Stratospheric Observatory for Infrared Astronomy SOFIA

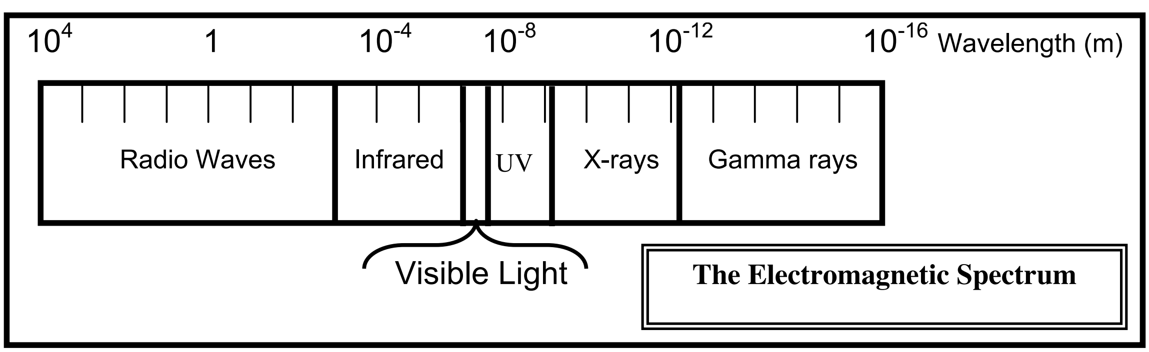
Active Astronomy
Classroom Activities for Learning about Infrared Light

1.1 For the Teacher

Most students are familiar with the rainbow of colors that make up visible light. They're often less comfortable dealing with light from the other portions of the electromagnetic spectrum — gamma rays, x-rays, ultraviolet light, visible light, infrared light, microwaves, and radio waves. Students may not realize the important role played by non-visible light in their everyday lives. For example, TV remote controls, car-locking systems, and some grocery store check-out scanners use infrared light to signal between devices or read bar-codes. Computers use infrared light to read CD-ROMs. Night-vision goggles register infrared light (also known as heat radiation), as do search-and-rescue monitors that look for the heat given off by someone lost in the wilderness at night.

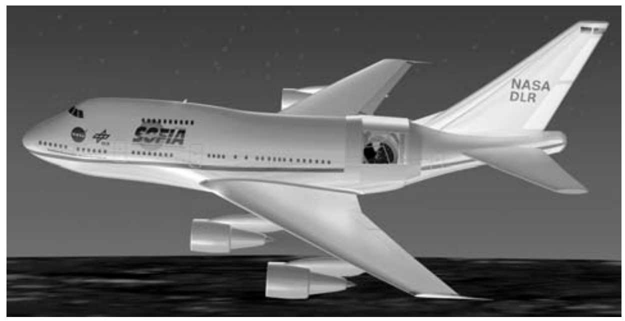
The activities in "Active Astronomy: Classroom Activities for Learning about Infrared Light" focus on improving student understanding of infrared light, which occupies the portion of the electromagnetic spectrum between visible light and microwaves, the shortest of the radio waves.

It is appropriate to refer to each portion of the electromagnetic spectrum as "light." All forms of light—from the lowest energy radio waves to the highest energy gamma rays—can be described as waves. The major difference distinguishing one from the other is wavelength; the shortest wavelength gamma rays have a wavelength about the size of the atomic nucleus, whereas the wavelength of radio waves from FM 101 is about 3 meters. Visible light is only a small part of the electromagnetic spectrum with wavelengths ranging from 0.4 to 0.7 microns (a micron is a millionth of a meter). The wavelengths of light in the infrared region vary from about 1 to 350 microns.



The Electromagnetic Spectrum

To understand the universe, astronomers must observe at all wavelength regions, including the infrared. However, water vapor in the Earth's atmosphere absorbs infrared light, keeping it from reaching telescopes on the ground (some narrow bands of infrared light do reach the ground and can be observed from the tops of high mountains). To study infrared emissions from space, astronomers have put telescopes in airplanes, which can fly high above most of the water vapor in the atmosphere, or in space.



The Stratospheric Observatory for Infrared Astronomy (SOFIA), developed by NASA and the German Aerospace Center, DLR, is the latest in a series of "flying telescopes." For SOFIA, technicians modified a Boeing 747SP aircraft to carry a 2.5-meter (8.2-foot) infrared telescope that observes the sky through a hole in the side of the airplane. When fully operational, SOFIA will be the largest airborne telescope in the world, and will make observations that are impossible for even the largest and highest of ground-based telescopes. SOFIA will observe the universe from visible (0.3 microns), through infrared (1 to 350 microns), and microwave (1600 microns) wavelengths.

Every object that has a temperature above absolute zero (0 K) emits energy in the infrared region of the spectrum. Infrared astronomy covers nearly everything in the universe. Objects too cool or too faint to be seen in visible light, such as dim, cool stars and interstellar dust particles, can be studied in the infrared. Infrared light can penetrate deep into interstellar clouds of dust and gas that block visible light, revealing astronomical phenomena that would otherwise be obscured from view. Because of this, astronomers interested in exploring the interstellar clouds that serve as the birthplaces of stars observe them in infrared light.

Previous ground-based, satellite and airborne infrared observatories have explored the infrared region of the spectrum. SOFIA will exploit and extend this scientific legacy with instruments that reveal even greater details in spectra and photographs taken in the infrared. Topics to be addressed by SOFIA scientists include:

- how stars form and evolve over time;
- how planets form around stars;
- the conditions in space between stars;
- the origin and evolution of the complex atoms and molecules important to life;
- the study of comets, planetary atmospheres and rings in the Solar System;
- how other galaxies compare to our own Milky Way Galaxy;
- the dynamic activity surrounding the super massive black hole in the center of the Milky Way Galaxy.

SOFIA is a mission in NASA's Origins Program (http://origins.jpl.nasa.gov). The Origins Program asks questions humans have pondered for centuries: Where do we come from? Are we alone? Additional information about SOFIA and its astronomical research can be found at the SOFIA web site: http://www.sofia.arc.nasa.gov.

The Activities

These activities are designed to *supplement* classroom instruction about the electromagnetic spectrum, and are not intended as a complete curriculum. The activities in this packet have been designed for use with middle school and high school physical science, astronomy and space science courses. Each activity has been designed to take 1-2 class periods (see the individual activities for more details about activity length). The activities are:

What's Getting Through to You?

Students are introduced to light and colored filters(gels), and learn about the usefulness of filters to astronomers.

Sensing the Invisible

Just as our ears cannot hear all wavelengths of sound, our eyes cannot see all wavelengths of light. Students learn that "invisible light" exists and that we can detect this light with instruments other than our eyes.

Reflection

Students learn that infrared light is reflected in the same manner as visible light. Students deduce that infrared light is another form of light and is a part of the electromagnetic spectrum.

Listening to Light

Students learn that light carries information and that infrared radiation is a form of light that in some cases behaves like visible light and other cases behaves very differently.

Student Prerequisites and Common Misconceptions

- Students are assumed to be familiar with the visible spectrum before beginning these activities, 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.”
- Students may not realize that light travels from one object to another. This may create problems for students in understanding the material in these activities. Teachers may want to address this misconception in their teaching.

  "Many elementary- and middle-school students do not believe that their eyes receive light when they look at an object. Students’ conceptions of vision vary from the notion that light fills space (‘the room is full of light’) and the eye ‘sees’ without anything linking it to the object to the idea that light illuminates surfaces that we can see by the action of our eyes on them… The conception that the eye sees without anything linking it to the object persists after traditional instruction in optics; however, some 5th graders can understand seeing as 'detecting' reflected light after specially designed instruction." *Benchmarks for Science Literacy*: p. 339.

- Students are assumed to have some familiarity assembling and working with electronic circuits.

Science Standards

These activities support the following standards and benchmarks:

National Science Education Standards — Grades 5-8

Content Standard A: Abilities necessary to do scientific inquiry (NSES, page 145)

- Use appropriate tools and techniques to gather, analyze, and interpret data
- Develop descriptions, explanations, predictions, and models using evidence

Content Standard B: Physical Science, Transfer of Energy (NSES, page 155)

- Light interacts with matter by transmission (including refraction), absorption, or scattering (including reflection). To see an object, light from that object—emitted by or scattered from it—must enter the eye.

- 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.

Content Standard E: Science and Technology (NSES, page 166)

- Science and technology are reciprocal. Science helps drive technology as it addresses questions that demand more sophisticated instruments and provides principles for better instrumentation and techniques. Technology is essential to science, because it provides instruments and techniques that enable observations of objects and phenomena that are otherwise unobservable due to factors such as quantity, distance, location, size and speed. Technology also provides tools for investigations, inquiry and analysis.

National Science Education Standards — Grades 9-12

Content Standard A: Abilities necessary to do scientific inquiry (NSES, page 175)

- Formulate and revise scientific explanations and models using logic and evidence

Content Standard B: Physical Science (NSES, page 180)

- 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.

Benchmarks for Science Literacy — Grades 6-8

The Physical Setting, 4f: Motion (pages 90-92)

- Light from the sun is made up of a mixture of many different colors of light, seen though to the eye the light looks almost white. Other things that give off or reflect light have a different mix of colors.

- Human eyes respond to only a narrow range of wavelengths of electromagnetic radiation—visible light. Differences of wavelength within that range are perceived as differences in color.

Benchmarks for Science Literacy — Grades 9-12

The Physical Setting, 4f: Motion (page 92)

- Waves can superimpose on one another, bend around corners, reflect off of surfaces, be absorbed by materials they enter, and change direction when entering a new material. All these effects vary with wavelength. The energy of waves (like any form of energy) can be changed into other forms of energy.

PLEASE NOTE: Everything from here through the bottom of the page refers to the original SOFIA kit; not all of these materials are provided as part of the NITARP kit!

These activities are designed to use easy-to-obtain materials. Information on where to obtain materials and components is listed in section 1.5.

For demonstrations (one set of materials & hardware required):

- Photocell Detector
  - Photocell (solar cell)—NOTE: Photocells may not be in stock at local electronic parts stores. But they can be special ordered, or ordered directly online or by phone (see section 1.5 for more information). *Allow at least a week for delivery.*
  - Amplifier/Speaker
  - 9-Volt battery for amplifier/speaker
  - Audio Cable with 1/8” mini-plug on one end
  - Two Jumper Cables with alligator clips on both ends
- Transmitter Circuit
  - Infrared Light-Emitting Diode (LED)
  - 0.22 μF (microfarad) Capacitor
  - Audio Cable with 1/8” mini-plug on one end
  - 5 Jumper Cables with alligator clips on both ends
  - AA Battery
  - AA Battery Holder
- Large magnifying glass, with focal length around 15 cm (fairly standard)
- Flashlight
- Laser pointer (or other laser device)
- Collection of remote control devices (TV, VCR) from several different manufacturers
- Sony Walkman, transistor radio or other music source
- Clear plastic bag
- Colored plastic bag