SPACE SCIENCE

K - 8 Science Unit Study

THE GOOD AND THE BEAUTIFUL

SPACE SCIENCE

CREATED BY THE GOOD AND THE BEAUTIFUL TEAM

Table of Contents

The Good and the Beautiful

UNIT INFORMATION

Science Journal

All The Good and the Beautiful science units include activities for a science journal. For each child, prepare a 1–2-in. 3-ring binder to function as his or her science journal. Tabbed divider pages can be used to separate the different units. Also, have wide-ruled paper and blank white paper on hand for journal activities. All completed journal activities are to be kept in the science binder. If desired, have the child create a cover and insert it under the clear cover of the binder.

Science Wall

All science units include vocabulary words to be placed on your science wall, which is a wall or three-fold presentation board in your learning area to which you can attach the vocabulary words and other images. **Cut out the vocabulary word cards at the beginning of the unit.** The course will indicate when to place them on the wall.

Lesson Preparation

All science units include easy-to-follow lesson preparation directions at the beginning of each lesson.

Lesson Mini Books

Some lessons in this unit incorporate science mini books. If you bought the PDF download only, print the pages single-sided. To assemble the mini books, cut them in half along the dotted lines, stack the pages together with the page numbers in the correct order, and staple twice along the left side.

Video Recordings

Go to **goodandbeautiful.com/sciencevideos** and scroll down to the *Space Science* section to see videos that are integrated with the course.

Activities and Experiments

Many of The Good and the Beautiful science lessons involve hands-on activities. The *Space Science* unit features activities that involve potentially messy and/or harmful materials.

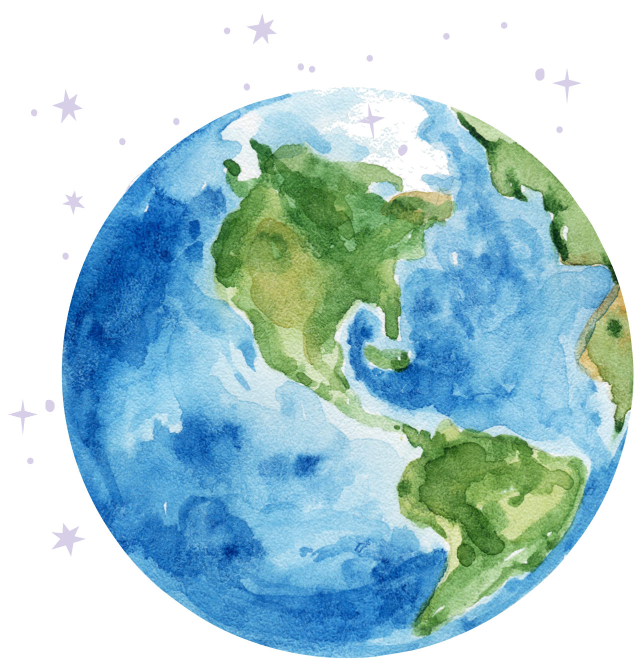
An adult should always closely supervise children as they participate in the activities to ensure they are following all necessary safety procedures.

Older Children and Younger Children

Some lessons include extra content that is more applicable for older children (grades 5–8). Parents or teachers may choose to skip this content if instructing only younger children.

Worldview

The unit takes a general Christian worldview that supports Creationism. The unit does not attempt to define how long it took God to make items in the universe, thus allowing for use by both those who believe in a young earth theory and those who believe in an old earth theory. If parents want to get into more detail on dates and time periods of the universe, they can include the doctrines specific to their own beliefs.



READ-ALOUD BOOK PACK

The two books below are optional read-aloud books that complement this unit. These books can be purchased as a book pack by going to **goodandbeautiful.com/science** and clicking on the *Space Science* unit link.

Mars Exploration: 1960–2016
by Megan Noel

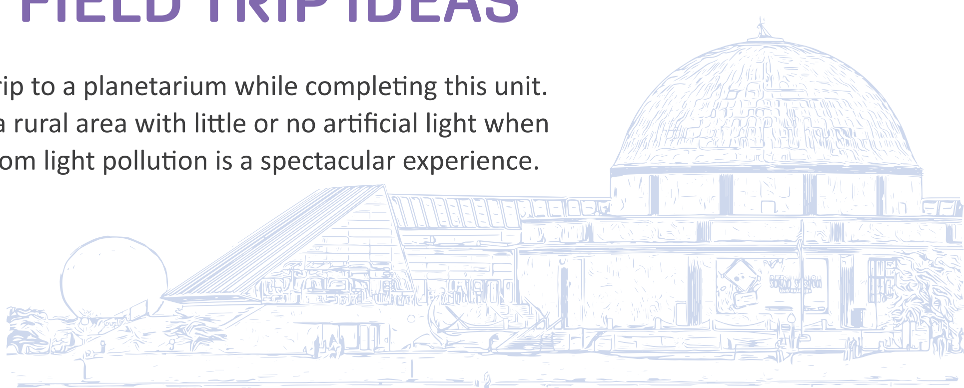
The Story of Mae Jemison
by Amy Drorbaugh

CORRELATED BOOKS

The Good and the Beautiful Library has several books that correlate well with the *Space Science* unit. It can be a wonderful experience for children to read books on their levels related to the subjects they are learning in science. The library includes both fiction and nonfiction books that are organized according to reading level. Find these correlated books by going to **goodandbeautiful.com/science** and clicking on the *Space Science* science unit product page.

FIELD TRIP IDEAS

If possible, consider taking a field trip to a planetarium while completing this unit. Also, consider taking a field trip to a rural area with little or no artificial light when it is dark. Seeing the night sky far from light pollution is a spectacular experience.



GRADES 7–8

LESSON EXTENSIONS

How the Extensions Work

Each lesson has an optional lesson extension for children in grades 7–8. Complete the lesson with all the children, and then have the older children complete the self-directed lesson extension. These extensions are generally located at the end of the lesson, though some are combined on a page, and you will need to turn back to them.

Answer Key

The answer key for the lesson extensions can be found by going to **goodandbeautiful.com/science** and clicking on the *Space Science* unit link.

Flexibility

The amount of time it will take to complete each lesson extension will vary for each child. The average time is about 10–15 minutes per extension. Parents/teachers and children may choose to omit parts of the lesson extension if desired. Encourage the children to stretch their capabilities, but also reduce work if needed.

Science Journal

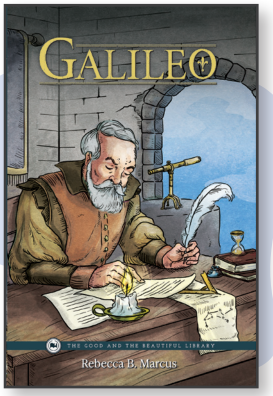
The extension pages are nonconsumable. The children will do their work on separate sheets of paper and insert them into their science journal binders along with any science journal pages done during the lessons. Children are encouraged to take ownership of their science journals and put forth effort to make the journals visually appealing. The journals will be something the children can treasure. The children should use color and illustrations where possible. Have the children view the sample pages below.

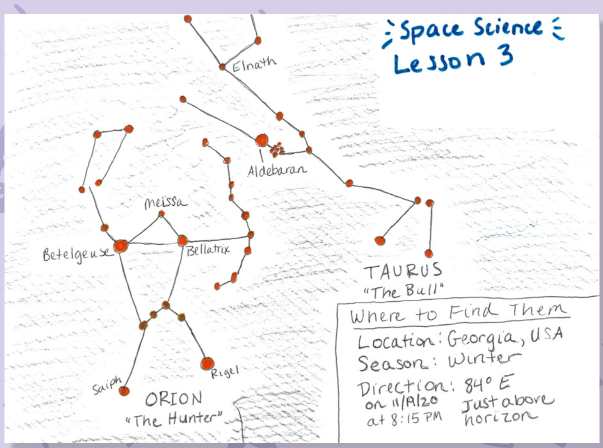
Taking Notes

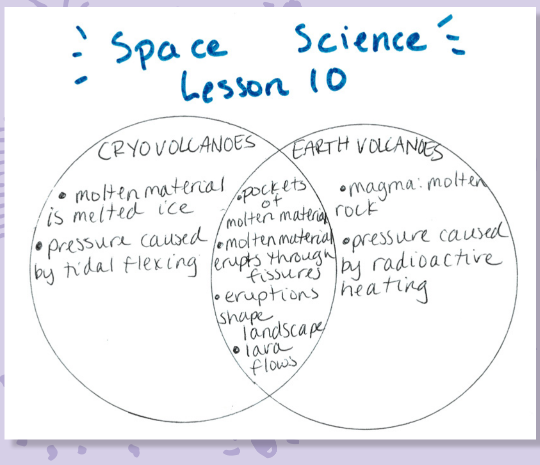
Some of the grades 7–8 lesson extensions have the children summarize the material they have read. Teach the children to look for key information and summarize the most important points. Students can also add notes with their thoughts and the facts that are most interesting to them.

Optional Grades 7–8 Reading Book

We recommend *Galileo* by Rebecca B. Marcus as extra reading for students in grades 7–8. This book can be purchased by going to **goodandbeautiful.com/science** and clicking on the *Space Science* unit link.







EXTENSION

Instructions:

Lesson 1: Watch the video "The Scale of Space" at **goodandbeautiful.com/sciencevideos**. Then imagine you are an astronomer who invents a new unit of measure that is greater than light-years to calculate the distance between galaxies. In your science journal, record what you would call it and why.

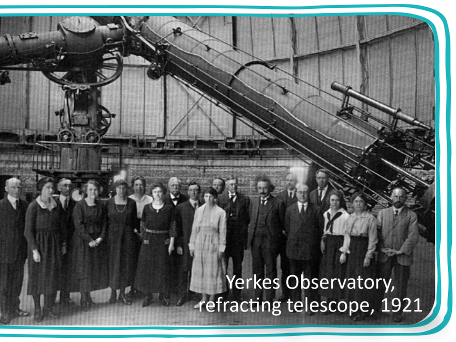
WATCH ONLINE

Lesson 2: Read the information below. In your science journal, write a definition for refracting, reflecting, and compound telescopes.

Telescopes

On a dark night, far from city lights, the night sky is a spectacular sight, even to the naked eye. But to observe distant galaxies or to see detail on the surfaces of the moon and planets, you need a telescope. A ***telescope*** is a device that collects the light from a distant object and provides a magnified and enhanced image. To do this, most telescopes use either lenses or curved mirrors to focus the light from objects in the night sky.

Surprisingly, magnification isn't the most important role of a telescope. To understand why, imagine taking an old, grainy photograph from the 1800s. What if you were to use a magnifying glass to try to get a better view? The photograph would still be blurry, and magnifying it just makes the blurriness more noticeable. For a telescope the goal is to collect as much light as possible from the observed object in order to provide a bright, sharp image. The size of the opening, called the ***aperture***, determines how much light enters the telescope. Thus, a telescope with a large aperture will produce a sharper image than one with a small aperture. The observer then looks through an eyepiece lens, which magnifies the image. Astronomers must select the proper combination of aperture and magnification in order to get the clearest image.



Yerkes Observatory, refracting telescope, 1921

The three main types of telescopes are refracting, reflecting, and compound. A ***refracting telescope*** uses a lens to collect and focus light. Refracting telescopes require a long thin tube. It's difficult to make and support very large lenses, but they provide the sharpest, clearest images of all the telescopes. A ***reflecting telescope*** uses a curved mirror instead of a lens to focus light. Since light doesn't have to pass through the mirror, it can be supported from the bottom. This allows the telescope to have a larger aperture with a shorter tube length, making it very convenient to use. A ***compound telescope*** combines both mirrors and lenses to get the best features of both types of telescopes.

Lovell Telescope, radio telescope

One factor that limits the clarity of telescope images is the earth's atmosphere. Temperature variations cause turbulent air that distorts the light coming from distant objects; this is why stars appear to twinkle when you look at them. Scientists can correct this distortion by using mirrors with adaptive optics. These telescopes use computers to subtly adjust the shape of the mirror in order to cancel out the atmospheric distortion. Another way of avoiding atmospheric distortion is to put the telescope in space, where there is no air. The Hubble Space Telescope and James Webb Space Telescope (expected to launch in 2021) are examples of this.

Telescopes can be made to gather information from other regions of the electromagnetic spectrum as well. Radio telescopes use large dish antennas to gather and analyze radio waves from objects in space. Some are very large, like the one at the Arecibo Observatory, a dish over 305 m (1,000 ft) wide in Puerto Rico. Others, like the Very Large Array in New Mexico, combine the data from many smaller antennas in order to produce an image. Scientists have also built telescopes that detect ultraviolet rays, x-rays, and gamma rays. Scientists then combine the information they receive from all regions of the spectrum to gain a better understanding of objects in space.

Infrared Telescopes

The James Webb Space Telescope is especially interesting because it is designed to "see" beyond the visible part of the spectrum into the infrared region. By observing a different region of the spectrum, the telescope can gather information that may not be detectable using visible light. For example, infrared telescopes can detect dust disks that may be in the early stages of planet formation around some stars.

Lessons 3-4 | Grades 7-8

EXTENSION

Instructions:

Lesson 3: With permission, use an app (such as SkyView® or Night Sky) or a reputable website to find out which stars are visible in your area during the current season. In your science journal, sketch two constellations visible in the night sky, label them, and write where to find them.

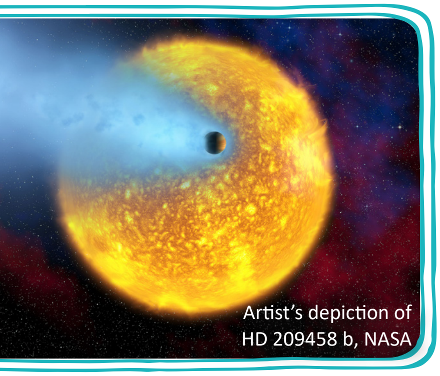
Lesson 4: Read the information below. In your science journal, write at least two characteristics of a "hot Jupiter" exoplanet. How does it differ from planets in our solar system?

Exoplanets: Planets Around Other Stars

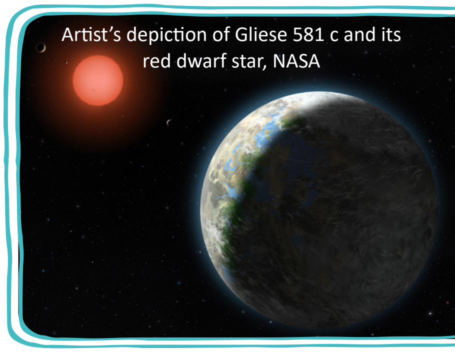
Astronomers have long wondered if our solar system is unique in the universe. Are other stars, like our sun, orbited by planets? Yes! Other stars are very far away, however, and detecting those planets, called ***exoplanets***, is difficult. (The Greek prefix *exo-* means "outside.") The first exoplanets were discovered in 1992. Those exoplanets astounded scientists because they were found orbiting the remnant of a dead star, called a ***pulsar***, rather than a sunlike star. Since that time thousands of other exoplanets have been discovered orbiting a variety of different types of stars, including stars much like our own sun.

When astronomers first started searching for exoplanets, they had expected to find planetary systems like ours. Instead, they discovered that many exoplanets are very different from anything found in our solar system. For example, exoplanets like HD 20782 b have extremely eccentric orbits—they are more stretched out than those of planets in our solar system. This means part of their orbit is very close to their sun, while the other part is far away from it. What do you think happens to the temperature on those planets as they travel around their orbits?

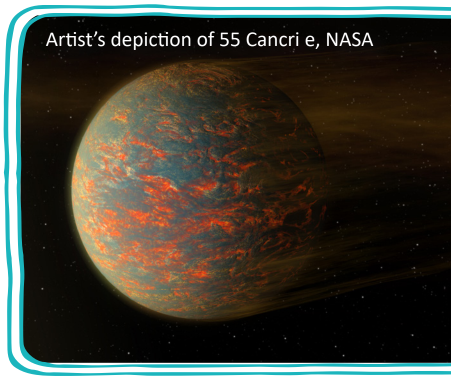
Some planets orbit much closer to their star than Mercury does to our sun. One exoplanet called HD 209458 b is so close to its sun that the planet itself is evaporating away, leaving a long comet-like tail behind it. This planet is made mostly of gas, like Jupiter, but it is much hotter. These so-called "hot Jupiters" came as a surprise to astronomers because their theories of how the solar system formed said that gas giants could not form that close to a star. As a result of this new discovery, scientists had to modify their theories. If HD 209458 b continues to lose gases into space, eventually its entire atmosphere will be blown away. All that will be left is a baked rocky core called a Chthonian [THON—ee—un] planet.


Artist's depiction of HD 209458 b, NASA

Similar to the planets in our solar system, exoplanets can be small rocky terrestrial planets or large gas giants. Some terrestrial planets are much smaller than Earth, while others are called "super-Earths" because they are so massive. These super-Earths have high gravity and are often covered by thick atmospheres. The largest ones have air that is so thick and dense that they are hard to distinguish from giant gaseous planets like Neptune. Other terrestrial planets are thought to be water worlds, their surfaces completely covered by ocean. It's difficult to say for sure which planets have liquid water on their surfaces because they are so far away, and the observations are prone to error. The planet Gliese 581c was once thought to be a water world, but later observations showed that it likely is not. Scientists are very interested in discovering liquid water on exoplanets because life as we know it relies on the existence of water.


Artist's depiction of Gliese 581 c and its red dwarf star, NASA

The exoplanet 55 Cancri e orbits so close to its sun that astronomers believe its surface may be covered with molten lava. Other exoplanets are freezing cold because they are too far from the warmth of their suns. The region around the sun-star where a planet receives enough heat for liquid water to exist on its surface is called the star's "habitable zone." A planet that lies within its star's habitable zone is sometimes called a Goldilocks planet because its temperature is just right. It's possible to have more than one exoplanet orbiting within its star's habitable zone.


Artist's depiction of 55 Cancri e, NASA

Could humans survive on the other planets? Scientists don't have enough information to answer that question yet, but they are fascinated by the possibility.

EXTENSION

Instructions:

1. Read the information below.
2. During the Cold War, the United States and the Soviet Union competed against each other in space exploration. Some people think that this competition drove people to work harder and enhanced the exploration of space. Others think that we could have accomplished more if the two countries had cooperated. Which do you think is correct? Write 2–4 sentences in your journal explaining your opinion.

Venera Probes

What was the first space probe to land on another planet? If you're like most people, you probably thought it was one of the American space probes sent to Mars. In reality, the first probe to land on another planet was *Venera 7*, launched by the Soviet Union in 1970. At the time, the United States and Soviet Union were rival superpowers engaged in a space race. Both struggled to be the first nation to land people on the moon, but their competition also extended into the farther reaches of the solar system. While the United States had the most success exploring Mars and the outer planets, the Soviet Union focused its attention on Venus.

Over a period of 22 years, starting in 1961, the Soviets sent a series of space probes to explore Venus. In those days scientists had to learn how to do things that modern-day scientists consider routine. Their first goal was to attempt a landing. When first attempts failed, they worked on orbiting the planet before taking the next step of impacting the surface. After that they could work on making a soft landing. They realized it was a waste of resources to start off with an expensive lander before they even knew if they could get the spacecraft to Venus! When early probes failed, scientists used the failures to learn and construct better spacecrafts.

1961–1967: The first two probes, *Venera 1* and *2*, were intended to make contact with the planet, but both stopped communicating with ground controllers a few days (*Venera 1*) or months (*Venera 2*) after launch and were lost. The *Venera 3* probe included a spherical probe intended to enter Venus' atmosphere and send information about it back to Earth. Communication with the spacecraft was once again lost, but the probe successfully impacted the surface of Venus. Soviet scientists were more successful with the *Venera 4* probe, which became the first spacecraft to send information from another planet's atmosphere. What they found was a burning hot world with crushing pressure.


Venera 4


Venera 7

1970: With the goal of landing a space probe on the hostile surface of Venus, Soviet scientists worked to design a probe that could survive the intense heat and pressure. *Venera 7* was built with a solid titanium shell with no seams or welds. Because of the heavy armor, the probe was able to carry only the most basic scientific instruments. The probe arrived at Venus, dove into the atmosphere, and dropped the lander. On the way down, the lander's parachute failed, and the probe crashed onto the planet's surface. It was damaged but sent weak signals back to Earth for 23 minutes. The Soviet Union had managed to transmit the first data from the surface of another planet.

1975–1983: Starting with *Venera 9*, the probes were designed to first establish orbit around Venus, then drop a lander. The lander sent data to the orbiter, which then relayed it back to Earth. These probes survived approximately one to two hours on the surface and sent data back from the surface. *Venera 9* was the first to send pictures from the surface of Venus. The final two Venera probes, *Venera 15* and *16*, took a different approach. These probes remained in orbit of Venus and used radar to penetrate Venus' clouds and map the surface of the planet.

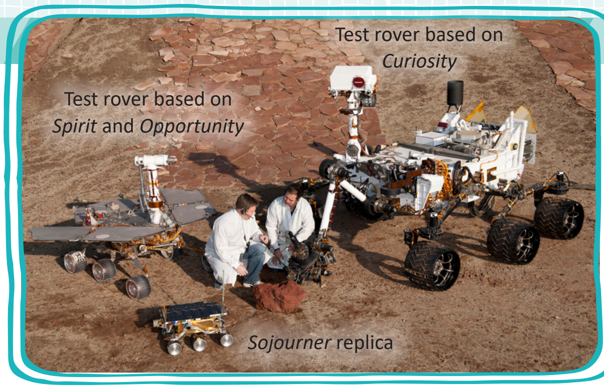

Venera 10

The Venera probes taught scientists a great deal about the surface conditions, the composition of the soil, the high-speed winds in the upper atmosphere, and the existence of sulfuric acid clouds on Venus. When early probes failed, scientists didn't give up the effort to explore other worlds. They analyzed the reasons for each probe's failure and made improvements in the design of the next probe.

EXTENSION

Instructions:

1. Read the information below.
2. NASA likes to give its rovers fanciful names like *Spirit* and *Opportunity* in order to give people a sense of wonder about the probes. Why do you think they do this? With that in mind, come up with your own name for the next rover to go to Mars. In your journal, briefly explain why you chose that name.



Our Favorite Martians

Ever since astronomers in the 1800s thought they saw canals on Mars, people have been fascinated with learning about the surface of the red planet. The astronomers were incorrect, of course, and there are no canals on Mars. But what is the surface really like, then?

1962 From the 1960s to 1970s, NASA sent several *Mariner* probes to fly by Mars and send back pictures and other data. The last of them, *Mariner 9*, became the first space probe to orbit Mars. These probes gathered information about the planet and allowed scientists to take the next step: landing on Mars.

1976 A spacecraft called *Viking 1* became the first probe to land successfully on Mars and send pictures from the surface. *Viking 2* followed the next year. These landers were stationary, meaning they were unable to move from their positions, but they still managed to make plenty of discoveries. They found a cold world with an atmosphere made of carbon dioxide. They took soil samples and analyzed them for signs of life. But perhaps most intriguingly, they saw signs that Mars once had liquid water on its surface.

1997 Landers like the *Viking* probes were limited to exploring only the places where they touched down, but scientists really wanted to explore the planet with rovers, which are robotic vehicles that can drive around and explore large areas. The first rover landed in 1997 with the *Pathfinder* lander. The *Pathfinder* mission included a rover called *Sojourner* that drove around the landing site and sent back a tremendous amount of data about the surface conditions. *Sojourner* operated for 83 (Mars) days and wandered no more than 12 m (40 ft) from the landing site. The panoramic pictures it sent back from Mars caught the public's attention. People were excited about little *Sojourner*'s adventures on Mars!

2003 NASA sent a pair of rovers, *Spirit* and *Opportunity*, to explore the surface of Mars. The rovers, which landed in 2004, were designed to explore much larger areas than *Sojourner*. These rovers wandered over several kilometers of the Martian landscape and once again captured the public's imagination. People enjoyed thinking about the rovers as though they had their own personalities. When *Opportunity*'s battery was almost dead, it sent back a final message about its condition that people interpreted as, "My battery is low and it's getting dark." The probe was a simple machine, of course, and not capable of poetic thoughts, but people enjoyed personifying it. The two spacecrafts provided a wealth of information about Mars. Perhaps the most important discovery is that Mars was once a wet planet that could have supported life.

2012 A more advanced rover called *Curiosity* landed on Mars. *Curiosity* was much larger than the previous rovers and required NASA scientists to develop a specialized landing apparatus called a sky crane in order to land it safely. Designed with a wide array of scientific instruments, *Curiosity*'s mission was to determine if Mars might have had microbial life at one time. Although the rover was intended to last only two years, as of 2020, *Curiosity* was still actively exploring Mars. These vehicles are designed with durability in mind since there are no garages to do repairs on Mars! *Curiosity* is extremely heavy and has features that help it avoid getting stuck or tipping over. Whenever a rover wears out, it remains with its fellow probes on Mars.

Did you know?

More missions to Mars are constantly being planned. When you read this, there may well be more rovers rolling around on the red planet.

EXTENSION

Instructions:

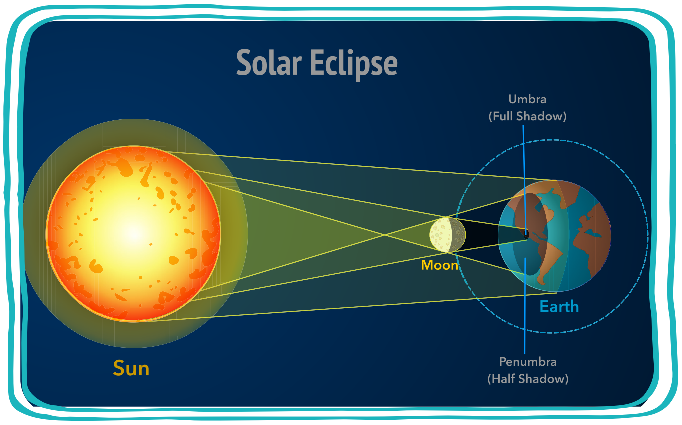
Lesson 7: Read the information below. With permission from a parent, go to **www.timeanddate.com/eclipse** to find out when the next lunar or solar eclipses will occur in your area. Write down the dates in your journal. How old will you be when the next solar eclipse occurs in your country?

Lesson 8: Follow the instructions on the next page to complete the activity. In your journal, discuss the results of your experiment. How does the activity show what is happening during a solar eclipse and a lunar eclipse? Why can you see a lunar eclipse more often than a solar eclipse?

Solar Eclipses

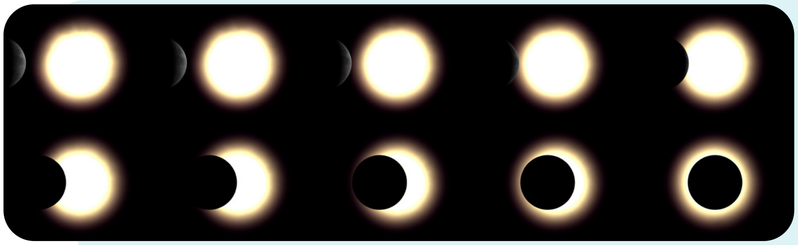
A solar eclipse is an exciting, dramatic event. In the middle of the day the sky goes dark, temperatures drop, and winds slow down and change direction. Some stars might even be visible! At its height the sun's disk is completely blocked out, allowing you to see the glowing ***corona*** (Latin for "crown") surrounding it. What causes this spectacular display of nature?

As the moon orbits the earth, it occasionally passes directly between the sun and the earth. When that happens, the moon's shadow falls on the surface of the earth. Since the moon is much smaller than the earth, the shadow covers only a small region. As the shadow passes across the earth, people on the surface see the moon passing in front of the sun. This is a ***solar eclipse***.



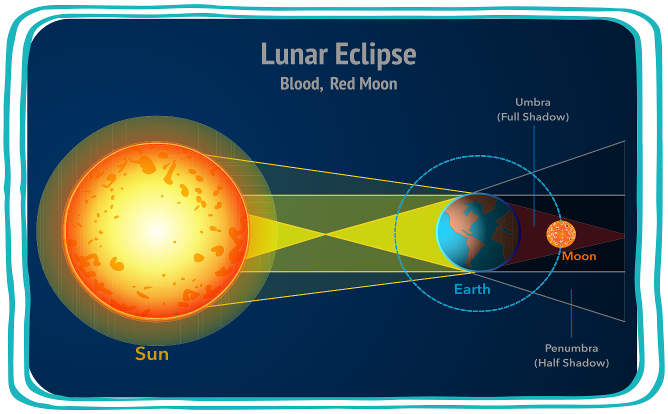
If you were watching the event happen, first you'd see the moon's shadow taking a tiny bite out of the edge of the sun. Then, as the moon advances, more and more of the sun vanishes until you're left with a crescent sun. Daylight becomes dimmer and dimmer as the amount of sunlight diminishes. But be careful! Even though much of the sun is covered, even a small sliver of the sun is bright enough to damage your eyes if you look at it. You should never look at an eclipse directly; it's just as dangerous as looking at the sun any other time. Finally, when the moon's shadow completely covers the sun, you have a total solar eclipse.

The moon's shadow has two components, the dark ***umbra*** and the lighter ***penumbra*** surrounding it. Within the umbra the eclipse is total; that is, the moon completely covers the sun. Within the penumbra the eclipse is partial, meaning that it never reaches totality. Did you ever notice that the sun and the moon appear to be roughly the same size in the sky? The moon is really much smaller than the sun, of course, but it is much closer. It's an amazing fact of nature that the moon is just the right distance away to appear around the same size as the sun in the sky, which allows beautiful solar eclipses to happen. If the moon were farther away, it would appear smaller and never completely block out the sun. Since the moon's orbit is an ellipse rather than a perfect circle, sometimes it is a little farther away than normal and thus appears a bit smaller during an eclipse. At these times a ring of sunlight is visible around the moon's shadow. These are called ***annular eclipses***.



Lunar Eclipses

When the moon passes behind the earth, Earth's shadow falls on its surface, making it dark. This is a ***lunar eclipse***. Since the earth is bigger than the moon, its shadow covers the entire lunar surface. As you watch, you'll see an edge of the full moon go dark. As the earth's shadow advances, more and more of the moon darkens. At totality the moon takes on a dim coppery glow. This is due to light scattering from the earth's atmosphere. Particles in the atmosphere scatter blue light (making the sky blue) and allow red light to pass through and slightly illuminate the eclipsed moon.



Since the moon orbits the earth roughly once a month, you might wonder why we don't see a lunar eclipse every month. The reason is that the moon's orbit is tilted a bit. Imagine placing a ball, representing Earth, at the center of a hula hoop. Now tilt the hula hoop at an angle so that it's not parallel with the ground. The hula hoop is the moon's orbit. You can see how the moon is often either below the earth or above it when it orbits. That means most of the time it passes either above or below the earth's shadow, and therefore no lunar eclipse happens. Only when the moon happens to be level with the earth and directly behind it do we see a lunar eclipse. The same thing happens for solar eclipses, but since the moon's shadow only covers a small portion of the earth's surface, solar eclipses are even more rare.

Gather the following supplies so you are prepared for the activity in the Lesson 8 extension below: a lamp, a basketball, and a tennis ball. You can substitute any large ball or very small ball if needed. Just make sure the balls are different sizes.

Lesson 8: Activity

Let's try to make an eclipse of our own. We'll use a light source like a lamp to represent the sun, a basketball to represent the earth, and a tennis ball to represent the moon.

1. In a darkened room, shine the light source onto the basketball. The basketball represents the earth in space, illuminated by the sun. Note that the side facing the light is brightly lit (day), and the opposite side is dark (night).

2. Now use the tennis ball to represent the moon. Hold the tennis ball between the basketball and the light source. Does it cast a shadow on the basketball? If not, you may need to move the tennis ball closer or farther away. The shadowed region of the basketball is experiencing a solar eclipse.

3. Once you have a shadow, move the tennis ball and see how the shadow moves across the surface of the basketball. Tiny inhabitants on our basketball world would see a solar eclipse as the shadow passes over them.

4. Experiment with moving the tennis ball closer to and farther away from the basketball. What happens to the shadow?

5. Now move the tennis ball so it passes behind the basketball. When the basketball's shadow falls over it, the tennis ball goes dark. This is a lunar eclipse. Again, experiment with moving the tennis ball closer and farther away to see what happens to it.

Proportional distance and size of the earth and moon.

EXTENSION

Instructions:

1. Read the information below.
2. How old will you be when Halley's comet returns? Write a brief journal entry from the future where you are observing the comet's return. You may include some details of your future life, the technology you're using to view the comet, and so on.

Famous Comets

Perhaps the best known of all comets is Halley's Comet. Named after Sir Edmund Halley (rhymes with valley), this comet returns every 75 years. Halley observed the comet in 1682. After some calculations he determined that several previous comets were in fact the same comet returning over and over. He predicted that the comet would return in 1757. Although he didn't live long enough to see it, his prediction was correct, and the comet was named in his honor. In 1910 Halley's Comet passed particularly close to Earth, giving people of the time an impressive view. The most recent appearance of this comet was in 1986. Several space probes were sent to observe the comet as it passed by. Halley's Comet is due to return to our skies in 2061.

The years 1995 and 1996 saw two comets back to back. Hyakutake was discovered by an amateur astronomer using only a pair of binoculars. The comet had an ice-blue color and the longest tail of any comet ever recorded. The next year, Hale-Bopp was an exceptionally bright comet. Its brightness is due to its very large nucleus. It was so bright that it was visible to the naked eye before it passed Jupiter's orbit and remained visible for 18 months.

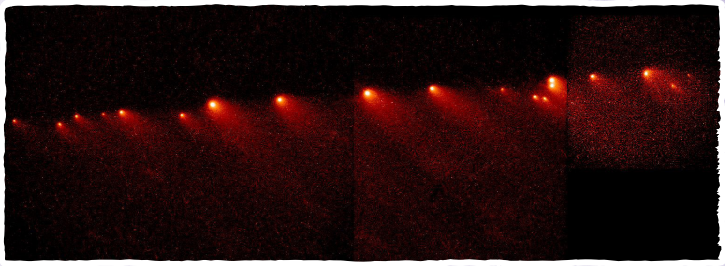
Several comets are famous because space probes were sent to examine them. The comet Wild [vilt] 2 was visited by the *Stardust* probe, which flew past the comet, collected dust particles from it, and returned them to Earth. The European space probe *Rosetta* orbited the comet Churyumov-Gerasimenko, took close-up pictures of its oddly shaped nucleus, and then landed on its surface. NASA's *Deep Impact* space probe dropped a projectile onto the surface of comet Tempel 1. By observing the material ejected from the impact, scientists gained important clues about the material found deep within comets.

Shoemaker-Levy 9 is perhaps the most famous comet that was not visible to the naked eye. The comet passed close to Jupiter in 1992. The planet's gravity broke the comet up into 21 fragments that spread out like a string of pearls in its orbit. Two years later, the fragments crashed into Jupiter one by one. The Hubble Space Telescope, earthbound telescopes, and the space probe *Galileo* all watched the impacts. This was the first time collisions between objects in space had ever been observed. The comet fragments impacted the planet at high speed, creating massive explosions more powerful than millions of atomic bombs. The impacts sent plumes of hot gases high into the planet's atmosphere and left dark scars in the clouds.

Interstellar Comet

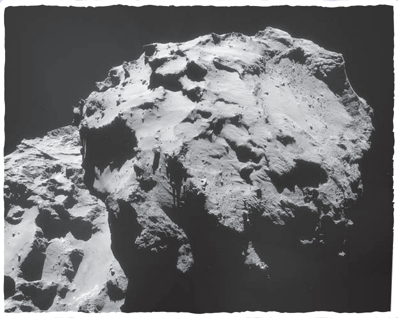
Perhaps the strangest comet known is Oumuamua [oh—MOO—ah—MOO—ah], whose name in Hawaiian means "a messenger from afar arriving first." Oumuamua is the first-known interstellar comet, meaning that it came from outside our solar system. The object surprised astronomers by varying in brightness, which indicates that it is very long and thin. While originally classified as a comet, further observation showed that it probably has very little ice remaining. This strange alien object is like nothing in our solar system, having characteristics of both comets and asteroids. Oumuamua passed closest to our sun in 2017 and is now headed back out into interstellar space.

Shoemaker-Levy 9 photo collage



Hyakutake

Churyumov-Gerasimenko nucleus



EXTENSION

Instructions:

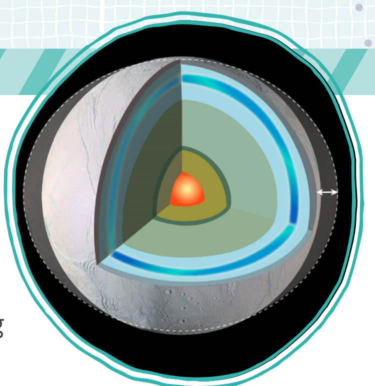
1. Read the information below. Then, in your journal, complete one of the following activities:
   a. Write a brief paragraph explaining at least two ways in which cryovolcanoes are similar to volcanoes on Earth and two ways in which they are different.
   b. Create a Venn diagram that includes at least two differences and two similarities between volcanoes and cryovolcanoes.

Icy Eruptions

When you think of volcanoes, you probably imagine fiery eruptions with red-hot magma and superheated steam burning everything it touches. But in the outer reaches of the solar system, some planets and moons experience a different form of volcanism—eruptions that spew ice-cold water. These ***cryovolcanoes***, or ice volcanoes, shape the landscapes of distant worlds much like geologic forces on Earth sculpt its surface.

When scientists first sent space probes to explore the outer solar system, they expected to find uninteresting cratered surfaces on the moons of planets like Jupiter and Saturn. To their surprise, they found that some moons had geologically young surfaces with few craters. That means that some forces must have resurfaced the moon in the recent past. Then, in 2005, scientists were amazed when the *Cassini* space probe sent back pictures of icy geysers on Saturn's moon Enceladus. This was the first direct evidence of cryovolcanic activity.

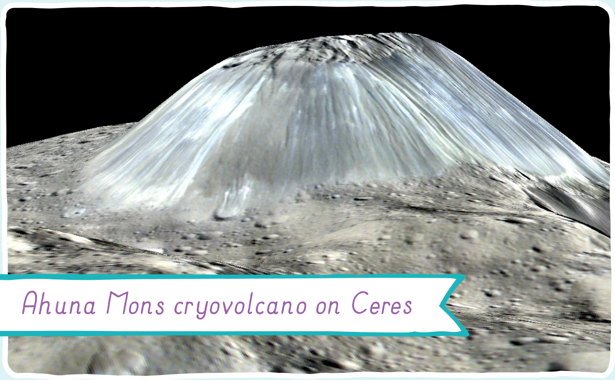
Scientists had long known that many moons of the gas giant planets are composed of rock and ice. To an astronomer, the word *ice* means more than frozen water; it also includes frozen ammonia, methane, carbon dioxide, and other substances that would be liquids or gases on Earth. Just like the earth is layered, many moons in the outer solar system have a rocky core surrounded by an icy mantle and crust. At the very cold temperatures so far from the sun, the ices that make up these moons are as hard as rock. So what heat source could possibly melt them to produce volcanoes?



For many icy moons, the heat comes from a process called ***tidal flexing***. Enceladus orbits Saturn, a huge planet with powerful gravity. The gravity force pulls on the moon as it orbits, stretching and compressing it over and over again. These forces, combined with the periodic tugging of other nearby moons, heat the interior of Enceladus enough that some of the ices below the surface melt. These pockets of molten ices act much like pockets of magma on Earth. The molten material works its way through fissures toward the surface, where it eventually escapes in an eruption. Some moons, like Jupiter's moon Europa, experience so much tidal heating that scientists believe there is an entire ocean of liquid water hidden beneath the ice.

When the *New Horizons* probe passed Pluto in 2015, it discovered signs of eruptions on that world and its moon Charon. With a surface temperature averaging -226 to -240 °C (-375 to -400 °F), even gases like nitrogen and methane are frozen on Pluto. Yet the tidal forces that the dwarf planet and its moon exert on each other produce enough heat to melt ice. The solar system has turned out to be a much more fascinating place than anyone had dreamed!

Saturn's moon Titan is the only moon in the solar system with a thick atmosphere. That alone made it interesting enough to send probes to explore this moon. In addition to the discovery of liquid lakes on Titan's surface, space probes have found that the moon has mountains shaped much like earthly volcanoes. Some surface features have changed between space probe visits, indicating that cryolava flows have happened in the time between one visit and the next.



Ahuna Mons cryovolcano on Ceres

Perhaps the most unusual cryovolcano yet discovered is Ahuna Mons on the dwarf planet Ceres. Discovered by the *Dawn* space probe in 2015, this cryovolcano expels muddy, salty ice water. The salts help keep the muddy water from freezing deep inside Ceres, and occasional upwellings of this material create cryovolcanoes like Ahuna Mons. When the water evaporates after an eruption, the salt crystals left behind create a white, brightly reflective surface. Similar processes may have produced the mysterious bright spots found elsewhere on Ceres.

EXTENSION

Instructions:

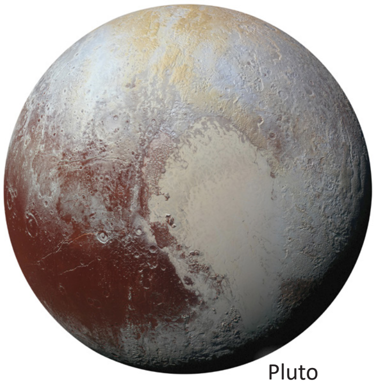
1. Read the information below.
2. In your journal, describe the difference between a planet and a dwarf planet. Then write your opinion on whether you think Pluto (and other dwarf planets) should be considered planets or dwarfs and why.

Dwarf Planets

If you had gone to school before 2006, you would have been taught that there were nine planets. Currently the International Astronomical Union (IAU), an organization responsible for classifying celestial bodies, only recognizes eight regular planets in our solar system. So what happened to the ninth one? Pluto, first discovered in 1930, held the title of the ninth and smallest planet until 2006.

Pluto might have still been the ninth planet today if astronomers had not discovered three additional small planets in the Kuiper Belt and an asteroid named Ceres. The discoveries of Eris and Haumea in 2003 and Makemake in 2005 led to many disagreements among scientists on how to classify the tiny planets. Finally, the IAU met to decide if these new celestial bodies should be added to the list of planets, which would have brought the total to 12. Instead, they created a new category of dwarf planet and made the controversial decision to classify Pluto and the four newly discovered planets with that title.

According to the IAU definition, dwarf planets are very similar to planets—they both orbit around the sun and have enough gravity to pull their mass into a rounded shape. The primary difference is that dwarf planets have not cleared their orbit of other smaller objects. That means that usually the gravity of planets will either attract or push away other objects along their orbital path to clear it out, but the gravity of dwarf planets is not strong enough to make that happen.


Pluto

Some astronomers do not agree with the IAU's decision and believe that Pluto should be reclassified as a planet. Some argue that all celestial bodies with enough gravity to allow them to become spherical in shape should be classified as planets. Under this definition even a moon could be classified as a planet. Others say there should not be a distinction between planets and dwarf planets. With the possibility of hundreds of additional dwarf planets existing in the Kuiper Belt and beyond, there is still a lot that can be learned about planets. It's possible that one day Pluto could be considered a regular planet again.

Did you know?


Ceres

Ceres orbits the sun in the Asteroid Belt area between Mars and Jupiter. First discovered in 1801, Ceres was also originally considered a planet like Pluto, but it was reclassified as an asteroid around 1850. In 2006, Ceres was reclassified again, this time as a dwarf planet. Among the known dwarf planets, Ceres is the smallest one. It is also the closest to the sun.

Additional Facts on Pluto

NUMBER OF EARTH YEARS TO ORBIT THE SUN ONCE: 248

SIZE: 2,370 km (1,473 mi) wide; smaller than Earth's moon

NUMBER OF KNOWN MOONS: 5; Pluto's moon Charon is only ever seen from one side of Pluto.

AVERAGE TEMPERATURE: −225 °C (−375 °F)

ONE DAY ON PLUTO: equal to 6.4 Earth days (or 153.3 hours)

- The sunlight on Pluto is very dim, similar to light at early dawn or dusk on the earth.
- Pluto spins the same direction as Venus and Uranus (which is opposite of all the other planets).
- For 8% of its orbit, Pluto is actually closer to the sun than Neptune. The last time that Pluto was closer to the sun was from 1979 until 1999, and it will be more than 200 years before it happens again.

EXTENSION

Instructions:

1. Read the information below.
2. In your science journal, write 1–2 sentences about each of the following prompts:
   a. Describe some of the life challenges that Henrietta Swan Leavitt had to overcome.
   b. How did Henrietta Swan Leavitt's discoveries impact the study of astronomy?
   c. What inspired you the most about Henrietta Swan Leavitt?

Astronomer Henrietta Swan Leavitt

Have you ever heard of someone being called a forerunner? A forerunner is a person who precedes or leads the way for someone else. Henrietta Swan Leavitt was certainly a forerunner in astronomy: her discoveries influenced the work of famous astronomers who came after her. Despite humble beginnings, prejudices against women, and multiple health challenges, Henrietta Swan Leavitt beat the odds to make far-reaching contributions to astronomy.

Born on July 4, 1868, in Lancaster, Massachusetts, Henrietta was the eldest of seven children. Due to her father's work as a minister, her family moved regularly. One of those moves took them to Cleveland, Ohio, where Henrietta attended Oberlin College, beginning at age 17. During her early college years, Henrietta studied music, which she enjoyed, but she had not yet found a subject of study that fully captured her interest.

After her third year of study, the Leavitt family moved back to Massachusetts, where Henrietta hoped to continue her education. However, Harvard University did not admit women at that time. Instead, Henrietta enrolled at the Harvard Annex (later called Radcliffe College). There she shifted her studies to mathematics and, during her final year, stumbled into the field of astronomy. Instantly, she was fascinated by the vastness of space and the limitless discoveries to be made.

Upon graduating at age 23, Leavitt volunteered as a research assistant at Harvard's observatory. As one of the human computers at the observatory, Leavitt measured and cataloged the brightness of stars as they appeared on photographic plates. But Leavitt's aspirations of becoming an astronomer soon came to a halt when ongoing health problems confined her to home for two years. As her illness advanced, she became aware of a horrifying side effect: she was losing her hearing! Over a short period of time, Leavitt became increasingly deaf. At first the realization weighed heavily on her heart, but taking courage and placing her faith in God, Henrietta Swan Leavitt pressed forward toward her goal.

In 1902, with her health finally improving, Leavitt returned to the Harvard College Observatory, this time as an employee. Variable stars remained her central focus. Leavitt worked diligently to discover the relationship between the overall brightness of stars and the time it took them to change from bright to dim and back again (called a ***pulse rate***).

After carefully observing these ***Cepheid variable stars***, she made her breakthrough discovery: the brightness of these stars was directly related to pulse rate! Brighter stars have longer pulse rates, while dimmer stars have shorter pulse rates. Why was this so important? It provided a standard for measuring distances outside our solar system and determining a galaxy's size. She established 17 magnitudes of brightness that were used for decades to order stars by their brightness.

Additionally, Leavitt's discovery advanced the work of other astronomers, such as Harlow Shapley, who proved that our sun was not at the center of the galaxy. Astronomer Edwin Hubble also relied on the ***Leavitt law***, as it came to be known, to establish his theory that the universe is expanding. And when Hubble found Cepheid stars in other galaxies, Leavitt's law helped prove that galaxies existed outside the Milky Way and that our galaxy was not the center of the universe.

Henrietta Swan Leavitt's work was so pivotal to the field of astronomy that she was nominated for a Nobel Prize in 1926. Sadly, she could not win because the prize cannot be awarded posthumously (after a person dies). After years of ill health, Leavitt had succumbed to stomach cancer in December of 1921 at the age of 53. Despite significant social and health-related challenges, Henrietta Leavitt retained a positive attitude and made invaluable discoveries in astronomy. As a forerunner to the many great scientists who built upon her discoveries, she truly paved the way for those who came after her.

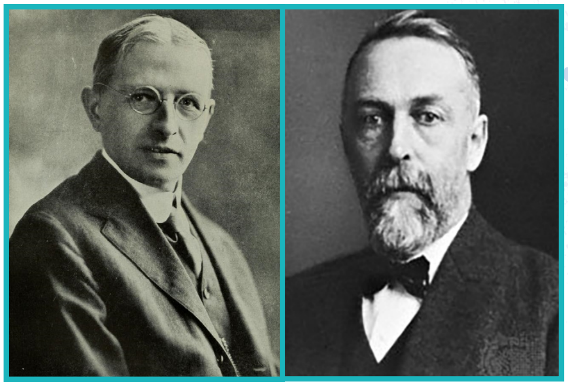
EXTENSION

Instructions:

1. Read the information below.
2. Students often use memory devices to help remember the order of things. For example, you learned the sentence "**M**y **V**ery **E**nthusiastic **M**other **J**ust **S**erved **U**s **N**oodles" to help you remember the order of the planets. Each word represents a planet name. In your journal, try to come up with a sentence or phrase to help you remember the order of spectral types for stars (O, B, A, F, G, K, M).

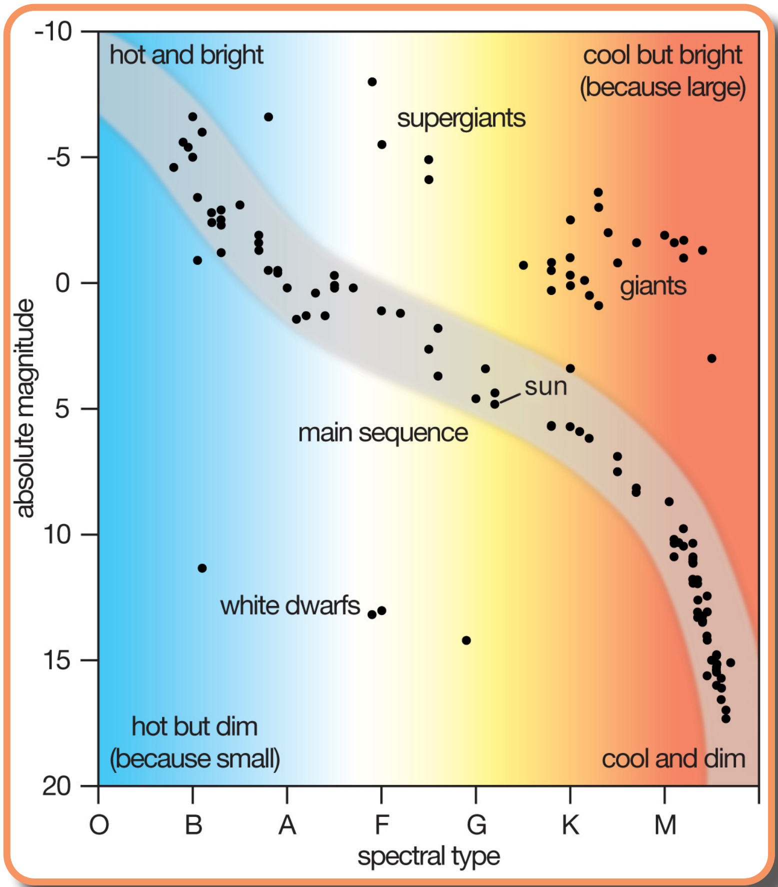
Hertzsprung-Russell Diagrams

A look at the night sky shows that there are different types of stars, some bright and some dim, some blue and some red. In the early 1900s, it occurred to Ejnar Hertzsprung and Henry Norris Russell that they could construct a graph of the stars based on their properties. They graphed the star's color on the x-axis and the star's brightness on the y-axis. The resulting graph is called a Hertzsprung-Russell diagram, or ***HR diagram***.



RUSSELL HERTZSPRUNG

You might be wondering how they placed the colors of stars on a graph. It turns out that a star's color is a result of its surface temperature. The coolest stars burn red hot. Our sun is hotter than that, and so it glows yellow. Hotter stars are white hot, and the hottest stars are so hot their glow has a bluish tint. Astronomers came up with a series of code letters called ***spectral type*** in order to quickly determine the color and temperature of a star. The most common spectral types are O, B, A, F, G, K, and M, ranging from bright blue type O stars down to red type M stars. Our sun is a yellow G-type star. Graphing spectral type versus a star's brightness gives us an HR diagram.



When Hertzsprung and Russell first drew their HR diagrams, they found that most stars fall on a band running diagonally across the graph from the upper left (hot and bright) to the lower right (cool and dim). This band is called the ***main sequence***. Most stars, including our sun, fall on the main sequence. This makes sense; the hotter the star's surface, the brighter it tends to be. The dim red stars on the bottom right on the main sequence are often called red dwarfs; the bright blue stars on the upper left are blue giants. Rigel, the bright blue star at Orion's knee, is a blue supergiant. The nearest star to our solar system, Proxima Centauri, is a red dwarf. Our sun lies near the middle of the main sequence.

There are also stars that do not fall along the main sequence. The HR diagram shows a cluster of stars near the top right: cool red stars that are very bright. These are the red giants. As the name suggests, they are very large stars; some of them would engulf the innermost planets of our solar system if placed where our sun is! Betelgeuse, the bright red star on Orion's shoulder, is a red supergiant.

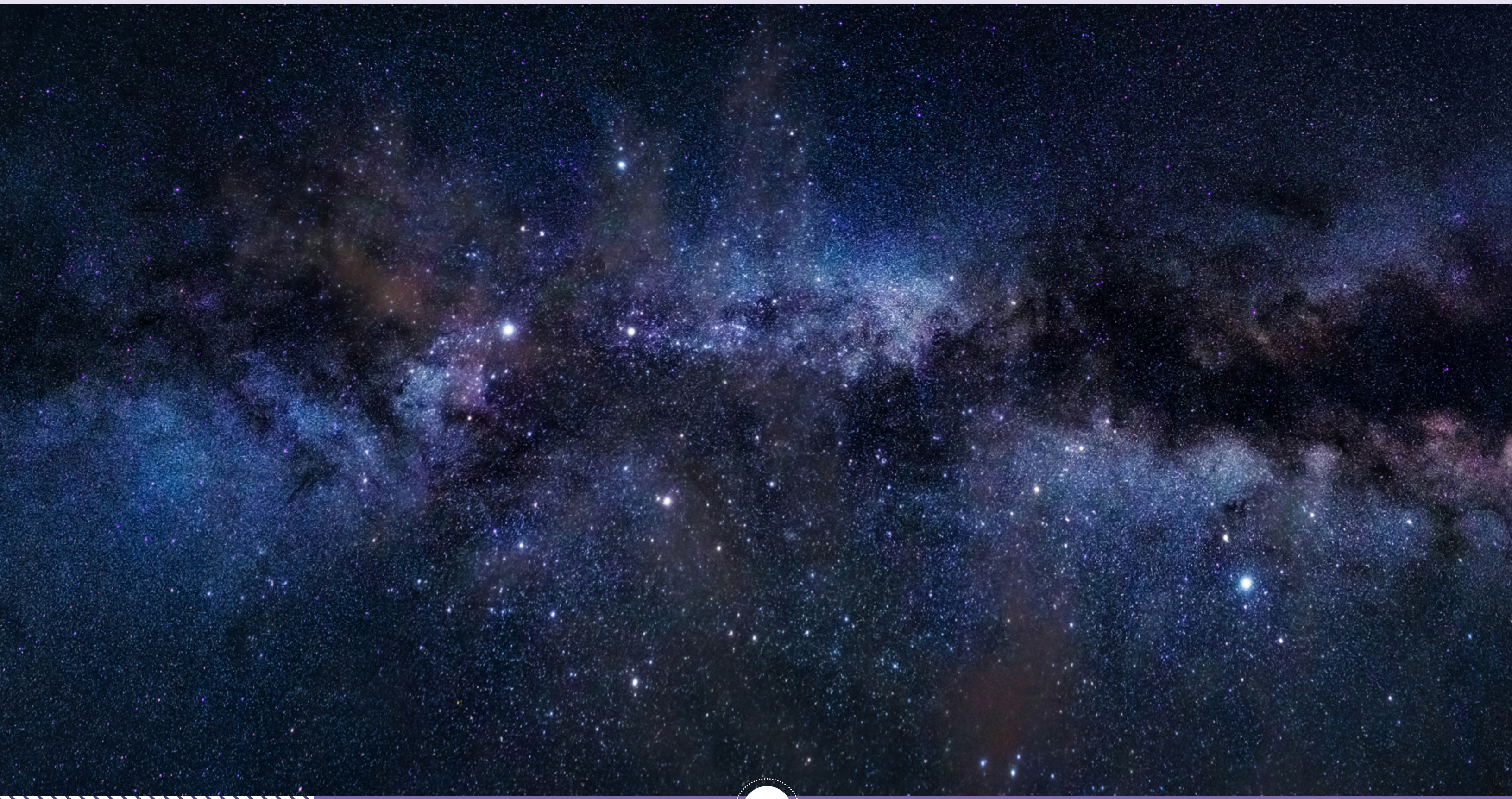
Hertzsprung and Russell also found another cluster that showed up below the main sequence. These are the white dwarfs, intensely hot but very tiny. White dwarfs are far too dim to see with the naked eye. A relatively nearby white dwarf is a tiny companion that orbits Sirius, the Dog Star.

The HR diagram is a valuable tool in analyzing the properties of stars. A star that lies on the main sequence is burning hydrogen in its core much like our sun. When the star runs out of hydrogen, its outer layers expand and cool, and it becomes a red giant. Eventually the star's outer layers drift away, leaving behind the tiny hot core as a white dwarf. Large stars burn their fuel faster than smaller ones, and so the stars at the top left of the main sequence tend to move into the red giant region faster than the cooler stars lower along the main sequence. As a result, astronomers can judge the ages of stars based on their locations on the HR diagram.

Spectral Class	Color	Surface Temp
O	Blue	40,000
B	Blue-white	20,000
A	White	10,000
F	Yellow-white	7,500
G	Yellow	5,500
K	Orange	4,000
M	Red	3,000

Note: "Surface Temp" is in Kelvin.

By graphing the stars in a cluster or galaxy, astronomers can estimate the age of the cluster by seeing how many of the brighter stars remain on the main sequence. In a young star cluster, there will be few red giants and plenty of bright blue stars. A middle-aged cluster will have lost the brightest stars of the main sequence since they will have drifted over to the red giant region. In a very old cluster, most of the brighter stars have left the main sequence and become red giants and then white dwarfs.



EXTENSION

Instructions:

1. Read the information below.
2. In your journal, write which job at NASA you would enjoy doing most and why.

The Supporting Cast

A well-known saying in American culture advises the following: "There is no I in TEAM." While Neil Armstrong, Michael Collins, and Buzz Aldrin received recognition for landing on the moon during the Apollo 11 mission, they knew they could not have done it without the work of a huge team of directors, scientists, mathematicians, engineers, and others supporting them back home. Let's take a closer look at some of the people and the roles they played that contributed to the success of the Apollo missions.

Mission Controllers

The Mission Control Center (MCC) is the location where people worked together to coordinate each aspect of a space mission—from prelaunch, launch, and flight through space to lunar landings and reentry. Some of the people in the MCC included the following:

- **Flight director**—oversaw and managed the Mission Control Center, led the planning and coordination of every part of the mission, and approved any instructions or procedures given to the astronauts. Gene Kranz was the flight director who directed the lunar landing of the Apollo 11 mission. Four other directors were in charge of other aspects of that mission (such as the launch).


GENE KRANZ

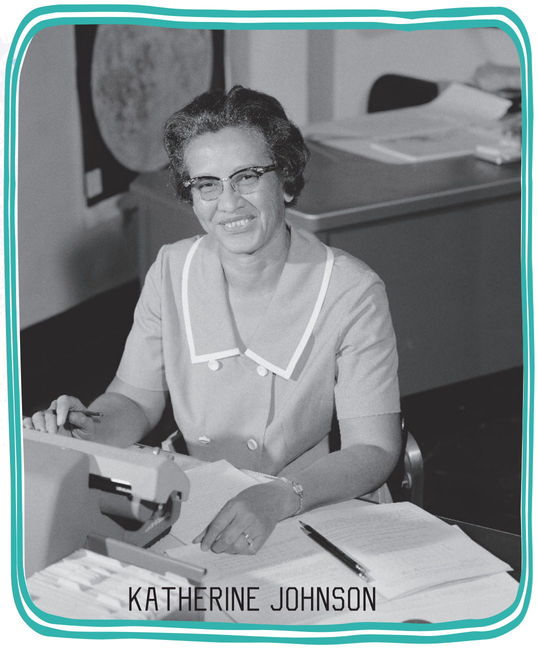
- **Spacecraft communicator** (also called the CAPCOM)—talked with the astronauts via radio. All messages were relayed by a single person so the radio lines would not become jammed with too many people talking at once, and astronauts had a familiar voice they could rely on. This job was often performed by a fellow astronaut.


DUKE, LOVELL, AND HAISE–CAPCOMS

- **Flight controller**—coordinated and computed the exact times, speeds, and trajectories for the astronauts to stay on the correct flight path. For example, he or she would tell those on the moon exactly when to launch the lunar landing module so they could meet up with the orbiting spacecraft at the right time.
- **Communications operator**—managed all the communications systems, including the video footage that came in from the moon landing.
- **Flight doctor**—monitored the health of the astronauts throughout the mission by the use of little sensors placed on their bodies.

Other Jobs at NASA

Countless others—as many as 400,000 people—contributed to the Apollo missions behind the scenes. Many of those people worked at NASA's Langley Research Center in Virginia.



KATHERINE JOHNSON

Human Computers: In the early days of astronomy and space exploration, mathematical computations were all done by hand with a pencil, paper, and slide rule. Computers and digital calculators capable of processing complex equations had not been invented yet. During this era the people who did these calculations were called human computers because they were computing information.

MARY JACKSON

Beginning in the 1940s during WWII, these jobs were increasingly performed by women. The contributions of human computers were brought to the attention of the public when a movie named *Hidden Figures* was made about Katherine Johnson, Dorothy Vaughan, and Mary Jackson, who worked at Langley for decades. One of Johnson's most significant contributions was the computation that synced the Apollo 11 lunar landing module to the orbiting command module.

Geologists: Ahead of the Apollo 11 mission, several geologists studied photographs of the moon's surface, analyzing its qualities in order to determine the best place for the lunar module to land. After the astronauts returned to Earth with soil and rock samples, the geologists studied the samples to increase their understanding of the moon and improve landing recommendations for future Apollo missions.

Tailors: These talented seamstresses were tasked with designing space suits that would protect the astronauts from the extreme conditions of outer space. The suits had to protect them from extremely cold temperatures and be airtight while still allowing the astronauts to move freely enough to climb out of the lunar landing module.

JUDY SULLIVAN

Engineers: From testing and building the Apollo spacecrafts to developing the systems to run them, engineers were involved in almost every aspect of the Apollo missions. Judy Sullivan, one of the first female engineers to be hired by NASA, worked closely with the astronauts to help monitor their vital signs. She was the lead engineer for the Apollo 11 biomedical system.

This article has discussed only a small handful of the countless individuals working behind the scenes at NASA. Even though you may not have known of these people and their jobs before, each person made vital contributions to the success of the Apollo missions and was an important part of the team.

MISSION CONTROL CENTER

EXTENSION

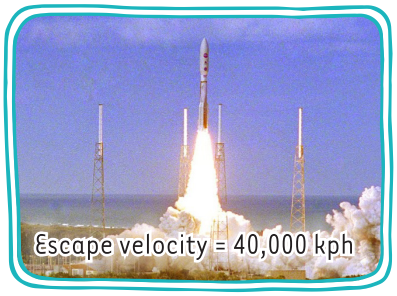
Instructions:

1. Read the information below.
2. Imagine that you're the captain of a spaceship that survives a close encounter with a black hole. In your journal, write a "captain's log" entry describing the encounter. The entry should be about a paragraph long.

Black Holes

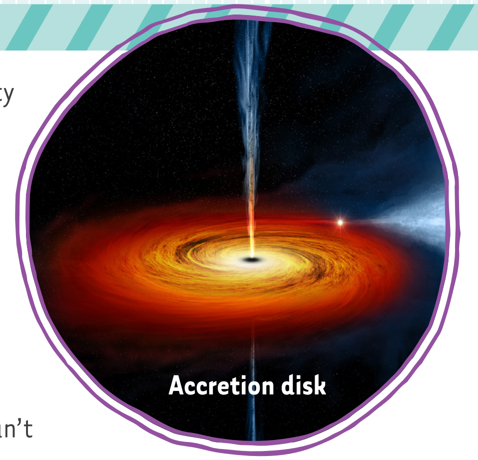
Black holes. The very term is both terrifying and exciting. Objects so massive that even light can't escape their gravitational pull, black holes inspire a sense of wonder in scientists and laypersons alike. But what are these mysterious objects? What would happen if you got close to one? How do scientists detect them?

Think about a rocket launched from the surface of the earth. If it is moving too slowly, Earth's gravity will bring it crashing back down. The rocket needs to be moving at a speed called ***escape velocity*** in order to escape Earth's gravitational pull. Remember that gravity gets weaker the farther you get from the center of the earth. The opposite is also true; gravity gets stronger as you approach the center. Of course, that increase in gravity stops when you reach the surface. But what if you were to squish the earth, making it smaller but keeping the same mass? The surface would now be closer to the center, and therefore surface gravity would be greater. That means that escape velocity would also be greater. If you keep compressing the earth, eventually the velocity you need to escape would become greater than the speed of light. At that point, observers in space would no longer be able to see Earth's surface because no light could escape. The earth would have become a black hole.


Escape velocity = 40,000 kph

The radius at which an object is compressed into a black hole is called the ***Schwarzschild radius***. For Earth the entire mass of the planet would have to be compressed into a radius less than a centimeter—the size of a large marble. It would take an unimaginably great force to do that. Many black holes are formed when the core of a dying star is compressed by tremendous forces in a supernova explosion. Only the most massive stars are capable of producing the forces necessary to create these stellar mass black holes.

There are no black holes close enough to Earth for anyone to visit, but we can imagine what might happen if a spaceship came near one. Gravity force would pull the spaceship inward. At first it isn't too difficult to escape by firing the rockets, but as it gets closer, the rockets have a harder time, until eventually the ship can't break free no matter how much force its rockets apply. The intense gravity begins to distort time so that someone watching the spaceship would see it falling in slow motion. Space becomes warped as well; if the black hole is rotating, space itself gets dragged along with it, so the outside universe appears to spin even if the spaceship isn't moving.


Accretion disk

Worse, now that it's really close to the center of the black hole—a point called a ***singularity***—gravity begins to increase sharply. Now one end of the spaceship feels more gravitional force than the other end. The result is that the spaceship gets stretched and eventually pulled apart. This process is called ***spaghettification*** because it stretches objects out like spaghetti. Close enough to the center of the black hole, the gravity forces are so strong that even atoms get ripped apart by this process. Nearby matter falling into a black hole often forms a flat disk called an ***accretion disk***. The gas in this disk is rotating so rapidly that friction makes it hot enough to give off x-rays that we can see. The bright accretion disk gives astronomers a chance to detect black holes. Cygnus X-1, for example, is a bright blue star that is orbiting a black hole. Material from the star is pulled off and forms a glowing accretion disk around the black hole, which can be detected by astronomers.

Using telescopes scattered around the world, scientists can catch a glimpse of the shadow of a supermassive black hole against the bright background of its accretion disk. In 2019 a team of scientists managed to capture the first picture of a black hole. The picture they took of M87 at the center of a distant galaxy was the result of painstaking work using computer processing to analyze data from the Event Horizon Telescope Array. In all, more than 200 scientists from many nations worked together to produce the spectacular image.