FINGERPRINTING THE COSMOS: USING COLORED FILTERS IN ASTRONOMY

ACTIVITY J-11

GRADE LEVEL: 7-12

Source: This activity was developed by Dr. Elizabeth Roettger, a planetary scientist and astronomy educator, who was one of the first astronomers to participate as a Project ASTRO volunteer. It incorporates additional material by Dennis Schatz and Andrew Fraknoi, the editors of *More Universe at Your Fingertips.* In its current form it is ©1999 Project ASTRO, Astronomical Society of the Pacific, 390 Ashton Ave., San Francisco, CA 94112. Permission to use for any non-profit educational purpose is hereby granted. For any republication or commercial use, please contact the Society. An alternate version of this activity by Dr. Roettger can also be found on the Web at: http://www.nthelp.com/eer/HOAcolorAstron.html

What's This Activity About?

Astronomers must determine the characteristics of celestial objects from the light and other radiation they send us. "Decoding" the information in the light of the planets, stars, and nebulae is one of the most important techniques in astronomy.

What Will Students Do?

Students use colored filters to examine slides of stars and nebulae. The filters allow them to distinguish stars of different temperatures and nebulae with different compositions.

Tips and Suggestions

- A better (more organized) version of the color analyzers activity (to which the present activity is a follow-up to) can be found in the book *GEMS Color Analyzers Teachers' Guide*, available through the GEMS Program at the Lawrence Hall of Science, University of California, Berkeley, CA 94720. 510-642-1016; www.lhs.berkeley.edu
- The darkness of the room and the quality of the filters are both crucial to the success of this activity.

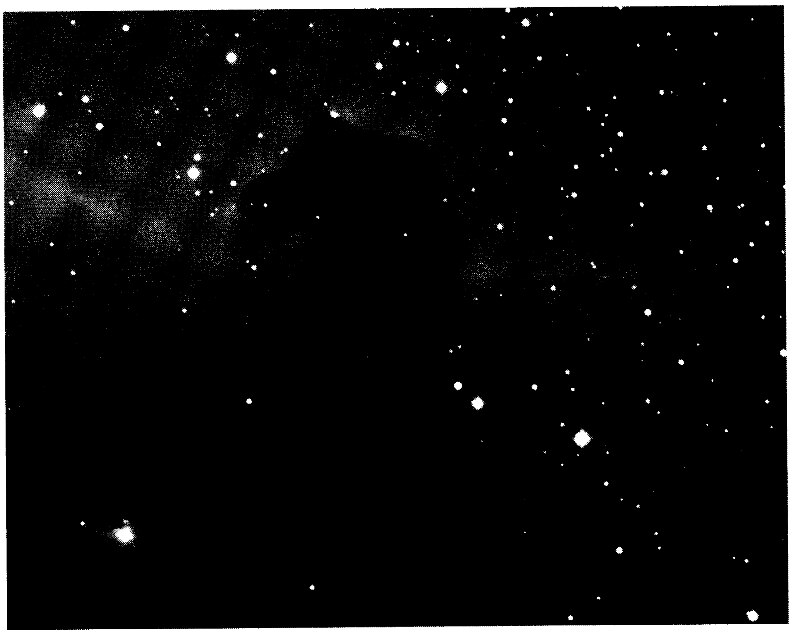
What Will Students Learn?

Concepts
- Color filters
- Transmission of light
- Determining star temperatures from colors
- Using colors to determine the composition of nebulae
- Dust in space and its effects on starlight

Inquiry Skills
- Observing
- Comparing
- Explaining
- Inferring
- Reasoning

Big Ideas
- Energy
- Interactions
- Systems
- Patterns of Change

FINGERPRINTING THE COSMOS: USING COLORED FILTERS IN ASTRONOMY



by Elizabeth Roettger
DePaul University

Introduction

This activity is best done after completing the "Color Analyzer" activity outlined in Activity J-4 (Light and Color) in *The Universe At Your Fingertips.* After they do that activity, students know that the color of a filter indicates what color of light passes through the filter. So, for example, an ideal red filter passes only red colors and keeps the other colors from going through. Seen through such a red filter, a red shirt will look red, but a green shirt will look black. Once the students understand how filters work, the activity which follows allows them to apply the same ideas to study various astronomical images.

Concepts

Astronomers for the most part study objects that are much too far away to visit, and they must therefore learn about such objects from the light (and other radiation) the objects send our way. Luckily, nature has "coded" a lot of information about the nature of astronomical objects into their light. If we can learn to look for and decode this information, we can, for example, learn about the temperature, composition and density of stars and clouds of gas and dust (the cosmic raw material).

One of the first things astronomers can do with light from cosmic objects is to examine it through filters (similar to, but more sophisticated than, the ones the students are using). By looking at astronomical objects through different colored filters, astronomers can identify objects with the kinds of characteristics they are interested in. For example, stars that give off much more blue light than red turn out to be relatively hot, whereas stars dominated by reddish colors are cooler. In giant clouds of gas found among the stars – called *nebulae* – a reddish color usually indicates the presence of the element hydrogen at high temperatures and low density.

Objectives

Students will understand:

- that colored filters let astronomers identify certain kinds of objects for study
- what can be learned about these objects by examining them through colored filters

Materials

- Color filters [see **note 1** on page 84]
- Slide projector and screen
- Slides of astronomical objects, for example those in the Astronomical Society of the Pacific's *Splendors of the Universe* #1 Slide Set
- A room that can be reasonably darkened

Advance Preparation

- Assemble the filters for the students (see **note 1** on page 84), or be sure students have the ones they constructed.
- Be sure slide projector works and room is dark enough to see the effect of viewing slides through the colored filters (this is really important to check – if the room is leaking light, it might be OK for showing vacation slides, but proper viewing of astronomical slides might be very difficult).

Procedure

1. Ask students to tell you what they learned from the Color Analyzer activity regarding what colored filters do to the light coming from an object. Review the results of that activity if it has been a while since you did it. Use this time to reinforce the idea that the color of a filter indicates what color of light passes through the filter.

2. Show the first slide and ask students to tell you what they see and how what they see changes when looking through different filters. If your students have completed activities J-4 (Light and Color – Activities from the FOSTER Project) and/or Activity J-7 (Spectroscopes and Spectrometers) from *The Universe At Your Fingertips*, then they may already know that hot stars are bluish in color, while cool stars are reddish in color. In addition, they may know that the red color in many nebulae is due to hydrogen gas (while other gases glow with different colors; oxygen, for example, is seen as a greenish glow). If they do not know these ideas, then you will need to introduce them.

3. Ask students to think about how looking at these slides through the filters might help them study hot vs. cool stars, or the gases in nebulae. Have them make suggestions, but don't come to any final conclusions until you have looked at least a few slides, if not all the slides. You will probably need to go back and forth among the slides as you have this discussion. Get as many ideas generated as possible, before you review what is in the slides and what astronomers can learn about them by looking through different colored filters.

4. Use the information given for each slide to discuss what is being observed and how the filters help isolate certain features (e.g. cool stars versus hot stars, hydrogen in nebulae versus other gases like oxygen).

5. Summarize by discussing how this kind of activity is like fingerprinting – we can identify the temperature or composition of cosmic objects because these characteristics leave their "fingerprints" (identifying marks) in the light. If students are ready (and you have the equipment) you can move on from this activity to more detailed "fingerprinting" – i.e. studying the line spectrum from discharge tubes filled with different gases and then applying the ideas to astronomical spectroscopy. (See activity J-7 in *The Universe at Your Fingertips.*)

SLIDES TO USE:

Many color slides of astronomical objects lend themselves to being examined with colored filters. See **note 2** on page 85 for sources of such slides. This particular activity was developed for some slides of astronomical objects taken with the large Anglo-Australian Telescope (under the supervision of master photographer David Malin). These slides are distributed in the U.S. by the Astronomical Society of the Pacific (see address in **note 2**). The set of slides is called *Splendors of the Universe*, set #1.

Slide 12: The Helix Nebula, NGC 7293

What to say: Use this slide before Slide 8, to set up the 'oh!' experience in that slide. Talk a bit about planetary nebulae and what they are, since they show up again in the third slide. (Astronomers use the term nebula for any kind of glowing clouds of gas.) Ask students whether they see different parts of the slide through different filters.

What is in the slide: Late in their lives, when their main fuels for producing energy (hydrogen and helium) run out, star that are not too massive (stars like the Sun, roughly) will have a "last gasp" or two before they are ready to die. The stars shed their outer layers to produce a beautiful planetary nebula like the one seen here. A planetary nebula doesn't have anything to do with a planet – it's a term we're stuck with historically. The gas in the shell is hot (heated and set aglow by what's left of the dying star in the center). The star itself is heating up as it collapses under its own weight, and its energy can light up the shell. The elements in the nebula determine the colors with which it is glowing.

Slide 8: The Cone Nebula

What to say: This is the real 'oh!' experience. Ask students what they see through the red filter? Through the green? What does the difference tell them?

What is in the slide: The Cone Nebula contains both gas and dust. The red gas is hydrogen. The dark areas are generally dust blocking the light from the hydrogen gas and the stars beyond. There are stars hidden in the dust, and they tend to make the dust around them glow, so when you see a large, roundish glowing area, it's generally a hidden star lighting up the dust closest to it. If you were to see a wide-angle view of the area, you'd see that the dark cone shape is a finger of dust from a nearby dark (dusty) area that is much larger.

Slide 5: Galaxy NGC 6822 in the Local Group

What to say: Make sure students understand that they are looking at a separate galaxy (island of stars) outside of, but not too far away from, our own Milky Way Galaxy.

In this slide, the fuzzy stuff is the blended-together light of many hotter blue stars. Have them check out what they can see on the slide with different filters. The blue stars are newer than the middle-aged yellow ones. Encourage students to think like an astronomer: tell them they are engaged in a study of this galaxy and that they need to figure out whether this galaxy consists of only new stars, or if there are older stars in it too. How would they figure this out? (Note: whether students can see the more subtle glow from the yellow stars that are also present in the galaxy depends on how bright the projector image is.)

Ask students if they can see anything else familiar. There are objects that look like the planetary nebulae in an earlier slide. Actually these are called bubble nebulae, which are much larger than planetary nebulae, and are caused by much bigger and brighter stars, sometimes a whole group of them.

What is in the slide: Galaxy NGC 6822 is a collection of stars about 8000 light years across and 1.6 million light years away. The newer, blue stars form a slightly different pattern than the older, yellow stars. The latter form a fairly smooth ellipsoid (flattened ball-shape), and the new stars form a somewhat irregular shape.

Slide 10: Dust Cloud and Open Cluster NGC 6520

What to say: Ask students to talk about what's happening here. Is there a hole in space? Are stars absent in the direction that looks black? After the discussion has gone on for a while, ask if they see the brownish stars near the edges of the dark region. Have they ever looked through polluted air? What could be causing the stars to look brownish? Where are the blue stars we can see inside the dark region? See if the students can come up with the idea that the dark region is a dust cloud, and the stars we can see in the same zone must be stars that are between us and the cloud.

What is in the slide: Old stars tend to be yellowish, young stars bluish. Here is a cluster of young stars (NGC 6520). They're in front of most of the yellow stars. There's also a dark cloud (called Barnard 86) blocking the light from the distant stars, although some of the blue stars are in front of it. Around the edges (where the cloud is thinner), it doesn't block all the light, and the stars behind seem faint and brownish. For more advanced groups, you may want to note that both the dust cloud and star cluster have a similar "keyhole" shape. It is possible that the group of stars formed from the dust cloud, but that the two later separated.

Slide 14: The Horsehead Nebula in Orion

What to say: People say the dark tongue in this slide looks like a horse or dinosaur or dragon. The red glow is gas, but what is the horse-head? Remind students that if they are not sure, they could use their filters to check. Have them look through the green filter and compare the density of stars in the two areas. What does this mean? Is the dark shape "something" or "nothing"? They should conclude that there is something there. It turns out to be dust, blocking the starlight. Ask the students if they have ever been outside on a foggy day? Do distant objects disappear? Are they really gone? So what might be going on here? See the blue at the bottom? There's a star inside that dust, lighting up the dust in this area.

Hint: It is particularly effective to raise your hand so that it forms a shadow similar to the horsehead. This can demonstrate how a 3-D form can be seen against a glowing background as a 2-D shape.

What is in the slide: The red part is glowing hydrogen gas. The dark region is a cloud of dust obscuring the gas, stars, and galaxies behind it. The horsehead is a tendril of this cloud of dark dust. Because there's no light shining on it, you don't see the dust, only its effect on the other light. However, there is a star buried in the dust and lighting up an area of it; the blue, roughly round area (NGC 2023) is dust lit by an embedded star.

The comments above are just a few suggestions. You can experiment with many other slides, including slides of planets. One warning: Just as computer image processing techniques have revolutionized science fiction films and TV commercials, so they are being used more and more frequently in producing astronomical images that look good in the news media. If the colors of a slide have been changed substantially from the originals in the course of producing the image, then the viewer has to be careful about drawing too many conclusions from the use of filters.

NOTE 1: MAKING FILTERS

Activity J-4 in *The Universe at Your Fingertips* contains instructions for making a "color analyzer" from a 3 x 5 index card and red, green, blue, and yellow-colored filters obtained from a theatrical lighting supply store. Locating a reliable source of filter material is the hardest part of doing these activities, but once you buy the large sheets of colored filter material, you can cut them up into small pieces, and make durable filter cards that your students can use for many years.

Among the sheet colors that have been found to be especially useful for this activity are:

RED: #27 Medium Red

GREEN: #90 Dark Yellow Green or #94 Kelly Green

BLUE: #74 Night Blue or #80 Primary Blue

YELLOW: #12 Canary or #10 Medium Yellow

Colored cellophane or plastic report covers are not discriminating enough (in terms of color) to be used effectively as filters. You really do need good filter material. Look in the phone book for theatrical supply houses, and ask what color sheets they have.

J-11, Fingerprinting the Cosmos

NOTE 2: WHERE TO OBTAIN SLIDES

The number one source of good quality astronomical slides (with detailed caption booklets) is the non-profit Astronomical Society of the Pacific, located at 390 Ashton Ave., San Francisco, CA 94112. Their toll free catalog line is 1-800-335-2624, and their web site is: www.aspsky.org.

Many NASA Resource Centers allow teachers to come in with their own roll of slide film and copy slides for free. However, depending on how well the equipment is maintained, the quality of the duplicate slide can vary widely.

Slides are also available from a commercial supply house, Finley-Holiday Films, 1-800-345-6707, and from the Hansen Planetarium, 1-800-321-2369.

In addition, many astronomical images are available for viewing on the World Wide Web, and can be downloaded onto slide film if your local audio-visual department has the right equipment (this equipment is not cheap, but is coming down in price).

Some excellent web sites of astronomical images include:

- **Anglo-Australian Observatory Image Collection** [www.aao.gov.au/images.html]

A marvelous library of images (focusing on nebulae and galaxies) taken using large Australian telescopes. Many are by David Malin, who is acknowledged to be one of the finest astronomical photographers of our time. Includes captions and ordering information for the copyrighted images.

- **Astronomy Picture of the Day** [antwrp.gsfc.nasa.gov/apod/astropix.html]

On this popular site, astronomers Robert Nemiroff and Jerry Bonell feature one relatively new celestial image each day with a brief non-technical caption. Over the years, some of the best astronomical images have been featured here and an index is available on site.

- **European Southern Observatory** [www.eso.org/outreach/gallery/]

This growing album contains images from the large telescopes in the southern hemisphere run by a consortium of European countries. With the advent of the Very Large Telescope, there will be an increasing number of important new images and results on this site.

- **Hubble Space Telescope** [oposite.stsci.edu/pubinfo/pictures.html]

All the magnificent Hubble images, with captions and many with detailed background information, can be found at this site. You can see the latest images, the ones the staff considers the Hubble's "greatest hits," or search for objects of interest to you. Not all images are natural color.

- **National Optical Astronomy Observatories Image Gallery** [www.noao.edu/image_gallery]

NOAO includes a number of major telescopes in the U.S. and the Southern Hemisphere, and is a national facility where any astronomer can apply for time. Some of the best images from NOAO instruments are collected at this site.

- **Planetary Photojournal** [photojournal.jpl.nasa.gov]

This site, run by the Jet Propulsion Laboratories and the U.S. Geological Survey Branch of Astro-geology in Flagstaff, is one of the most useful resources on the Web. It currently features over 2000 of the best images from planetary exploration, with detailed captions and excellent indexing. You can dial up images by world, feature name, date, or catalog number, and download images in a number of popular formats. The one problem with the site is "NASA chauvinism"; only NASA mission images are currently included.