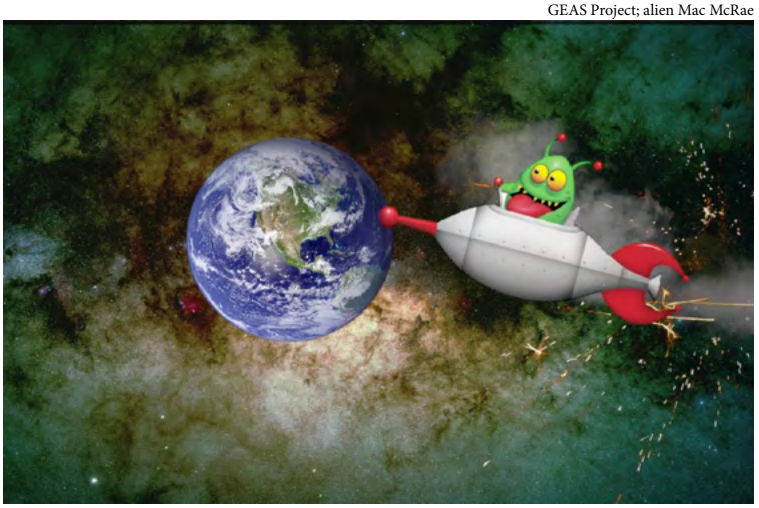
Astronomy Counts!

Teacher & Learner Guide

This guide gives background information about the astronomy topics mentioned in the video, provides questions and answers children may be curious about, and suggests topics for discussion.

Educational video for children
https://vimeo.com/56117755

GEAS Project; alien Mac McRae



This guy doesn't exist, but there might be other life out there.

0 There are 0 space aliens on planet Earth.

Have you ever seen something you thought could have been an alien? What did it look like? Sound like? Smell like?

How do we know aliens aren't on Earth?
Celestial matter, such as asteroids, does land on Earth, but as far as scientists know, nothing from the skies has brought sentient life from other planets to Earth. (Though tiny molecules might have hitched a ride down on an early asteroid …)

Is there evidence of life on other planets?
Scientists have not yet discovered life on other planets, but by learning about the atmosphere and composition of our planet and other planets and moons (a science called astrobiology), they are trying to figure out which ones might be able to support life (or might have supported it in the past). A great starting place to search would be the moons surrounding Jupiter.

1 There is 1 star in our solar system: the Sun.

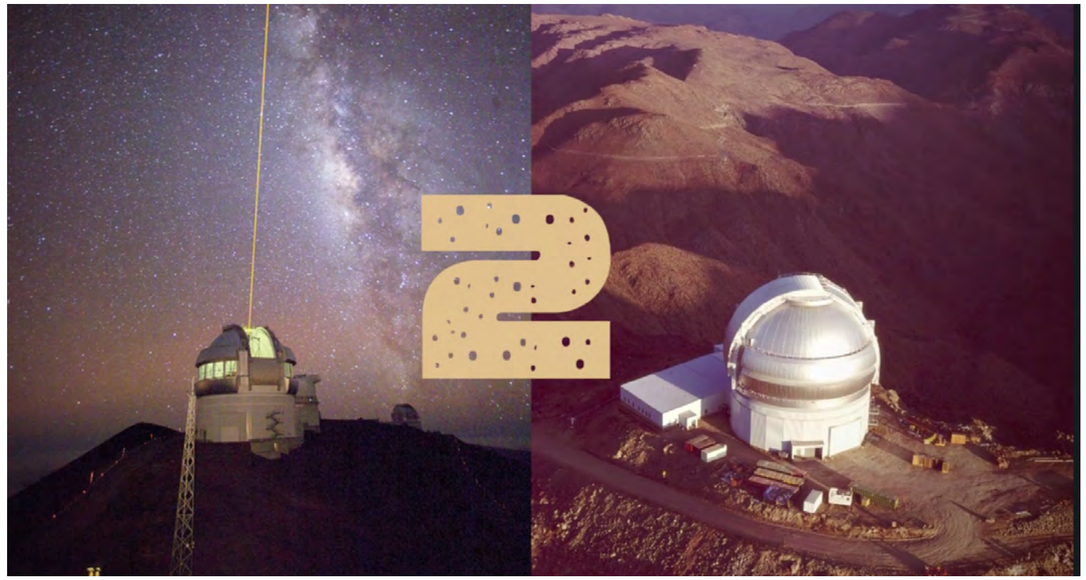
What is a star?
You may know that there are three common kinds of matter: gas, liquid, and solid. Air is made up of gasses, liquids are substances like water and milk, and solids are things like rocks or your chair or the curb you tripped over on the way to school. A star is made up of very hot gasses, forced into a round compact shape by gravity.

What makes the Sun a star?
The sun is made up of hydrogen, helium, oxygen, carbon, and other less common elements. Over time these gasses were drawn together into a dense ball. The center of the ball was so hot and so dense that it caught fire.

What kind of star is the Sun?
The Sun is what is called a Main Sequence star or a yellow dwarf, and is billions of years old. Most stars spend most of their lives in the dwarf phase, so our star is a middle-of-the pack star (not too bright, not too faint, but just right).

What does the term 'solar system' mean?
The word *solar* is derived from the word sol, which is Latin for sun. Because the Sun is the center of our planetary system, our system is called the *solar system*.

Are there star systems with more than one star?
There are other planets that revolve around a central star



The two Gemini telescopes, exploring the universe from high places in Hawaii (left) and Chile (right). GEAS Project; Gemini Obs.

(or several stars), forming a planetary system which includes satellites, asteroids, comets, and dwarf planets, just like our solar system. The most common sort contains two stars, though you can find triplets, and even quadruplets, if you look long enough.

2 There are 2 Gemini telescopes, one in Hawaii and one in Chile.

Why are they called "Gemini" telescopes?
The Gemini telescopes are named after Castor and Pollux, twins from Greek and Roman myth. The telescopes are twins too, one looking at the northern sky and one looking at the southern sky. Together, these twins can search out the entire sky!

What is a Gemini telescope?
They are large reflecting telescopes which allow astronomers to observe faint objects in the sky at high magnification. They are similar to an optical telescope that you could buy for your own stargazing (though a tad more expensive). There are also radio telescopes which see radio waves instead of visible light.

What do astronomers look at through the Gemini telescopes?
The Gemini telescopes are very powerful, and they allow astronomers to look at planets, stars, galaxies, and other bodies that lie incredibly far away from Earth.

Why do you think scientists decided to put the two telescopes in Hawaii and Chile?
The telescopes are located in Hawaii and Chile because these two locations have exceptionally clear skies and good atmospheric conditions, and are not too close to the bright lights of civilization.

3 There are 3 stars in the nearest star system: Alpha Centauri A, Alpha Centauri B, and Proxima Centauri.

Why do these stars have 'Centauri' in their names? What do their names mean?
The three stars in the nearest star system (the Alpha Centauri system) are all named *Centauri* because they belong to the constellation Centaurus. It forms the image of a centaur, a mythical half-horse, half-man being.

How are star systems and galaxies different?
A galaxy is composed of millions and billions of stars and planets, all held together by gravity. Our solar system and the Centauri system exist as next-door neighbors within the Milky Way galaxy.

In our solar system, all the planets revolve around the Sun. What happens when there is more than one star in a star system? How do the planets move?
In a two-star system, known as a binary, two stars orbit a central point where their masses balance. (A simple way to understand this is to try to balance an unevenly weighted plank on your hand. The center of mass will be closer to the heavy end of the plank.) When a star system is made up of more than two stars, the movement of the celestial bodies can be chaotic and disorderly! Try imagining a teeter-totter (a seesaw) with several people, each with their own plank and seat.

How can a binary star system have three stars?
The Centauri system consists principally of Alpha Centauri A and Alpha Centauri B. These two stars determine the movements of the system. Tiny, outlying Proxima Centauri is just along for the ride — and is barely noticed. (It was't discovered until 1915, while its bright companions make up the third brightest star seen from Earth.)

4 Galileo discovered 4 moons dancing their way around Jupiter: Io, Europa, Ganymede, and Callisto.

Who was Galileo?
Galileo Galilei was an Italian astronomer who is sometimes called the "father of modern astronomy." In his time scientists had not yet agreed upon the fact that the Earth revolves around the Sun, but Galileo thought it did.

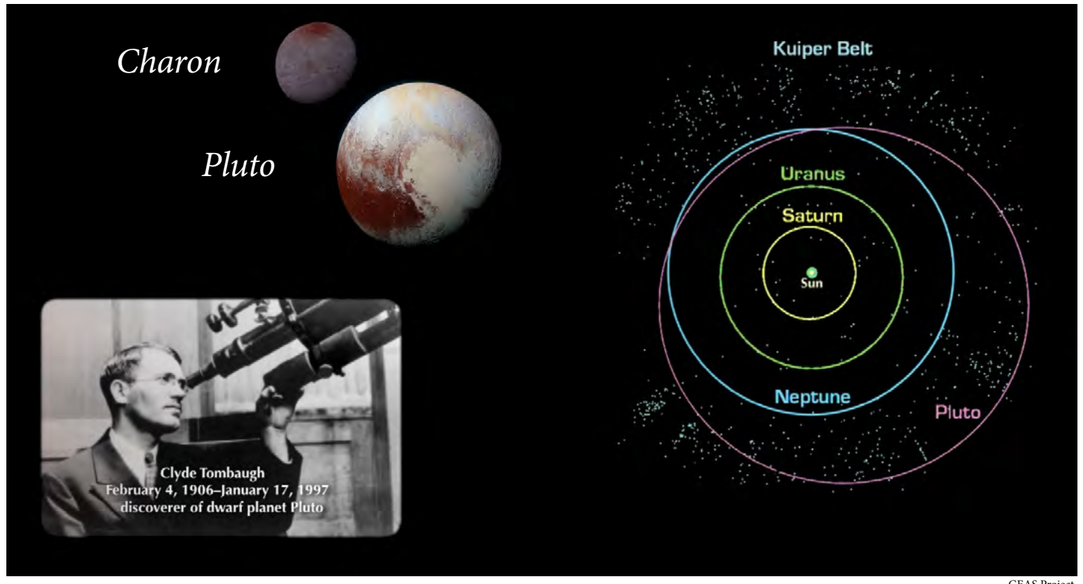
How did Galileo discover Jupiter's four largest moons?
In 1610, Galileo increased the magnification of his telescope and discovered four faint celestial bodies near Jupiter. They appeared and disappeared from view over time, but never left its vicinity. Galileo concluded that they were orbiting Jupiter, the way the Moon orbits Earth.

Why do these moons have such funny names?
Galileo wanted to name the moons after four of the Medicis (Italian patrons of the sciences). The moons could have been Cosimo, Francesco, Carlo, and Lorenzo! Instead, they were named for lovers of the Greek god Zeus.

Why does Jupiter get four moons when we have only one?
Life is unfair! Some moons formed when the planets formed, while others are accreted small bodies (like asteroids) caught by the gravitational field of a planet. Because

Galileo must have been very pleased to discover 4 faint celestial bodies near Jupiter — its moons Io, Europa, Ganymede, and Callisto. This was possible because of an early telescope he built, one which magnified objects by a factor of 8 in size. In a single 2 month period in 1610, he discovered the Jovian moons, oberved mountains on the Moon, and determined that the Milky Way itself was made up of a multitude of tiny stars. He revolutionized our view of the heavens above!

GEAS Project; portrait Justus Sustermans



GEAS Project
2 TNOs: NASA/JHUAPL/SwRI

A day on dwarf planet Pluto lasts 6 Earth days. What would your day be like if you lived on Pluto?

Jupiter is so much larger and more massive than Earth, it casts a strong pull and has caught many such unwary neighbors, trapping them into orbit around it.

Can we ever observe all of Jupiter's large moons together at the same time?
Jupiter's moons each take a different amount of time to travel around Jupiter, so it is highly unlikely that they would all line up on the same side at the same time. Our moon takes a month to orbit the Earth, but if we had a second moon a bit farther away it might take six weeks. Their orbital positions would match every three months when their cycles brought the moons into the same part of the sky at the same time. If we had a third moon whose cycle was eight weeks, all three moons would line up only once every six months. You can see how catching the four large Jovian moons all at once might take a while.

5 NASA launched 5 rockets in 5 minutes.

NASA is the National Aeronautics and Space Administration. It is most well-known for being the branch of the American government responsible for launching rockets into orbit and spacecraft into space. What you might not know is that NASA does many things related to space, like researching the atmospheres of planets (including Earth). For instance, NASA has been involved in research on ozone depletion.

Why did NASA launch so many rockets at once?
What do you see when you think of rocket launches? You probably imagine vehicles carrying astronauts into orbit around Earth, or robotic spacecraft setting off to visit other planets. In March 2012, five rockets were launched 80 seconds apart to study our own planet. They released chemical tracers to form visible clouds in the sky. This enabled scientists to study the jet stream (air currents in the atmosphere) by looking at how the clouds moved.

To learn more about the time NASA launched 5 rockets in 5 minutes, visit:

NASA
https://www.nasa.gov/mission_pages/sunearth/missions/atrex.html

Space.com
https://www.space.com/14939-nasa-5-rocket-launches-saturday-night.html

Where did the rockets go?
After the rockets released their chemicals and took temperature and pressure measurements in the ionosphere (part of our atmosphere), they fell back down into the Atlantic Ocean. Unlike the manned craft that make big news, these rockets didn't carry people into space.

6 A day on dwarf planet Pluto lasts 6 Earth days and a year lasts 250 Earth years.

What makes a day last so long?
The length of a day is determined by how long it takes a planet to complete a full rotation on its axis. Pluto's rotation takes six Earth days (almost 150 hours), which means that Pluto turns verry slooooowly in comparison with Earth.

What determines how long a year lasts?
When a planet orbits around a star, a complete orbital cycle is called a year. In other words, a year is how long it takes the planet to reach the same place while circling around the star, like the long hand on a clock making a full circle from the 12 through all the numbers and then returning to the 12. It takes the Earth only 365 days to make a complete circle around the Sun, but it takes Pluto 250 times as long. (This is why we've never observed a birthday cake on or for Pluto.)

Why is Pluto a dwarf planet instead of a planet like the others in our solar system?
For many years Pluto was considered the ninth planet of our solar system, but because of new discoveries about the outer reaches of our solar system, many scientists now consider it to be different from the other eight planets. It is small and is made of ice and rock, like many of the bodies found far from the Sun in the Kuiper Belt or beyond. It is thought to belong with them.

To learn more about what constellations you can see from your area, visit:

Sky and Telescope
https://www.skyandtelescope.com/observing/ataglance

7 There are 7 sisters of the Pleiades sailing the northern sky.

What are the Pleiades?
The Pleiades are a star cluster in the constellation Taurus. They are named for seven sisters, the daughters of Atlas, in Greek mythology. Within the star cluster, there are actually nine bright stars — the seven sisters and their parents.

Why are so many celestial bodies named after Greek myths?
The constellations have so many connections to Greek myth because it was the Greeks who first catalogued them. Eudoxus of Cnidus and Ptolemy were two Greek astronomers who described many of the constellations we recognize today.

Have you ever found any of the constellations, or the Pleiades, in the sky? Could you see the Pleiades from where you are if you went out to look at the stars tonight?

In 2006, the Hubble Space Telescope sent the world a winter holiday card featuring the Pleiades star cluster.

NASA, ESA, and AURA/Caltech

GEAS Project

It takes the Moon 29 ½ days to shift smoothly through all 8 phases shown above, spending almost 4 days per phase.

8 There are 8 phases of the Moon: new moon, waxing crescent, first quarter, waxing gibbous, full moon, waning gibbous, third quarter, and waning crescent.

What causes the Moon to have different phases?
The Moon doesn't actually get larger and smaller, but it can seem that way to us on Earth. The half of the Moon facing toward the Sun is always illuminated by sunlight. As the Moon orbits around the Earth, though, the portion of that illuminated half that we can see from Earth varies. During the new moon phase the Moon lies in between the Sun and Earth and the bright side of the moon faces away from the Earth. As the Moon travels around to the back of the Earth, we see more and more of its brightly lit half — till eventually we see the bright, bold full moon.

How long does a full cycle of lunar phases take?
A full cycle of all eight phases takes 29 ½ days, or approximately a month. Long ago, a month was literally the time between one new moon and the next, which is why our words for *month* and *moon* are related.

Do the moon's phases ever change unexpectedly?
The Moon's movements are very predictable and follow a regular schedule. The only time there is a fast, dramatic change in the appearance of the Moon is during a lunar eclipse.

What happens during a lunar eclipse?
A lunar eclipse occurs when the Sun, Earth, and Moon all line up, with the Earth in the middle. The Earth blocks the Sun's light from striking the full moon, causing the Moon to temporarily grow dim. The eclipse last a few hours at most, until the Moon moves on far enough in its orbit to break the straight line formation and come out of the Earth's shadow.

How does the Moon look in different parts of the world?
The Sun is always shining the same amount of light on the Moon, so it looks the same throughout the world (as long as it isn't hiding behind clouds). However, not everyone can see the Moon at the same time. The Moon rises and sets in the sky, just like the Sun. People in Hawaii witness moonrise at a later time than people in New York, but they all see the Moon in the same phase on a single night.

To learn more about the phases of the moon and access an interactive animation, visit:

GEAS Project
https://astronomy.nmsu.edu/geas/hci/html/welcome.shtml

Questions for children to ask themselves:
Why do you think there are so many stories about the full moon? What are some superstitions related to the phases of the moon?

Can you ever find the moon in the sky during the day?

9 There are 9 planets in the solar system: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune (and let's not forget little Pluto).

Can we see any of the planets without a telescope?
We can find the neighboring planets without a telescope. They look very similar to stars, but they appear a bit brighter and rounder. Traditional mythical bodies celebrated in many cultures include the Sun, the Moon, and the planets Mercury, Venus, Mars, Jupiter, and Saturn.

Where did the names of the planets come from?
As with the constellations, the names of the planets came from the Greeks. With the exception of Earth, all of the planet names are also names of Greek gods. The name of our planet comes from Old English and German.

Could we live on any of the other planets?
In the movies adventurous people build colonies on Mars, but we would need all kinds of complicated life support systems in order to remain there for any length of time. None of the other planets in our solar system could support human life easily, but it's very possible that an Earthlike planet in another star system could. We could also head out to the Asteroid Belt, or visit the moons of Jupiter.

Could someone else live on any of the other planets?
Scientists have tried to imagine what sorts of life forms might exist within radically different environments than our own. If you could invent a creature to live on a gas giant like Jupiter, or out amongst the asteroids and comets, what would it look like? How would it survive?

What are effects of a planet's distance from the Sun?
Distance from the Sun affects temperature and the length of the year — the farther a planet lies from the Sun, the cooler it is and the longer it takes to circle around the Sun. Planets that lie farther from the Sun receive less sunlight, though the amount of light reaching the surface also depends on its atmosphere and how much light it absorbs. The length of the local day is of course dependent upon how fast the planet rotates on its axis. The planet's atmosphere and composition depend upon how the planet formed and from what materials it grew. It is no coincidence that the Terrestrial (rocky) planets lie close to the Sun, while the Jovian (gas giant) planets lie further afield.

Recently, some scientists wanted to change Pluto from a planet to a dwarf planet. Why?
A planetary system includes a star and the bodies that circle around it, held in place by gravity. These bodies can be planets, dwarf planets, asteroids, or even comets. Pluto orbits the Sun like the other planets in our solar system, but it lies so far out that some scientists think it should be classified with other dwarf planets in the Kuiper Belt, a region of space containing many small rocky and icy bodies (like asteroids and comets). Because Pluto is large for a dwarf planet and small for a Terrestrial planet, it isn't as easy to classify as other bodies in our planetary system.

We found Pluto at a playground in New Mexico. GEAS Project

Astronomers can observe comets like these three colorful characters, using large telescopes.

The Rosetta spacecraft actually landed on a rocky, irregular comet nucleus, revealing tall crags and deep crevices!

Best of all, though, we can all appreciate Great Comets like Comet McNaught from our own backyards here on Earth. Let's hope another one comes by to visit soon!

Column 1: NASA and ESA/D. Jewitt (UCLA), MSFC/Jacobs Technology/ESSSA/Aaron Kinger; Row 1: ESA/Rosetta and Carreau/ATG medialab, NAVCAM, MPS/UPD/LAM/IAA/SSO/INTA/UPM/DASP/IDA

10 The core of a comet is 10 kilometers across, and its tail is another 10 million kilometers long.

Have you ever seen a comet?
Ten kilometers is about 6 miles. Do you think that's big for a comet? Bigger than you expected? How big did you think a comet was? The Earth is nearly 13,000 kilometers across, not nearly as long as a comet but definitely wider!

What are various comets we can see from Earth and how often do they pass by?
Few comets can be seen from Earth without using a telescope, but once every ten years or so, it's possible. These objects are known as Great Comets. Halley's Comet, perhaps the most well-known comet of all, passes by the Earth once every 76 years. Unless we begin living a very long time, we'll each only have one chance in our lives to see that particular comet. Another well-known comet is Comet Hale-Bopp, which appeared in Earth's skies in 1997.

What exactly is a comet? What is it made of? What are its parts?
A comet is an icy celestial body that contains rock, dust, water, and various carbon-based gasses. It has a nucleus, a dense concentration or core. Thin trailing tails of gas and dust are enhanced when a comet passes near to the Sun and sunlight heats the core. The word *comet* comes from the Greek for long-haired (star) because of the long tails that stream behind the comet. The gas tail of a comet always points away from the Sun due to the forces of solar radiation and solar wind. Most comets come from the Kuiper Belt or the Oort Cloud, both of which lie at the far reaches of our solar system, beyond Neptune.

Are comets and asteroids related?
Asteroids are essentially teensy, rocky planets or, more officially, minor planets, because they orbit the Sun. Scientists hypothesize that some asteroids used to be comets! Asteroids and comets have similar composition, but asteroids are less icy so they don't leave trails of gas and dust in their wake.

11 A brilliant gamma ray burst once lasted 11 days.

What is a gamma ray burst?
Gamma rays are a type of high frequency radiation, even higher frequency than x-rays, which means that the high energy levels emitted by gamma rays are harmful to people. A gamma ray burst is exactly what it sounds like: a concentrated emission of gamma rays. These bursts are can be associated with explosions that occur with supernovae or high-mass star collapse events.

How long do gamma ray bursts usually last?
Gamma ray bursts tend to last between a fraction of a second and a few minutes, so a burst that lasts 11 days is really, really long!

What can we learn from gamma ray bursts?
By observing gamma ray bursts we can learn what is happening in distant galaxies and also learn more about the stars themselves – how they collapse at the ends of their lives.

What would happen if a gamma ray burst happened somewhere near Earth?
Since gamma rays are a form of intense radiation, a burst near Earth (in the Milky Way) could be devastating to life. We don't know exactly what would happen, but many species could die from radiation exposure. Fortunately, most gamma ray bursts occur in far away galaxies.

12 There are 12 constellations of the zodiac, forming a belt high in the sky above the Earth's equator.

Who thought up these constellations?
These constellations (and the corresponding zodiac symbols) are Greek in origin, but there are other names for constellations, just as there are myths and tales different from the ones we have each been told. People from the southern hemisphere and people from the northern hemisphere tend to see different sets of constellations, and so tell different stories to remember them.

What is the zodiac?
You may think of the zodiac as having to do with astro-

A brilliant gamma ray burst lasted 11 days, like a shining lighthouse beaming across the universe. NASA, ESA, and M. Kornmesser

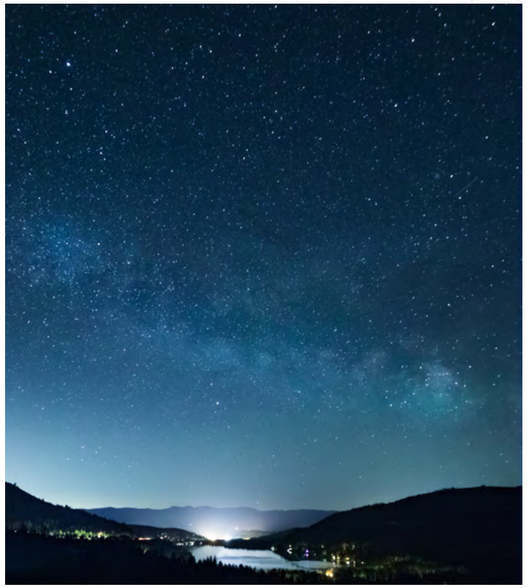
logical signs and horoscopes, but to astronomers the zodiac is a way of dividing the sky into sections by using the Sun's path through the Earth's skies over a year as a central line from which to measure.

The Sun's path is called the *ecliptic*, and the constellations of the zodiac are spaced around it, forming a wide belt in the sky above the equator. This belt is divided longitudinally into twelve sections (each 30 degrees wide), and each of these sections is associated with a constellation. The birth signs you might know from astrology come from these constellations.

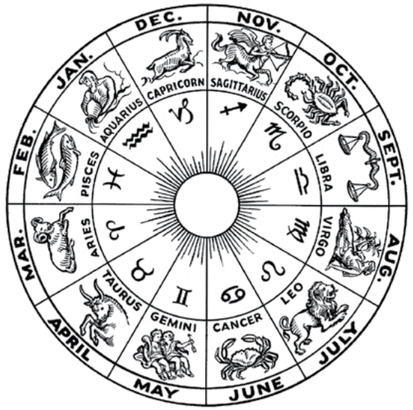
What are the 12 constellations of the zodiac?

Aries, the ram	**Libra, the scales**
Taurus, the bull	**Scorpius, the scorpion**
Gemini, the twins	**Sagittarius, the centaur**
Cancer, the crab	**Capricornus, the goat**
Leo, the lion	**Aquarius, the water carrier**
Virgo, the maiden	**Pisces, the fishes**

Sam Willis



What patterns do your eyes see in this piece of the sky?



Are there other constellations that aren't in the zodiac?
There are many! The constellations in the zodiac are only the ones that are located in a ring above the equator. The Big Dipper and Orion are two examples of constellations that aren't a part of the zodiac.

13 The sleeping volcano, Mauna Kea, in Hawaii, hosts 13 telescopes.

What does Mauna Kea mean?
It means white mountain. The Hawaiians so named the volcano because it often has snow on its peak. Yes, snow in Hawaii! Mauna Kea's peak is located at an elevation of almost 14,000 feet, so it is much cooler there than in the rest of Hawaii. (Astronomers sometimes get funny looks on planes when they fly to Hawaii and bring along parkas instead of swim suits.)

Why is Mauna Kea called the sleeping volcano?
Just like stars, volcanos go through different stages of development. They are most active during the shield stage when they gain most of their mass. Mauna Kea has long outgrown its shield stage, but it is still capable of erupting. Its last eruption was a mere 4,600 years ago. Just a blink of an eye in volcano time!

Why are there so many telescopes there?
Mauna Kea has many qualities that make it an excellent site for observatories. Its high elevation places it above much of the Earth's atmosphere, allowing a clearer view of the stars. The peak is also very dry, an important factor for collecting infrared and submillimeter radiation. Finally, as you know if you are an amateur astronomer or just someone who enjoys looking at the stars, it is more difficult to see the stars in or near cities due to light pollution. Mauna Kea lies far from Hawaii's brighter cities, and levels of light pollution are very low on the summit.

Wynona

Of the 13 telescopes on Mauna Kea, 9 are optical and infrared telescopes, 3 are submillimeter wavelength telescopes, and one is a radio telescope. Different types of telescopes look at different electromagnetic wavelengths.

Radio telescopes are sensitive to radio waves, which are much longer than visible light waves. Optical telescopes are what most of us think of when we think of telescopes. If you own a telescope, it's most likely an optical one.

14 The universe is almost 14 billion years old. That's ancient!

How old are you? How many lives would you have to live before you turned 14 billion?
If you lived to be 70, you'd have to live millions and millions of lives before you turned 14 billion.

What kinds of things tell us the age of the universe?
One way we can think about the minimum age of the universe is to look for the oldest things in it. Since we know how long stars spend in each stage of their lives, we can make educated guesses about how old the oldest stars are.

Even when we can figure out the age of the oldest stars, that's still not enough. What if the stars in the universe were toys in your bedroom, and the universe were your house? Even if you knew when the oldest toy in your bedroom was created, you might not know the age of your house. The house could be a lot older than the oldest thing inside it. Therefore, in addition to looking at objects in the universe scientists have developed theories about the universe as a whole in order to determine its age.

One of these methods is to estimate how much radiation, or heat, was present during the Big Bang (the event that created the universe). Using this information and what we know about how fast radiation dissapates, we can calculate how many years it has taken to get from Big Bang levels of radiation to today's levels.

Another way we can think about the age of the universe is to look at how big it is. If we know the rate at which the universe is expanding, we can count backwards to figure out when the universe was tiny –14 billion years ago.

Thank you, Young Astronomers, for counting with us from zero to the Age of the Universe!

For more information about our educational film series or to discuss its use in an educational setting, please contact the GEAS Project at New Mexico State University.

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https://astronomy.nmsu.edu/geas