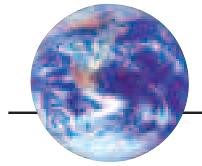

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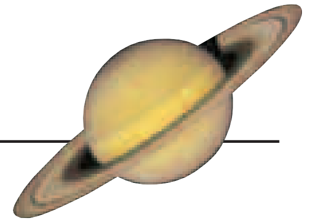
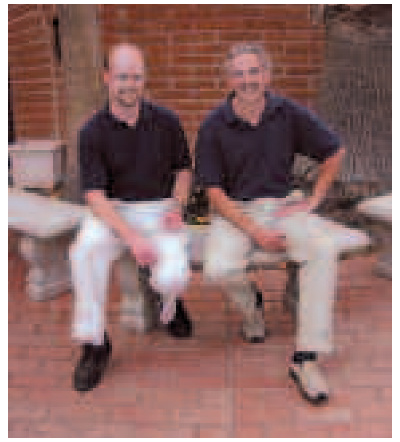


PART I ★ Armchair Tour

PART II ★ Self-guided Tour

Acknowledgements



Scott Tucker (left) and Dean Koenig

Kris Koenig next to a 30-inch diameter reflector telescope.

You can't go through life without the support of others, and writing a book is no different. This book was inspired by the proddings of Kris Koenig and his older brother Dean Koenig. Within a span of six months, both mentioned that I should write a full-color, beginning astronomy book for adults. I know this wasn't a coordinated effort because their twists were different, but maybe this is a case for genetically like minds thinking similarly. Anyway, I thought about what they said and agreed, so I pursued this book wholeheartedly, ahead of others in the queue.

The support needed to complete a book does not have to be direct. My astronomy buddies, Ken Don, Larry Moore, Scott Tucker, Joe Jakoby, as well as David and Wendee Levy, have provided uplifting friendship that keeps me pushing forward. I thank them for being who they are and the kinship they provide.

I lied a little about Larry Moore and Scott Tucker not providing any direct support. Scott and Dean Koenig spend most of their recreational time with astrophotography. I thank them immensely for letting me use their beautiful photos which rival those from professional observatories. Larry Moore also kindly let me use several of his photos that he has taken over the years.

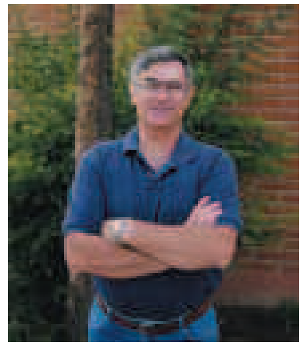
My parents have supported my interest in astronomy since childhood. Without their love and encouragement, I would not be who or where I am today. I thank them from my heart and I am glad that both have seen the fruits of their labor.

Shortly after I came to Tucson in 1988, I met the talented art director Debbie Niwa, who has been instrumental in creating many of my wonderful covers. Not only do I appreciate her artistic ability, but I have also enjoyed our philosophical and political chats.

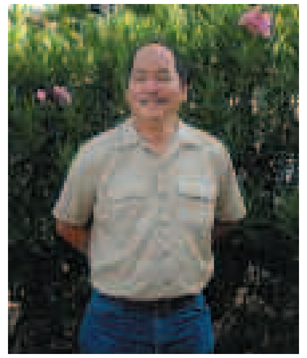
Isabelle Houthakker did the final editing and has assisted me in other projects. Her attention to detail is very much appreciated, because mine runs dry at the end of a project like this.

Finally, I want to acknowledge the patience and understanding of my wife, Suzanne and daughter, Adrea. Without their tolerance and giving of "space," this book could not have been written.

Thank you all.



Larry Moore



Ken Don

Introduction

Why 2017? That was the question that came up time and again when I told people the planned title of this book. Why stop at 2017 when 2020 is such a nice round number and only three more years?

Well, there is a good reason. I want everyone in the United States to keep 2017 on their minds. I want North Americans to plan on traveling to a 60-mile-wide strip stretching from Lincoln City, Oregon to Charleston, South Carolina, for the August 21, 2017 total solar eclipse of the Sun. This is going to be one spectacular event that everyone in the United States will have an opportunity to experience, and see something that they will remember for the rest of their lives. I guarantee it. Send this book back to me in September 2017 if you don't agree.

As you can probably guess, the intent of this book is to get as many people to step out and experience the beauty of the Universe. I am not steering you to become a fanatic, just a participator. All of nature is beautiful, but please experience its grandest displays. Hopefully, this will lead to a greater appreciation of what has been given to us, as well as a desire to preserve it.

In August 2017, you will be able to witness an event like this that lasts just two minutes but will provide a life-long memory.

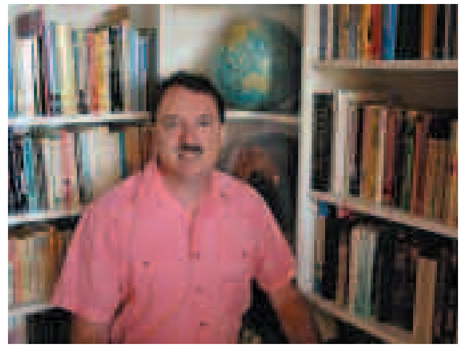
I wrote this book to accommodate a wide range of astronomy enthusiasts. It details a plethora of observing activities for those just beginning or others who are more knowledgeable. Those who are just beginning won't need binoculars or a telescope to enjoy the heavens, only a small commitment of time. For the most part, nature does the work for you, so all you have to do is look up and enjoy the show.

Now, if you have a basic knowledge of astronomy or get the "bug," I have noted over 100 objects on the star charts that you can observe with binoculars or a small telescope. This should keep you busy while you decide where you want to go next with this wonderful science.

Astronomy is dynamic. Meteors streak across the sky, the Moon waxes and wanes, eclipses occur, comets come and go and stars occasionally flare up. There is always something exciting, interesting or different happening. For this reason, I am providing 16 years of celestial information to keep you abreast of the most predictable events so that you can pick up wherever you may have left off.

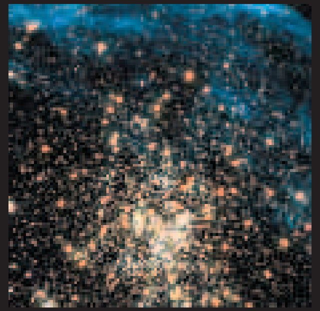
Now go out and enjoy the splendors of the heavens. You won't regret it!

Ken Graun
Tucson, Arizona
July, 2002



The author at home in Tucson.

A History of Astronomy



14.5 billion years ago. The Universe began from a "Big Bang."

14.4 billion years ago. First batch of largest stars had died from supernovae explosions.

4.5 billion years ago. Sun and solar system formed.

4.4 billion years ago. Moon forms from object that collides with Earth.

540 million years ago. Life suddenly proliferates during the Cambrian period.

65 million years ago. Dinosaurs wiped out by cosmic impact.

100,000 years ago. Homo sapiens begins to spread across the globe.

4240 BC. Egyptians institute the first 365-day calendar.

3000 BC. Babylonians predict eclipses.

2296 BC. Chinese make the first known record of a comet.

763 BC. Babylonians make the earliest known record of a solar eclipse.

500 BC. Pythagoreans teach that Earth is a sphere.

270 BC. Aristarchus of Samos (Greek island near Turkey) challenges Aristotle's teachings by asserting that the Sun is the center of the solar system and that the planets revolve around the Sun.

240 BC. Chinese records indicate first known visit of Halley's Comet.

165 BC. Chinese astronomers record sunspots.

635 AD. Chinese record that a comet's tail always points away from the Sun.

1300. Eyeglasses become common.

1504. Christopher Columbus of Spain uses knowledge of a total lunar eclipse to frighten a group of Native Americans.

1543. On his deathbed, Nicolas Copernicus of Poland, publishes his works stating that the Sun is the center of our solar system.

1604. Johannes Kepler of Germany observes a supernova in the constellation Ophiuchus — the last supernova observed in our galaxy. In 1609, he publishes fundamental laws of planetary orbits.

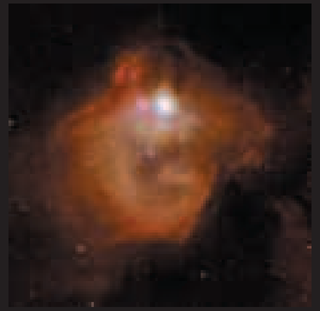
1609. Galileo Galilei of Italy builds one of the earliest refractor telescopes and observes four of Jupiter's moons.

1668. Isaac Newton of England makes the first reflecting telescope and in 1687, publishes theory of gravity.

1682. Edmond Halley of England observes "The Great Comet." He predicts its return in 1758. In his honor it is named after him.

1781. Charles Messier of France, a comet hunter, publishes his famous catalog listing a hundred star clusters and nebulae. William Herschel of England discovers Uranus.

1801. Piazzi of Italy discovers the first asteroid, Ceres.



1821. Catholic church lifts ban on teaching the Sun-centered Copernican system.

1839. Harvard College Observatory, the first official observatory in the United States, is founded. A 15-inch refractor is installed in 1847.

1846. Johann Galle of Germany discovers Neptune using the predictions of its position by Urbain Le Verrier of France and John Couch Adams of England.

1863. William Huggins of England uses the spectra of stars to show that the same elements that exist in stars also exist on Earth.

1864. John Herschel, son of William Herschel, publishes a catalog of nebulae and star clusters that contains more than 5,000 entries.

1877. Giovanni Schiaparelli of Italy thinks he has discovered channels on Mars.

1882. David Gill photographs Halley's comet and notices the multitude of stars surrounding the comet — the idea of stellar cataloging by photography is born.

1884. International meeting in Washington, DC, sets the Prime Meridian through Greenwich, England.

1897. George Hale sets up the Yerkes Observatory in Williams Bay, WI. The Yerkes telescope, at 40 inches, is still the largest refracting telescope ever built.

1912. Studies of short-period variable stars in the Small Magellanic Cloud by Henrietta Leavitt lead to the period-luminosity law of Cepheid variables — a key that is used to unlock the distances to the stars.

1913. Russel and Hertzsprung propose theory of stellar evolution.

1917. Hale builds 100-inch reflecting telescope at Mount Wilson, CA.

1924. Hubble demonstrates that galaxies are true independent systems rather than parts of our Milky Way system. In 1929, he establishes that the more distant a galaxy is, the faster it is receding.

1930. Clyde Tombaugh discovers Pluto from Flagstaff, Arizona.

1931. Jansky founds radio astronomy.

1938. Bethe and Weizsäcker of Germany propose that the energy produced by stars is the nuclear fusion of hydrogen into helium.

1946. V-2 rocket carries a spectrograph to record a spectrogram of the Sun.

1947. Spitzer speculates that astronomers might put telescopes of various kinds in orbit around Earth.

1948. The 200-inch Hale reflecting telescope is completed at Palomar, California.

1949. Whipple suggests that comets are "dirty snowballs." A rocket testing ground is established at Cape Canaveral, Florida.

1955. US Vanguard project for launching artificial satellites is announced.

1957. First artificial satellite, *Sputnik I*, is launched by the Soviet Union on October 4.

1958. Wernher von Braun's team launches the first American satellite to reach a successful orbit around Earth.

1961. Soviet cosmonaut Yuri Gagarin becomes the first human being to orbit Earth. Alan Shepard, Jr., becomes the first US astronaut in space.

1962. John Glenn, Jr. is the first American to orbit Earth. US *Mariner 2* becomes the first spacecraft to voyage to another planet — Venus.

1965. US *Mariner IV* reaches the vicinity of Mars.

1966. Soviet *Luna 9* becomes the first spacecraft to soft land on the Moon.

1969. On July 20, US astronaut Neil Armstrong becomes the first human to stand on the Moon.

1970. Soviet *Venera 7* becomes the first spacecraft to soft land on a planet — Venus.

1976. US *Viking 1* & *2* land on Mars. Space probes *Voyager 1* & *2* are launched on journey to outer planets.

1981. First space shuttle, *Columbia*, launched.

1987. Astronomers discover first planet orbiting a star.

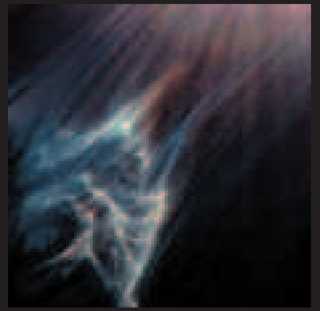
1990. *Hubble Space Telescope* (HST) placed in orbit around Earth.

1994. Comet Shoemaker-Levy 9 slams into Jupiter.

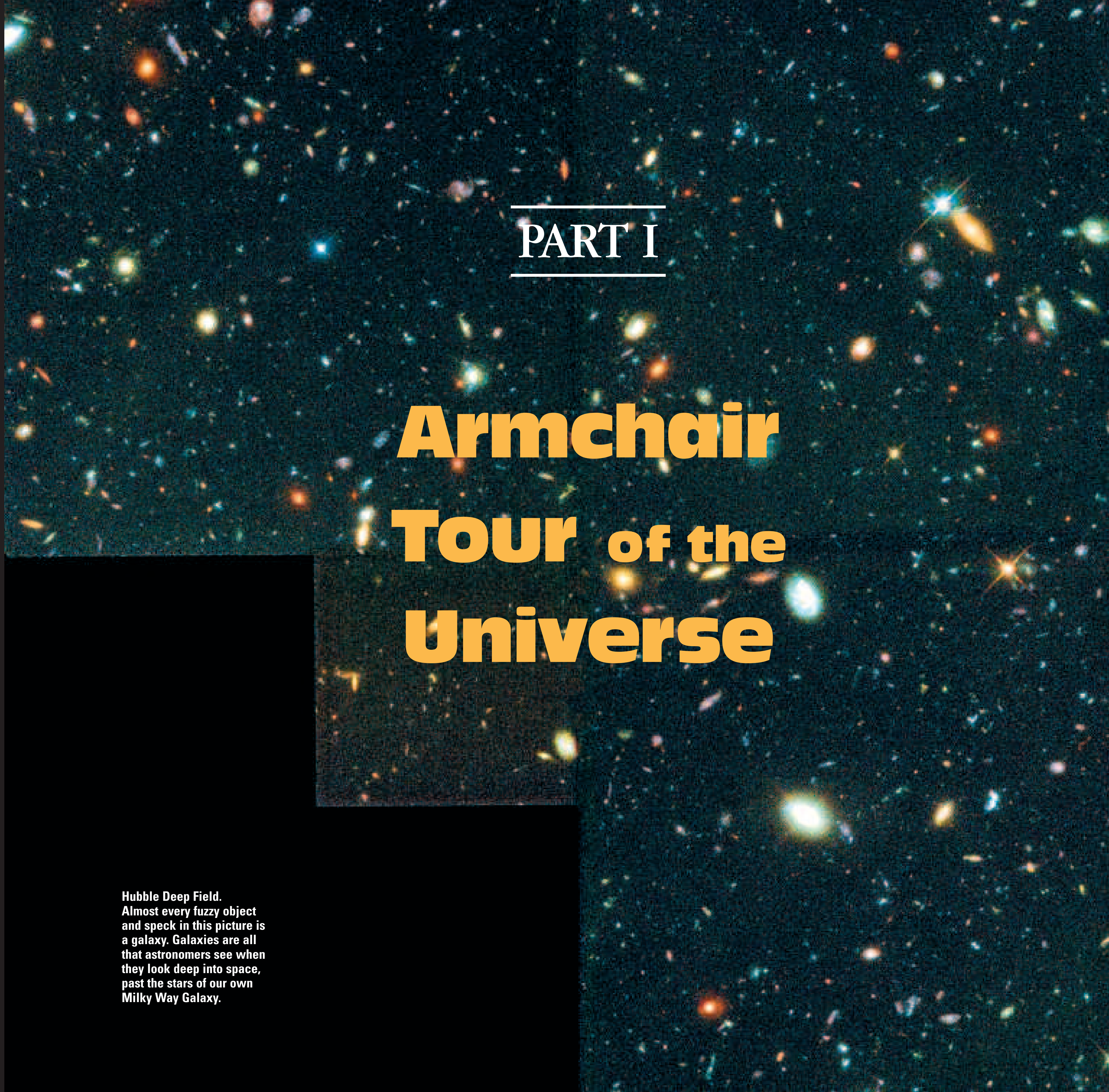
1997. *Pathfinder* becomes the first roving vehicle on another planet — Mars.

1998. *Lunar Prospector* detects frozen water at poles on Moon.

1998/99. Construction on the *International Space Station* begins.



Picture Captions:
First column. Double star cluster in the Large Magellanic Cloud.
Second column. Birthing area of a young, massive, ultra-bright star.
Fourth column. Heart of the Whirlpool Galaxy (designated M51).
Fifth column. Gas in the Pleiades or Seven Sisters star cluster.



PART I

Armchair Tour of the Universe

Hubble Deep Field. Almost every fuzzy object and speck in this picture is a galaxy. Galaxies are all that astronomers see when they look deep into space, past the stars of our own Milky Way Galaxy.

Our Solar System

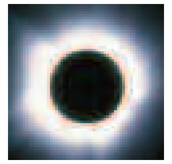
I begin this armchair tour with our own solar system because of its familiarity. It is our cosmic backyard and serves as a good stepping-stone to the stars. Like everything in the Universe, our solar system had a beginning. For us, it started 4.5 billion years ago, when the Sun and planets condensed out of a giant hydrogen cloud. We're middle-aged now and have matured a bit since those earlier years.

A solar system is a star that has planets, asteroids and comets revolving around it. Stars are at the center of every solar system because they are so large and massive that their gravity keeps all the other objects bound to them.

Solar systems form inside huge hydrogen clouds called nebulae. They start as protoplanetary disks, which are concentrations of hydrogen gas and other elements that eventually come together to form the gases, rocks, metals and various ices which make up the planets and stars. These disks take a million or so years to produce newborn solar systems.

Our Earth is part of a solar system that has nine planets and billions of asteroids and comets. We call the star that we orbit the "Sun" or "Sol." The diameter of our solar system out to Pluto is over seven billion miles. If you got in a car and drove this distance at 75 miles per hour, it would take you 11,000 years. Light, which travels at 186,282 miles per second, could go this far in 11 hours!

Astronomers have and are discovering planets around other stars, but they do not yet have the instrumentation to detect planets as small as Earth.



Sun

Our Sun is a star just like the other stars in the night sky; however, it is special to us because it is the star that our planet, Earth, orbits. And because of its majestic brilliance, metaphorically it is the center of our Universe.

Solar systems form within giant hydrogen clouds called nebulae, like the Eagle Nebula pictured here. This nebula is so large that many solar systems are forming inside. See page 28 for more about this cloud.

Our Sun is a star just like all the others in the night sky. It only appears bigger and brighter because we are orbiting close to it.

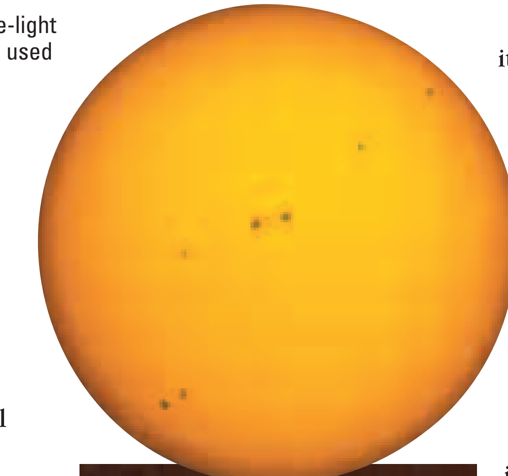
A star is a huge ball of mostly hydrogen gas that creates energy by a special process called nuclear fusion. Since stars are very massive, they produce tremendous pressure and heat at their centers, which forces hydrogen atoms together to become helium atoms. During this "fusing" process, a very small amount of excess matter gets converted into an enormous amount of energy. This is the same energy that is produced from nuclear hydrogen bombs. We see some of this energy as the light of stars or the brilliance of our Sun.

Although our Sun is huge, approaching a million miles in diameter, it is only an average-sized star. Its mass, that is, the amount of matter it contains is equivalent to 330,000 Earths. Its surface temperature averages 10,000°F, but its core temperature is estimated to reach 27 million degrees.

Our Sun is composed of 92.1% hydrogen, 7.8% helium, 0.061% oxygen and even smaller amounts of other elements. It is yellowish in color because of its surface temperature. Cooler stars look reddish, and hotter ones look blue or white.

A star like our Sun will shine for 10 to 12 billion years. At the end of its life it will puff up and become a red giant, then shrink down to a white dwarf, a star about the size of Earth.

When you glance at the Sun, the bright part that you see is the photosphere. Photo means light, so you are seeing the part of the Sun that gives off visible light. If you attach a solar filter to a telescope, you can often see sunspots. These dark spots are cooler than their surroundings and indicate areas of intense magnetic fields. Because the Sun rotates, sunspots "move" across its surface, forming, growing and finally dissolving away. Many are larger than Earth.



Top. The appearance of our Sun through a regular white-light solar filter, which is the most common type of solar filter used by amateurs. Numerous sunspots are frequently visible during the height of 11-year cycles.

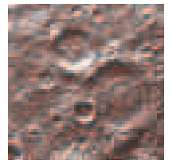
Middle. It takes a special hydrogen-alpha filter to see prominences that jet off from the Sun's surface. The chromosphere outlines this surface.

Immediately above the photosphere is a thin red layer of gas, about 1,000 miles thick, called the chromosphere. This layer separates the lower photosphere from the outer corona. The corona is a magnificent veil of hydrogen gas that reaches temperatures of millions of degrees and extends millions of miles from the surface. The corona is visible as an irregular halo surrounding the Sun during a total solar eclipse.

Our Sun becomes active about every 11 years. During these times, the number of sunspots, prominences and flares increases. Over 100 sunspots per day can often be counted. Huge prominences jet off from the surface and some loop back. And flares also shoot out charged particles into the solar system creating the wonderful displays of the northern Aurora Borealis and the southern Aurora Australis.

The Terrestrial Planets

The first four planets, in their order from the Sun, are Mercury, Venus, Earth and Mars. These planets are known as the "terrestrial planets" because they are similar to Earth in size and composition. Composed of hard, rock-type materials, these planets have solid surfaces that you can stand and walk on. All four terrestrial planets orbit inside the asteroid belt; the remaining planets orbit outside.



Mercury

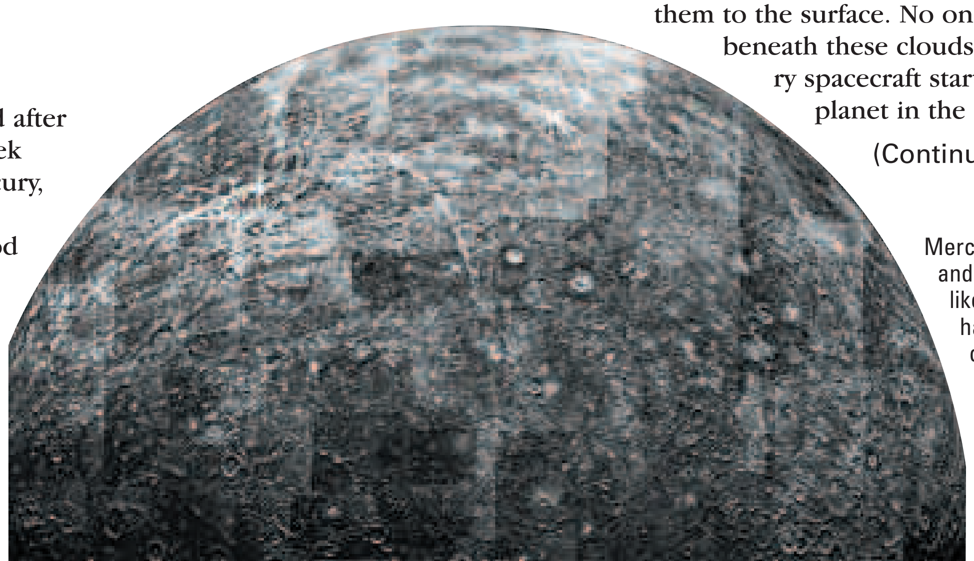
The planets were named after ancient Roman and Greek mythological gods. Mercury, the closest planet to the Sun, was identified with the Roman god who had wings attached to his feet and a helmet on his head. He swiftly delivered messages to the other gods. As the name so well implies, the planet Mercury revolves rapidly around the Sun, more swiftly than any of the others.

Mercury resembles our Moon. Like our Moon, it is small in size, pitted with craters, and has no atmosphere. Its craters were formed from a heavy bombardment of asteroids and comets during the first billion years of the solar system's existence. The interior of Mercury, once molten, has cooled and is now solid. It is composed mostly of iron ore.

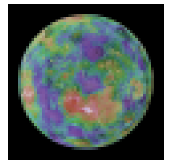
Mercury is difficult to study with a telescope because it is so close to the Sun. All of the close-up pictures of it were obtained by the one spacecraft, *Mariner 10,* that visited it in 1975.

Since Mercury orbits inside Earth's orbit, it cycles through phases like our Moon. When we see phases, we are seeing nothing more than the day and night sides of the planet at the same time.

Mercury in the sky. Mercury is visible as a fairly bright star several times a year; however, most people never see it, because it can only be seen for a short time after sunset or before sunrise.



Mercury has no atmosphere and is pitted with craters just like our Moon. *Mariner 10* has been the only spacecraft to visit this planet (in 1975). Less than half of its surface was photographed.



Venus

Venus was named after the Roman goddess of love. It is the planet closest and most similar in size to Earth. Like Earth, Venus is a terrestrial planet that is composed of rock-type material, so it has a surface that you can stand and walk on.

If you are at least middle-aged, you may remember Venus referred to as Earth's sister planet. This connotation ended once we learned more about conditions on the planet's surface.

Venus' atmosphere consists mostly of the colorless gas carbon dioxide. However, within this colorless atmosphere are opaque white clouds so thick that it is impossible to see through them to the surface. No one knew what lay beneath these clouds until exploratory spacecraft started visiting the planet in the late 1970s.

(Continued on page 12)

Our Solar System at a Glance

Our solar system consists of the Sun and orbiting planets, asteroids and comets. Our Sun is a star just like all the other stars in the night sky. It appears brighter and larger because we orbit close to it. In 1987, astronomers discovered the first planets orbiting other stars, and many more since. One estimate is that half of the stars may have solar systems. At this time, astronomers do not have the instrumentation to detect planets as small as Earth.

How did our solar system form? Inside a huge gas cloud called a nebula, like the one pictured on page 8 — the Sun and planets condensed out of a dense disk of hydrogen gas and other elements.

How old is our solar system? The Sun, Earth and all the other planets formed about 4.5 billion years ago.

How big is our solar system? Its diameter out to Pluto's orbit is over 7 billion miles or 11 light hours. The outer reaches of our solar system, where the most distant comets reside, stretch halfway to our nearest solar neighbor, the star Proxima Centauri, which is 4.2 light years away.

What type of star is our Sun? Our Sun is a very average star, in size, temperature and its color.

How long will our Sun last? A star like our Sun will shine for 10 to 12 billion years. Near the end of its life, it will shed its outer atmosphere in one final heave. Outwardly, this will produce a planetary nebula like those pictured on page 34. The remaining core will shrink to become a white dwarf, a star about the size of Earth.

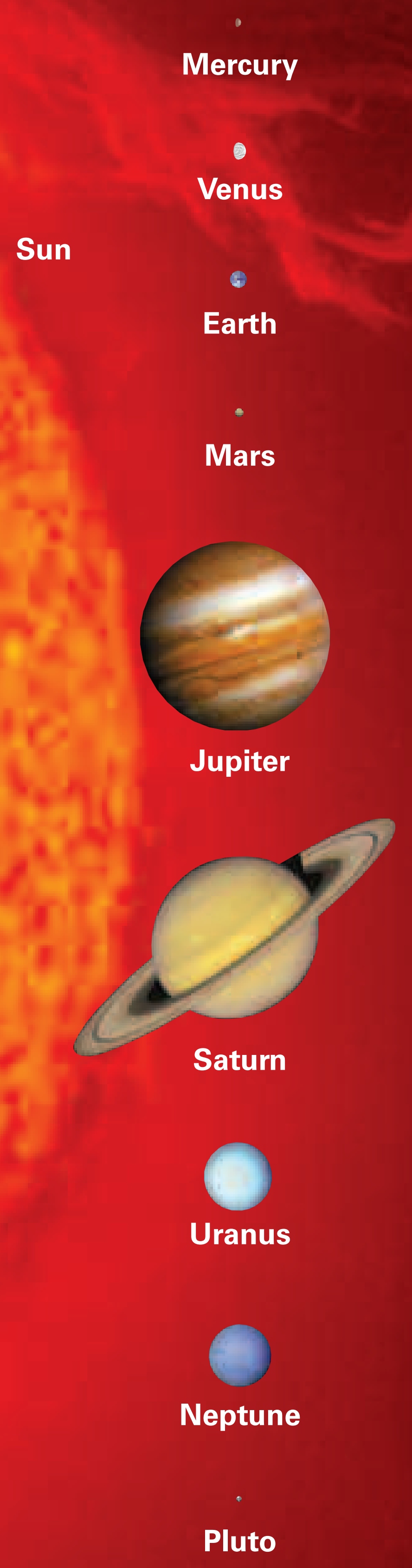
What are the major differences between the planets? Mercury, Venus, Earth and Mars are known as the Terrestrial Planets because they are Earth-like and have surfaces that you can stand on. Jupiter, Saturn, Uranus and Neptune are known as the Gas Giants, because they are large and composed mostly of hydrogen gas. They do not have surfaces that you can stand on. Pluto is a third type of planet that is composed of ices and rocks.

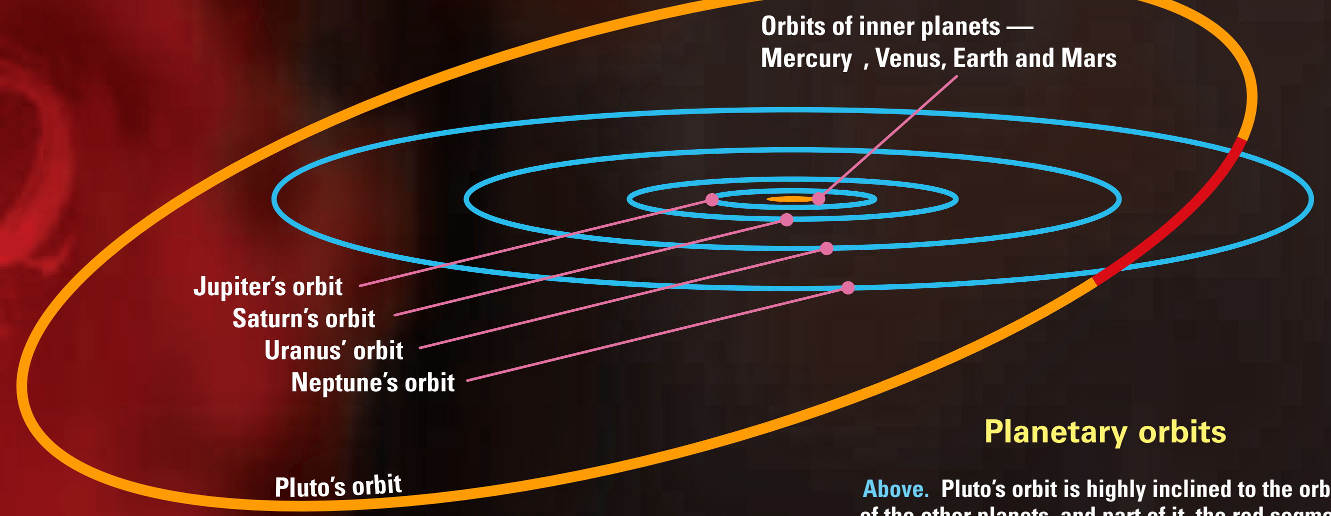
Where and what is the asteroid belt? It lies between Mars and Jupiter and consists of about a billion giant rocks, some rich in metal ores. These represent leftover material from the formation of the solar system.

Where are all the comets? There are three belts of comets. The innermost has orbits inside Jupiter's. The next group has orbits that extend past Pluto, while the majority reside in a giant cloud surrounding the solar system.

Solar System Basics

	Diameter in Miles	Rotation on Axis	# of Moons	Distance from Sun: Miles	Distance from Sun: Light Time	Revolution about Sun	Mass Earth = 1	Gravity Earth = 1	Atmosphere
SUN	865,000	30 days	–	–	–	–	333,000	28	92% hydrogen, 7.8% helium
MERCURY	3,032	59 days	0	36 million	3.2 minutes	88 days	0.06	0.38	None. High 800°F, low –300°F
VENUS	7,521	243 days	0	67 million	6 minutes	225 days	0.82	0.90	96% carbon dioxide, high 900°F
EARTH	7,926	24 hours	1	93 million	8.3 minutes	365 days	1	1	77% nitrogen, 21% oxygen
MARS	4,222	24.6 hours	2	142 million	13 minutes	687 days	0.12	0.38	95% carbon dioxide, 2.7% nitrogen
JUPITER	88,844	9.8 hours	52	484 million	43 minutes	11.8 years	318	2.53	90% hydrogen, 9% helium
SATURN	74,900	10.2 hours	30	887 million	80 minutes	29 years	95	1.11	97% hydrogen, 3% helium
URANUS	31,764	17.9 hours	21	1.8 billion	2.7 hours	84 years	15	0.90	83% hydrogen, 15% helium
NEPTUNE	30,777	19.2 hours	11	2.8 billion	4.2 hours	164 years	17	1.14	74% hydrogen, 25% helium
PLUTO	1,429	6.4 days	1	3.7 billion	5.5 hours	248 years	0.0025	0.08	100% methane, low –419°F

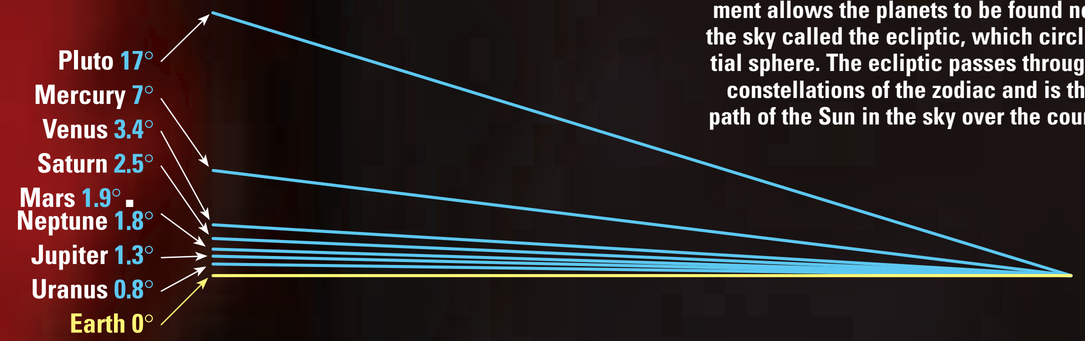




Planetary orbits

Above. Pluto's orbit is highly inclined to the orbits of the other planets, and part of it, the red segment, lies inside Neptune's orbit for a period of 20 years.

Below. Except for Pluto and Mercury, the planets orbit in almost the same plane as Earth. This alignment allows the planets to be found near a path in the sky called the ecliptic, which circles the celestial sphere. The ecliptic passes through the twelve constellations of the zodiac and is the apparent path of the Sun in the sky over the course of a year.



Leftover solar system material

Asteroid Belt

The Asteroid Belt lies between Mars and Jupiter and represents leftover material from the formation of the solar system. Ceres, the largest asteroid, is 568 miles in diameter and is the only asteroid that is roughly spherical in shape. Kleopatra, pictured above, looks like a dog bone.

Comets

Comet Hale-Bopp was one of the largest comets of the twentieth century. Comets are composed of ices and sand particles. Their long orbits occasionally bring them close to the Sun.

The white clouds in Venus' atmosphere are made of sulfuric acid. Venus has numerous volcanos that continually release sulfur dioxide which combines with a small amount of water vapor to form the widespread sulfuric acid clouds.

Venus is also hot! What happens inside a car that is out in the Sun with its windows rolled up? The interior temperature rises because the windows trap the sunlight's heat. The same thing happens to Venus. Its atmosphere of carbon dioxide acts like the windows of a car, trapping the heat energy of sunlight. This type of heating is called the greenhouse effect. On Venus, the greenhouse effects pushed the temperature near the surface to 900°F, the hottest of any planet and hot enough to melt the metal lead.

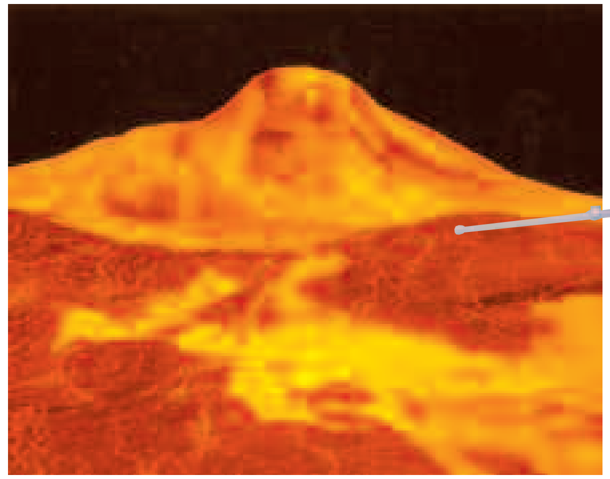
Overall, Venus' atmosphere contains about 100 times more gas than Earth's. This "heavy" atmosphere creates tremendous pressure at Venus' surface — more than 90 times greater than ours, and equal to the pressure found at an ocean depth of 3,000 feet.

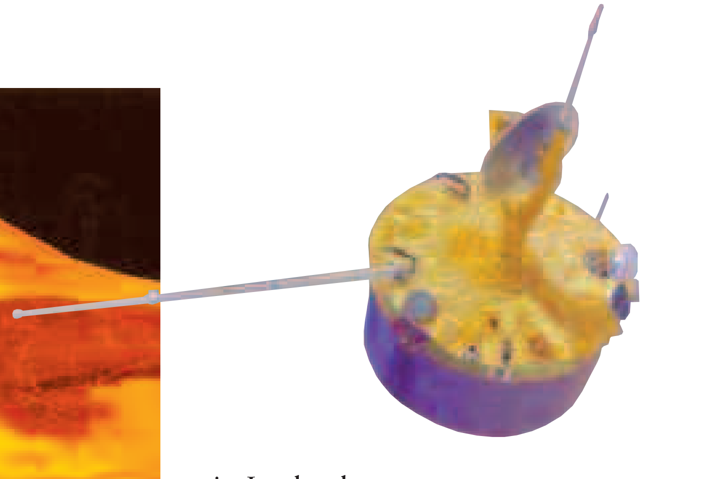
Venus' barren surface is riddled with rocks and volcanos. Scientists believe that its surface may circulate with its upper level interior and thus renew itself every 100 million years or so.

Surprisingly, the former USSR landed the *Venera 13* and *14* probes on Venus in 1982. These landers were able to transmit pictures of the surface and other data for one to two hours before succumbing to the hostile environment.

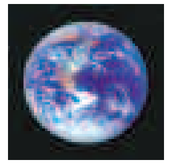
Venus rotates nearly upside down compared to the other planets. As a result, if you viewed Venus from the top of the solar system (from the direction of Earth's north pole), it would appear to rotate backward. Also, Venus rotates very slowly on its axis. It takes longer to rotate once on its axis than to revolve around the Sun.

Venus in the sky. Often, Venus is the brightest "star" in the sky. Its white clouds make it highly reflective and its closeness to Earth makes it even brighter. Because Venus orbits inside Earth's orbit, it displays phases.



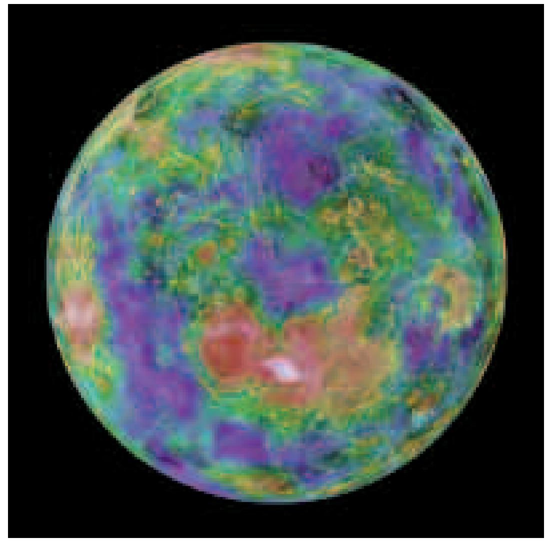


Above. A colorized image (produced from radar) of the surface of Venus. It is riddled with active volcanos. **Right.** The *Pioneer Venus Orbiter* circled Venus from 1978 to 1992 and gathered general information about the planet. In 1992, it ran out of positioning fuel and burned up in Venus' atmosphere.



Earth

The Earth is our home, and as far as we know, the only planet with life. No one understands exactly how life developed on Earth, but scientists feel certain that two major factors are necessary for life to start and then to flourish. First, a planet must have liquid water. Our Earth's surface is 71% water. Second, the temperature must stay in a narrow range. If the Earth were just a little closer or a little farther away from the Sun than it is now, it would be either too hot or cold for life to *flourish*. There are many other factors necessary for life to flourish, but if these two conditions were not met, humans, animals and plants would not exist in the abundance that they do now.



A false-color mapping of Venus produced from radar imagery by the spacecraft *Magellan* in the early 1990s. Blue indicates low altitude areas and red the higher terrain. Areas of the same color are at the same altitude. Venus' surface can only be mapped with radar because its opaque-white, sulfuric acid clouds are too thick to see through.

The original seven American Mercury astronauts. **Top, from left**: Alan Shepard (first American in space), Virgil "Gus" Grissom and L. Gordon Cooper. **Bottom, from left** are Walter Schirra, Donald "Deke" Slayton, John Glenn (first American to orbit the Earth) and Scott Carpenter. The Mercury program was America's first attempt to send a man into space. The Gemini program followed, with the goal of gaining experience in manned orbits and reentry. This led to the Apollo program that landed 12 men on the Moon from July 1969 to December 1972.

Moon

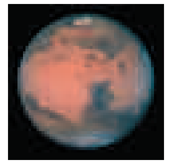
The Moon is visible at night as well as during the day. It forever cycles through phases, from crescent to full and back. The phases occur as the Moon circles the Earth and are nothing more than our seeing its day and night sides at the same time.

On July 20, 1969, Neil Armstrong became the first person to walk on the Moon. The last astronauts to visit were Eugene Cernan and Harrison Schmitt, in December 1972. Schmitt, a geologist, was the first scientist in space and the only scientist to walk on the Moon.

The Moon is full of craters. They vary in size from just inches to over 100 miles in diameter. Most of these bowl-shaped depressions were formed over four billion years ago when meteoroids, asteroids and comets bombarded its surface. In contrast to the cratered areas, there are darker, smoother areas called maria or plains. These plains were formed when very large asteroids or comets struck deep into the Moon, releasing interior lava that flowed to the surface. Scientists believe that the interior of the Moon has now completely cooled and is no longer molten.

The Moon was most likely formed when an object as large as Mars slammed into the Earth over four billion years ago. This impact produced a ring of rocky material that orbited the Earth and eventually coalesced to become the Moon. How do we know this? The astronauts who went to the Moon brought back rocks that contain the same materials as those found in the Earth's crust.

Observing the Moon. If you can observe the area around the terminator, which is the "line" that separates the lighted side from the dark side, with high power (200x to 400x magnification), you will feel as though you were flying over its surface.



Mars

Mars is named after the Roman god of war because of its "red" color. However, when we think of Mars, we often think of Martians. This idea started in the late 1800s when Giovanni Schiaparelli of Italy and Percival Lowell of America made drawings of what they thought to be channels or canals. Lowell believed that the channels were canals built by Martians to transport water from the poles to the lower latitudes. Mars does not have canals or Martians, but these ideas ignited imaginations throughout the world that have lasted to this day.

Mars shares many similarities with Earth. These include mountains, volcanos (extinct on Mars), hills, plains, grand canyons, sand dunes, craters, polar caps, weather and clouds. As you can see from the pictures on the next page, the surface of Mars resembles a rocky desert.

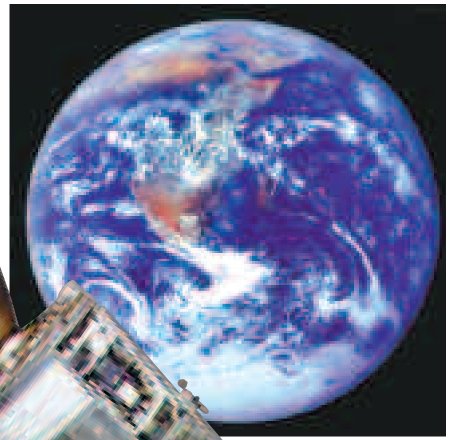
Since Mars' diameter is a half of Earth's, its total surface area is about the same as the total land area on our planet. The difference in altitude between the highest and lowest points on Mars is 19 miles. Valles Marineris (Val-Les Mar-A-Nair-Us), its deepest canyon, is four times deeper than the Grand Canyon and stretches over 2,500 miles. Olympus Mons is not only the largest inactive volcano in the solar system, but also Mars' highest point. Its cauldron alone is 55 miles across and the area of its lava flow is the size of the state of Arizona. Mars is riddled with craters, but the largest one is Hellas, a whitish oval in the southern hemisphere with a diameter of 1,200 miles. Hellas boasts the lowest point on Mars.

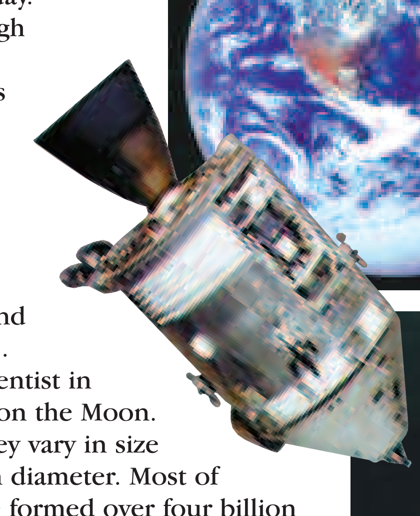
The surface rocks are reddish due to a form of oxidation or rust. There are large areas of coloration caused by regional differences in the hues of the rocks and sand. The boundaries of these regions shift because of wind storms.

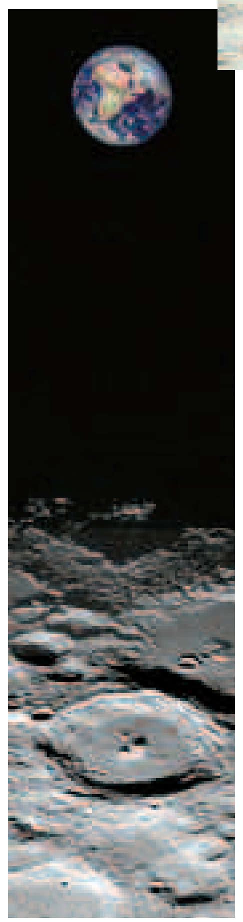
Overall, Mars appears to be geologically stable and volcanically inactive. Early in its history, it most likely had active volcanos and a thicker, warmer atmosphere supporting liquid surface water that flowed, and carved some of its terrain. Today's surface appears to have changed little in the past few billion years.

Mars' north polar cap is mostly made of frozen water; its southern cap is made of frozen carbon dioxide, commonly known as "dry ice."

Other than Earth, Mars is the most hospitable planet in our solar system. However, we could only live there in a protected environment. Its atmosphere is thin, unbreathable and cold.







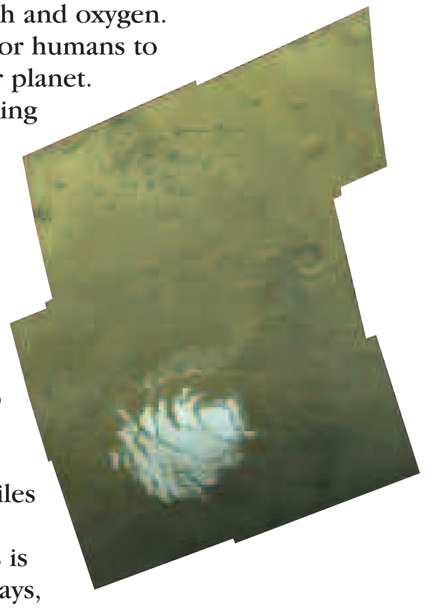
Top. A picture of Earth taken by the Apollo 17 crew on their way to the Moon in 1972. This was the last manned mission to the Moon. **Below Earth.** The Command and Service Modules circled the Moon with one astronaut aboard while the other two landed in the Lunar Module which Edwin "Buz" Aldrin is climbing down in the **above** picture. Buz became the second person to walk on the Moon. **Left.** A closeup of the crater Tycho, near the terminator and with the Earth hovering above. Tycho is a prominent crater that has magnificent emanating rays. This photograph was taken by the orbiting spacecraft *Clementine* in 1994.

The atmospheric pressure at Mars' surface is 1/100 that of Earth's and would be the same as what we experienced 20 miles above our surface. High performance jets can fly to a height of just over 20 miles. Commercial jetliners top out at 7 miles where the air pressure is 1/6 of sea level pressure. Oxygen is usually required to get to the top of Mount Everest, which is 5.5 miles high with half the air pressure of sea level. Even though Mars' atmosphere is thin, evidence of dust devils have been observed and the winds can "kick up" to produce huge, planet-wide dust storms.

Mars' atmosphere is 95% carbon dioxide, 2.7% nitrogen, 1.6% argon and less than 1% oxygen. Compare this to Earth's 77% nitrogen, 21% oxygen and less than 1/10 of 1% carbon dioxide. Although Mars' atmosphere is not poisonous, you could not breathe it to stay alive.

The average temperature is cold, around –81°F, but varies from –274°F to 72°F. The 72°F would last for just brief periods, close to the surface, around noon. Frost forms on surface rocks but evaporates as the day warms.

Because of Mars' low atmospheric pressure, any liquid water on its surface would boil away into vapor. Likewise, if we stood on the surface without a space suit, the low atmospheric pressure coupled with the heat from our bodies would cause our blood to slowly boil. To walk around on Mars, you would need a light space suit providing adequate air pressure, warmth and oxygen.

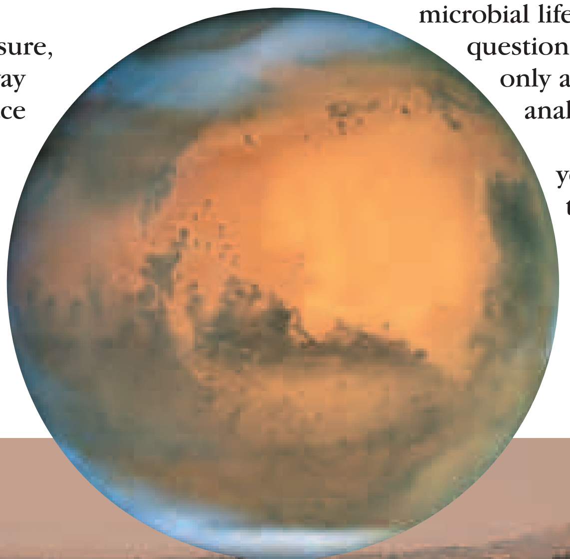


Water is absolutely necessary for humans to survive an extended stay on another planet. Its usefulness extends beyond drinking and watering plants, because it can also be used to make oxygen for breathing as well as hydrogen for fuel. Mars has frozen water at its north pole and underground, which will make it easier for people to stay and live there.

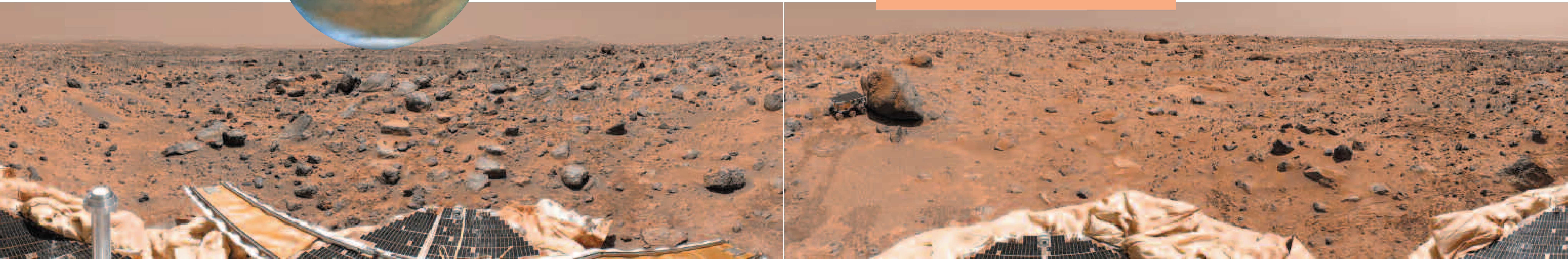
The two moons of Mars, Phobos and Deimos, are believed to be captured asteroids because their irregular shapes and composition resemble these. Phobos is 17x13 miles in size and orbits Mars in 7.7 hours, at a distance of 5,800 miles. Deimos is 10x8 miles in size, orbiting in 1.3 days, at a distance of 14,600 miles.

Is there life on Mars? Many suspect that there may be microbial life in its soil; however, the answer to this question is years away and will most likely come only after extensive soil samples are taken and analyzed.

Mars in the sky. About every two years, the orbits of Mars and Earth bring them close to one another, allowing the surface colorations of Mars to be observed even with small telescopes. During this same time, Mars is at its brightest and even outshines Jupiter.



Top. Olympus Mons' area of lava flow covers an area equal to the state of Arizona. The center cauldron spans 55 miles. **Upper right**. Mars' south pole boasts a permanent cap of frozen carbon dioxide or dry ice. **Right**. A *Hubble Space Telescope* picture of Mars showing the surface coloration and clouds around the poles. **Below**. A 360° vista taken by the *Mars Pathfinder* in 1997. Mars is a rocky desert. *Sojourner*, the first rover vehicle on another planet, is parked next to the rock.



Mars Recap

Physical characteristics

Diameter of 4,222 miles, which is about half of Earth's.
Total land or surface area is about the same as all the land area on Earth.
Rotates on its axis in 24 hours, 37 minutes (its day).
Revolves around the Sun in 1.9 years or 687 days (its year).
Tilt on axis is 25.2°, so it has "seasons."
Gravity is 1/3 of Earth's.

Weather & atmosphere

Atmosphere is 95% carbon dioxide, 2.7% nitrogen, 1.6% argon and 0.2% oxygen.
Atmospheric pressure is 1/100 of Earth's.
Temperature varies from –274° F to 72° F.
The **north pole** has a permanent cap of frozen water ice, while the **south pole** has a permanent cap of frozen carbon dioxide, otherwise known as "dry ice."
Other weather elements include clouds, surface frost, huge dust storms, and dust devils. There is no rain or lightening.

Geology

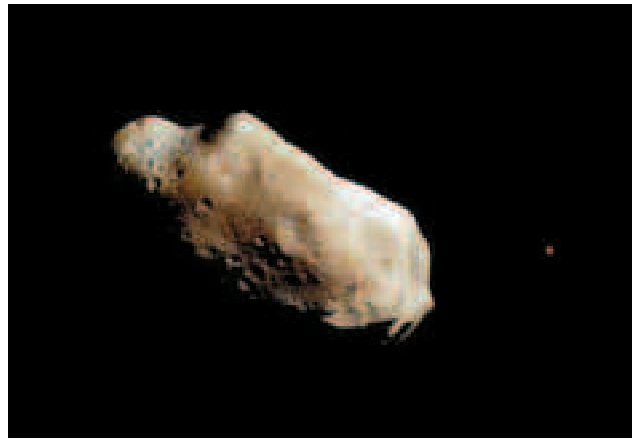
Mars has the **largest inactive volcano** in the solar system, named Olympus Mons, which is more than 15 miles high with a 55-mile-wide cauldron. It also has its own grand canyon called **Valles Marineris** which is 2,500 miles long. The terrain suggests that its surface was once carved by massive quantities of water. Overall, the planet appears **geologically stable** since it does not have active volcanos or moving tectonic plates like Earth. Also, there is **no magnetic field**, suggesting a core that has cooled.

The Asteroid Belt

The asteroid belt lies between Mars and Jupiter. It is composed of about a billion chunks of rock that vary in size from a dozen feet to more than 500 miles across. Their total mass is about 1/5 the mass of our Moon. Distances from the Sun vary from around 175 to 375 million miles, so orbits range from 3.5 to 6.5 years.

None of the asteroids have atmospheres. Most have odd shapes and resemble potatoes. They are pitted with craters, formed when the asteroids struck one another. Their colors range from reddish and light brown to dark gray. Asteroids vary in composition, from silicates, that is, sand, quartz and other rock-type materials, to metals such as nickel and iron. They represent remnants left over from the formation of the solar system and are not material from a planet that exploded.

Not every asteroid lies in the asteroid belt. Today, public interest in asteroids focuses on those that could possibly collide with Earth. There may be up to 700 "Apollo-Amor" asteroids that present collision hazards. This category has lengths of over 1/2 a mile and crosses the orbits of either Mars or Earth. Astronomers are hoping to find all of these by 2010. It is estimated that one large "Apollo-Amor" asteroid strikes the Earth every 250,000 years, but none are expected to do so in the foreseeable future. The orbits of these asteroids change because of the gravitational influence of Jupiter.



The asteroid Ida, as imaged by *Galileo*, a spacecraft passing by on its way to Jupiter. Ida is 32 miles in length and has a small moon about a mile in diameter named Dactyl (visible as the spot to the right).

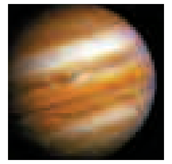
The Gas Giants

Outside the asteroid belt lie four large planets — Jupiter, Saturn, Uranus and Neptune. These planets are similar to each other, but fundamentally different from the four inner, terrestrial planets. They are referred to as the "gas giants" because they are composed mostly of hydrogen gas and because they are much larger than Earth.

Even though Neptune is the smallest of the gas giants, its volume is equal to 58 Earths. For Jupiter, that number jumps to more than 1,300.

The gas giants do not have surfaces that you can stand on, only cloud-type atmospheres that extend inward for thousands of miles. Beneath these clouds lie highly compressed mixtures of elements and chemicals. Because Jupiter and Saturn are so large, their internal pressure creates liquid metallic hydrogen which takes on the properties of metal, including the ability to conduct electricity. Uranus and Neptune are less massive, so their interiors are limited to a compressed mixture of water, methane and ammonia. All four giants probably have "small" rocky cores.

Other shared atmospheric traits include aurorae at their poles and lightning. All four planets have rings, but none as magnificent as Saturn's. Temperatures at their cloudtops are cold, ranging from a toasty –243°F for Jupiter to a mild –373°F for Neptune.



Jupiter

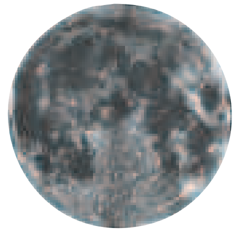
Jupiter is named after the supreme Roman god, ruler over all the other mythological gods. Jupiter is also the largest planet in our solar system, but was given its name by the ancients because it is consistently the brightest planet in the night sky. It is just a coincidence that the planet Jupiter turned out to be the largest planet in our solar system, because it was named thousands of years before anyone knew its size and what it really was.

The atmosphere of this planet has countless bands of clouds. They are very complex and display a tremendous amount of swirling and variation. There are two very distinct and easily observed bands, one in the northern hemisphere, called the North Equatorial Belt, and the other in the southern hemisphere, called the South Equatorial Belt. The most unique feature on Jupiter is its Great Red Spot. This giant, oval vortex is similar to a hurricane and extends into the South Equatorial Belt. It has been observed for over 150 years. No one knows if it is a permanent feature, but it does display some variation in size and color.

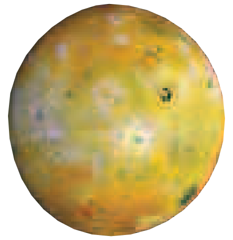
Jupiter has four large moons, called the Galilean moons, in honor of Galileo Galilei, who was one of the first scientists to observe them in 1610. These four moons are similar in size to our Moon. Io, the closest of the four to Jupiter has very active volcanos. Next out is Europa, which may have a vast ocean under its surface of ice. Ganymede, the largest of the four, is also the largest moon in the solar system, even larger than Mercury and Pluto. Finally, there is Callisto, which has craters with multi-rings around them.

Contrary to popular belief, Jupiter is not large enough to have almost become a small star. It would take the mass of 80 Jupiters to start nuclear fusion. There is not even enough mass in all the planets, asteroids and comets in our solar system to make a small star. Jupiter also has a a very faint ring system and a strong magnetic field which is induced by interior circulations.

Above center. The Great Red Spot on Jupiter is larger than Earth, spanning 14,000 miles across. With wind speeds reaching 270 miles per hour, it takes about 7 days to circulate. **Below**. The comparative sizes of our Moon and the Galilean moons. The four Galilean moons are *easily* seen next to Jupiter in a small telescope. They continually create striking geometric patterns. Although Jupiter has dozens of moons, only these four can be viewed easily because the fifth brightest moon, Amalthea, is as faint as Pluto.

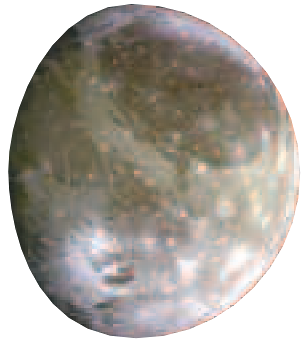


Our Moon
Diameter: 2,160 miles
Orbit Distance: 239,000 miles
Revolution Period: 27 days

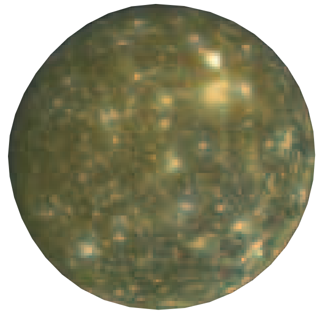


Io
Diameter: 2,255 miles
Orbit Distance: 262,000 miles
Revolution Period: 1.8 days

Europa
Diameter: 1,950 miles
Orbit Distance: 417,000 miles
Revolution Period: 3.6 days



Ganymede
Diameter: 3,270 miles
Orbit Distance: 665,000 miles
Revolution Period: 7.2 days



Callisto
Diameter: 2,980 miles
Orbit Distance: 1,171,000 miles
Revolution Period: 16.7 days