Radiation and Light

Stars and galaxies are so far away that we have no chance of visiting them. Everything we know about these distant objects comes from studying the energy, or radiation, they emit.

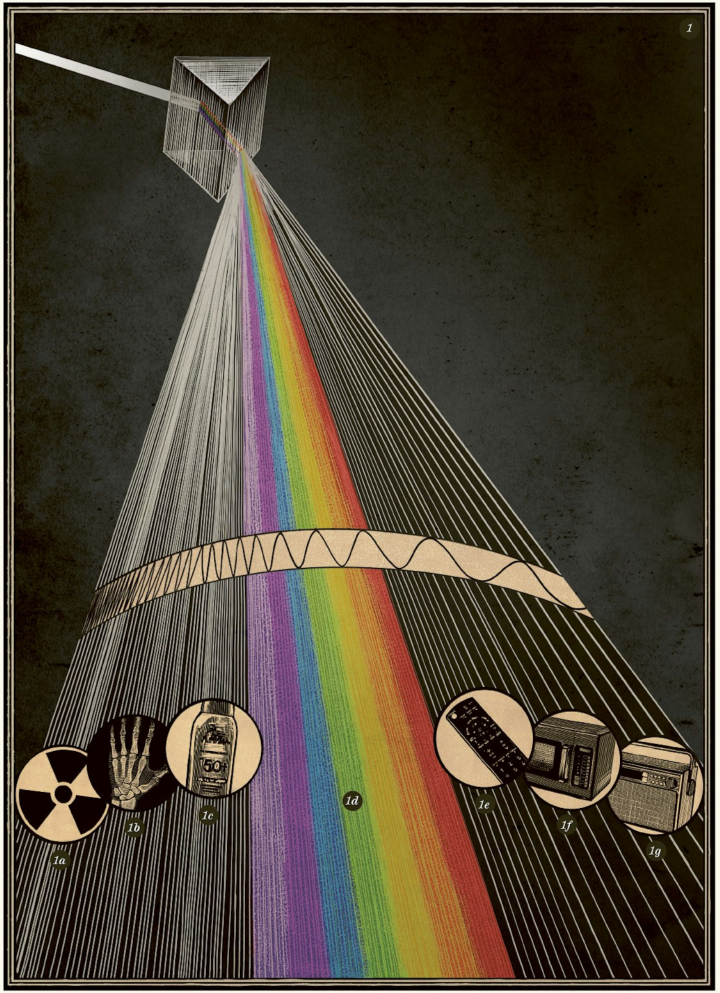
Light is the only radiation we can see with our eyes, but there are other types we cannot see, including gamma rays, X-rays, ultraviolet radiation, infrared radiation, microwaves and radio waves. They travel through space as waves of varying lengths, collectively known as the electromagnetic spectrum. This spectrum is often drawn as a line with the shortest wavelengths (the distance between each crest of the waves) at one end and the longest at the other. The sizes of wavelengths range from a fraction of an atom (in the case of gamma rays) to larger than buildings (for radio waves).

Each type of wave is emitted by different objects and events in space, so they can be studied by astronomers to tell us more about the Universe. For example, gamma rays are seen emerging from the most violent explosions in the Universe (like when two stars collide); X-rays can be emitted by exploding stars; and infrared light is given off by some of the coldest objects in space, such as the dusty clouds in which new stars are born.

Even the light we see, known as 'visible light', is made up of different parts. We see these components when water droplets in the air split sunlight to form a rainbow across the sky. The red, orange, yellow, green, blue, indigo and violet colours of a rainbow can also be seen by passing white light through a glass prism. Astronomers use this technique to split visible light from stars into its component parts so they can study the chemical make-up, speed and temperatures of these burning balls of gas.

Key to plate

1: The electromagnetic spectrum
a) Gamma rays
b) X-rays
c) Ultraviolet radiation
d) Visible light
e) Infrared radiation
f) Microwaves
g) Radio waves
Different radiation types are classified by their wavelengths (the distance between crests of each wave) and their frequencies (the number of waves in a space of time). Gamma waves have the highest frequencies and shortest wavelengths while radio waves have the lowest frequencies and longest wavelengths.



Telescopes

When we gaze at the night sky, we see thousands of stars as tiny pinpricks of light. Even with the naked eye we can make out their movement as Earth rotates and note their varying colours and brightnesses. However, in order to truly study them we depend on telescopes – optical instruments which make distant objects appear much larger.

Objects in space, such as stars and galaxies, are very far away, and only a tiny amount of the light they create reaches Earth. This is because the particles in light spread out as they move further from their source, making their light appear dimmer. Telescopes function like 'buckets' for collecting this faint light. Just as a bigger bucket catches more rainwater, a bigger telescope gathers more light, and this makes fainter images much brighter. Whereas the pupils of our eyes are barely 5mm in diameter, modern telescopes can be more than 10m wide. A telescope this size can see objects four million times fainter than those seen with the unaided eye.

Telescopes work in three steps: first they collect light using a lens or mirror; then the light is focused into a small sharp image; finally this image is magnified. Before the nineteenth century, astronomers simply looked at the magnified image with their eyes and made wonderful drawings of what they saw. Today, the images made by large telescopes are recorded electronically then stored on computers for analysis. The light can also be passed through a spectroscope to learn more about the wavelengths emitted by the object.

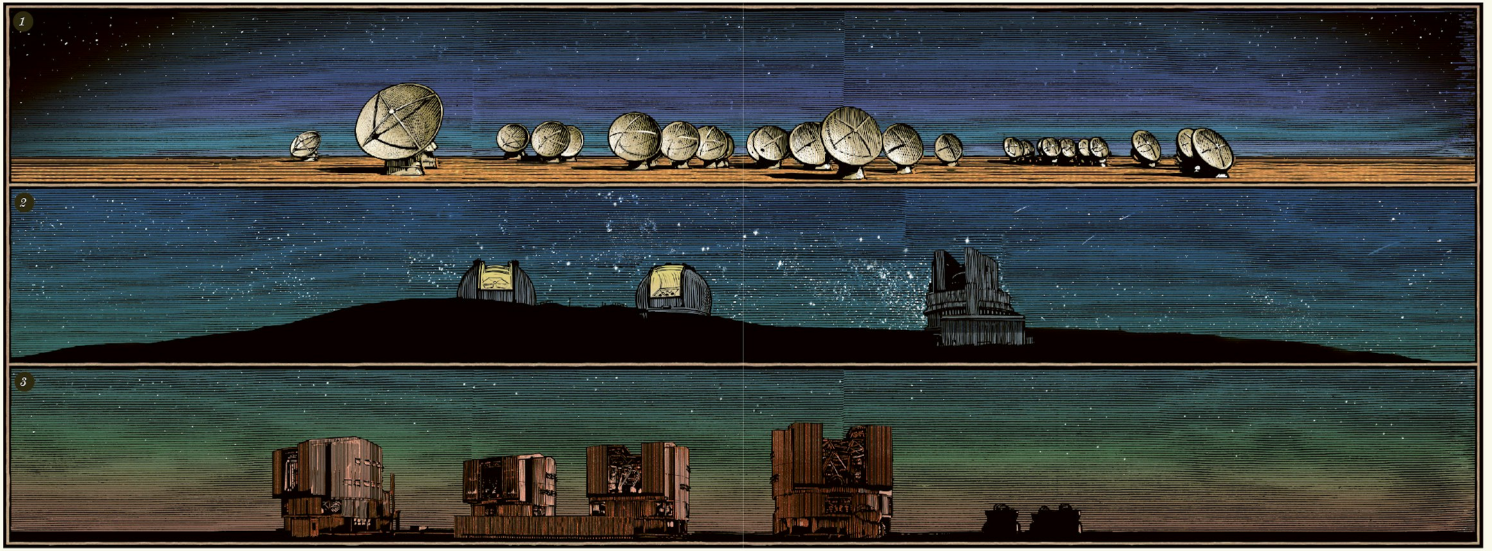
The two main types of telescope are refractors and reflectors. Refracting telescopes use lenses to bend, or refract, light. The light enters through the front lens and travels through the telescope to the eyepiece, where it is magnified. Reflecting telescopes use mirrors to reflect light. Light enters the telescope, bounces off a curved primary mirror, then is reflected off a smaller, secondary mirror, which magnifies the image.

Key to plate

1: Galileo's x20 telescope
Lens width: 37mm
This imagined view shows famous astronomer Galileo Galilei using a refracting telescope in 1609. It was one of the first telescopes ever made. Galileo's observations revealed mountains and craters on the Moon and, in 1610, revealed Jupiter's four largest moons.

2: Herschel's 40-foot reflecting telescope
Mirror width: 120cm
The musician and astronomer William Herschel started constructing the telescope in 1785, and began observations with it in 1789. At the time, it was the largest telescope in the world. Herschel used it to study the moons of Saturn.

3: James Lick telescope
Lens width: 91cm
At the time of its construction in 1888 this was the largest refracting telescope in the world – it is the third largest today. Its dome can rotate, and its floor can be raised and lowered to bring the viewer closer to the telescope. James Lick is buried under the floor at the base of the telescope.



Modern Observatories

We've come a long way since astronomers used the first telescopes in the seventeenth century to look at the Moon and our nearest planets. Since then, incredible technological developments have enabled us to see even further into space, looking far beyond our Solar System and even our galaxy. Over the past century, telescope technology has taken a huge step forwards thanks to increasingly sophisticated cameras, detectors, spectroscopes and computers, and to the sheer size of modern telescopes. The power of a telescope is mainly determined by its size, and the mirrors in some today can be 10m wide. (Refracting lenses become too heavy at these large sizes so are not used in modern telescopes.) Huge research telescopes, used mainly to study visible light, are housed in multi-storey buildings called observatories, which are usually perched high on mountaintops, where the air is clear, calm and dry. Together with dark night skies, these conditions greatly help in obtaining the sharpest possible images.

The next generation of ground-based telescopes will be larger than anything that predates them, and will allow us to see objects in space that have never been seen before. One example is the European-Extremely Large Telescope (E-ELT). Once assembled it will have a diameter of 39m and be able to detect both visible and infrared light, gathering eight million times more light than the telescope used by Galileo in 1609. It will detect light that has taken millions or even billions of years to reach Earth, so the astronomers that use it will essentially be looking back in time to a younger Universe! Their studies will answer questions about the origins of planets, stars, galaxies and the Universe itself.

Key to plate

1: ***Atacama Large Millimeter Array (ALMA)***
Located in the Atacama Desert in Chile, each of ALMA's 66 antennae detect radio waves, including low-energy emissions from new stars and young galaxies. The detectors are kept at a freezing -269°C to avoid background heat blurring their signals.

2: ***Keck Observatory***
The twin telescopes of the Keck perch 4200m high on Mauna Kea, Hawaii. Each primary mirror is 10m wide and made of 36 hexagonal pieces. Computer controls move the segments so they act as a single reflecting glass. They can detect light as faint as a candle on Earth's Moon!

3: ***Very Large Telescope (VLT)***
Placed high on a mountain in the Atacama Desert, Chile, the VLT enjoys some of the clearest night skies on Earth. Each of its four telescopes has a primary mirror 8.2m wide. Signals from up to three of the telescopes can be combined to increase their power.

Space Telescopes

Earth is surrounded by a blanket of gases called the atmosphere, which contains the air we breathe and shields our planet against harmful rays from the Sun. Fortunately, we can see right through the atmosphere to the planets and stars beyond it, but when we come to study these objects in detail, the atmosphere can present some problems: moving pockets of air obscure images taken by visible-light telescopes, and the atmosphere can block out whole parts of the electromagnetic spectrum. So to obtain the clearest images of space and detect the whole of the electromagnetic spectrum, astronomers have to position their telescopes high above the atmosphere.

Astronomers began to get around this problem in the 1950s, by attaching telescopes to large helium-filled balloons which carried their instruments up above the lower layers of air. However, it soon became clear that what they really needed were free-flying telescopes in orbit around Earth. During the late 1960s, several astronomical satellites were successfully launched, mounted with the first gamma ray, X-ray and ultraviolet telescopes to be placed in orbit. Then, between April 1990 and August 2003, NASA launched its four 'Great Observatories' in space. Marking a whole new era in space exploration, each telescope was designed to examine a particular part of the electromagnetic spectrum. The Compton Gamma Ray Observatory (which returned to Earth in 2000) observed gamma rays; the Chandra X-ray Observatory observes X-rays; the Spitzer Space Telescope observes infrared light; and the Hubble Space Telescope observes visible and near ultraviolet light (after a service mission in 1997 it can also detect near infrared light). The Hubble has sent back some of the most stunning images of space ever taken.

At the forefront of the next era of space telescopes will be the James Webb Space Telescope (JWST), orbiting at a vantage point 1.5 million km away from Earth. It will use infrared vision to peer more than 13.5 billion light years away into the darkness of the earliest times of the Universe.

Key to plate

1: James Webb Space Telescope
Location: 1.5 million km above Earth
Launched: Due 2020
This space telescope will study every main phase in the history of the Universe. It will be six times more powerful than the Hubble telescope.

2: Spitzer Space Telescope
Location: 230 million km above Earth
Launched: 25 August 2003
This infrared telescope has a liquid helium tank that keeps its instruments at -272°C, close to 'absolute zero', the lowest temperature possible.

3: Hubble Space Telescope
Location: 550km above Earth
Launched: 24 April 1990
During its long career, several astronauts have visited Hubble on the Space Shuttle to maintain it. Its main telescope collects about 40,000 times more light than the human eye.

4: Fermi Gamma-ray Space Telescope
Location: 550km above Earth
Launched: 11 June 2008
This gamma ray telescope detects the most high-energy objects in the Universe. These waves are given off by mysterious objects such as black holes and exploding stars. Located in low-Earth orbit, this telescope takes just 95 minutes to orbit Earth once.

5: Chandra X-ray Observatory
Location: max. 139,00km above Earth
Launched: 23 July 1999
Almost a third of the way to the Moon, Chandra detects X-rays emitted by very hot objects such as exploded stars and galaxy clusters.