LIGHT
ITS SECRETS REVEALED

LIGHT CONCEPTS

1 **Most light is invisible to our eyes**

2 **Light is a streaming "code" that tells about the chemical composition of its source**

3 **Light from a glowing object can reveal its temperature**

Find out how information about distant objects comes to us in the form of light. Explore these concepts further using the recommended resources mentioned in this reading selection.

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1

Most light is invisible to our eyes

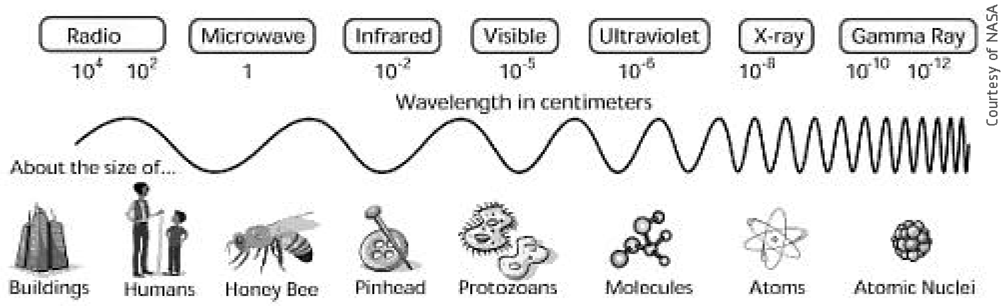
Visible or Invisible, It's All Light

When you look at a star, your eyes are capturing light that traveled all the way from the star to your eye. Astronomers learn about stars, nebulae, galaxies, and other faraway phenomena by collecting light from them with specialized instruments. But they do not collect just the kind of light your eyes can see. They also observe other kinds of light that eyes cannot see. This invisible light includes radio waves, microwaves, infrared light, ultraviolet light, X rays, and gamma rays.

All light, whether visible or invisible, is a kind of wave. These waves are like the ripples that move along the surface of a lake after a pebble is dropped. Light waves, however, are ripples in electric and magnetic fields—which is why they are also called electromagnetic waves.

There is no fundamental difference between visible light and invisible light such as radio waves and X rays. They are all electromagnetic waves that differ in only one way: their wavelength. The term "wavelength" simply means the distance from the peak of one wave to the peak of the next. The closer together these peaks are, the shorter the wavelength.

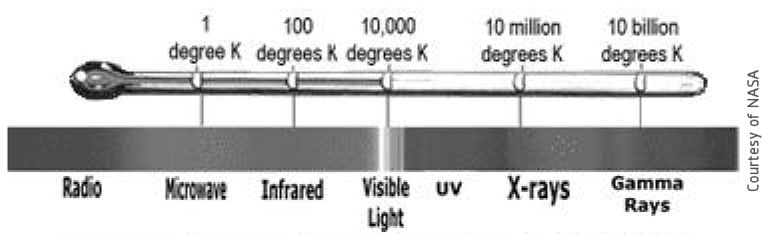
Radio waves, microwaves, and infrared rays are electromagnetic waves with longer wavelengths than visible light. Ultraviolet light, X rays, and gamma rays all have shorter wavelengths than visible light. To observe these wavelengths, astronomers use special instruments that can detect wavelengths our eyes cannot.



Wavelength = Color

Wavelengths of light are measured in nanometers (nm). One nanometer is a billionth of a meter. Visible light has wavelengths ranging from about 400 nanometers to 700 nanometers. Wavelengths shorter than 400 nm, or longer than 700 nm, are invisible to the human eye. X rays can have wavelengths as short as a few thousandths of a nanometer, while radio waves range from several meters to several thousand meters long.

The human eye sees different wavelengths as different colors. Red light has the longest wavelength you can see (around 700 nm), and blue or violet the shortest (about 400 nm). Wavelengths just longer than that of red light are called infrared



light. Wavelengths just shorter than violet are called ultraviolet, or UV. These wavelengths can be thought of as colors that your eyes cannot see.

Visible or Not?

What's the difference between visible light and invisible light? It's all in your head—specifically, in your eyes. Whether a particular wavelength of light is visible or invisible depends solely on which wavelengths your eyes can detect. If your eyes were tuned to different wavelengths, new wavelengths of light could become visible—and some colors you can see now might become invisible.

In fact, many animals see different wavelengths of light than we do. Their eyes detect wavelengths that our eyes cannot. Bees and butterflies, for example, can see ultraviolet light. Their eyes are tuned to shorter wavelengths than ours. Certain fish and snakes can perceive longer wavelengths than we can. They can detect infrared light (which we feel as heat). To these animals, ultraviolet and infrared are like additional colors of visible light.

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About half the sunlight reaching Earth's surface is visible light. Most of the rest is infrared, with about 3 percent ultraviolet. The shorter wavelengths are blocked by the Earth's atmosphere, particularly the ozone layer in the stratosphere, which is located several miles above the surface.

Seeing the Invisible

An infrared camera is just one tool for detecting invisible light. Other such tools abound in everyday life:

Radios gather invisible radio waves and convert them to sound.

Cellular phones detect microwaves and convert them to sound.

X-ray cameras—like those used in airports—send X rays through objects, then convert those X rays that pass through the object into visible light.

Infrared cameras detect heat leaking from houses to reveal where they need more insulation.

Televisions using antennas (not cable TV) detect radio waves and convert them to visible light and sound, while satellite TV dishes gather and decode microwaves.

Astronomers use instruments that can detect many wavelengths of light, visible, and invisible. Special cameras and telescopes let them "see" wavelengths of light the human eye cannot detect.

Try this Resource!

Detecting UV Light demonstrates the existence of light invisible to our eyes by making a bracelet from beads that detect ultraviolet (UV) light by changing color. This resource is available at http://www.amnh.org/education/resources/rfl/pdf/du_u01_uvlight.pdf

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If you're visiting the Moveable Museum, you can explore the concept of invisible light by using an infrared camera. This camera detects infrared waves and converts them to wavelengths our eyes can see. Hotter parts of your body, which radiate more infrared waves, appear bright white or yellow on the screen. Colder parts appear darker.

2

Light is a streaming "code" of information about its source

Astronomers depend on light from outer space to tell them what's out there. Light contains a surprising amount of information about its source. But that information must be decoded. Decoding light is how astronomers learn about objects in distant space.

Untangling White Light

The light from most stars, including the Sun, looks white. But what is white light, really? What color is it? What is its wavelength?

White light, in fact, is not any one color or wavelength. It is a mixture of all different colors of visible light. The first step in decoding starlight is separating white light into its component wavelengths. This can be done in many ways. A glass prism, for example, can split a single beam of white light into a rainbow-like spectrum.

A **spectrum** is the pattern made when light is spread out and arranged by wavelength. The instrument astronomers use to separate light into its component wavelengths is called a **spectroscope.** But many things can spread light into a spectrum—even a drop of water.

A Rainbow is a Spectrum

After it rains, there are many drops of water in the sky. When sunlight passes through these drops of water, it is spread into a spectrum. Rainbows occur because light bends, or refracts, when it passes from one density material to another. This happens when light goes from air into a water droplet, and again when it exits. The same thing happens when light passes through a glass prism.

Shorter wavelengths always refract, or bend, at sharper angles than longer wavelengths. The result is that sunlight is arranged by wavelength into a spectrum, with the shortest waves on one side and the longest on the other.

Sunlight also contains infrared and ultraviolet light, so a rainbow actually continues on each side—we just can't see those particular wavelengths.

Try this Resource!

White Light and Colored Light offers two simple ways to demonstrate that white light is made of different colors of light mixed together. This resource is available at http://www.amnh.org/education/resources/rfl/pdf/du_u02_white.pdf

Spectral Lines

When sunlight is spread into a spectrum, it reveals all the colors of the rainbow. But not all light that appears white contains every color. When spread into a spectrum, light from these "white" sources looks like a rainbow with certain colors missing. Some spectra contain a series of bright stripes, separated by dark stripes or gaps. Even sunlight, which appears to be a continuous spectrum, reveals very narrow dark lines when observed with a good spectroscope. These stripes are called **spectral lines.**

White light is not the only light that can be separated into a spectrum. What may look like a single color of light is often really several different colors mixed together. When separated by a spectroscope, stripes of two or more different colors appear.

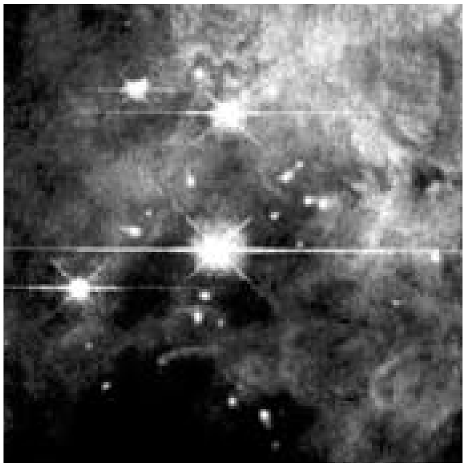
Light Fingerprints

Bright spectral lines are created by excited atoms that give off light at particular wavelengths, causing bright lines against a dark background. Atoms can also absorb light at particular wavelengths. This causes dark spectral lines in a bright spectrum, when a gas is lit from behind. Gases around the Sun, for example, absorb some of the Sun's light before it reaches us, leaving faint dark lines in the Sun's spectrum. These lines allow scientists to learn the chemical composition of the Sun's atmosphere.

Different atoms emit and absorb light at precise wavelengths that are unique for each element. When seen through a spectroscope, these specific colors of light appear as a distinctive pattern of spectral lines. These lines are like a "light fingerprint" of that element.

These light fingerprints can be used to identify the atoms that emitted the light, no matter how far away they are. Thus, light from a distant star can reveal the chemical composition of that star. Spectral lines are like a code containing information about the stars they came from.

! Helium, the gas used to inflate children's balloons, was first discovered in the Sun from its spectral lines. When a set of lines was found in the Sun's spectrum that did not match any known element on Earth, scientists named their new discovery helium, after the Greek Sun-god, Helios. Only later was helium found on Earth as well.



John Bally, Dave Devine, and Ralph Sutherland

This group of bright stars, known as the Trapezium Cluster, is the source of all light emitted by the Orion nebula.

Reading Starlight

To analyze the composition of a star, astronomers spread out its light into a spectrum. They then look for lines along the spectrum that are dark, and compare them to the lines of known elements.

Try this Resource!

Building a Spectroscope shows how to make your own spectroscope. You can use it to see the spectral lines emitted by streetlights, neon signs, and the fluorescent bulbs in your classroom. This resource is available at http://www.amnh.org/education/resources/rfl/pdf/du_u03_spectroscope.pdf

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If you're visiting the Moveable Museum, you can practice matching the light fingerprints of particular elements with actual spectral lines observed in light from nebulae and stars. Using these light fingerprints, they will be able to identify specific elements in a distant nebula.

3 Light from a glowing object can reveal its temperature

When energy is absorbed and released by gases, such as those in stars and nebulae, light is released at precise wavelengths. This is called **luminescence** or **fluorescence**. But light can also be released another way—by heating up solid things until they glow. This is called **incandescence**. Light created this way does not appear in separate stripes, but as a continuous smear of colors along a spectrum, like an entire rainbow. Both kinds of light contain information about their source. The colors in incandescent light depend on the temperature of the source, while those in fluorescent light depend on its chemical composition.

Two common sources of light are fluorescent and incandescent light bulbs. Incandescent lights work by heating up a metal filament inside the bulb. If you look at an ordinary incandescent bulb with a spectroscope, you will see a complete rainbow with no dark lines. If you look at light from a fluorescent light bulb, which is filled with a gas, you will see bright spectral lines with dark gaps in between.

! Incandescent lights actually produce more heat, or infrared light, than visible light. A full three-fourths of the light they radiate is in the form of invisible infrared light, which will warm your hand but will not help you read. Fluorescent lights, in contrast, emit almost no infrared light. If you put your hand next to a fluorescent bulb, it will hardly even feel warm. Because fluorescent lights produce most of their light in the visible wavelengths, they require less electricity to light up a room, making them more energy efficient than incandescent bulbs.

Light and Temperature

Incandescent light contains useful information about the temperature of its source. Hot, solid objects emit a wide range of wavelengths of light. The brightest color in this range indicates the temperature.

The hotter the energy source, the shorter the wavelengths of light it emits. A piece of metal, warm to the human touch, emits a lot of infrared light, whose wavelengths are too long to see. But if heated further, it will glow in the shorter, visible wavelengths. It will go from warm, but not glowing, to “red hot.” Heating it further will make it glow white hot, as shorter wavelengths are emitted.

Objects at even higher temperatures glow in ultraviolet light. Astronomers observe extremely hot stars by studying the UV light they emit. X rays from space reveal even hotter light sources, such as gases around a black hole. The shortest wavelengths astronomers can detect, called gamma rays, are released from only the very hottest sources and most energetic events, such as exploding stars. Cold, dying stars send out light at much longer wavelengths, such as infrared.

You may have noticed that some stars in the sky appear as slightly different colors, even to the naked eye. In general, bluish stars are hotter than yellow and red ones.

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The Kelvin Scale

In everyday life, two scales are used to measure temperature: Fahrenheit and Celsius. Astronomers, however, prefer to use a third scale, called Kelvin. The Kelvin scale is actually just a slight variation on Celsius. Temperatures in the Kelvin scale equal the temperature in the Celsius scale plus 273 degrees. So, for instance, 0° C = 273K. Scientists prefer the Kelvin scale because there are no temperatures below zero in the Kelvin scale. On the Kelvin scale, zero degrees is called absolute zero, because that is the coldest anything in the universe can get.