WHAT'S GETTING THROUGH TO YOU?
TEACHER NOTES

2.1 What's This About?

Students are introduced to light and colored gels (filters). Students make and test predictions about light and color using gels, by looking at messages written with differently colored crayons on differently colored paper with differently colored gels. Students then learn about the importance of gels (filters) to astronomers by looking at an astronomical image through red and blue gels and comparing the parts of the image that are enhanced by the gels. Then, they analyze images taken with regular and infrared cameras to see that objects opaque to light at one wavelength may be transparent to light of a different wavelength.

Suggested Grade Levels
7-12

Suggested Time Required
100 minutes

Suggested Learning Outcomes
After completing this activity, students will be able to:
- Predict the color of light that is transmitted through a gel.
- Describe why astronomers use gels to observe and interpret light emitted by objects in space.
- Compare the transmission qualities of visible and infrared light.

Student Prerequisites
- Students are assumed to be familiar with the visible spectrum and to have some knowledge of the electromagnetic spectrum, and how it relates to the visible spectrum.
- Students are assumed to have some familiarity with the idea of reflected, absorbed and transmitted light, and to understand the terms "opaque" and "transparent."

Common Misconceptions
Students may have the following misconceptions, which should be addressed in the activity.
- Students may not realize that light travels from one object to another, and that they "see" an object because of the light reflected off of it.
- Students may think that black represents all colors mixed together.

The Activity

PART I — HIDDEN MESSAGES

The students will make and test predictions about light and color using filters.

This activity familiarizes students with the behavior of filters or gels. The student begins by predicting what blank white, red, and black paper will look like through the red and blue gels, then testing their predictions. This gives students a better understanding of the function of gels (filters). The student is then asked to predict what they will see when they look through red and blue gels at two superimposed messages, one written in red, the other in blue, on white and black construction paper, before testing their prediction by looking at the messages through the gels.

Messages written with red and blue crayon work well in this activity, while those made using felt markers of any kind do not. Encourage students to use a heavy hand when writing their messages, that is, to write thick letters, to make the messages easier to see and read through the gels. The gels used should be theatrical gels because they are made in ways that ensure they transmit only certain wavelengths of light (see the Materials section below for more on the gels). Colored cellophane will not work properly. The darker the black construction paper, the better the results students will get.

When looking at the messages on the white construction paper, students should find that they need to look through the blue gel to read the red message, and vice versa. Conversely, when looking at the messages on the black construction paper, they need to look through the red gel to read the red message, and the blue gel to see the blue message.

Note that reading the messages on the black construction paper is more difficult than on the white paper and may cause problems for students. The point to stress is that students cannot see the same-colored message when looking through a gel at the white paper, but can see the same-colored message when looking at the black paper. This is easier to see when using the red gel, which does not allow any blue light to pass through it. Because of the way they are made, blue gels do allow some red light to pass through them. This can allow students to see both messages when looking through the blue gel at the black paper, which they may find confusing.

If this happens, encourage students to focus on the red gel. Ask students to note whether they can see the red message when looking through the red gel at the white paper. They should not be able to see it, or see it only faintly. The blue message, however, should be very noticeable (appearing black). Then ask students if they can see the red message when looking through the red gel at the black paper. The red message will appear bright against the black background, although they may not be able to read it clearly. Similarly, students should see the red message quite clearly when looking through the blue gel at the white paper, while having trouble seeing the blue message. And the blue message will appear brighter than the black background when viewed through the blue gel at the black paper. However, students may still be able to see the opposite-colored message through the gels when looking at the black paper, especially when using the blue gel; the messages will appear "blacker than black."

In the last activity of this section, students look at an image of the Crab Nebula (http://www.sofia.usra.edu/Edu/materials/activeAstronomy/crabnebula.html) through red and blue gels. You should download this image in advance and have it ready on a computer monitor that students can see. This relates what students have been doing with gels to the practical application of ways that astronomers use them. It shows how astronomers use filters to help them more easily observe particular aspects of astronomical objects. It also shows the effect that the background has on filter selection. On a white background, a red gel was chosen to see a blue message whereas on a black background, a red gel is chosen to see a red message. Be aware that your students may have improperly generalized the knowledge they gained and feel that to view a red object, you must use the blue colored gel, regardless of the background.

A more extensive treatment of light and color, intended for grades 5 - 8, can be found at http://www.lhs.berkeley.edu/GEMS/GEM225&226.html

PART II — HIDDEN STARS
The student will recognize that objects opaque to light of one wavelength may be transparent to light of a different wavelength.

The purpose of this section is to introduce students to the idea that different wavelengths of light can pass through some everyday objects but not through others. Students look at two images of a plastic bag over a toaster. One image was taken in visible light "Visible Light View of a Hot Toaster," the other with a camera that registers infrared light "IR Light View of a Hot Toaster." You should download all these images in advance from the *Section 2 Images File* on the CD and have them available on a computer monitor for students to see.

Students should notice that the infrared camera can "see" the toaster, even if something (like a plastic bag) blocks visible light reflected from it from reaching a camera. This reinforces the idea that not all wavelengths of light are visible to the human eye. Students may hold the belief that if an object is opaque to visible light, no other wavelengths of light will pass through it. Conversely, students may hold the belief that if an object is transparent to visible light, it will be transparent to all wavelengths of light. If your students seem to be having trouble with these ideas, show them that an opaque plastic bag does not block the IR signal from a remote control from turning on a television. Make sure they understand that the remote control emits infrared light (that's how it signals the television), and that the infrared light passes through the plastic bag in the same way that heat from the toaster passed through the plastic bag and was recorded by the camera.

Students may not realize that the toaster behind the bag emits infrared light, or heat. They may think they see it because of reflected infrared light, as the visible light reflected off the bag. This provides an opportunity to stress that infrared wavelengths corresponds to radiant heat.

Finally, students look at two images of logos covered by a piece of fabric (**http://www.sofia.usra.edu/Edu/materials/activeAstronomy/multiband-logo.html**) the "Multi-Band Logo" images are also included in the *Section 2 Images File* on the CD. One image shows the scene in visible light; students see only the fabric cover which hides the logos. The second image is taken in the infrared; students will see the logos through the fabric which is transparent to IR. Not all fabric is transparent to IR, only some synthetics. The papers on which the logos are printed are at room temperature, heated by the Sun and the bricks beneath them. As a result, they emit infrared radiation, the amount of which depends on the color of print on the paper (dark areas of the paper are cooler than light-colored areas). As a result, the logos (written with black ink on white paper) show up against the rest of the paper's background. The fabric is not a good emitter of infrared light, and so does not appear in the infrared photograph.

BACKGROUND SCIENCE

Astronomers often use different "filters" to make images with telescopes, but this name can be a little misleading. A *red filter* is designed to block out all colors *except* red; any green or blue light, for example, will not get through this substance. Often this is confusing because we think of filters being designed to keep a particular substance out. In an attempt to avoid this confusion, we have used the term *gel* (rather than filter) here to refer to the theatrical acetate sheets used in this activity. *Note: as you read the following description, it is helpful to do the activity at the same time.*

When you look through a red gel at a white sheet of paper, the paper appears red. White light – a combination of all colors – is reflecting off of the paper in all directions. However, only the red light is allowed to pass through the gel and go into your eyes. Thus, the paper looks red. If you switch to a blue gel, mostly blue light will pass through the gel and the paper will appear blue.

> SOFIA SCIENCE
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> *At the infrared wavelengths that SOFIA observes, interstellar dust does not interfere with the infrared light traveling through space. SOFIA is able to make observations of previously unstudied objects.*

What happens when you look at something red through the red gel? Look at the red and white construction paper at the same time. The red paper appears red to our eyes because it reflects the red light that hits it and absorbs all other colors. When you look through the red gel, since red is reflecting from both the red and white papers, both sheets will appear the same color: red. Now look at these with the blue gel. No blue is reflecting from the red paper, but blue will be reflected off the white paper. The white paper appears blue, but the red paper should look black, indicating an absence of light passing through the gel. In reality the sheet may not appear true black because of scattering, color variations in the paper, and gel density – but it should be a noticeable difference.

When you look through a red gel at a message written with a blue crayon on a white piece of paper, the blue light reflected from the blue crayon is absorbed by the red gel, and the writing looks black. On the other hand, red light reflected from the red crayon mixes with the red light reflected from the white paper, making it hard to distinguish the red message from the background paper. Similarly, the red light reflected from a red crayon message is absorbed by the blue gel, and the writing looks black. The blue light reflected from the blue crayon mixes with blue light reflected from the white paper, making it hard to see the blue message through the blue gel. Thus, a red gel makes it easier to see blue messages on white paper, and vice versa.

When you look through a red gel at a message written in blue crayon on a black piece of paper, however, the blue light reflected from the blue crayon is absorbed by the red gel, and the writing looks black. This writing mixes with the black background, making it hard to see the message. On the other hand, red light reflected from the red crayon, passes through the red gel, making the red message stand out against the black background. In the same way, the red light reflected from a red crayon message is absorbed by a blue gel, making the red writing look black and blend in with the black background. The blue light reflected from the blue crayon passes through the blue gel, making the blue message stand out against the black background. Thus, a red gel makes it easier to see a red message on black paper, and a blue gel makes it easier to see a blue message on the same paper.

Astronomers collect light of many different wavelengths emitted by objects in space. Each part of the spectrum emitted by an object contains specific information about that object, so different detectors can be used to learn about different things. For example, an infrared telescope can be used to view objects whose visible light images are obscured by interstellar dust. For some color pictures of this effect see SIRTF's web site at http://www.ipac.caltech.edu/Outreach/Edu/importance.html. The "IR Telescope Images" are also included in the *Section 2 Images File* on the CD. That's because the wavelengths of infrared light are too large to be scattered effectively by the tiny grains of interstellar dust. Visible light, however, with its smaller wavelengths closer in size to the dust grains, is effectively scattered by the dust. In a similar way, scattering also explains why sunsets are red and the sky is blue. Molecules in the Earth's atmosphere scatter blue light more effectively than red light, because blue wavelengths are closer in size to that of the molecules, hence, the sky is blue. When the Sun is near the horizon, its light must pass through a large amount of air, and, as a result, nearly all the blue light is scattered out of the line of sight (to be seen overhead as a blue sky), making the Sun look red.

The image used in this activity, the Crab Nebula, is a supernova remnant. In 1054 AD, Chinese astronomers recorded the sudden appearance of a star where they had never seen one before. It shone brightly in the night sky for several months, before fading from view. When modern astronomers look in the position in the sky where the Chinese recorded the "guest star," they see this nebula, a huge cloud of glowing gas and dust. A massive star, much more massive than our Sun, had ended its life in a super-explosion. Having used up all the nuclear fuel at its center, the star's core collapsed catastrophically, then rebounded in a powerful explosion that tore the star to pieces. What we see in the Crab Nebula now is the material that once made up the star expanding outward at speeds of several thousand kilometers per second.

Another example of how astronomers use other regions of the electromagnetic spectrum to observe the universe, an astronomer could detect x-rays from extremely hot matter, such as the material in the center of a supernova, even though visible light is blocked by surrounding dust (for more information about x-ray astronomy, see the web site for the Chandra x-ray satellite at http://xrtpub.harvard.edu/edu/chandra1018.html).

Infrared detectors used in astronomy are made out of materials sensitive to infrared light, such as lead sulfide, germanium, and indium-antimony alloys. Similarly, the cameras used to make the infrared photographs shown in this activity have detectors sensitive to infrared light. Many use

Charge-Coupled Devices, or CCDs, as detectors. CCDs are electronic chips made out of a grid-like array of squares, or picture elements (pixels for short). When a light photon strikes a pixel, it generates an electric charge. The more photons that strike the pixel, the higher its charge. At the end of an exposure, a computer monitors the total electrical charge in each pixel, resulting in a picture that shows how many photons are coming from where. More information about CCDs and how they work can be found at:
http://www.sciencenet.org.uk/database/tech/computing/t00246d.html

In the photographs studied by students in this activity, areas with high numbers of infrared photons (that is, areas that are warmer) appear bright, while areas emitting low numbers of infrared photons (colder) appear dark.

Materials Needed

- white paper
- black and red construction paper
- red and blue crayons*
- red and blue gels*
- Internet access or downloaded versions of the images mentioned (Crab Nebula, Visible Light View of a Hot Toaster, IR Light View of a Hot Toaster and the Multi-band logo)

*see section 1.5 for more details