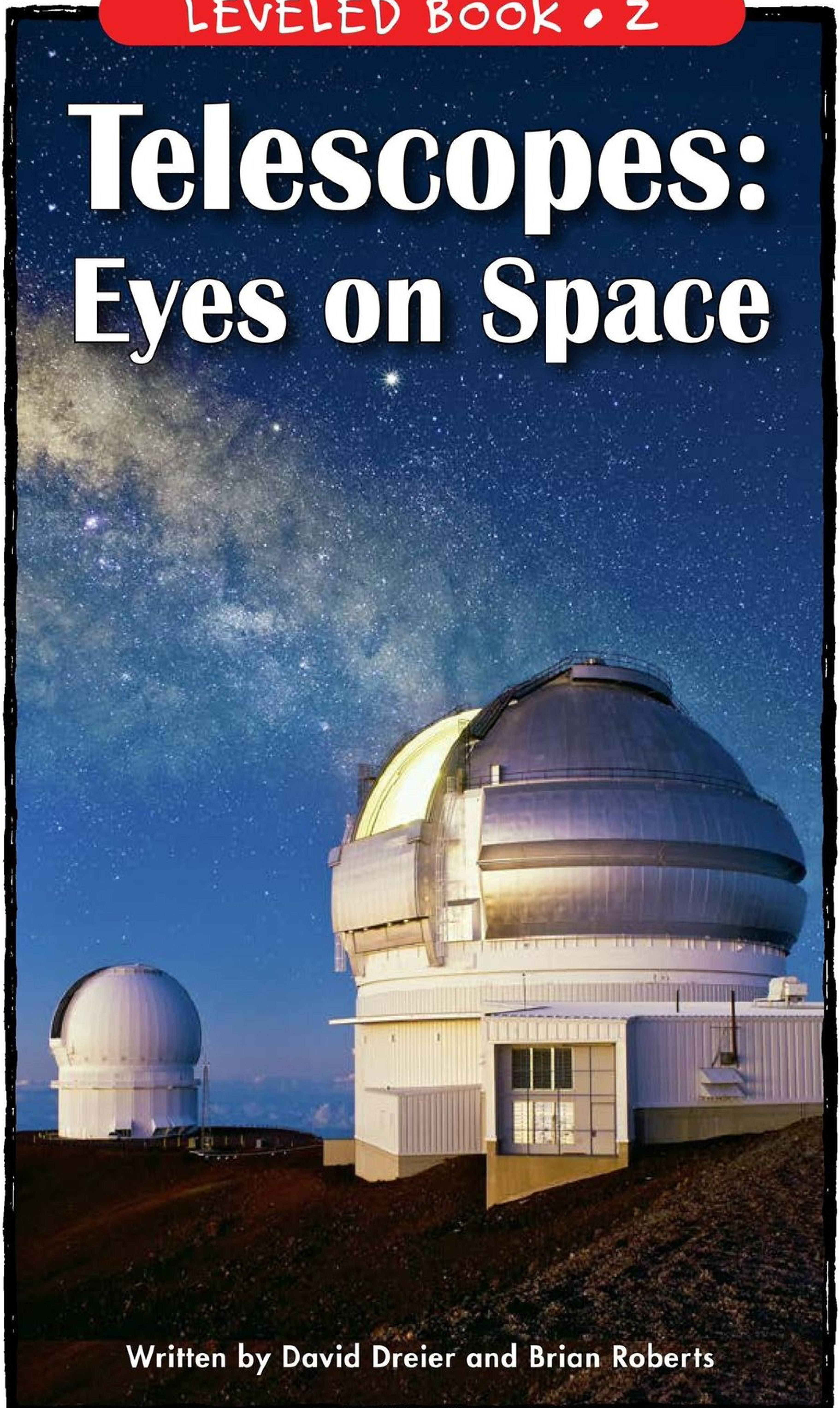
LEVELED BOOK • Z

Telescopes: Eyes on Space



Written by David Dreier and Brian Roberts

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NEAT comet, also known as C/2001 Q4

Introduction

For many thousands of years, curious people have gazed into the sky and wondered about the things they saw. Their observations were limited to what could be seen with the unaided eye. It wasn't until about 400 years ago, with the invention of the telescope, that our knowledge of space took a huge leap forward. Since that time, telescopes have evolved into powerful tools for viewing stars, planets, and other objects in space.

There are two major types of telescopes. The first type gathers light from distant objects and magnifies images formed by that light. It is called an **optical telescope**, or a light-gathering telescope. The second type of telescope, called a **radio telescope**, collects radio waves from space. While these waves are invisible, they can be converted into visible images we can examine.

We'll learn about the history of telescopes, how they work, and how scientists and others use them to study distant objects in space.

optical telescope

radio telescope

Word Wise

The word *telescope* comes from the Greek word *tele*, meaning "far off or distant" and the Greek word *skopos*, meaning "to watch or look at."

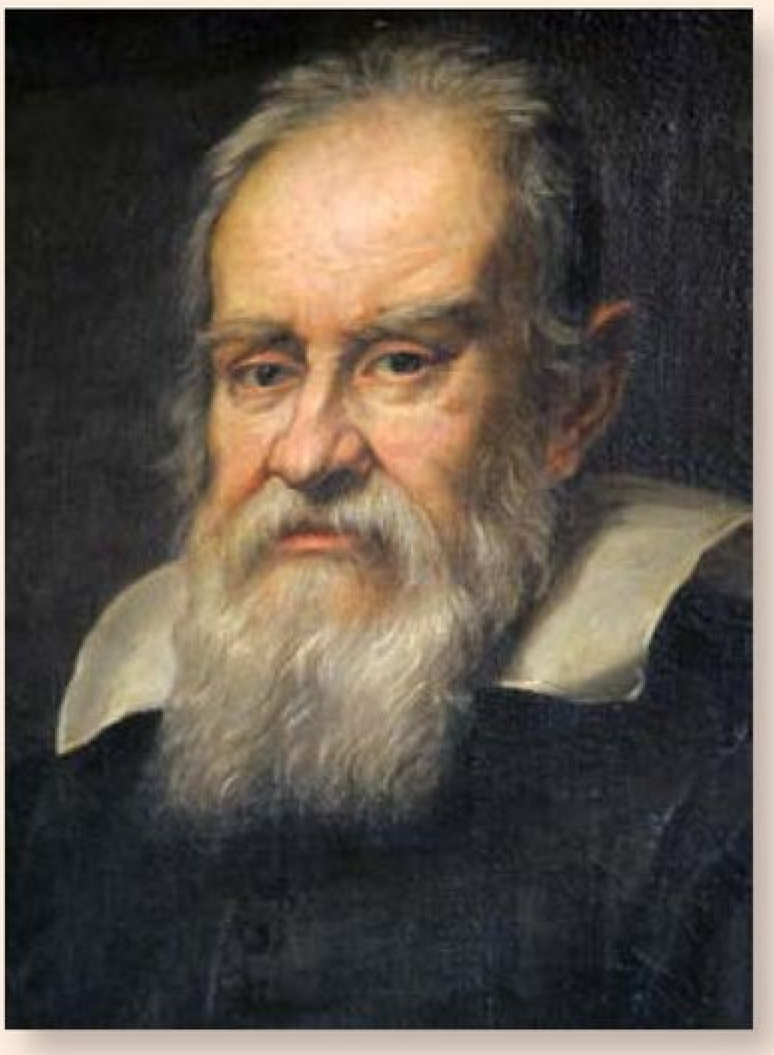
Example of an early telescope

Early Light-Gathering Telescopes

The invention of the telescope was first made possible through the development of the glass lens. A lens is a curved piece of glass that bends and focuses light. Early eyeglass lenses for reading were developed by Italian glassmakers. But it was the Dutch lens maker, Hans Lippershey, whom most historians say was the first to discover how to combine lenses to look at distant objects. He put two lenses in line so that the first lens magnified the light from the second lens. That made distant objects appear much nearer. In 1608, Lippershey built his first crude telescope which he named "The Looker." Other people were also experimenting with lens combinations, but Lippershey was the first to apply for a patent. His invention became an important military tool. The telescope provided a big advantage in warfare, allowing Dutch armies to watch enemy troop movements from afar.

A year after Lippershey invented his telescope, a man in Italy, Galileo Galilei, was hard at work building a telescope for observing objects in space. He greatly improved on the work of Lippershey and other Dutch lens makers, creating telescopes that magnified objects five times and, eventually, thirty times. Galileo used his telescope to observe distant objects in space. Because of this early work, he became known as the Father of Astronomy. Below is a list of the important observations Galileo made with his telescopes.

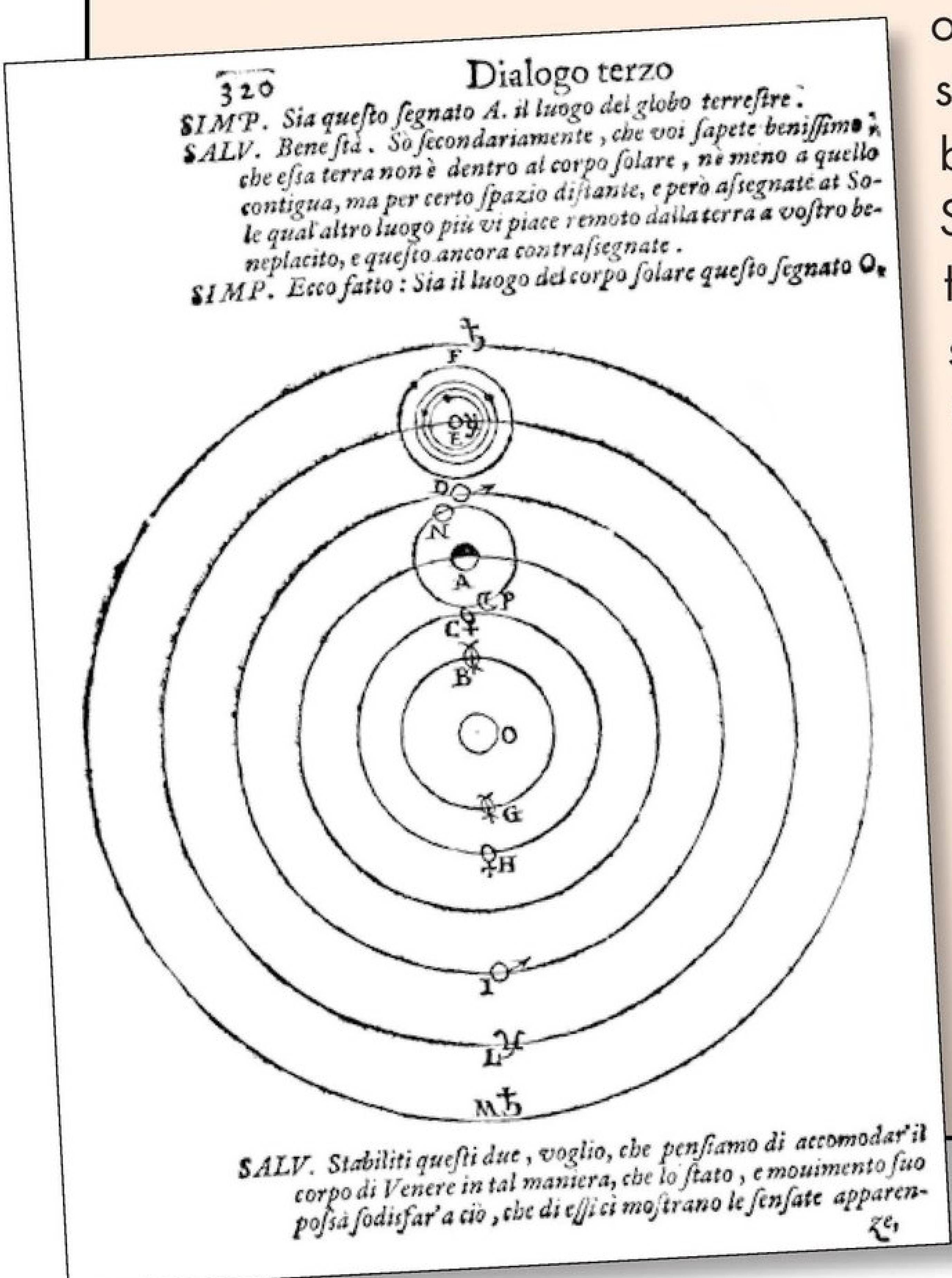
Galileo's Observations



- Craters and mountains on the Moon's surface
- Four of Jupiter's moons
- Phases of Venus—proving that it orbits the Sun
- Sunspots on the Sun's surface
- The Milky Way's composition as a galaxy of stars rather than a cloud of cosmic dust, as previously thought
- Neptune—though he failed to realize that it was a planet

Galileo’s Dilemma

As a professor of astronomy, Galileo was required to teach a model of the solar system that placed Earth at the center and had the Sun and all planets revolving around it. But his observations of space convinced him that a different theory might be more accurate. This theory placed the Sun at the center of the solar system, with the planets revolving around it. His teaching of this theory upset the Roman Catholic Church because the Church believed that God had designed the universe to revolve around Earth. Galileo’s theory displaced humanity from the center of the universe and made Earth just one of a number of planets revolving around one of many stars. The Church banned Galileo’s Sun-centered theory and sentenced him to life in prison. But because Galileo was already old, he was allowed to serve his sentence at home, under house arrest, for the rest of his life.



320 Dialogo terzo

SIMP. Sia queſto ſegnato A. il luogo del globo terreſtre.
SALV. Bene ſtà. Sò ſecondariamente, che voi ſapete beniſſimo, che eſſa terra non è dentro al corpo ſolare, nè meno a quello contigua, ma per certo ſpazio diſtante, e però aſſegnate al Sole qual altro luogo più vi piace remoto dalla terra a voſtro beneplacito, e queſto ancora contraſſegnate.
SIMP. Ecco fatto: Sia il luogo del corpo ſolare queſto ſegnato O.

SALV. Stabiliti queſti due, voglio, che penſiamo di accomodar'il corpo di Venere in tal maniera, che lo ſtato, e mouimento ſuo poſſà ſodisfar'a ciò, che di eſſi ci moſtrano le ſenſate apparenze, Other scientists followed in the footsteps of Galileo, improving the telescope and revealing even more about objects in space. One of the first was the famous British scientist Isaac Newton. Newton found that a polished, curved mirror could gather light from objects, much as Lippershey's and Galileo's lenses did. Unlike telescopes that use a lens to gather light, Newton's mirror telescope gathered light without separating it into a rainbow of colors. It was also possible to construct a mirror larger than a lens. These advantages made Newton's telescope superior to telescopes that only relied on lenses.

Technicians inspect the Hubble Space Telescope's mirror in 1984.

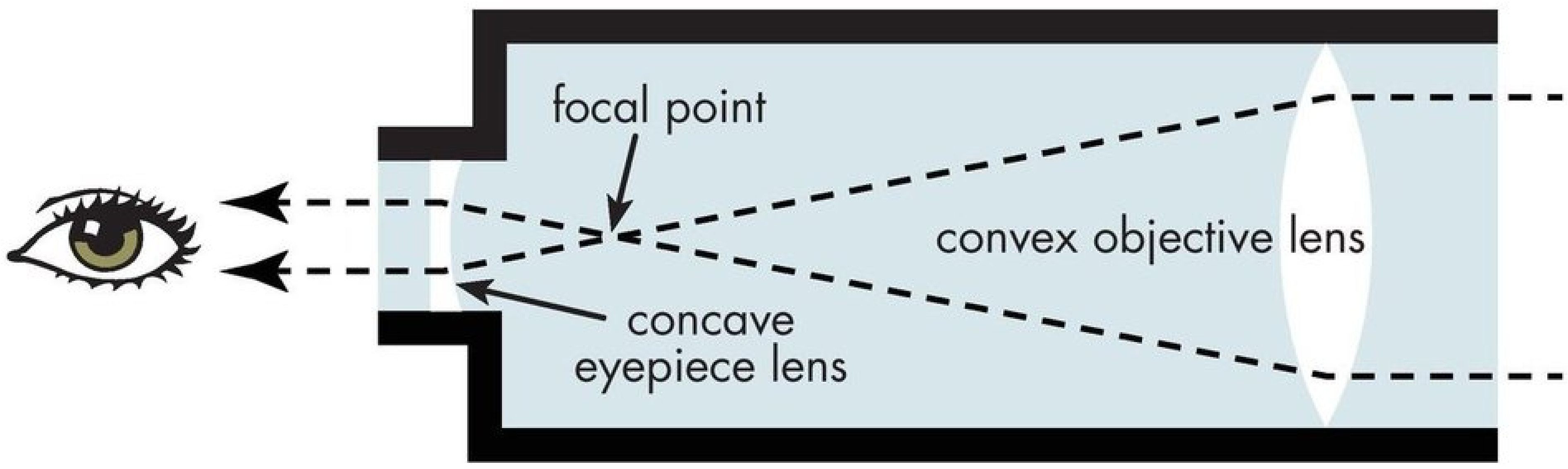
How Telescopes Work

Not all lenses work in the same way to magnify images. All optical telescopes work by gathering light to a point. Those that use a lens to bend light to a center point are called refracting telescopes. Those that use a curved mirror to reflect light to a center point are called reflecting telescopes.

Refracting telescopes have three basic parts—a tube and two lenses. The tube serves two purposes: (1) it holds the two lenses in place at the correct distance from each other, and (2) it keeps out dust and light that would interfere with the formation of a good image. The larger lens—the one farther from the eye—is a **convex** lens, which means it is thicker in the middle than at the outer edge. Light entering the telescope through the lens is bent to a point called the **focal point**. This forms an image of the object that the telescope is pointed toward. A smaller lens, called the eyepiece, is used to magnify this image before it enters the eye, making the distant object look larger and closer.

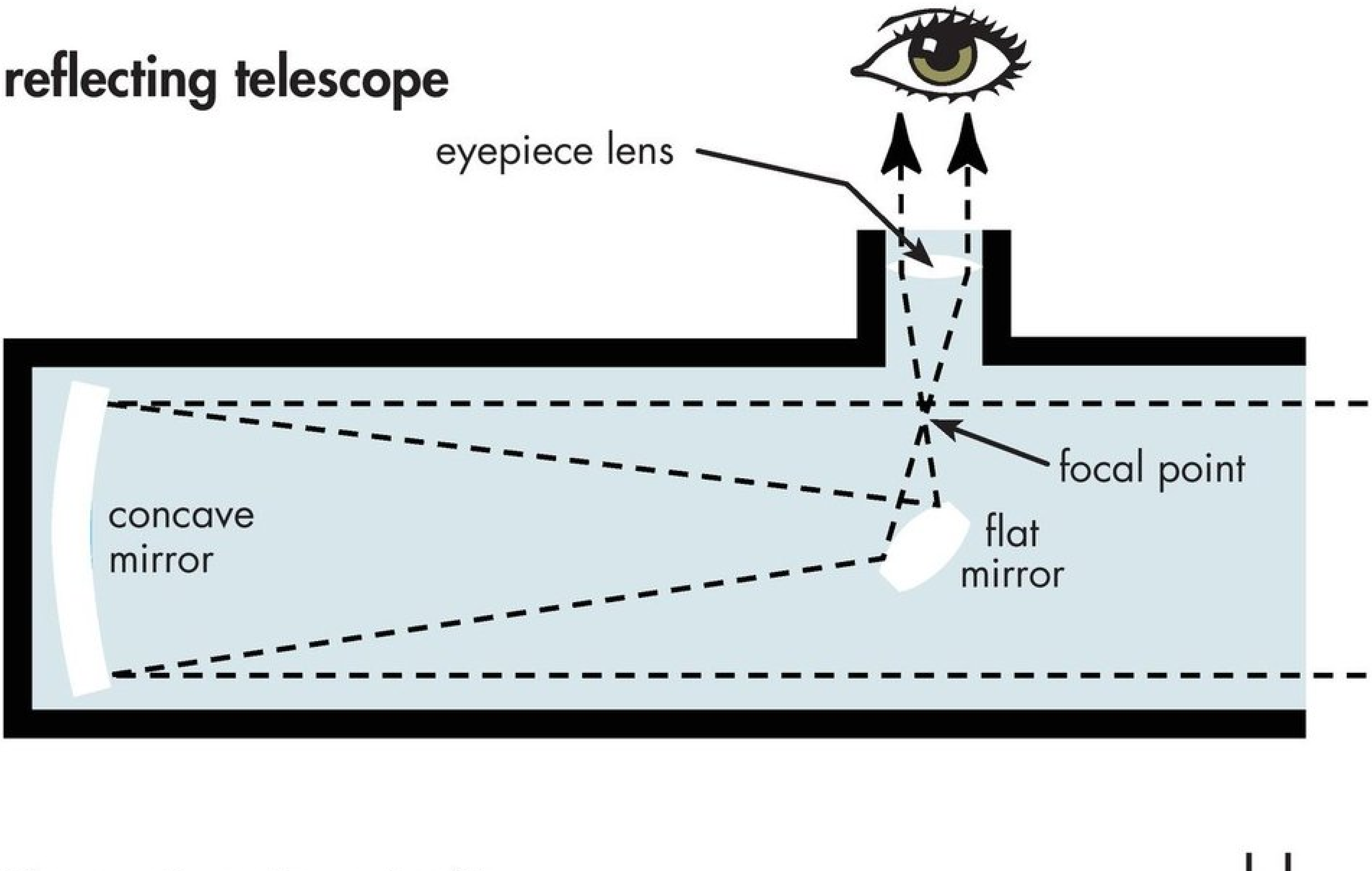

A convex lens in a magnifying glass

refracting telescope

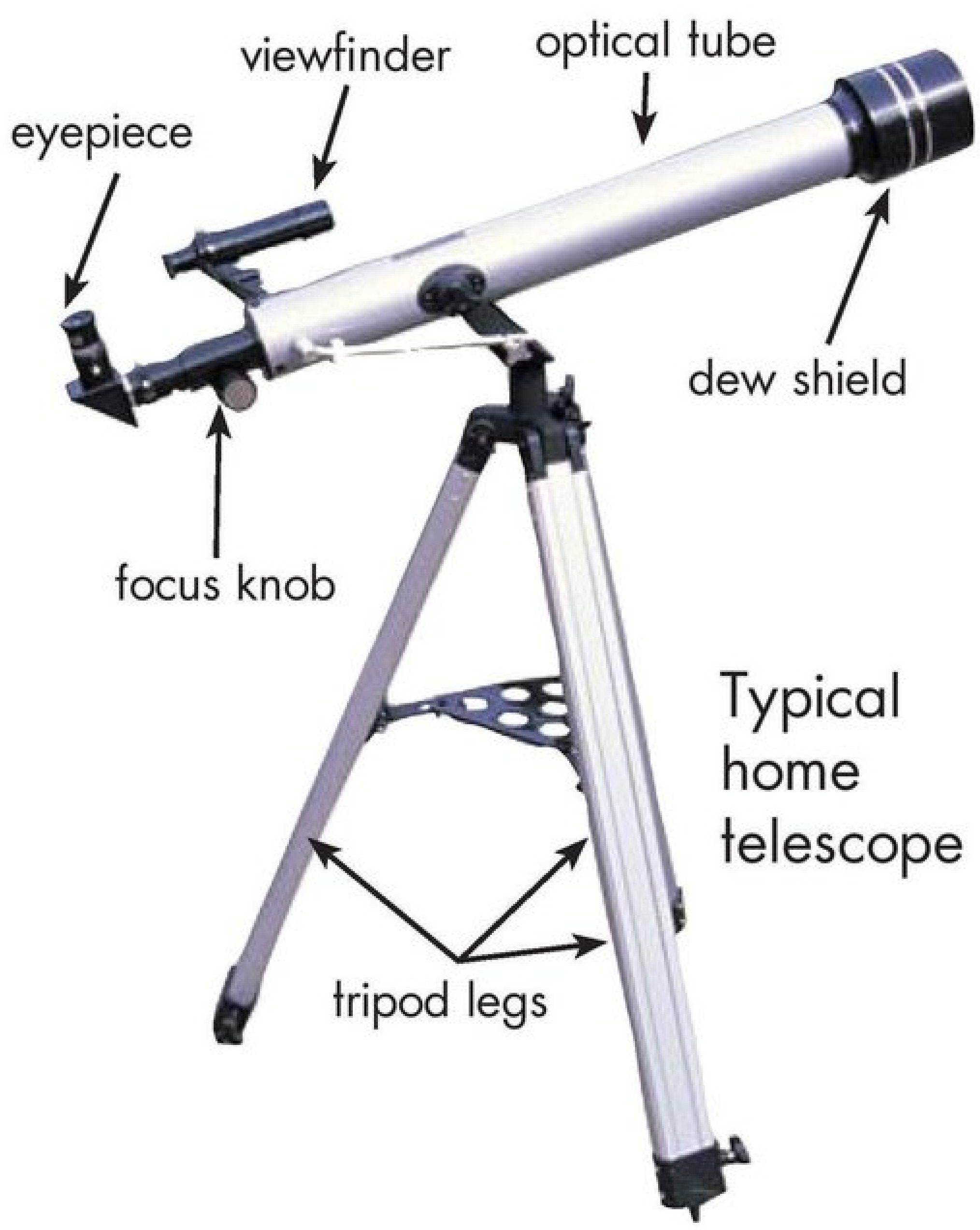


A reflecting telescope has four basic parts—a tube, two mirrors, and a lens. The tube holds the mirrors and lens in place. The primary mirror is a large, **concave** mirror, curved inward like the inside of a bowl. This mirror gathers the light and reflects it to a secondary, flat mirror. The flat mirror is mounted at an angle and is much smaller. Its angle allows more incoming light to pass by without distortion. It reflects the bright image from the concave mirror up to the eyepiece lens mounted on the side.

reflecting telescope



Reflecting telescopes have advantages over refracting telescopes. The most important advantage is that making and polishing a large concave mirror is much easier and less expensive than making a large convex lens. It is difficult to make a light-gathering lens more than 10 centimeters (4 in.) in diameter. Larger mirrors, on the other hand, are not only easier to make, but they also can gather more light. The more light a telescope can pick up, the greater the number of dim and distant objects that astronomers can observe in space.

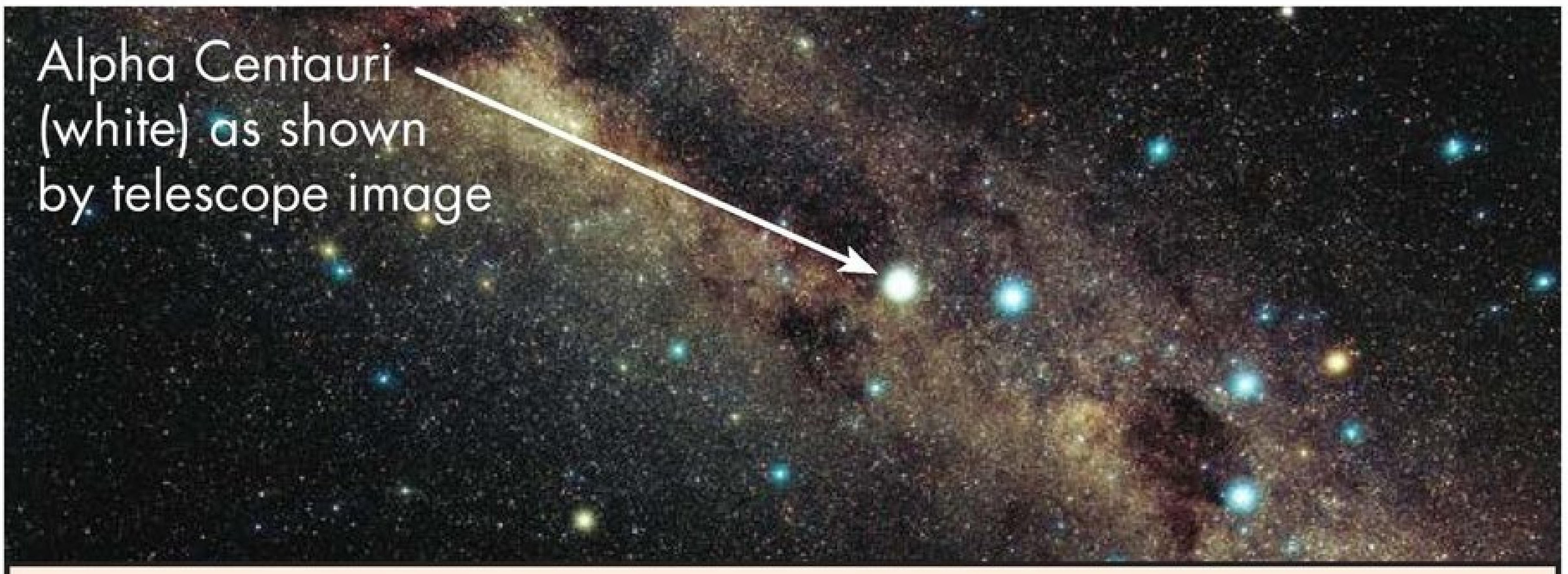


Typical home telescope

Math Minute

Light is very fast, traveling 300,000 kilometers (186,000 mi.) in just one second. The Sun is 149,000,000 kilometers (93,000,000 mi.) from Earth. How many minutes does it take light leaving the Sun to reach Earth?

Answer: 8.3 minutes



Do You Know?

Distances in space are so vast that astronomers have created a unit of measure called a light year to measure them. A light year is the distance that light, traveling at 300,000 kilometers per second (186,000 mi/sec), can travel in one year. The nearest stars to Earth are: Proxima Centauri, 4.2 light years away, and Alpha Centauri, 4.3 light years away

Modern Telescopes

Regardless of whether a telescope is the refracting or reflecting type, new telescopes are being built increasingly larger. In the 1840s, scientists in Ireland built a large reflecting telescope called the Leviathan. Its mirror was 1.8 meters (5.9 ft.) in diameter, which seemed incredibly large at the time.

As bigger telescopes were built, people created special buildings, called observatories, to house them. **Observatories** began popping up all around the world. Many of them were built on mountaintops, away from the glare of city lights.

In 1897, the United States built an observatory in Wisconsin to house the largest refracting telescope ever built. The telescope's extraordinary light-gathering lens measured 40 centimeters (15 in.) wide. It was housed in the Yerkes Observatory.

Beginning in the early 1900s, new observatories were built to house giant reflecting telescopes. They could be made larger and more powerful than refracting telescopes and, after all, astronomers wanted to see farther and farther into space. Seeing farther required gathering more and dimmer light. With the construction of two large reflecting telescopes, southern California began to emerge as a major center for astronomy and research.

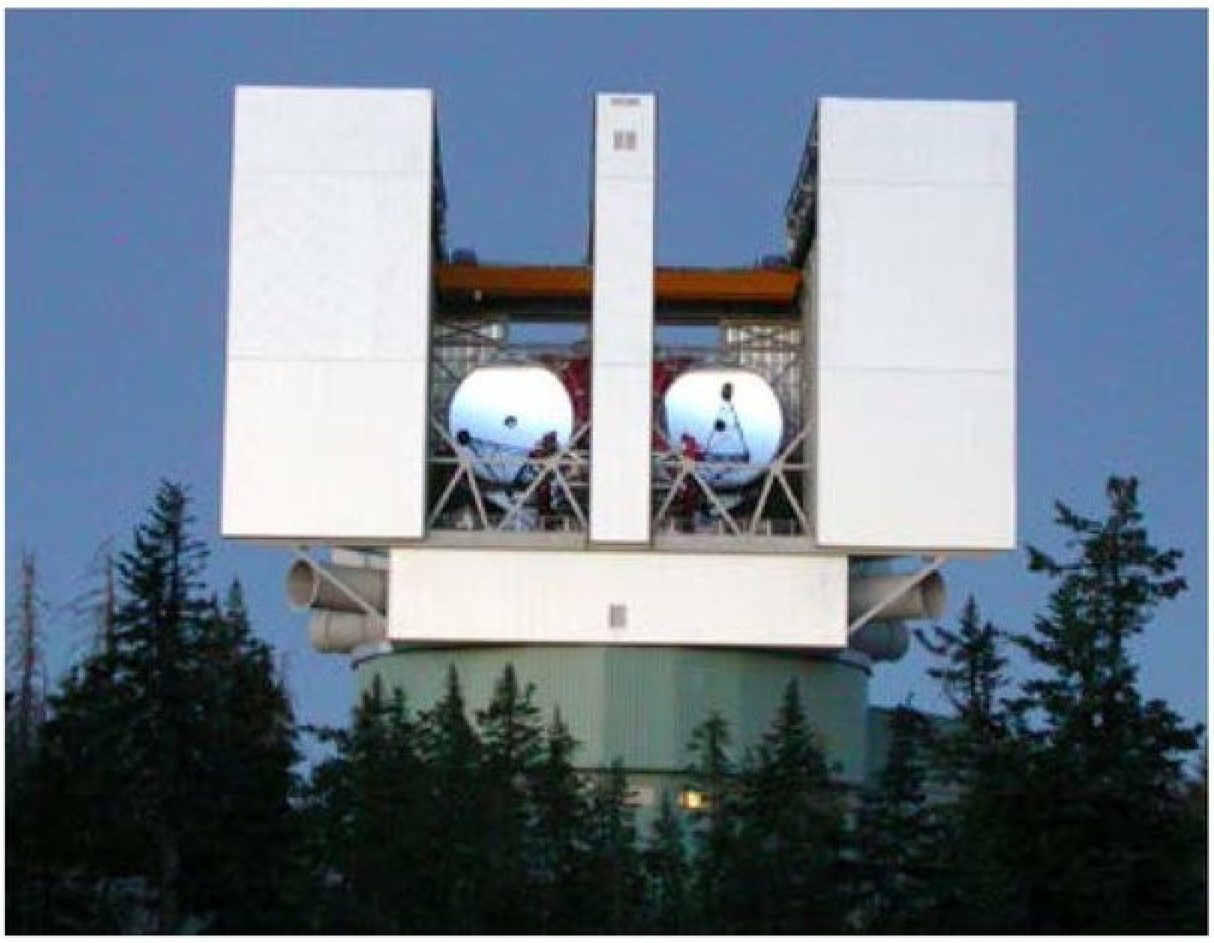
One of the telescopes, in the Mount Wilson Observatory near Los Angeles, had a mirror 2.5 meters (8 ft.) in diameter. Astronomers used this powerful telescope to help prove that many galaxies exist well beyond our Milky Way Galaxy.

The 2.5 m. (8 ft.) Hooker telescope on Mount Wilson

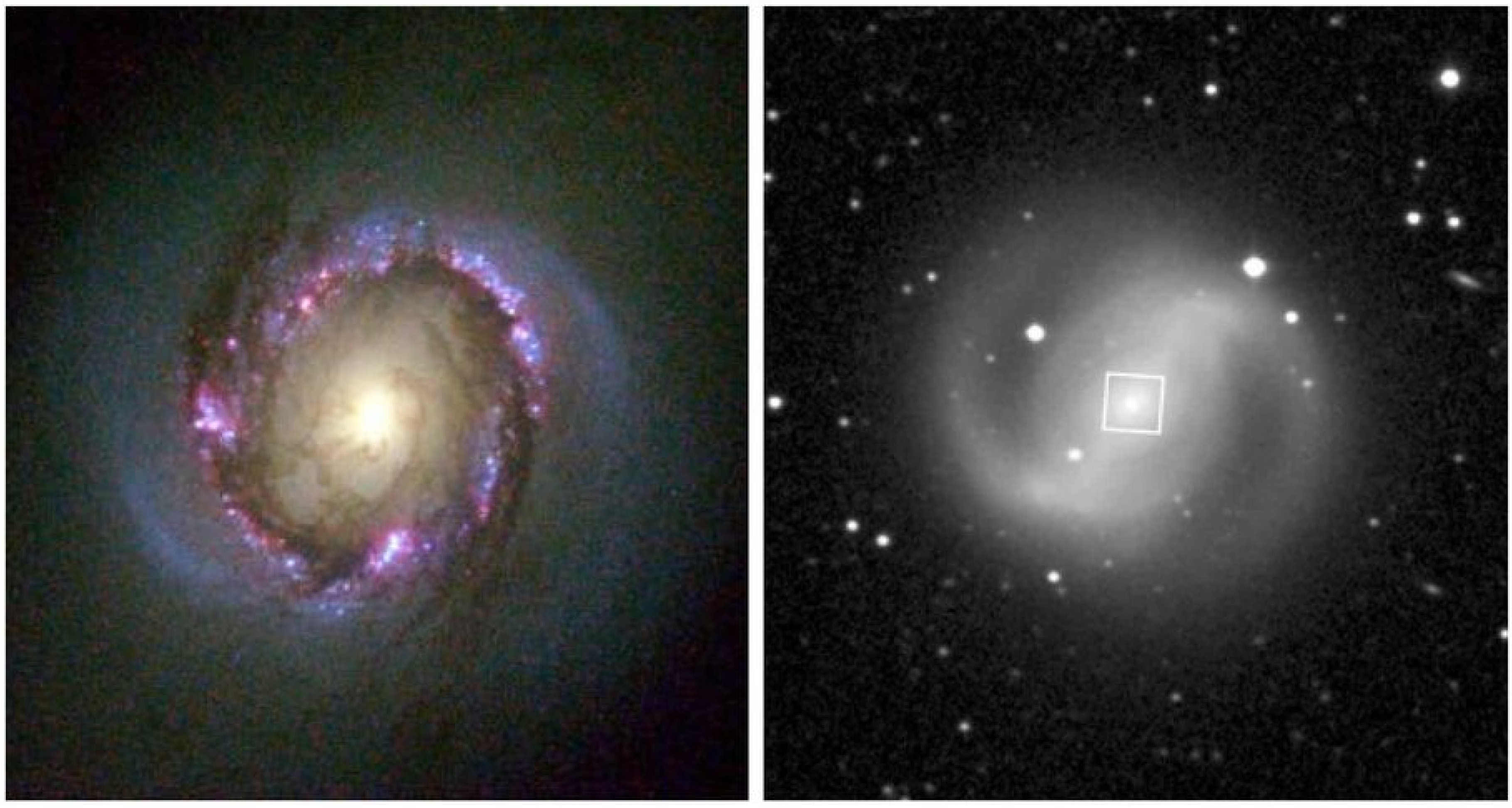
This building houses the Mount Palomar telescope. The dome opens when the telescope is being used.

The second major California observatory, Mount Palomar, opened in 1948, and its mirror was twice as large as the Mount Wilson telescope. This powerful telescope gave astronomers a much sharper view of distant planets and galaxies, revealing space objects that had never before been seen. Reflecting telescopes continued to get bigger. Some had mirrors with diameters of around 10 meters (33 ft.). If you were able to set one of these mirrors on its edge next to a building, it would reach the fourth floor. These mirrors had tremendous light-gathering power, allowing astronomers to see even farther into space.

One of the most powerful modern telescopes uses the combined power of two large reflecting telescopes that act as one extraordinarily powerful telescope. Because in some ways it works like a pair of binoculars, it is called the Large Binocular Telescope or LBT. Located on Mount Graham in Arizona, the LBT's images are more than nine times sharper than the Hubble Space Telescope's. Each of the two mirrors that make up this telescope is 8.4 meters (27.5 ft.) across. Their combined light-gathering power is equal to a single mirror nearly 12 meters (37 ft.) in diameter.



The Large Binocular Telescope (left) with its two mirrors allows astronomers to see distant space objects far clearer than ever before. The mirror's immense size dwarfs workers (below).

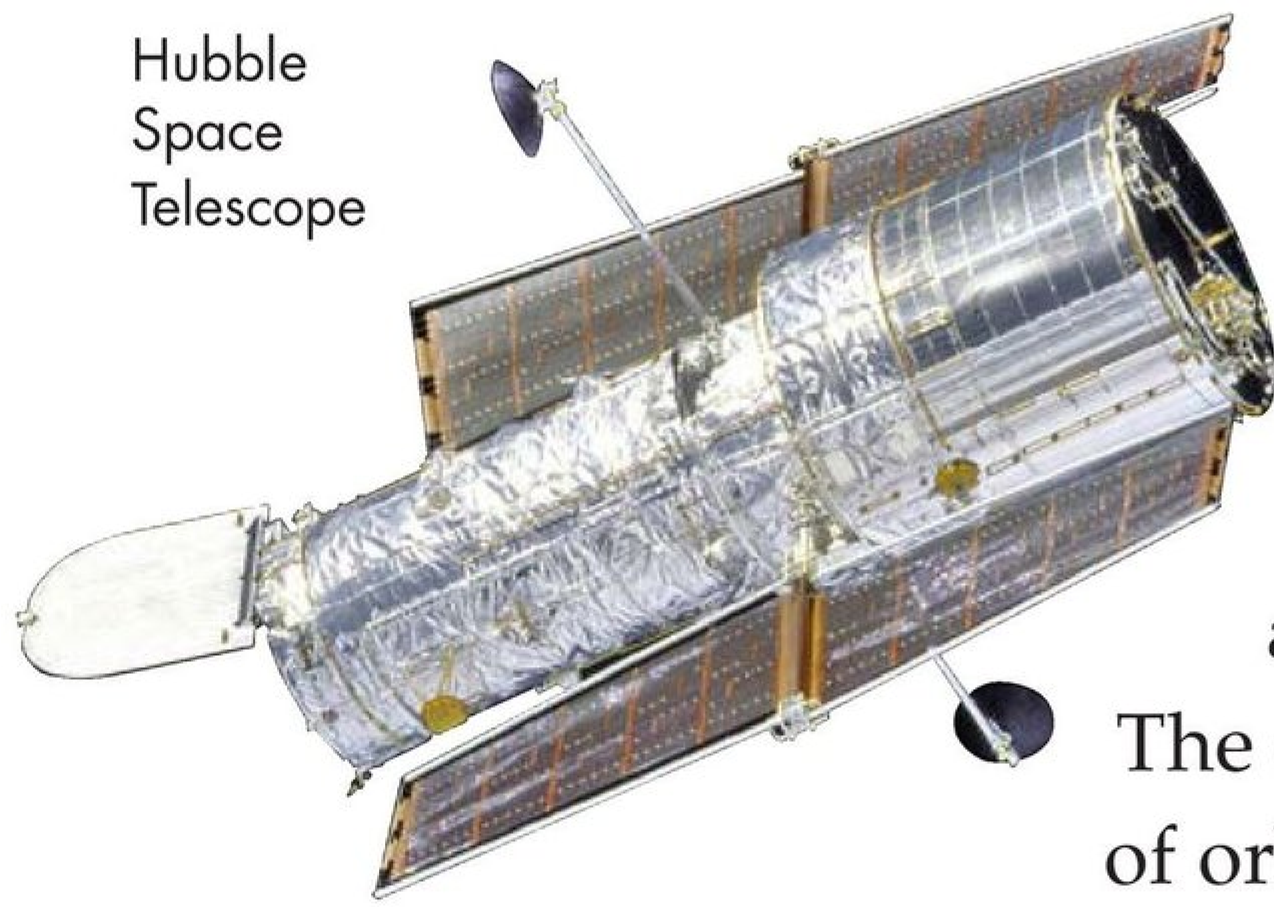


An image from the orbiting Hubble Telescope (left) reveals a ring of baby stars circling galaxy NGC 4314, about 40 million light years away. The baby stars are a blur when seen with a ground-based telescope (right).

Space Telescopes

Land-based telescopes have one large drawback. The light they gather from distant objects must pass through Earth's atmosphere to reach them. This atmosphere is a blanket of gases 50 kilometers (30 mi.) high surrounding our planet. The gases are in constant motion. Light passing through the atmosphere becomes **distorted**, blurring the images of stars and other objects in space before it even reaches a telescope. The distortion is like looking at an object at the bottom of a clear pool of water. Another problem is that light from some distant objects is so weak that it cannot penetrate Earth's atmosphere. The light gets scattered before ever reaching a telescope.

Some of the blurring effect of the atmosphere has been minimized by the use of computers. Computers can predict the amount of movement and adjust the curvature of a telescope's mirror to create sharper images. But even with these adjustments, astronomers realize that land-based telescopes will always have severe limitations when it comes to viewing distant objects in space.



Hubble Space Telescope

The only way to overcome this problem was to put telescopes above Earth's atmosphere. The development of orbiting satellites and space stations created the opportunity to place a telescope into orbit above Earth's atmosphere. Scientists went to work designing a telescope to orbit Earth and, in 1990, they launched the first orbiting telescope. It was named the Hubble Space Telescope in honor of Edwin Hubble, a famous American astronomer. The Hubble orbits 600 kilometers (370 mi.) above Earth, far outside the planet's atmosphere. From its position in space, it has an unobstructed view of distant objects.

The Hubble uses a 2.4-meter (7.8 ft.) diameter mirror to form images. Computers and other equipment on the spacecraft convert the light images into radio waves and send them to Earth. Ground stations receive the radio waves and convert them back to images that scientists and others on Earth can view. The Hubble Space Telescope has made it possible to see previously unseen objects in space and also to examine space objects in greater detail than ever before.

Hubble's Discoveries

The Hubble Space Telescope allowed us to see objects we had never seen before. It also provided evidence that answered many questions about the universe. The breakthroughs include:

- first firm evidence of black holes
- proof that planets exist outside our solar system
- first discovery of a rocky, Earth-like planet outside our solar system
- evidence that dust disks—from which planets form—are actually common around other stars
- first view of ancient galaxies, over 10 billion years old
- views of stars and supernovas that allowed astronomers to calculate the age of the universe more accurately
- first close-up view of a comet hitting a planet, when Comet Shoemaker-Levy 9 slammed into Jupiter

Radio Telescopes

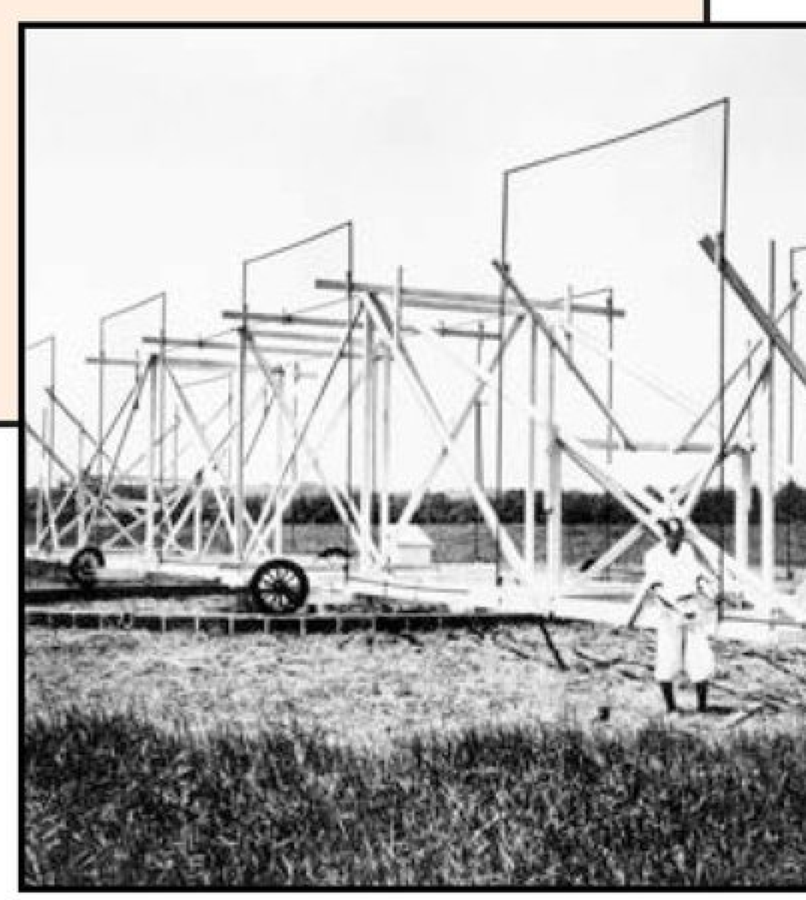
There is another type of telescope—the radio telescope. Rather than collecting light from distant objects and magnifying it, a radio telescope gathers invisible radio waves **emitted** by distant formations in space. You might say that radio telescopes listen to space rather than look into space. While optical telescopes are our eyes into space, radio telescopes are our ears on space.

This radio telescope in Puerto Rico is so huge it was built into the valley between mountains.

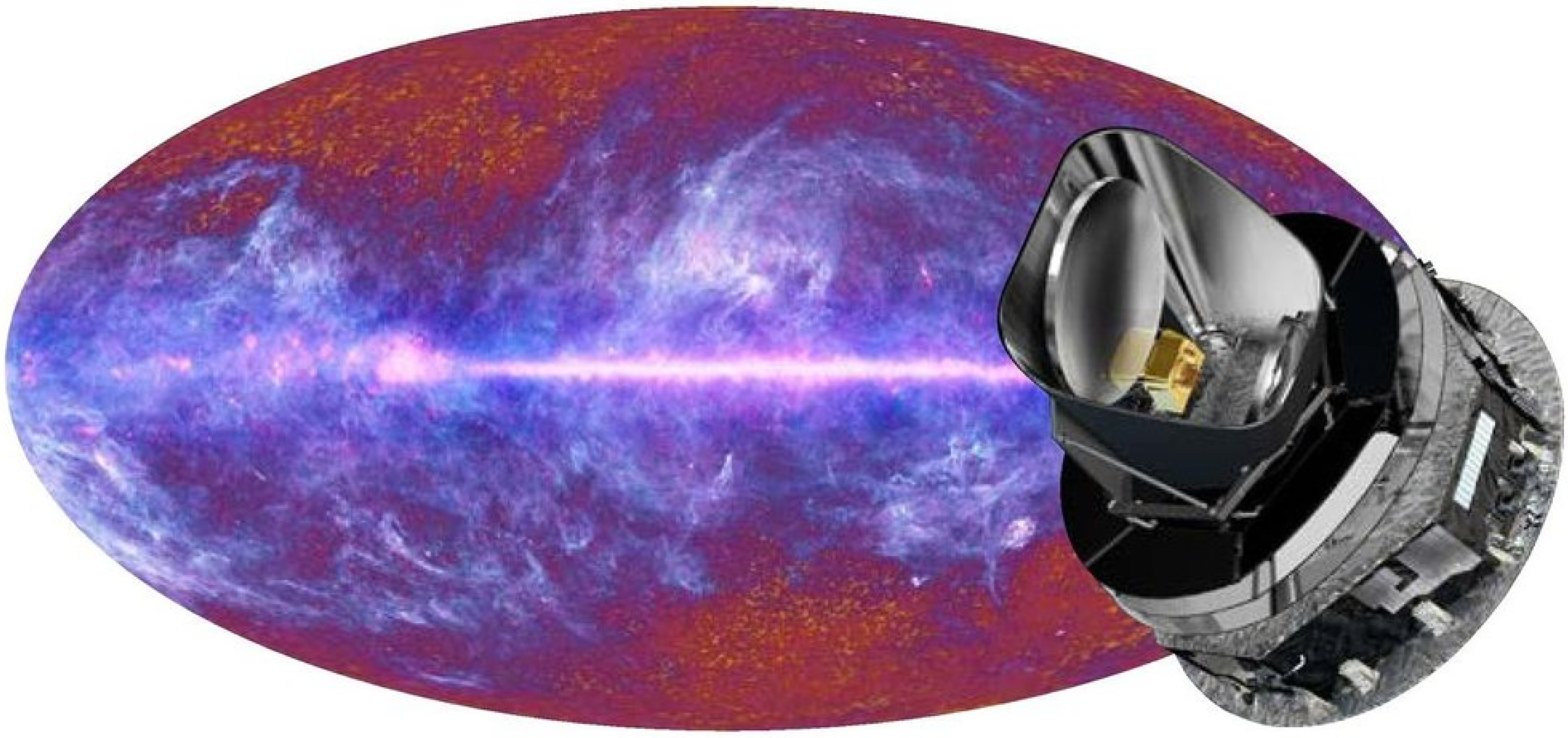
Most radio telescopes are large dish-shaped structures made of metal. The metal dish collects and reflects radio waves to an antenna in the center of the dish. Most average-sized radio telescopes have dishes that measure approximately 25 meters (82 ft.) across, but the dish of the radio telescope located on the island of Puerto Rico in the Caribbean Ocean is immense—305 meters (1,000 ft.) in diameter! Scientists also have linked together a number of radio telescopes in a single location. For example, on a site in New Mexico, 27 radio telescopes feed radio signals to a computer that then forms a large single radio signal.

People in Science

Radio astronomy began in 1933 when an American engineer named Karl Jansky accidentally discovered radio waves from space. Jansky built a 33-meter (100 ft.) radio antenna mounted on four tires from a Ford Model-T that allowed it to rotate. He built the antenna to study interference that was affecting phone lines strung across the floor of the Atlantic Ocean. Jansky detected static radio waves from thunderstorms and discovered a hissing sound coming from far off in space. He first thought the hissing sound was radiation from the Sun, but he later concluded it was radio waves emanating from the center of the Milky Way Galaxy. This discovery was purely accidental, and several years passed before other scientists took enough interest in Jansky's discovery to build their own radio telescopes.


Karl Jansky's rotating radio antenna

The radio waves collected by a radio telescope are sent to an **amplifier** that magnifies or increases the strength of the faint radio signals. The amplified signals are then sent to a computer. The computer converts the signals into an image that takes the shape of the radio waves emitted from their source. The computer also assigns different colors to various parts of an image to indicate the different strengths of radio waves within the image.



In July 2010, after a year-long mapping mission, the orbiting Planck Telescope of the European Space Agency (ESA) delivered its first full-sky survey of our universe. Planck's mission is to measure radiation left over from the ancient beginnings of our universe so that scientists can study how it was formed. As Planck sweeps the sky, it also measures the temperatures, density of matter, speed, and movement of galaxies.

Future Astronomy

Land-based telescopes will continue to grow in size and their technology will become more specialized. The powerful digital camera on the Pan STARRS 1 (PS 1) telescope in Hawaii tracks asteroids and comets that might threaten Earth. It can map one sixth of the sky every month. Once it becomes operational, the newer PS 4 will be four times as powerful as the PS 1. But there is little doubt that future observation of space objects will be best accomplished in space, beyond any interference from Earth's atmosphere. Scientists are hard at work building a telescope that will replace the Hubble.

The new telescope, called the James Webb Space Telescope, will have a 6.5-meter (20 ft.) diameter mirror. It will have a tennis-court-sized shield to block the Sun's radiation. The mirror's light-gathering capacity will be ten times greater than that of the Hubble Telescope.

The Webb Telescope will gather both visible light waves and low-energy infrared waves. In order to get an object this large into orbit, it will be launched folded up and then unfolded in orbit.

Most scientists agree that the ultimate telescope would be built on the Moon. Scientists are planning an observatory that would be built on the Moon's surface. Since the Moon has very little atmosphere, there would be minimal interference to light coming from distant objects in space.

The mysteries of space are slowly being revealed. No one knows what the newest telescopes will discover, but whatever it is, these powerful eyes on space will help us to see it for ourselves!


Earth as seen from the surface of the Moon

Glossary

amplifier *(n.)*	a piece of equipment that makes sounds louder (p. 21)
concave *(adj.)*	having a shape or surface that curves inward (p. 11)
convex *(adj.)*	having a shape or surface that curves outward (p. 10)
distorted *(adj.)*	changes so that it is no longer accurate (p. 17)
emitted *(v.)*	sent out from (p. 20)
focal point *(n.)*	a point where light rays come together or from which they spread; lenses and curved mirrors have focal points (p. 10)
observatories *(n.)*	places used for scientific observation of things in nature, such as astronomical objects (p. 13)
optical telescope *(n.)*	a light-gathering telescope (p. 5)
radio telescope *(n.)*	a telescope that collects radio waves from space (p. 5)

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