# The Electromagnetic Spectrum

## Overview

The light that we see with our eyes – visible light – represents only a small portion of the electromagnetic spectrum. Developing the technology to detect and use other portions of the electromagnetic spectrum – the "invisible" light that our eyes cannot see – has had a tremendous impact on our daily lives. When you listen to a radio, heat your food in a microwave oven, use a remote control, or have an X-ray taken, you are using "invisible" light.

In astronomy, scientists use the properties of light to learn about celestial objects that are too far away to visit. Each portion of the electromagnetic spectrum provides unique clues about the nature of our universe. The missions and research programs in NASA's Astronomical Search for Origins program use innovative technologies to observe the universe at a variety of wavelengths (ultraviolet, visible, and infrared) in search of the answers to two enduring human questions:

***Where did we come from?***

***Are we alone?***

### Vocabulary

**Electromagnetic energy**: A form of energy that travels through space as vibrations of electric and magnetic fields; also called radiation or light.

**Frequency**: Describes the number of wave crests passing by a fixed point in a given time period (usually one second). Frequency is measured in hertz (Hz).

**Spiral galaxy**: A large pinwheel-shaped system of stars, dust, and gas clouds.

**Wave**: A vibration in a medium or in space that transfers energy from one place to another. Sound waves are vibrations of air. Light waves are vibrations of electric and magnetic fields.

**Wavelength**: The distance between two wave crests, which is the same as the distance between two troughs.

## Classroom Activities

This poster contains three classroom activities designed to introduce middle and high school students (grades 6–12) to different portions of the electromagnetic spectrum, including those used by Origins missions. Suggested science standards, vocabulary, and science background information are provided to facilitate lesson planning. The activities can be done separately or together.

**The Visible Spectrum** provides instructions for creating a visible spectrum with an overhead projector. Introduce the electromagnetic spectrum by showing students that white light is composed of a rainbow of colors. Students can draw the visible spectrum and explore how common objects "filter" light. Use these activities to engage students' interest in electromagnetic energy.

**The Herschel Infrared Experiment** helps students to expand their knowledge of the electromagnetic spectrum. Students will discover the "invisible" light that lies just beyond the red end of the visible spectrum – infrared light. Use this as an outdoor class laboratory activity, a student learning station, a demonstration, or as part of a science fair project.

**Invisible Light Sources and Detectors** gives students direct experience with radio, infrared, visible, and ultraviolet waves. Students will identify sources of visible and "invisible" forms of light in our everyday lives, and identify ways to detect and to block these types of light. Teachers can use these concepts to discuss how we protect ourselves from harmful forms of light.

Visit the NASA Space Science Education Resource Directory (**http://teachspacescience.org**) or the Origins Education Forum website (**http://origins.stsci.edu**) to find additional education resources developed by NASA's Origins missions and programs.

# Background Information

### 1. What is the electromagnetic spectrum?

The electromagnetic spectrum consists of all the different wavelengths of electromagnetic energy, including radio waves, microwaves, infrared light, visible light, ultraviolet light, X-rays, and gamma rays. The only region in the entire electromagnetic spectrum that our eyes can detect is the visible region. Although the wavelength ranges for forms of light other than visible are not precisely defined, typical wavelength ranges are as follows: gamma rays, less than 0.001 nanometers; X-rays, 0.001 to 10 nanometers; ultraviolet light, 10 to 400 nanometers; visible light, 400 to 700 nanometers; infrared light, 700 nanometers to 1 millimeter; and radio waves, longer than 1 millimeter. The shortest radio waves (wavelengths between 1 millimeter and about 30 centimeters) are also referred to as microwaves. (One nanometer equals one-billionth of a meter.)

### 2. What is the relationship between wavelength, frequency, and energy?

The speed of light equals the frequency times the wavelength. This means that the frequency is equal to the speed of light divided by the wavelength. Because all electromagnetic waves travel at the same speed (300,000,000 meters per second) in the vacuum of empty space, the shorter the wavelength is, the higher the frequency. The energy of a wave is directly proportional to its frequency, but inversely proportional to its wavelength. In other words, the greater the energy, the larger the frequency and the shorter (smaller) the wavelength. Short wavelengths are more energetic than long wavelengths.

### 3. Do all types of electromagnetic energy reach the Earth's surface?

Our atmosphere blocks out harmful energy like X-rays, gamma rays and most ultraviolet rays. It also blocks out most infrared energy, as well as very low energy radio waves. Visible light, most radio waves, some ultraviolet rays, small wavelength ranges of infrared light, and some microwaves pass through the atmosphere.

### 4. Why do we put telescopes in space?

Astronomers put telescopes in space to study electromagnetic energy that does not reach the Earth's surface. Each type of electromagnetic energy provides important clues about the properties of celestial objects. We also put telescopes in space to study visible light, even though visible light passes through the Earth's atmosphere. Turbulence in our atmosphere blurs the images that scientists obtain with telescopes on the ground. By placing telescopes in space, above the Earth's atmosphere, scientists can obtain a much sharper view of the universe.

### 5. How do we detect "invisible" forms of light?

Scientists build electronic devices that are sensitive to the light our eyes cannot see. Then, so that we can visualize these regions of the electromagnetic spectrum, computer image-processing techniques translate the "invisible" light into pictures that we can see.

### 6. What are the different images of the Whirlpool Galaxy on the front of the poster?

The upper image, which was obtained by the Hubble Space Telescope, is a visible-light image of the Whirlpool Galaxy. This detailed image helps astronomers to study the structure and star-forming processes of this spiral galaxy.

The visible-light image in the lower portion of the poster shows a wider view of the same Hubble Space Telescope image, revealing a smaller, nearby companion galaxy. Four additional images, obtained with various space-based and ground-based telescopes, measure the "invisible" light emitted by the two galaxies. To visualize the "invisible" light, scientists have used computer image-processing techniques to translate the various electromagnetic energies into pictures we can see.

Each image provides important clues about the properties of this system. The visible-light image shows sweeping spiral arms, clusters of young stars, and clouds of molecular gas and dust. Young stars dominate the appearance of the ultraviolet image, which provides a unique view of the spiral structure. The X-ray image shows clouds of multi-million-degree gas and point-like objects associated with black holes and neutron stars. Longer infrared wavelengths track warm dust heated by recent star formation. The radio image maps the locations of star-forming regions and supernova remnants produced by the deaths of massive stars.

### 7. How do scientists use the electromagnetic spectrum to learn about the universe?

The images of the Whirlpool Galaxy on the front of the poster show how combining information from each region of the electromagnetic spectrum leads to a more complete understanding of a celestial object. In addition to taking images of celestial objects, scientists also use devices called spectrographs to disperse, or separate, the light from celestial objects into its component wavelengths. Features in the resulting spectrum help astronomers to measure an object's properties, such as its temperature, composition, density, and motion.

Scientists in NASA's Astronomical Search for Origins program will image stars and galaxies at ultraviolet, visible, and infrared wavelengths. We will also look for characteristic patterns of light, or spectral "fingerprints," emitted by atoms and molecules to measure elements in the early universe and to search for signatures of life. Combining the light from multiple telescopes will allow us to achieve the capabilities needed to identify and study terrestrial planets orbiting nearby stars.

# The Visible Spectrum

**Target Grade Levels: 6–12**

## Purpose

To introduce the electromagnetic spectrum. Understanding electromagnetic energy often begins with studying the visible spectrum. Visible light is accessible and emphasized in most textbooks. Students bring personal observations of the spectrum from the natural world: rainbows; prisms; diffraction grating glasses; and other commercial items decorated with refractive materials (pencils, signs, etc.). Begin with these observations to engage students' curiosity about light and, more broadly, electromagnetic energy.

## Materials

Overhead projector; diffraction grating*; and two pieces of 8" x 10" dark paper.
**OR**
Slide projector; diffraction grating*; one 35-millimeter slide mount; and unexposed film or black electrical tape.

Color pencils or crayons; common transparent objects like sunglasses; colored report covers; and plastic wrappers.

## Projecting the Visible Spectrum

The visible spectrum can be boldly projected with a diffraction grating or, less optimally, a prism* using an overhead projector or a slide projector as a light source. Both projectors produce a full spectrum of white light. (**Note:** video projectors do not produce a full spectrum.)

**To use an overhead projector**, place two pieces of 8-inch by 10-inch dark paper on the projector to create a "slit" about 2.5 centimeters (1 inch) wide on the base plate of the projector. Turn on the projector lamp and focus the "slit" on a white wall or screen. Place the diffraction grating (about 4 or 5 inches square) in front of the upper lens (head) of the overhead, and rotate the grating until the spectrum appears on either side of the projected slit on the wall or screen.

**To use a slide projector**, create a 35-millimeter slide that has a clear "slit" about 0.5 centimeters (1/4 inch) wide by using unexposed film, or black electrical tape in a slide mount. Turn on the projector and focus the "slit" on the wall or screen. The diffraction grating is placed in front of the lens. Again, rotate to produce the spectrum on the wall.

With either type of projector, the spectrum will appear on both sides of the "slit" You can move the projector to place the spectrum at the best place for students to observe. Note that this works best in a darkened room.

## Activities

### 1. The Colors of the Visible Spectrum

Students use color pencils or crayons to draw and label the spectrum. They may record more or fewer colors than the classic "ROY G BIV" (red, orange, yellow, green blue, indigo, violet) scheme. (Many people do not distinguish dark blue [indigo] from violet.) The visible spectrum appears to have boundaries. Asking if there is anything beyond the red and violet ends of the spectrum introduces the notion of "non-visible" electromagnetic energy. Human skin is sensitive to the ultraviolet energy beyond the violet light; it sunburns. And, skin senses the infrared energy beyond the red light as heat.

### 2. How Do Color Filters Work?

Transparent, colored objects transmit only a portion of the visible spectrum. Place common transparent objects like sunglasses, colored report covers and plastic wrappers on the "slit" of the overhead projector (or into the beam from the slide projector) to discover how they "filter" light. The filters used for theatrical lighting are designed to selectively transmit color, and offer a more dramatic demonstration of how light is filtered. Viewing objects in different regions of the electromagnetic spectrum through the use of filters and different kinds of telescopes gives astronomers more information about the universe.

***Note on Diffraction Gratings and Prisms:**
Diffraction gratings produce a bright, broad visible spectrum that students find easier to observe. Holographic gratings perform best. A prism placed in a light beam of a slide projector will also produce a visible spectrum, but it will likely be fainter, with the colors dispersed in a narrow band.

### Going Further

These activities were adapted from ***Active Astronomy: Classroom Activities for Learning About Infrared Astronomy***. ***Active Astronomy*** offers hands-on activities and demonstrations that focus on sensing infrared energy as a way of exploring "invisible" light.

Download *Active Astronomy* on the Web at: **http://www.sofia.usra.edu/Edu/materials/edu_materials.html**.

# Herschel Infrared Experiment

### Target Grade Levels: 6–12

## Purpose

To perform a version of the experiment of 1800, in which a form of electromagnetic energy other than visible light was discovered by the famous astronomer Sir Frederick William Herschel.

## Background

Herschel discovered the existence of infrared light by passing sunlight through a glass prism. His experiment is similar to the one described here. As sunlight passed through the prism, it was dispersed into a rainbow of colors called a spectrum. A spectrum contains all of the visible colors that make up sunlight.

Herschel was interested in measuring the amount of heat in each color and used thermometers with blackened bulbs to measure the various color temperatures. He noticed that the temperature increased from the blue to the red part of the visible spectrum. Herschel then placed a thermometer just beyond the red part of the spectrum in a region where there was no visible light. He found that the temperature was even higher!

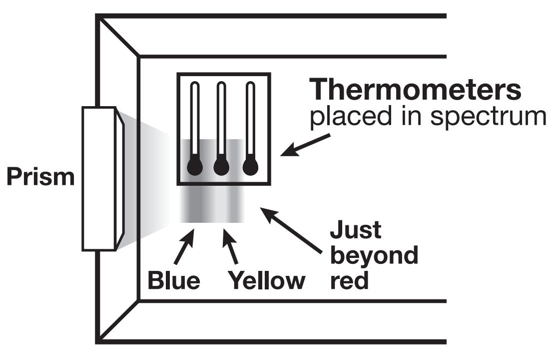



Figure 1

Herschel realized that there must be another type of light beyond the red, which we cannot see. This type of light became known as infrared. Infra is derived from the Latin word for "below." Although the procedure for this activity is slightly different than Herschel's original experiment, you should obtain similar results.

## Materials

One glass prism (plastic prisms do not work well for this experiment); three alcohol thermometers; black paint or a permanent black marker; scissors or a prism stand; a cardboard box (a photocopier paper box works fine); and one blank sheet of white paper.

## Preparation

You will need to blacken the thermometer bulbs to make the experiment work effectively. One way to do this is to paint the bulbs with black paint, covering each bulb with about the same amount of paint. Alternatively, you can also blacken the bulbs using a permanent black marker. (Note: the painted bulbs tend to produce better results.) The bulbs of the thermometers are blackened in order to absorb heat better. After the paint or marker ink has dried, tape the thermometers together so that they line up as in Figure 1.

## Procedure

The experiment should be conducted outdoors on a sunny day. Variable cloud conditions such as patchy cumulus clouds or heavy haze will diminish your results. The setup for the experiment is depicted in Figure 2. Begin by placing the white sheet of paper flat in the bottom of the cardboard box. The next step requires you to carefully attach the glass prism near the top (Sun-facing) edge of the box.

If you do not have a prism stand (available from science supply stores), the easiest way to mount the prism is to cut out a notch from the top edge of the box. The cutout notch should hold the prism snugly, while also permitting

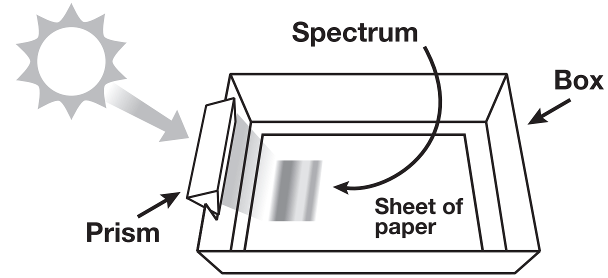



Figure 2

its rotation about the prism's long axis (as shown in Figure 3). The length of the notch should be slightly shorter than the length of the prism. The notch should be slightly deeper than the prism's width. Next, slide the prism into the notch cut from the box and rotate the prism until the widest possible spectrum appears on a shaded portion of the white sheet of paper at the bottom of the box. The Sun-facing side of the box may have to be elevated (tilted up) to produce a sufficiently wide spectrum. After the prism is secured in the notch, place the thermometers in the shade and record the ambient air temperature. Then place the thermometers in the spectrum so that one of the bulbs is in the blue region, another is in the yellow region, and the third is just beyond the (visible) red region (as in Figure 1).

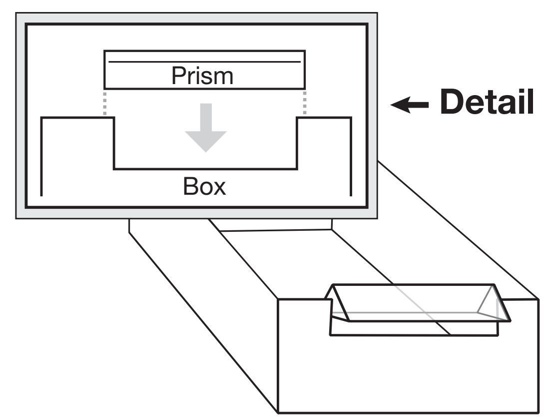



Figure 3

It will take about five minutes for the temperatures to reach their final values. Record the thermometer temperatures in each of the three regions of the spectrum: blue, yellow, and "just beyond" the red. Do not remove the thermometers from the spectrum or block the spectrum while reading the temperatures.

## Questions

What did you notice about your temperature readings? Did you see any trends? Where was the highest temperature? What do you think exists just beyond the red part of the spectrum? Discuss any other observations or problems.

## Remarks to the teacher

Ask students to answer the above questions. The temperatures of the colors should increase from the blue to the red part of the spectrum. The highest temperature should be just beyond the red portion of the visible light spectrum. This is the infrared region of the spectrum.

Herschel's experiment was important not only because it led to the discovery of infrared light, but also because it was the first time someone showed that there were forms of light that we cannot see with our eyes. As we now know, there are many other types of electromagnetic energy ("light") that the human eye cannot see (including X-rays, ultraviolet rays and radio waves).

You can also ask the students to measure the temperature of other areas of the spectrum, including the area just beyond the visible blue. Also, try the experiment during different times of the day. The temperature differences between the colors may change, but the relative comparisons will remain valid.

## Data/Observations:

| **Temperature in the shade** | Thermometer#1 | Thermometer#2 | Thermometer#3 |
|---|---|---|---|
| | | | |
| **Temperature in the spectrum** | Thermometer#1 (blue) | Thermometer#2 (yellow) | Thermometer#3 (just beyond re |
| After 1 minute | | | |
| After 2 minutes | | | |
| After 3 minutes | | | |
| After 4 minutes | | | |
| After 5 minutes | | | |

### Going Further

For more activities and further information on the Herschel infrared experiment, see:

**http://coolcosmos.ipac.caltech.edu/cosmic_classroom/classroom_activities/herschel_experiment.html**.

# Invisible Light Sources and Detectors

### Target Grade Levels: 6–12

## Purpose

At classroom stations, students gain direct experience with different sources of electromagnetic energy — most of which is not visible to the human eye. Each station will have a source of electromagnetic energy, possible "detectors," and sheets of material to test as potential "transmitters" or "shields" for the electromagnetic energy. Detecting and blocking ("shielding") various forms of electromagnetic energy helps students realize there are forms of electromagnetic energy that we cannot see.

Note: X-rays and gamma rays are not included as part of this classroom activity for several reasons, most importantly because they are harmful if not used properly.

## Materials

### For the class:

Activity worksheets for each student

3-6 station number signs

3-6 sets of shields/transmitters in a manila folder or envelope, one for each station, plus one additional set for the demonstration station. Each set has the following materials:

- blank overhead transparency
- aluminum foil, 12" x 12"
- plain white paper, 8 1/2" x 11"
- cloth, 12" x 12"
- black plastic, 12" x 12", 2-4 mil thick
- clear plastic baggie, 1 gallon size
- wax paper, 12" x 12"

### For the stations:

**Demonstration Station**
**Visible Light**
SOURCE: flashlight (with batteries)
DETECTOR: plain white paper 8 1/2" x 11"

**Radio (FM)**
SOURCE: radio station
DETECTOR: small battery-operated FM radio. Aluminum foil (enough to completely cover the radio, its antenna, and any headphones).

[For large classes, set up two of each of the numbered stations.]

**Station 1**
**Infrared Light**
SOURCE: infrared light (heat lamp)
DETECTOR: student's hand

**Station 2**
**Infrared Light**
SOURCE: VCR/TV remote control
DETECTOR: TV monitor or other device triggered by remote

**Station 3**
**Ultraviolet Light**
SOURCE: black light — fluorescent
DETECTORS: sheet of "bright" paper; styrofoam peanuts; detergent; tonic water containing quinine; glow-in-the-dark stars; ultraviolet beads.*

***Note:** Black light sources are often found in party shops or entertainment/theater catalogs. Ultraviolet beads are available from many science education suppliers. The white beads that turn red in ultraviolet light are preferred.

### Safety Issues

We advise against incandescent black light bulbs. If that type of bulb is the only one available, be aware that they can become very hot, so caution students not to touch the bulb. And although normal fluorescent black lights are considered completely safe, please advise students not to stare directly into the fluorescent bulbs for extended periods or from close range. Shorter wavelength black lights used in mineral exploration or to sterilize surfaces should NOT be used. They can be dangerous to eyes and skin and can burn them much like a severe sunburn.

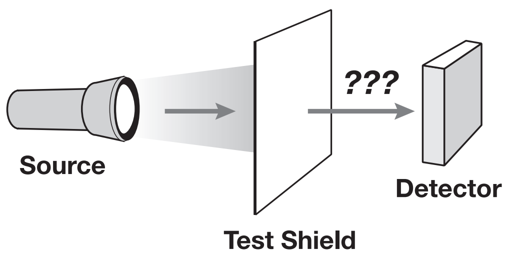
## Procedure

### Demonstration – Defining Sources, Detectors, Transmitters, and Shields

**1. Sources.** Shine the flashlight from the demonstration station at students. Say, "This flashlight is a source of light." Ask, "What are some other sources of light energy that we can see?" Explain that while most objects reflect light, they are not considered to be the source of that light. Sources of light generate and emit the light themselves.

**2. Detectors.** Ask, "Can you tell me where there are light detectors in the room?" [The students' eyes!—If necessary give them the hint that some light detectors are a couple of centimeters below their eyebrows!] Then ask, "Are there other light detectors that you know of?" [Cameras, camcorders...] Explain that the white paper at the demonstration station reflects visible light so that our eyes can detect it. We can call the white paper a "detector," but our eyes are the real detectors.

**3. Transmitters and Shields.** Explain that some materials let light through and are called transmitters of light. Other materials do not let light through; they block the light, and can be called shields. Use the test shields at the demonstration station to show how different objects/materials can either transmit, partially transmit, or block visible light. For each test shield listed in the Visible Light worksheet, ask the class to predict whether the material will transmit/partially transmit (T) visible light or block/shield (S) visible light, and to record their predictions on the worksheet. Insert each material in the flashlight beam and have students record the observed results. Completing the Visible Light worksheet in this fashion will prepare students for the experiments with invisible light.




**4. Exploring Invisible Light.** Tell the class that, in addition to the visible light energy they can see in the room, there is a lot of invisible energy too. For example, the radio at the demonstration station detects radio waves from a radio station. [With radios, it is easy for confusion to arise about the energy source. In addition to the radio waves emitted by the radio station, the radio is powered by a battery, and there is also sound energy. Emphasize that it is the radio waves we are concerned with here.] Tune a small battery-operated radio to an FM music or news station.

To show how invisible energy can be blocked, completely wrap the radio and its antenna in aluminum foil or place it in a box completely lined with aluminum foil (including the lid). [Headphones and headphone cords, if present, also should be wrapped in foil since headphone cords often contain an antenna.] The radio waves from the radio station should now be shielded (blocked), and static will be heard. The static indicates that the radio is still working, and reinforces the fact that the signal — the radio energy — has been blocked. Tell the class that the other materials at the demonstration station will not block the radio waves.

## Student Experiment and Discussion

**5. Explain** that the stations set up around the room each have a source of energy, a detector of that energy, and a set of materials (test shields) to see which materials transmit or block the invisible energy.

**a.** Have students identify the Source and Detector at each station (as listed in the "Stations" section of the Materials list above).

**b.** Divide the class into groups. Tell students they will have about 7–10 minutes per station. Explain that students will use the procedure demonstrated with visible light to determine which materials transmit/partially transmit or shield (block) invisible light. Ask students to record their predictions and results on the Invisible Light worksheet. When a given time period is up, have students go to the station with the next highest number, unless they are already on the highest number, in which case they should go to Station 1.

**6. Discussion of results.** Ask questions about each station, such as the ones below. Each group will report their results to the class. Encourage other groups to ask questions of the reporting group, and be sure to ask students in the reporting group for any questions they still have.

- **What did you find out?**
- **What was the source?**
- **What was the detector?**
- **What blocked the source?**
- **What let the invisible light through?**
- **Did anything surprise you?**

**7. Summarize the class experiences** on a large paper or the overhead so students can view the conclusions and unresolved questions. Help familiarize them with the names for each type of invisible light and the electromagnetic spectrum by looking at the front of the poster.

**8. Consider other invisible sources.**

**a.** "What kind of invisible energy do we use to cook with?" [microwaves and infrared] Explain that water is especially good at absorbing microwaves, so any food containing water (most food) will be efficiently heated in a microwave oven.

**b.** X-rays. If possible, show the class an X-ray image, and ask, "Where did the rays come from?" [an X-ray machine] "When you get a dental X-ray, they put a lead shield on you. Why?" [to protect you from any dangerous effects associated with the X-rays] "Why don't they use an aluminum foil shield?" [Aluminum foil will not block X-rays.] "They had you bite on something. What was it?" [It holds the film (which detects the X-rays).] "What was between the X-ray source and the film?" [teeth]

**c.** Let students know that even though people can't see invisible waves, some animals can. We can't see infrared rays, but snakes can. We can't see ultraviolet waves, but bees and some other insects can. Can we see radio waves? [No]

## Light Sources, Detectors, and Shields Worksheet

**Code:** **T = Transmitter**
**S = Shield**

Test Shield

| **Visible Light** | **Clear plastic** | **Black plastic** | **Aluminum foil** | **Paper** | **Cloth** | **Wax paper** | **Plastic bag** | **(other)** |
|---|---|---|---|---|---|---|---|---|
| **Flashlight** (Visible light) | Prediction / Result | Prediction / Result | Prediction / Result | Prediction / Result | Prediction / Result | Prediction / Result | Prediction / Result | Prediction / Result |

Test Shield

Light Source

| **Invisible Light** | **Clear plastic** | **Black plastic** | **Aluminum foil** | **Paper** | **Cloth** | **Wax paper** | **Plastic bag** | **(other)** |
|---|---|---|---|---|---|---|---|---|
| **Black light** (Ultraviolet) | Prediction / Result | Prediction / Result | Prediction / Result | Prediction / Result | Prediction / Result | Prediction / Result | Prediction / Result | Prediction / Result |
| **Heat lamp** (Infrared) | Prediction / Result | Prediction / Result | Prediction / Result | Prediction / Result | Prediction / Result | Prediction / Result | Prediction / Result | Prediction / Result |
| **Remote control** (Infrared) | Prediction / Result | Prediction / Result | Prediction / Result | Prediction / Result | Prediction / Result | Prediction / Result | Prediction / Result | Prediction / Result |



### About the Activity

This activity is adapted from ***The Invisible Universe***, a teacher's guide in the Great Explorations in Math and Science (GEMS) series, available from Lawrence Hall of Science, (510) 642-7771. E-mail: **gems@berkeley.edu.** On the Web: **http://www.lhsgems.org**.

***The Invisible Universe*** was created with support from NASA's Swift Gamma-ray Burst mission. For more information, see **http://swift.sonoma.edu**.

## What is the Astronomical Search for Origins?

Recent discoveries have given us a vastly expanded sense of the universe and our place in it. We have measured the glow of the "Big Bang" – the cosmic event that gave birth to the universe – and observed distant galaxies. We have captured snapshots of newborn stars and discovered planets around other stars. We now know that liquid water once flowed on the surface of Mars and may still exist below the icy crust of Jupiter's moon Europa. Life on Earth has been traced back nearly 4 billion years and found thriving in extreme environments, from Antarctic rocks to boiling hot springs. We appear to be on the brink of answering some fundamental questions: Where do we come from? Are we alone? The missions and research programs comprising NASA's Astronomical Search for Origins program seek to answer these questions.

# National Standards

Each activity can be used to support the following National Science Education Standards (National Academy Press, 1996):

**Grades 5–8:** Physical Science: Content Standard B: Transfer of Energy: "The sun is a major source of energy for changes on the earth's surface. The sun loses energy by emitting light. A tiny fraction of that light reaches the earth, transferring energy from the sun to the earth. **The sun's energy arrives as light with a range of wavelengths, consisting of visible light, infrared, and ultraviolet radiation.**"

**Grades 9–12:** Physical Science: Content Standard B: Interactions of Energy and Matter: "Electromagnetic waves result when a charged object is accelerated or decelerated. **Electromagnetic waves include radio waves (the longest wavelength), microwaves, infrared radiation (radiant heat), visible light, ultraviolet radiation, X-rays, and gamma rays.** The energy of electromagnetic waves is carried in packets whose magnitude is inversely proportional to the wavelength."

## The Origins Missions include:

| | |
|---|---|
| The Far Ultraviolet Spectroscopic Explorer | **fuse.pha.jhu.edu** |
| The Hubble Space Telescope | **amazing-space.stsci.edu** |
| The James Webb Space Telescope | **jwstsite.stsci.edu** |
| The Kepler Mission | **kepler.nasa.gov** |
| The NASA Astrobiology Institute | **nai.arc.nasa.gov** |
| The Navigator Program* | **planetquest.jpl.nasa.gov** |
| The Spitzer Space Telescope | **spitzer.caltech.edu** |
| The Stratospheric Observatory for Infrared Astronomy | **www.sofia.usra.edu** |
| The Wide-field Infrared Survey Explorer | **wise.ssl.berkeley.edu** |

*The Navigator missions include: the Keck Interferometer, the Large Binocular Telescope Interferometer, the Space Interferometry Mission and the Terrestrial Planet Finder.


### Image Credits

Multiwavelength images of the Whirlpool Galaxy:
Radio image – National Radio Astronomy Observatory, NRAO/AUI/NSF;

Infrared image – Spitzer Space Telescope, NASA/JPL-Caltech/R. Kennicutt (Univ. of Arizona);

Visible image – Hubble Space Telescope, NASA, ESA, S. Beckwith (STScI), and The Hubble Heritage Team (STScI/AURA);

Ultraviolet image – Galaxy Evolution Explorer, NASA/JPL-Caltech;

X-ray image – Chandra X-Ray Observatory, NASA/CXC/UMd./A.Wilson et al.

**Poster Credits:** This poster is a collaborative product of the missions and staff comprising the Origins Education Forum. The Origins Education Forum is an association of the education and public outreach leads of NASA's Astronomical Search for Origins missions: the Hubble Space Telescope, the Far Ultraviolet Spectroscopic Explorer, the Spitzer Space Telescope, the Stratospheric Observatory for Infrared Astronomy, the Kepler mission, the Wide-field Infrared Survey Explorer, the James Webb Space Telescope, the Navigator program, and the NASA Astrobiology Institute. The Forum is headquartered at the Space Telescope Science Institute, operated for NASA by the Association of Universities for Research in Astronomy (AURA). Poster illustrations and design by Stephanie Smith (STScI).

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