Be a Scientist!

Why do we need telescopes in order to observe stars that are very far away? Why do stars look bright in the sky while most galaxies, which have billions of stars, are too dim to see without a telescope?

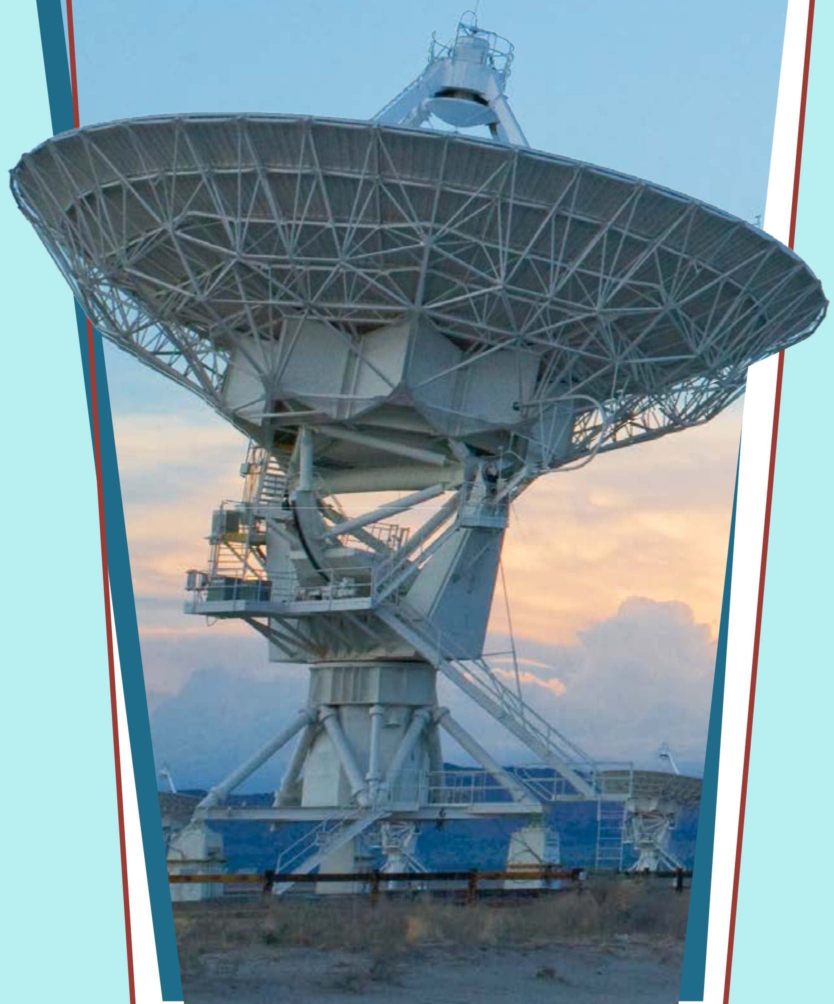
Design an experiment to compare how an object looks when illuminated by flashlights at two different distances. Decide how you will judge how bright the object appears when the light shines on it in a darkened room. Compare the object's brightness when the light shines on it from different distances. Make a chart or graph to compare the results.

Beyond the Book

Use the Internet to research a telescope that is currently being designed or built. What type of telescope is it? How do scientists and engineers hope it will be different from other telescopes? Does it use new technology to help us see farther or more clearly than before?

FOCUS Book

POWERFUL TELESCOPES



Science A–Z

POWERFUL TELESCOPES

FOCUS Question

How do telescopes help us see far into the universe?

Structure and Function

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Looking into Space

Are there planets outside our solar system? What are stars made of? Is there a black hole at the center of the Milky Way galaxy? How big is the universe?

Astronomers rely on a very important type of tool to help answer these questions: the *telescope*. Telescopes allow us to see distant objects. They *magnify* these objects so that they appear bigger than they do when you look at them with the naked eye.

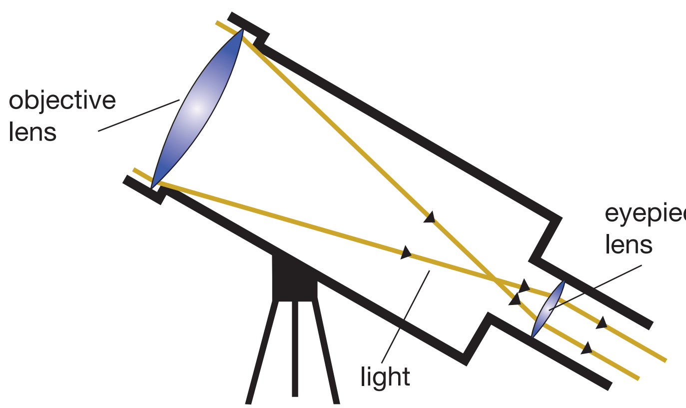
There are many different types of telescopes. Some use mirrors to collect light, while others use glass lenses. Some collect visible light, while others detect light that we can't see. Some make observations from Earth, while others are out in space.

Refracting Telescopes

The first known telescope was invented in 1608. In 1609, Thomas Harriot and Galileo Galilei used telescopes to look into the sky. They were amazed at what they saw. Harriot drew maps of the Moon with details not seen before. Galileo discovered four moons orbiting the planet Jupiter. Soon, scientists were building more powerful telescopes to observe objects in the sky.

Galileo's telescope was a *refracting telescope.* In a refracting telescope, light first travels through a piece of curved glass called a *lens.* The curve of the lens causes the light to bend, or *refract.* Light rays pass through a tube, come together, and pass through a second lens. The second lens refracts the light again before it passes into the eye. The eye sees a large image of the object.

REFRACTING TELESCOPE



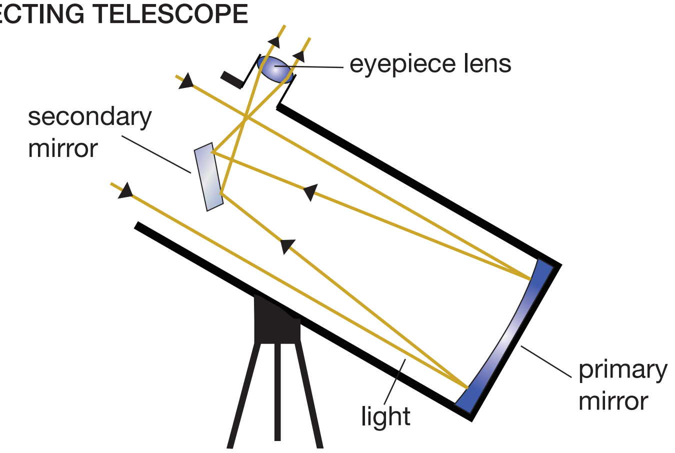
Reflecting Telescopes

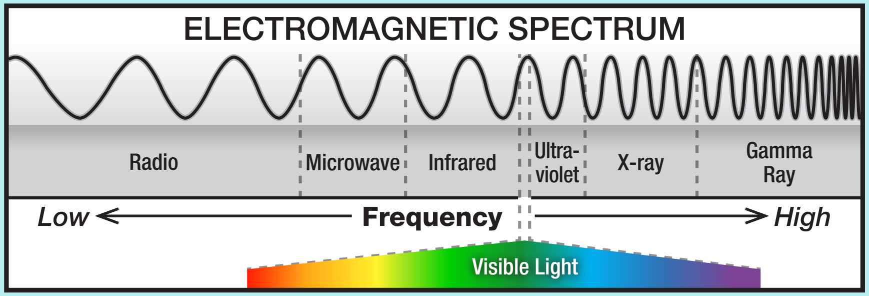
Early refracting telescopes had some problems. It was hard to grind the glass lenses perfectly, so the images were often fuzzy and the colors were not quite right.

In 1668, Isaac Newton invented the *reflecting telescope.* These telescopes use mirrors instead of lenses to gather light. In a reflecting telescope, light from the object travels through the telescope and *reflects*, or bounces off, a curved mirror. The curved mirror focuses light to a small point, where there is another, smaller mirror. The light then bounces off that mirror and travels to the eye. Most large modern telescopes are reflecting telescopes.

Compare the telescope diagrams on pages 3 and 4.

REFLECTING TELESCOPE





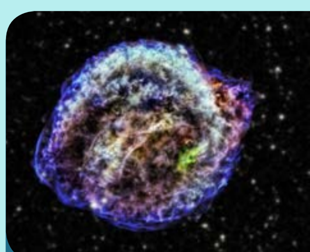
source: earthobservatory.nasa.gov

Invisible Forms of Light

Objects in space give off many different forms of light, or *electromagnetic radiation.* We can see visible light, but we can't see the other forms of light. These include *radio waves*, *microwaves*, *infrared*, *ultraviolet*, *X-rays*, and *gamma rays.* Engineers have designed telescopes that detect these invisible forms of light. For example, the Goldstone radio telescope in California collects radio waves from space. Radio telescopes help us search for signs of intelligent life in the universe.

Goldstone radio telescope

The image to the right is from the Chandra X-Ray Observatory in space. It shows X-rays from an exploding star called Kepler's Supernova. The image uses false colors. Each color represents a different X-ray wavelength.



Kepler's Supernova

Earth-Based Telescopes: The Bigger, the Better

Increasing the size of a telescope's mirror usually leads to a more powerful telescope. Bigger reflectors gather more light. They allow us to see objects that are much smaller, fainter, or farther away than smaller telescopes do.

However, it is very hard to make large mirrors that are perfectly shaped. Also, their weight causes them to bend. Then the light does not bounce off the surfaces in the right direction. The images become distorted.

To avoid this problem, engineers often make mirrors that are actually many smaller mirrors put together. The large mirror of the Southern African Large Telescope (SALT) is made of 91 mirrors, each of which is 1.2 meters (4 ft.) across. Together, they make a mirror that is 11 meters (36 ft.) by 9.8 meters (32 ft.). It can help us see objects that are one *billion* times fainter than what you can see when you look at the sky.

The SALT primary mirror is made of many sections working together.

Eight individual telescopes work together to make up the Very Large Telescope (VLT) in Chile.

Another way to avoid extra large mirrors that can bend is to build several identical telescopes close to each other and combine the light from them. This is called a telescope *array*. The Very Large Telescope (VLT) in Chile is an array of four telescopes. Each telescope has a mirror that is 8.2 meters (27 ft.) across. In addition, it has four movable telescopes. Each of these has a mirror that is 1.8 meters (6 ft.) across. When the telescopes work together, astronomers can see details 25 times finer than when using just one of the telescopes.

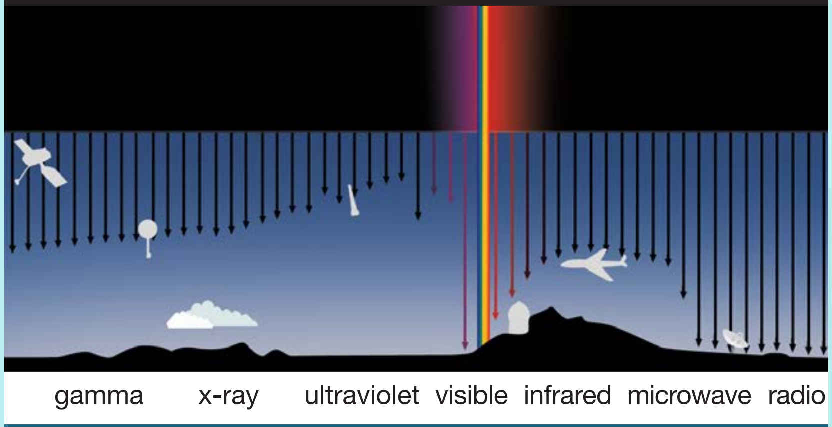
Space Telescopes and Time Machines

Astronomers answer many questions about the universe using large telescopes and telescope arrays on the ground. But even the best ground-based telescopes have challenges.

As light travels from space to Earth's surface, the gases in Earth's atmosphere reflect and absorb it. As a result, not all the light from space reaches telescopes on the ground.

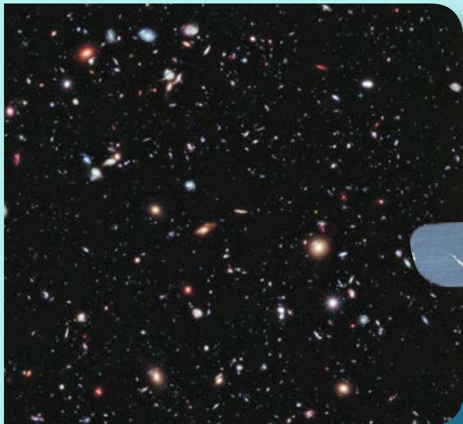
For example, almost all gamma rays are absorbed by Earth's atmosphere. There is no way to study gamma rays in space by using telescopes on Earth's surface.

EARTH'S ATMOSPHERE BLOCKS SOME RAYS

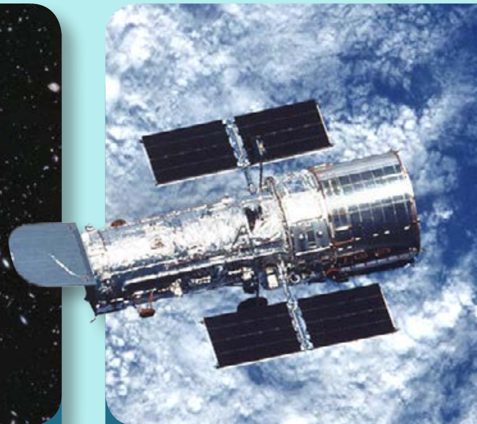


Not all wavelengths of light (shown with arrows) reach the surface of Earth. Which wavelengths do reach Earth's surface?

source credit: STScI/JHU/NASA



Hubble Space Telescope (HST) image of distant galaxies



HST outside Earth's atmosphere

To solve this problem, engineers have designed space telescopes. These telescopes are launched into orbit around Earth or the Sun. From there, they can make observations far outside our atmosphere. They use radio signals to send data to scientists on Earth. Like ground-based telescopes, space telescopes are designed to make different kinds of observations. The Hubble Space Telescope (HST), for example, has been able to gather light from galaxies more than 13.2 billion light-years away! These galaxies formed shortly after the universe itself formed.

Do You Know?

One *light-year* is the distance light travels in one year. When we look at stars that are 13 billion light-years away, we see what they looked like 13 billion years ago. Some people call giant telescopes that can see deep into space "time machines."

Read-Think-Write

Write your answers on separate paper. Use details from the text as evidence.

1. Contrast what happens to light inside a refracting telescope to what happens to light inside a reflecting telescope.
2. Using the spectrum diagram on page 5, name one form of electromagnetic radiation that has a *lower* frequency than visible light.
3. What is the difference between a telescope and a telescope array?
4. Why can space telescopes make sharper images than ground-based telescopes?
   - Ⓐ They have bigger mirrors.
   - Ⓑ They are closer to the stars.
   - Ⓒ They are above Earth's atmosphere.
5. Explain why someone might call a powerful telescope a "time machine."

FOCUS Question

How do telescopes help us see far into the universe? Describe two ways that telescopes increase what we can see in space compared to looking with our eyes.