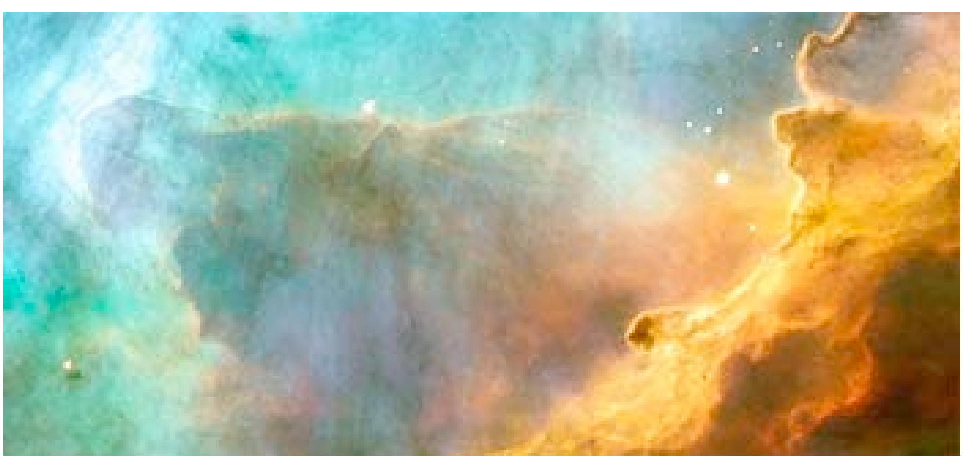
What does the universe look like in color?

The challenge

You have been asked by an astronomy magazine to write a short article about some part of the universe that interests you. The editor would like you to illustrate the article with an original color image that you create using the telescope.

- The image should be related to your article—but it doesn't have to be the exact object you are writing about.
- Help your readers interpret what the colors in your image might reveal about the object. For example, does the object's color tell you anything about its temperature or composition?
- Your image should try to recreate the most natural color you can. In your article, describe the choices you had to make in producing the image.



Star-forming region in the Swan Nebula (colors altered and enhanced.) *Image: NASA / Hubble Space Telescope.*

Part 1. Your ideas about light and color

Where does light come from? How many things can you name that emit light of their own?

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Which of the sources you named are hot?

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Is the Moon a source of light? Is the daytime sky a source of light? (One way to think about it: How would you "turn off" the Moon or the sky? Is there a source of energy to produce the light?)

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Here's a tough one: If you close your eyes or if you dream, you can still see the *sensation* of light. Is this really light?

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From your list of sources of light, above: Which of the light sources you mentioned give off colored light? Does the color give you information about the source of the light? What kinds of information?

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The telescope is "color-blind," because its sensor only registers brightness or absence of light. Any thoughts on how you might get color images from the telescope?

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Part 2. Planning your exploration

Before you create a color image using the telescope, you'll need to know where color comes from and how to work with it. Try the following experiments with color images and color filters. They will help you understand how you can use the telescope's color filters to capture information about the color in a scene, and how to use that information to recreate the scene in full color.

Experiment 1: Just 3 primary colors can produce the sensation of any color.

Turn on your computer monitor and bring up a colorful image on the screen. (Connected to the Web? Then try this image: http://[to be provided].

Look at the screen through your magnifying glass. (No magnifier? Place a *single* drop of water on the screen. The water will act as a powerful magnifying glass.)

What do you observe?

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What colors are the dots or lines you see?

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No matter what colors are in the image onscreen, do the colors of the dots remain the same? (Try looking at yellow, purple, orange, and white parts of the screen.)

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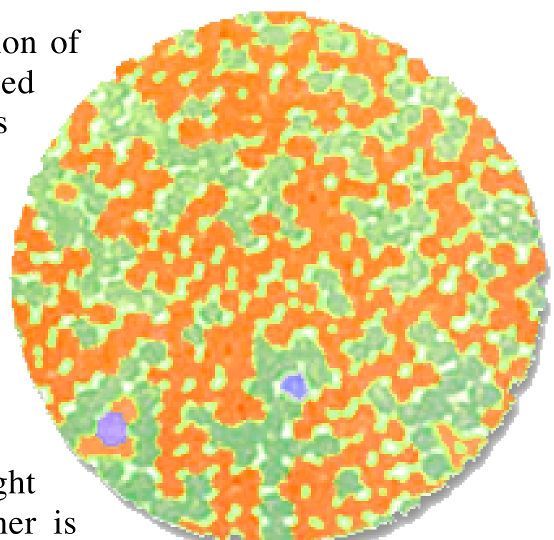
These colors—red, green, and blue—are called PRIMARY colors of light, because any color you can perceive can be produced from these three.

Why are there 3 primary colors?

To really understand color, you have to first understand your own eye.



The image at right shows a portion of the retina of your eye, magnified thousands of times. The circles are the color-sensing cells, called "cones."

Note that there are 3 different types of cone cells. (We've colored them in to make them easier to distinguish.)

One type is stimulated by red light (cells colored red here). Another is stimulated by green light (colored green here). And a few cells are switched on by blue light. (For some reason, there are only 1% as many blue-sensitive cells as red- and green-sensitive cells.)

Each of the many colors you can see is caused by just these three types of cell being stimulated in a particular proportion.

Experiment 2: Working with color filters

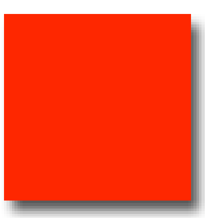
In order to create a full-color image, you'll need to work with the telescope's three *color filters*. To get a feeling for how filters work, try this experiment.

1. **Create a rainbow of colors** on your computer monitor by going to this Website:

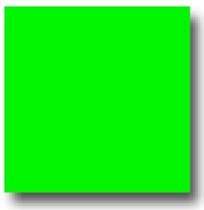
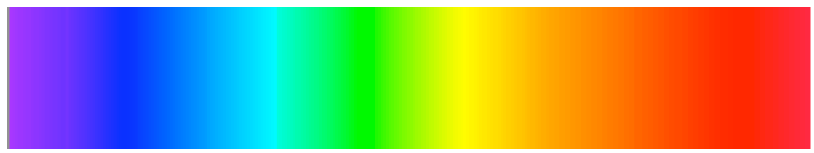
   http://mo-www.harvard.edu/Java/MiniSpectroscopy.html

2. **Make a prediction**. Which part of the spectrum do you think will appear the *brightest* when you look at the spectrum through the **red-passing filter** (the filter that lets through only red light)? Circle the part below you think will look brightest.

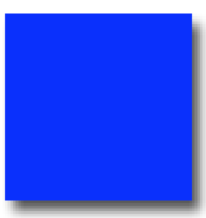
My prediction:

"Through the red filter...	...I think *this* part will look brightest." (Circle it.)
	

How about the **green-passing filter**? Which part of the spectrum will look *brightest* when seen through the green-passing filter?

"Through the green filter...	...I think *this* part will look brightest." (Circle it.)
	

And the **blue-passing filter**?

"Through the blue filter...	...I think *this* part will look brightest." (Circle it.)
	

3. **Now observe using the filters.** How does what you observe compare with what you predicted?

4. **Suppose you were color-blind**. If you looked at the world through each of the three filters, *could you tell that the filters are different*, based on what you saw? How could you tell?

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5. **Color-blind telescope?** Will images taken with the telescope look different if you use different filters—even though the telescope only registers light and dark?

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Experiment 3: "Breaking down" a color scene, using filters

As strange as it may seem, you can save the color information in a scene in a series of 3 black-and-white pictures! To see how this is done, try the next two experiments.

First, take a look at the sunflower image at right. What are the major colors in this scene?

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Next, try to *predict*: Which areas of the picture do you think will appear the brightest when you look through the red-passing filter? Which will be darkest? How about the other filters? Fill in your predictions:

My predictions:

	Red-Passing Filter	Green-Passing Filter	Blue-Passing Filter
Brightest Areas			
Darkest Areas			

Now look at the image through the different filters. What do you observe?

My observations:

	Red-Passing Filter	Green-Passing Filter	Blue-Passing Filter
Brightest Areas			
Darkest Areas			

Kitten Challenge

Which areas of the picture do you think will appear the brightest when you look through the red-passing filter? Which will be darkest? How about the other filters? Fill in your predictions:

My predictions:

	Red-Passing Filter	Green-Passing Filter	Blue-Passing Filter
Brightest Areas			
Darkest Areas			

Now look at the image through the different filters. What do you observe?

My observations:

	Red-Passing Filter	Green-Passing Filter	Blue-Passing Filter
Brightest Areas			
Darkest Areas			

Kids Challenge:

Which areas of the picture do you think will appear the brightest when you look through the red-passing filter? Which will be darkest? How about the other filters? Fill in your predictions:

My predictions:

	Red-Passing Filter	**Green-Passing Filter**	**Blue-Passing Filter**
Brightest Areas			
Darkest Areas			

Now look at the image through the different filters. What do you observe?

My observations:

	Red-Passing Filter	**Green-Passing Filter**	**Blue-Passing Filter**
Brightest Areas			
Darkest Areas			

Puzzler: Can you tell which filter was used?

Oops! Each of the sunflower images below was taken through a different filter—either a *red-passing, green-passing, or blue-passing filter*. But the photo-lab lost the information about which picture is which.

Can you help the lab figure out which image was taken with which filter?

Image #1:

Image #2:

Image #3:

Image #1 was taken with a ______________ -passing filter. Why do you think?:

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Image #2 was taken with a ______________ -passing filter. Why do you think?:

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Image #3 was taken with a ______________ -passing filter. Why do you think?:

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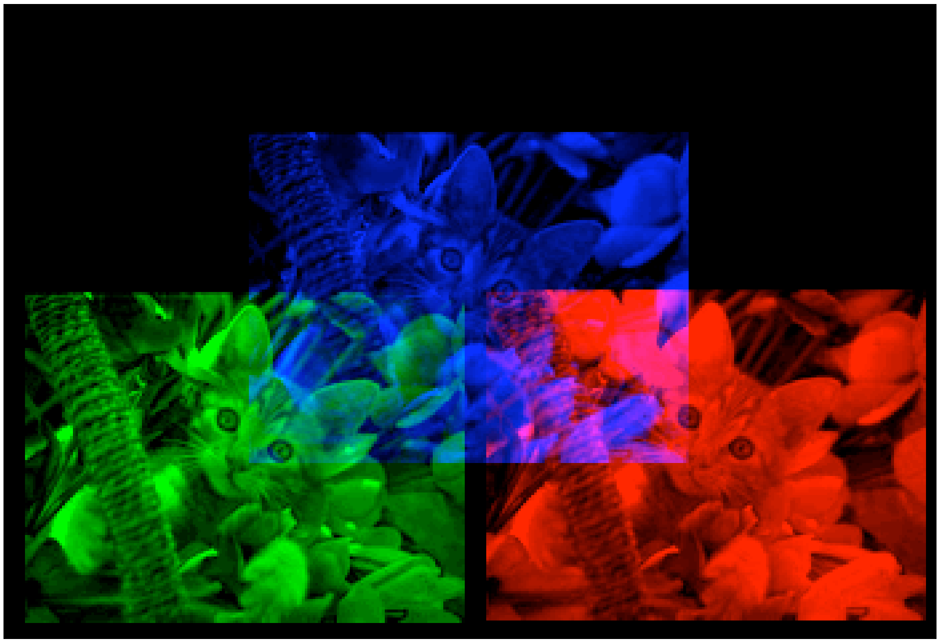
Experiment 4: Creating color from red, green, and blue

The kitten image has been separated into its red, green, and blue color components. Can you combine these three portions of the kitten image to produce full color again?



To experiment with adding the red, green, and blue images back together, try using the *From the Ground Up!* interactive color-mixing program at:

http://cfa-www.harvard.edu/webscope/inter/color

Just click and drag the images until they are on top of each other. Note how the color suddenly pops out at you when all hree images are superimposed. (This activity requires the Shockwave plug-in, which should already be installed on your computer.)

For additional experiments in color mixing, visit the Project LITE webite at

http://www.bu.edu/smec/lite

Experiment 5: Creating full-color images using software.

In order to create full-color images using the telescopes, you'll need to use the MOImage software on your computer. To get started with the program, see if you can reconstruct the full-color sunflower using only black-and-white images that were taken through color filters.

1. Download the three black-and-white images from the "From the Ground Up!" website at this address:

   http://cfa-www.harvard.edu/webscope/activities/color

2. Launch the MOImage software on your computer.

3. Open the flower files that you just downloaded: First open *flowerR.gif*. This is the red portion of the flower image. Under the **Process** menu, select **Color Tables / Red**. This automatically colors the image red. In the same way, open the green image (*flowerG.gif)* and color it green by selecting **Process/Color Tables/Green.** Finally, open *flowerB.gif* and color it blue.

4. Under the **Process** menu, select **Stack**, and select **Convert Images to Stack**.

   Take a moment to scroll through the stack, using the or arrows at the bottom edge of the image. Note that the three images contain very different information about the picture. The third image is very dark, because there is no blue in the scene, except for the sky.

5. To create the color picture, go to the **Process** menu, select **Stack,** then **Convert Stack to RGB** (which stands for red, green, blue color).

Did you get a full-color picture? (To get really strange color, try the process again, but this time try mixing up the color of the images—for example, coloring the red-filtered image green. You'll get a full-color picture, but it won't be the color of the original image.)

Planning your exploration with the telescope.

How would you use the MicroObservatory telescopes to create a color image of an object in the night sky?

With your team, develop an outline for how you would proceed. As tools, you'll be able to use:

- the telescopes
- the telescopes' filter wheel, which lets you take images through filters that pass red, green, or blue light
- MOImage software for combining the red, green, and blue information to form color.

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After you have outlined a procedure, discuss with your team what kind of object you would like to image. Remember that large celestial objects such as nebulae often form the best subjects. If you like, you can choose from the list of suggested targets.

Part 3. Creating color images with the telescope.

In this part of the challenge, you'll create your own full-color images using the MicroObservatory telescopes and its color filters. Here's how:

Taking and downloading the images

1. Choose an object you'd like to image. Use the handy chart for suggestions, or you can use a target not on the list.

2. Take *three* images of your target—one each using the red-, green-, and blue-passing filters. For each image, use the exposure time suggested below.

3. When the telescope has taken the images and posted them on the Web, download the three images in FITS format. (See Web page for instructions.)

4. Be sure to name the files clearly so that you know which image was taken through which filter (e.g., "orionRed.FITS"). The filter color is listed in the Image Info file and FITS header that comes with each image.

Creating full-color images

5. **Open your three images.** Launch the MOImage processing program on your computer. Open the image taken through the red-passing filter. Do the same for the images taken through the green- and blue-passing filters. You should have three images open.

6. **Adjust brightness and contrast:** Under the **Process** menu, select **Adjust Image.** When the Adjust Image window opens, select the **Auto** button to get a good first look at the image. Further adjust the brightness and contrast as necessary. Do the same for the other two images: Hit the auto button to automatically adjust brightness and contrast.

7. **Color each image red, green or blue:** Work with the red-filtered image first. Under the **Process** menu, select **Color Tables / Red**. Your image will turn red. Then work with the green-filtered image, selecting **Color Table / Green** to turn the image green. Finally, color the blue-filtered image blue.

What's going on? The areas in the original scene that had a lot of red became the ***brightest*** areas in the red-filtered image. In turn, these bright areas in the red-filtered image will become the ***reddest*** areas in the final image. The same holds for the green- and blue-filtered images.

8. **Align the images:** Your three images will probably be slightly out of alignment. You'll need to align, or "shift" the images so that when you combine them the result won't be blurred. Under the **Process** menu, select **Shift**. As prompted, select one of your images as the background image over which you'll shift (i.e. align) the other two images. Then select an image to shift. (You should see the background image through the slightly transparent foreground image.) Using the mouse keys and the i,j,k,l keys as prompted, align the two images and then hit the Okay button. Align the third image in the same way and hit Okay.

9. **Stack the images.** Under the **Process** menu, select **Stack / Convert Images to Stack**. You can flip through these images if you like, to see them individually.

10. **Create the final color image.** Under the **Process** menu, select **Stack / Convert Stack to RGB**. The program now

merges the three red, green, and blue images to create the final image. Congratulations!

11. **Save the final image.** Make sure you save your final image and label the filename clearly.

Suggested challenges for color photographs

Orion Nebula

R.A. 5hr 35.4min **Dec:** -5° 27’

Exposure: 30-60sec

Best Visible: Oct-Mar from North America

This big cloud of glowing gas is visible by eye in the constellation Orion. It's easy to tell where the stars are that are lighting up the nebula: they're right in the center of the cloud.

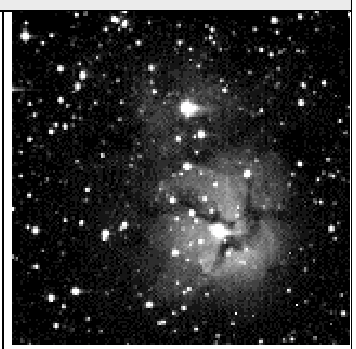
Trifid Nebula

R.A.: 18hr 02.3min **Dec:** -23° 02’

Exposure: 60 sec

Best Visible: April-Sept from North America

This is one of the few nebulae where you can see THREE different color effects of gas and dust: fluorescing red hydrogen, blue reflection from dust particles, and dark black dust lanes. Also look for differently-colored stars! Telescopes further south get a better view of this nebula.

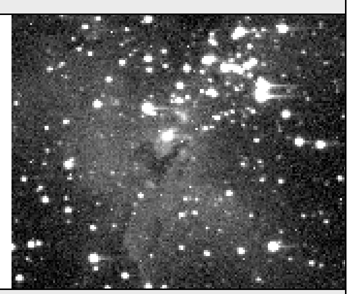


Eagle Nebula (M16)

R.A.: 18hr 18.8min **Dec:** -13° 47’

Exposure: 60 sec

Best Visible: Apr-Oct from North America



Swan Nebula (M17)

R.A. 18hr 20.8min **Dec:** -16° 11’

Exposure: 60 sec

Best Visible: April-Oct from North America

If Orion is not up, try this nebula in color to see the red glow of hydrogen gas. The stars that are lighting up this star-birth nebula are hidden by the dust.

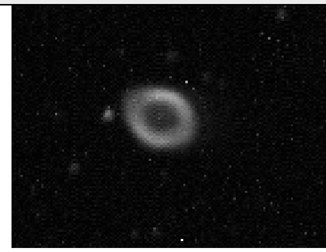
Middle of this Month	***RA highest at midnight***
Jan	*07h*
Feb	*09*
Mar	*11*
Apr	*13*
May	*15*
Jun	*17*
Jul	*19*
Aug	*21*
Sep	*23*
Oct	*01*
Nov	*03*
Dec	*05*

Find the current month in the table. The number at right shows the Right Ascension that will be highest at midnight.

A Right Ascension that is several hours less (or more) than this will be highest that many hours earlier (or later) in the evening.

Example: In March, a star with RA of 11 will be highest around midnight. A star with RA of 7 will be highest 4 hours before midnight, at 8 PM.

Ring Nebula (M57)



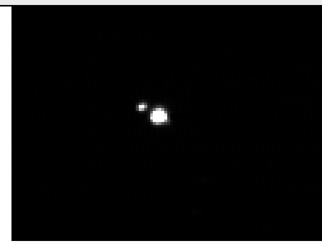
R.A. 18hr 53.5min **Dec:** 33° 02’

Exposure: 10-30 sec

Best Visible: Feb - Dec from North America

In the constellation Lyra. Expanding at about 12 miles per second, formed about 20,000 years ago.

Albireo



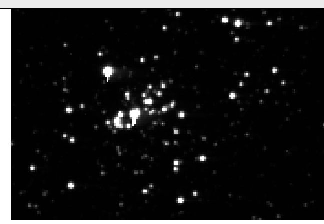
R.A. 19hr 28.7 min **Dec:** 27° 52’

Exposure: 10-30 sec

Best Visible: Feb - Dec from North America

When seen through a telescope, the “tail” star of Cygnus the swan just lines up with a much more distant, dimmer star. One of these is quite red and the other much bluer. Can you tell which is which?

NGC 869



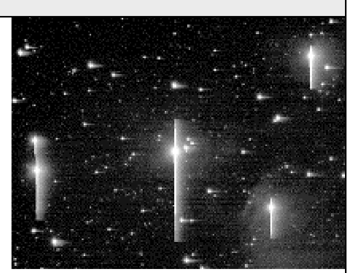
R.A. 2hr 8 min **Dec:** 57° 09’

Exposure: 30 sec

Best Visible: Year round from North America

This “open” cluster of stars is quite young – only 10 million years old or so— and is full of hot blue stars (and a few red giants as well). It is part of a double cluster of stars in the constellation Perseus that is quite visible with binoculars.

Pleiades (M45)



R.A. 03hr 47.4min **Dec:** 24° 07’

Exposure: 10-30 sec

Best Visible: July – Mar from North America

The bright stars of the Pleiades are noticeably bluish. If you overexpose your images, you may be able to just pick out the blue reflection off the dusty nebulae surrounding the brightest stars. The Pleiades stars are about 80-100 million years old.

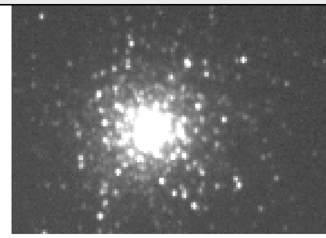
Hercules cluster (M13)

R.A. 16hr 41.5 min **Dec:** 36° 28’

Exposure: 10-30 sec

Best Visible: July – Mar from North America

Because all the stars in M13 are about 12 billion years old, it was selected in 1974 as target for one of the first radio messages addressed to possible extra-terrestrial intelligent races, and sent by the big radio telescope of the Arecibo Observatory.

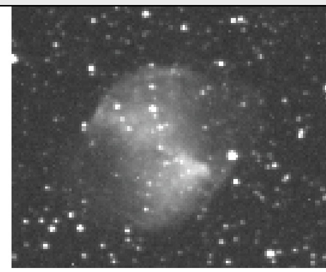


Dumbbell nebula (M27)

R.A. 19hr 59.4 min **Dec:** 22° 42’

Exposure: 30 sec

The central star is extremely hot. The nebula is believed less than 2.5 light-years wide.



Part 4. Reflecting on your results.

In writing your article, include the following discussion questions.

What kind of information does the color of the object in your image tell you about the object?

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The telescope's light sensor is *not* equally sensitive to red, green, and blue light. How might this affect the color of your final image?

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When you added the three images together, did you boost the brightness of any of the images? If so, how did this affect the final color image?

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How closely do you think that your image captures "reality"—and why?

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Suppose you have imaged a very faint object that no human has ever seen with the naked eye—because it is so faint. Do you think there *is* such a thing as how the object *should* look? How would you determine the *best* color balance, or the best image processing?

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To learn more about how color images are constructed and interpreted by astronomers, try visiting the Hubble Space Telescope online guide, at:

hubblesite.org/sci.d.tech/behind_the_pictures/meaning_of_color/index.shtml

Or visit the Anglo-American Observatory collection of color astro-photographs at:

www.aao.gov.au/images.html/