Color CCD Images
Earth & Sky

Name: ____

Introduction

You've probably seen some of the incredible pictures from the Hubble Space Telescope, the Mars Exploration Rovers, the Cassini spacecraft, or one of many other space science missions. You may have wondered what the colors in these images mean. In this activity you'll investigate how and why astronomers produce color images.

Pre-test

1. Do you think astronomers use color cameras?

2. Do you think color images from astronomy match what you would see with your eyes?

3. How would you make color images if you only had a black and white camera?

Acquiring images

As you learned in the CCD observing lab, the observatory uses an SBIG ST-8E CCD camera. You will now use this camera and a set of filters to gather some data.

Get the telescope and camera ready for observing, following what you learned in the first observing lab. For an imaging target, use the Ring Nebula, which is a good candidate for color imaging. You can find under ACE's Messier database as M57. Once you **GO TO** M57, look for it using the 50mm eyepiece. Center it using the hand paddle.

1. How does the nebula appear in the eyepiece? Draw a sketch below and describe any colors you see.

Replace the eyepiece with the red cap and move the sliding mirror so that the camera is in the light path. Turn off the computer monitors and dome lights and move your operations to the warm room. Using the ACE controls, take a five second image. You should be able to see the nebula. Remember to adjust the screen stretch settings settings in MaxIm to improve contrast. Be sure to try the **Low**, **Medium**, and **High** settings. Use **Telescope** > **Center CCD** in ACE to center the image. Take a thirty second exposure and save it.

Using the filter wheel

Now you will take images of M57 through different color filters, which only let through light in a specific wavelength range. Attached to the camera is an SBIG CFW-8A filter wheel. This is a rotating wheel that holds up to five filters. Generally, the first position on the wheel is left blank to allow for unfiltered imaging. This is the default setting unless you tell the software differently. ACE uses this position automatically when you use the **Observations** window.

Since you now want to use filters, you must use MaxIm DL's **CCD Control Window**. Under the **Expose** tab is a box that should read **None**. Use the pull-down arrow to reveal your other options. There should be clearly labeled **Red**, **Green**, and **Blue** filters available. Switch to the red filter.

Now, use the controls in this tab to take a 60 second light exposure of M57. Save the image, making sure it is clearly marked as taken through a red filter (e.g., **M57-r.FITS**). Take 60 second exposures using the green and blue filters and save them in a similar manner.

2. Astronomers genereally take longer exposures when imaging through filters. Why do you think this is so?

False color images

Open your first image, taken using no filters. Calibration should be set, so use **Process** > **Calibrate** to calibrate the image. Try adjusting the screen stretch to bring out detail.

3. Does the calibrated image look similar to what you saw in the eyepiece? Draw a sketch below.

Now go to **Color** > **Pseudo Color**. This tool allows you to make a *false color* image from a black and white image. Different colors are assigned to different pixel values based on a color map you define in the triangle. For example, if you click once in the right of the triangle, then once in the center, the lowest values pixels will be assigned black, the highest will be assigned white, and those in the middle will be assigned shades of red based on that color being along the line you defined. (The defined color gradient will be displayed in the strip at the left of the window.) Try this for yourself. You should click on the **Auto** button next to **Full Screen** so you can see the changes you make applied to the whole image. Note that the **Mouse Coordinates** display shows the values of the colors you are choosing, allowing you to be more quantitative in defining the color gradient.

There are several other options you should experiment with. (This is a good time to note the **Color Scheme** drop-down menu, which can store up to ten different color schemes, and the **Clear** button, which resets a given scheme.) For any defined color gradient, you can adjust the screen stretch settings to set the range of brightnesses used in making the false color image. The **Cycles** setting controls how many times the color scheme is run through in defining colors. If you check **Reverse Mapping**, the color gradient is reversed. Changing the **Map Type** from **Linear** to **Logarithmic** compresses the dynamic range of the original image, bringing out more detail. Experiment with these settings to see what details you can bring out in the image. If you want to save your false color image, click **OK**;

otherwise, click **Cancel** when you're finished.

4. Which kind of image makes it easier to see details in the structure of the Ring Nebula — black and white or false color?

Image alignment

Open your three images taken through the color filters, and calibrate them (**Process** > **Calibrate All**). Arrange the images so they can all be viewed simultaneously, and adjust the screen stretch for each image.

5. How do the filtered images compare to one another?

Go to **Color** > **Combine Color** to make a color image. Make sure that **Conversion Type** is set to **RGB**, then select your **Red**, **Green**, and **Blue** filtered images using the drop-down menus. (If you used filenames ending in -r, -g, -b, they will be selected automatically.) Again, be sure to click on the **Auto** button next to **Full Screen** so you can see the changes you make applied to the whole image.

Before you do anything else, you need to make sure the images are aligned properly. Click on **Align** and make sure that **Bicubic Resample** is checked. (This improves the accuracy of sub-pixel shifts.) Note that the window tells you which image is currently displayed. You can use the **Next Image** and **Previous Image** buttons to change the displayed images. Clicking **Set As Reference** will make the current image the reference, moving the other images in relation to it.

There are several **Align Modes** you can choose. **Auto - Correlation** is the simplest, requiring no other input. However, be sure to click **Overlay All Images** to see if the calculated alignment is good. (Don't click **OK** until you are finished, since alignment can only be undone by canceling the color combine and using **Edit** > **Undo** on each non-reference image.) Try this now and check the overlay. Another useful mode is **Auto - star matching**, which again requires no other user input, but is usually more accurate if there are stars in the image. Try using this mode and checking the overlay.

If they above modes don't work, you can try **Manual 1 star - shift only**. Be sure that **Use Centroid** and **Auto Next** are checked, then click on a bright star in the image. You don't have to be totally accurate, because MaxIm will calculate the star's center automatically. The next image will then automatically display, and you should click on the same star. Once you have clicked on the same star in all three images, check the overlay.

The most basic mode is **Overlay**. Once you've decided on a reference image, use **Next Image** and **Previous Image** to view the other images compared to the reference. You can then use the arrows to nudge the image around, adjusting **Nudge Size** if need be. You can also click on a point in the image and rotate it, but it is unlikely you will need this feature. Try using this mode and checking the overlay.

6. Which mode gave you the best results? Which was the easiest to use?

Color images

Once you have a satisfactory alignment, click on **OK** to return to the color controls. If you have space in the background, check **Bgd Auto Equalize** to ensure it turns out black. (Make sure you preview the image as you make changes.) You can now adjust the color balance by changing the numerical values on the input–output diagonal. This is a subjective process: you can try to make your image look like someone else's, or to make the stars white. When you are satisfied with your results, click **OK**. You can now save your color image.

7. Does your color image resemble what you saw in the eyepiece?

8. How well does your color image match up with images of M57 found online?

Conclusions

The red, green, and blue filters you used for this activity are designed for producing accurate color images. Astronomers can choose from a variety of filters. There are standardized color filters for measuring star brigtnesses. There are also filters that only let through targeted wavelength ranges, which can be used to select out light emitted by particular elements. This lets astronomers see the distribution of particular elements (such as hyrdrogen and oxygen) in an object such as the Ring Nebula.

Frequently, these "element map" images are used to make the color images you see in NASA press releases. For example, a picture of a nebula may have hydrogen set to red, sulfur to green, and oxygen to blue. Sometimes these choices may correspond to actual visible colors, but sometimes they may not. This is especially true for images taken outside the visible spectrum (such as the infrared images produced by the Spitzer Space Telescope). However, these images still represent what the telescope saw — just not what your eye would see.

8. You've probably noticed that when you looked through the eyepiece, you didn't see any colors. This is because the color-sensing cells in your eyes ("cones") are not nearly as sensitive to faint light as the brightness-sensing cells ("rods"). Give three reasons why the telescope-CCD combination is more sensitive to color than your eyes:

Post-test

1. Do you think astronomers use color cameras?

2. Do you think color images from astronomy match what you would see with your eyes?

3. How would you make color images if you only had a black and white camera?