GENESIS
SEARCH FOR ORIGINS
Education

Cosmic Chemistry: Planetary Diversity

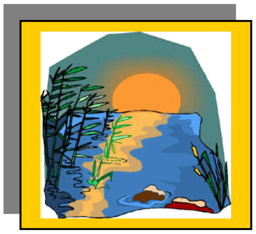
Infrared Radiation: Here Comes the Heat

STUDENT TEXT

An enormously important technique for gathering useful scientific information about the composition of material in space is to observe the emission or absorption of electromagnetic radiation that is characteristic of the material. This is especially true of radiation with wavelengths in the visible and infrared parts of the electromagnetic spectrum. In this activity the focus will be on the infrared region.

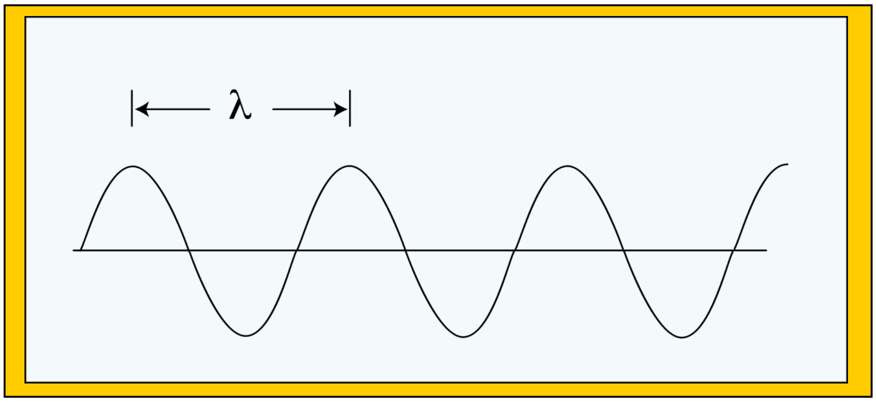
Before continuing we need to consider electromagnetic radiation in general. The first, and perhaps most important thing to know about electromagnetic radiation is that it carries energy through a medium, including empty space, where it travels at the speed of light--because it is light! And no energy can be transported faster than this. Nor is the transport hindered in the slightest way as long as the radiation is travelling in empty space.

As is often the case in science, electromagnetic radiation is modeled since we cannot see it directly. We envision it as propagating through space as a dance of oscillating electric and magnetic fields, and there are beautiful equations that describe the oscillations in great detail. For our purposes it will be sufficient to define only three characteristics of the radiation—wavelength, frequency, and energy.



As electromagnetic radiation moves from place to place it can be envisioned as being much like ripples on a pond. With this model in mind we can define the wavelength as the distance between adjacent wave crests and this distance is usually given the symbol λ, lambda. See the figure below.

Figure 1



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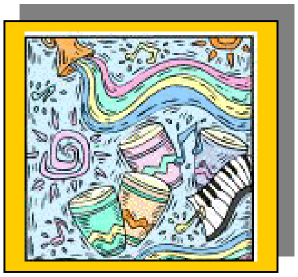
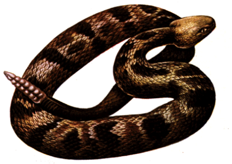
The wavelengths of electromagnetic radiation vary enormously depending on the source. Very short wavelengths, say 300 nanometers, nm, provide what is called ultraviolet light, intermediate wavelengths provide visible light (500 nm wavelength = green light), and very long wavelengths (say 80 m) provide such things as radio waves. So, when we speak of infrared or visible radiation we are just talking about electromagnetic radiation within a certain range of wavelengths. The human eye is designed to receive only the visible wavelengths from about 400 nm to around 780 nm. Radio waves are too long to affect the sensors inside the eye, which perhaps is a good thing. Can you imagine what it would be like to "see" music by Aerosmith or Garth Brooks?



Astronomers often report infrared wavelengths in microns (µm) instead of nanometers (1000 µm = 1 mm). Note that we normally would pronounce µm as micrometer, but the word micron is used universally instead. It also is the case that the "m" frequently is dropped off, with microns being represented simply by the symbol "µ," mu. Green light has a wavelength of 0.5 µm, and the visible portion of the electromagnetic spectrum would run from 0.4 to about 0.78 microns. The infrared spectrum runs from about 0.8 µm to 1000 µm (1 mm).

Even though we cannot "see" infrared radiation, we are able to detect it! Within the first few seconds of turning on a toaster or an electric heater you can detect heat, but you do not see any light, even though radiation is emitted. The radiation detected as heat is just another "color" of light that you cannot detect visually. Seconds later, as the filaments get hotter they begin to glow red, emitting visible light as well as heat. If you were to continue to turn up the power, the filaments would glow "white hot" like the filaments in a light bulb (if they did not burn up first). In other words, if an object is not quite hot enough to radiate in the visible part of the spectrum, it will emit most of its energy in the infrared. All warm (warm defined as above 0 Kelvins in temperature!) objects emit infrared radiation and the hotter the object is, the shorter will be the wavelength emitted. While it is not possible to analyze the phenomenon of infrared emission in detail, note that an object's atoms, molecules, and electrons are always in motion, vibrating and radiating electromagnetic waves. As the object's temperature increases these motions increase, causing changes in the wavelength and intensity of the radiation.



Timber Rattlesnake
(*Crotalus horridus*)

So it becomes clear that measurements of infrared emissions from a warm object may be used both to locate the object and to determine its temperature! Certain snakes—the pit vipers—are able to detect infrared radiation exceedingly well. They locate prey, such as mice, by imaging the infrared "heat" emitted from the animal (even at night when most other predators could not see the mice). With two infrared receptors (pits), a snake has even has some infrared depth perception. Living animals stand out brightly against their background, being especially bright at wavelengths around 10 µm.

Astronomers use infrared radiation in a similar fashion to locate warm objects in space. The technique of infrared astronomy has developed rapidly over the past few years. Many new stars and other objects that are not observable through regular telescopes have been discovered by observing their infrared signatures. A large number of these stars have temperatures ranging from 1000 to 2000 Kelvins, making them much cooler than the sun.