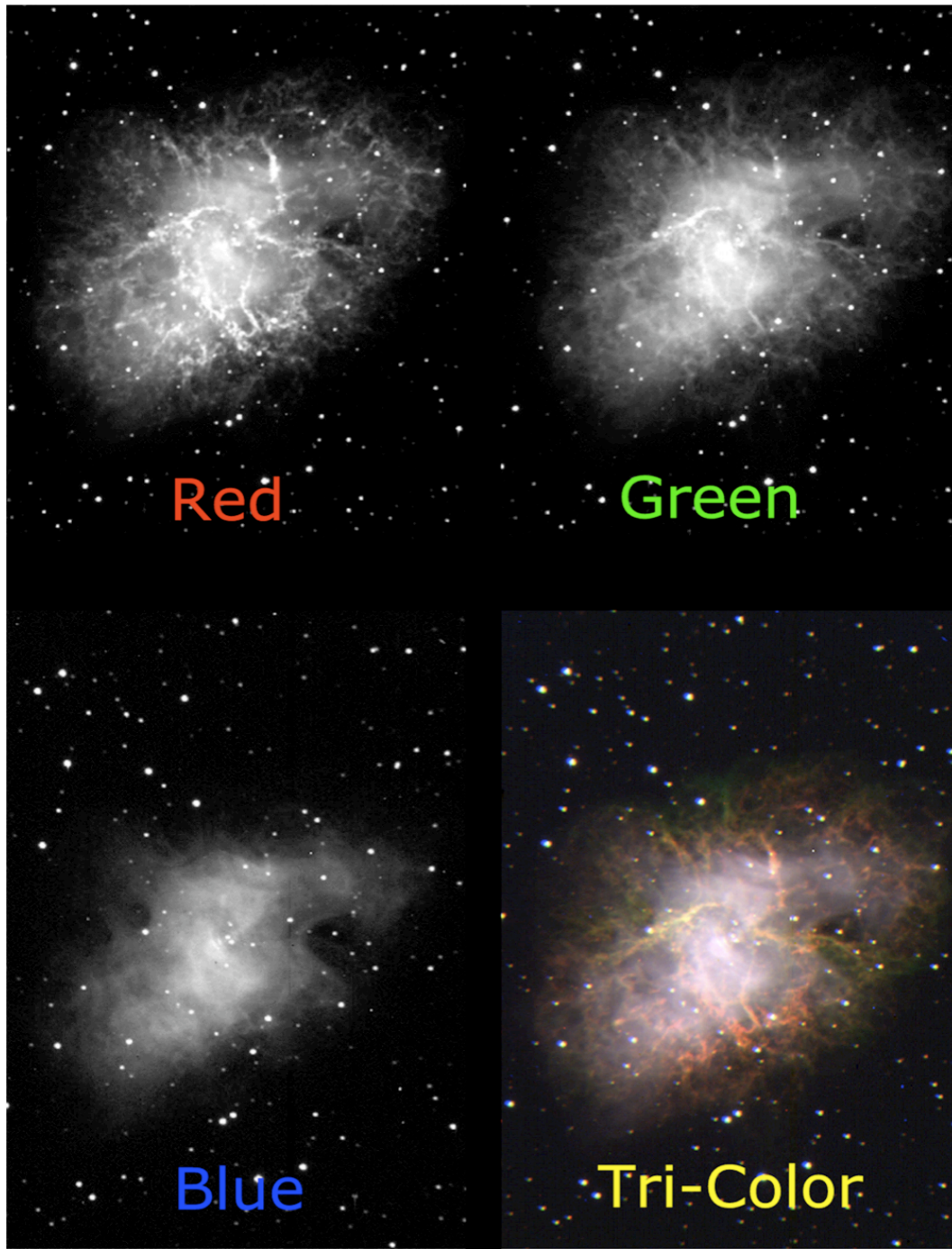
Part A: Creating a true-color image of the Danforth Chapel Using RGB Images.

1. Run MaxIm. Open the tricolor directory and load the chapel images **CHAPEL.JPG**, **CHAPEL-R.JPG**, **CHAPELB.JPG**, and **CHAPEL-G.JPG**. These images were taken across Hubbard Park from the Danforth Chapel near the IMU on campus in June 2001.
2. 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.
3. Move the three filtered image windows 5 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 do you see in the images (e.g. the blue sky is quite dark in the R image).
4. 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 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

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look like the original (unfiltered) image, click OK. Note how the image is similar to the original, but there are some differences.

5. Discard the image you just produced and repeat the above step. This time change your mixing ratios and examine the preview image closely to try to match the original image. How close did you come? Note that you will not be able to reproduce the original image exactly.



6. Close all your chapel images.

Part B: Tri-color image of the Crab supernova remnant

1. 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) 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.
2. 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.
3. **Notice that the images are obviously different from each other.**
 - i. **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).**
 - ii. **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.**
 - iii. **The green (visible) image contains both synchrotron radiation and the Balmer H β line.**
4. 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.
5. 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.) 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.

Part C: Tri-color imaging of M27 (the Dumbbell Nebula)

The Dumbell 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 gas surrounds the star, and the ultraviolet radiation from the star causes the gas to glow.

1. Open the images **M27-C.FTS**, **M27-G.FTS**, **M27-B.FTS**, and **M27-R.FTS**. 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.
2. 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.
3. 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.
4. Click on the OK button and you will now have a brighter true color image than just the plain RGB image, and more detail should be visible than previously. What differences are visible between the two images?
5. Compare your color image of M27 with the web image at

<http://antwarp.gsfc.nasa.gov/apod/ap981009.html>

The nebula is caused by glowing gas surrounding a dying star (at the center). 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).

3. Tricolor Imaging Worksheet

PART A

1. What differences do you see in the filtered images?

2. What differences in colors do you see between the original image and the image made with equal ratios of R, G, and B?

3. What ratios of red green and blue did you use for your true color image?

R		G		B	
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4. Explain any differences you see between the original image and your correctly combined image:

PART B

30 MARKS

- 1.1 How were the color ratios different for combining the crab images than the chapel images?

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R		G		B	
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1. Can you think of a reason why this would be?

2. Expansion:

				Workspace
Radius	(pixels)	(arcsec)	(km)	
	Age	(sec)	(yr)	
	Expansion Velocity	(km/sec)		

PART C

40 MARKS

1. How were the color ratios different with M27 than the previous two combinations?

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2. What differences did you see between the standard (RGB) combination and the LRGB combination?

3. Do you think that adding a brightness factor is better for making color images? Why or why not:

4. Can you think reason(s) why your image may be different from the web image?