EXPLORING THE SOLAR SYSTEM

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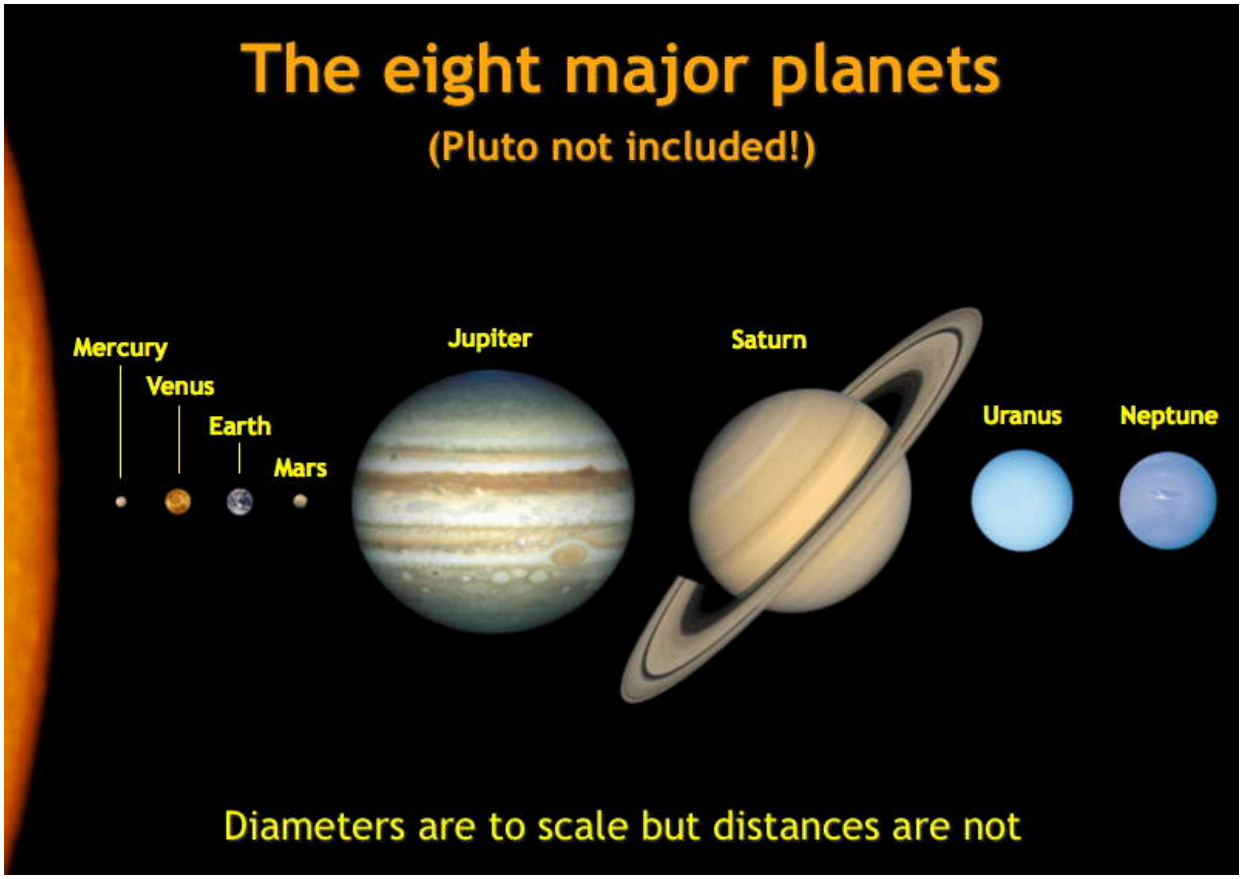
WE live on a planet called Earth, one of eight major planets orbiting a fairly average star called the Sun. The difference between a star and a planet is that a star is a hot body that gives out light of its own, whereas planets are cool and shine simply by reflecting sunlight. Together, the Sun and all the objects that orbit it make up the Solar System. The Solar System is the Sun's system.

The Earth is the third planet from the Sun. It has a smaller companion going around it, called the Moon. Most planets have at least one moon of their own, and the giant planets have dozens. Only Mercury and Venus, the two planets closest to the Sun, are moonless.

In addition to the eight major planets, there is a lot of debris in the Solar System. A band of rubble called the *asteroids* lies between the orbits of Mars and Jupiter, while beyond Neptune is a swarm of icy bodies called the *Kuiper Belt*. There lies Pluto, once regarded as the ninth planet of the Solar System. Pluto is so much smaller than the other eight planets that in 2006 astronomers reclassified it as a *dwarf planet*. Other dwarf planets also exist in this outer region of the Solar System beyond Neptune.



Many small, frozen bodies called *comets* move around the Sun on highly elongated paths. When they come close to the Sun they heat up and can grow long, flowing tails. Comets are the subject of a separate background article which you can download here.

Mercury, the innermost planet

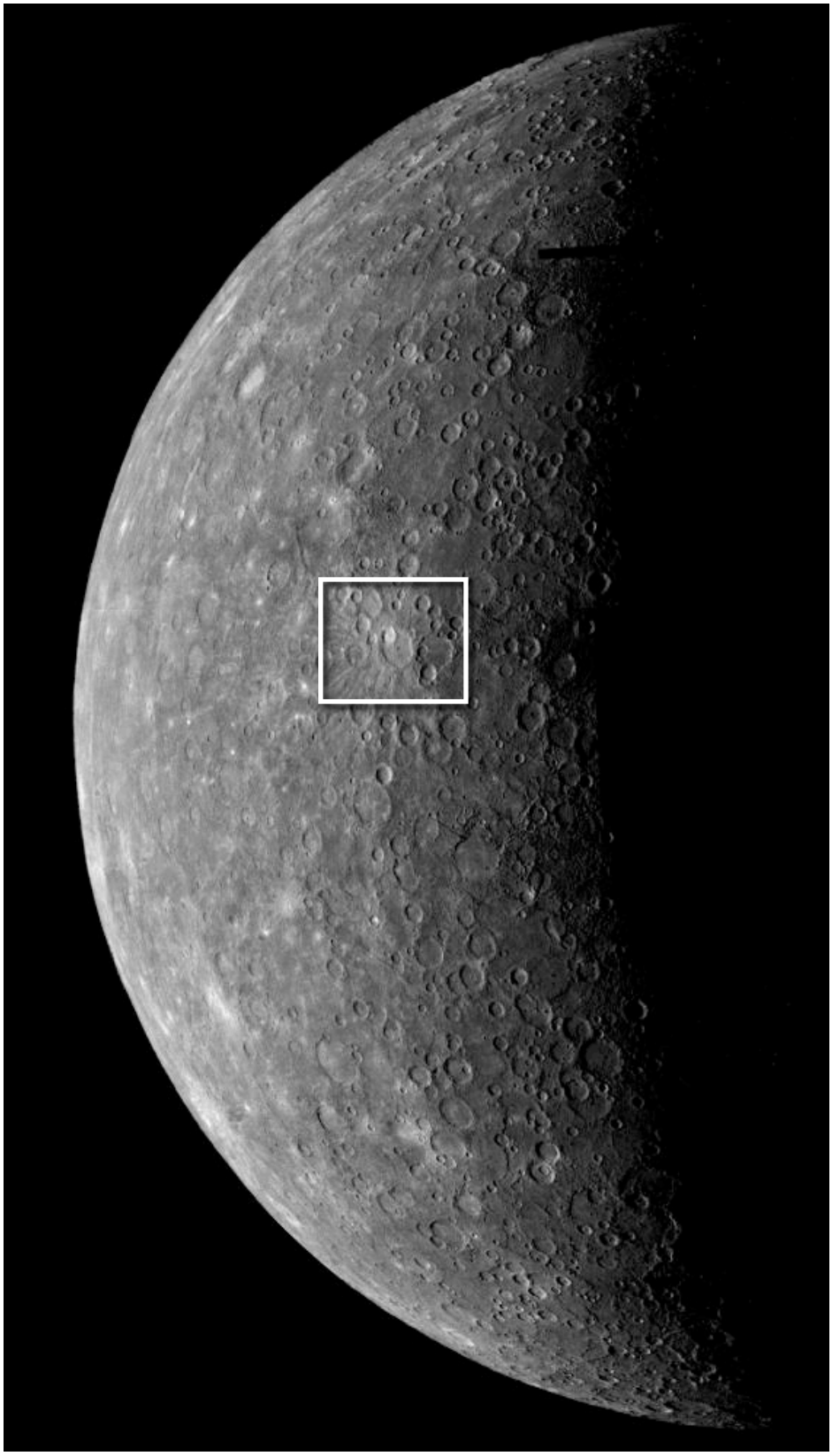
The planet closest to the Sun is Mercury. It's the smallest of the eight planets, not a lot bigger than our own Moon, and like the Moon it's a rocky body without air or water.

Mercury is pretty difficult to see from Earth because it keeps so close to the Sun. Even through a telescope you can't make out much detail, so we knew very little about it until a NASA probe called Mariner 10 got there in 1974. Mariner 10 showed that Mercury is covered in craters like those on the Moon (see photograph on next page). This was no real surprise given that Mercury hasn't got any atmosphere, so it is wide open to bombardment by debris floating around in the Solar System, just like the Moon.

After Mariner 10's visit Mercury was largely forgotten about until a US probe called Messenger zoomed past it in 2008 and 2009 before going into orbit around it in 2011. As well as mapping the entire planet in detail, Messenger spent several years studying the composition of its surface rocks.

Messenger will be followed by a joint European—Japanese probe called BepiColombo, which is due to be launched in 2017 and to go into orbit around Mercury in 2024.

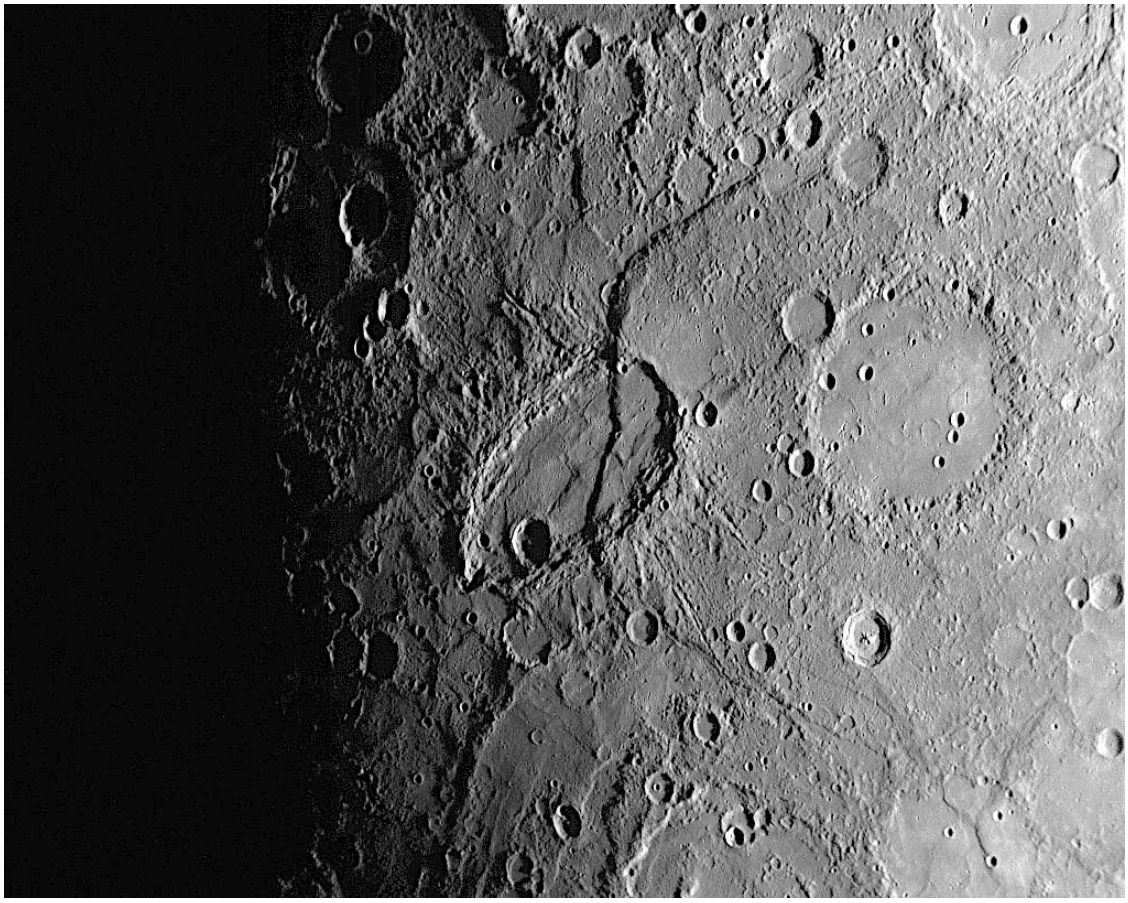
MERCURY DATA	
Diameter	4,880 km (38% that of Earth)
Distance from Sun	46–70 million km (30–47% that of Earth)
Time to orbit Sun	88 days (24% that of Earth)
Time to spin on axis	59 days (59 times longer than Earth)
Mass	0.06 that of Earth (17 times less)
Average density	5.4 times water
Tilt of axis	0°
Number of moons	None



Mercury photographed by NASA's Mariner 10 spacecraft in 1974, showing its heavily cratered surface. The bright crater with rays inside the white box is named Kuiper after a Dutch-American planetary scientist. It is 62 km in diameter and can be seen in close-up here.

Something on Mercury that you don't see on the Moon are long ridges called *rupes*, which means 'cliffs' in Latin. These are thought to have been caused as Mercury cooled and shrank, so the surface has wrinkled like the skin on an old piece of fruit.

The ridge in the photograph below cuts through a crater that is noticeably elongated. The crater got this shape because the meteorite that formed it came in at a shallow angle – very obliquely to the surface. The ridge, called Beagle rupes, is about half a mile high. The ground to the right of it has been pushed up and to the left, so clearly the ridge formed after the crater. From arrangements like this, geologists can begin to piece together the history of a planet's surface.



Beagle rupes, a cliff on Mercury over 600 km long, passes through a highly elongated crater called Sveinsdottir, 220 km long and 120 km wide. Beagle rupes is named after the ship that Charles Darwin sailed on. For the full-resolution original image see here.

Why did Mercury shrink so much to cause these wrinkles on its surface? The answer lies in the planet's core. Mercury has an unusually large core about three-quarters its diameter, which is proportionally much bigger than the core of the Earth. The core is made of iron, and it's the contraction of this iron core as it cooled over long periods of time that caused the planet to shrink as much as it did.

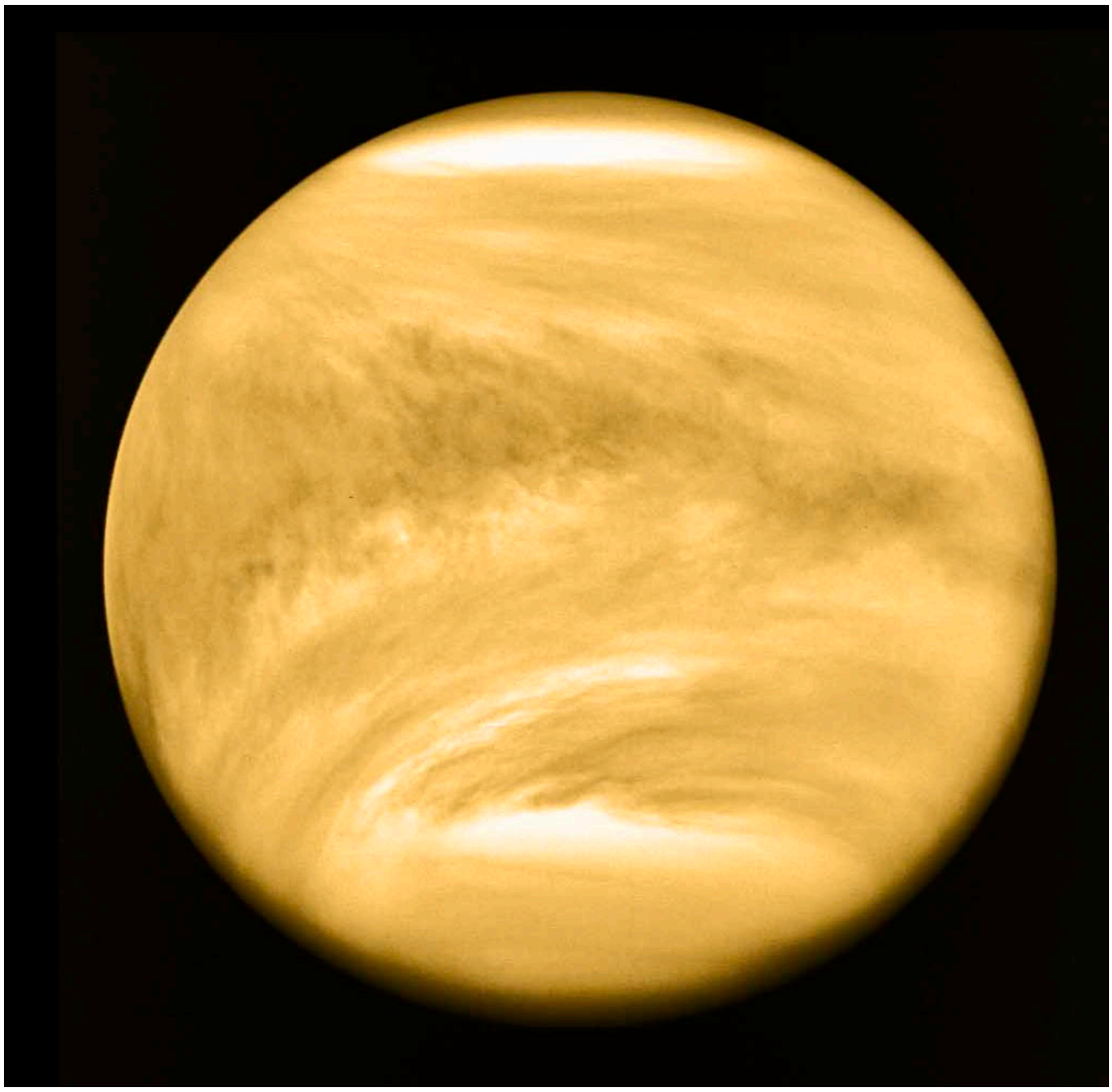
That leads to a second question: why should the core of Mercury be much larger than the cores of the other planets? One suggested explanation is that Mercury might originally have been bigger but it suffered a huge collision with another body early in its history which stripped away its outer layers. If so, this wouldn't be the only case of a large impact having a major effect on a planet in the Solar System.

Venus, the brightest planet

Second planet in line from the Sun is Venus, just a touch smaller than the Earth. It lies nearly three-quarters our distance from the Sun so it comes closer to us than any of the other planets.

Whereas Mercury is very difficult to see, Venus is impossible to miss – it's the brightest object in the sky after the Moon. It's what we popularly call the evening star or the morning star depending which side of the Sun it's on, although of course it's not really a star but a planet.

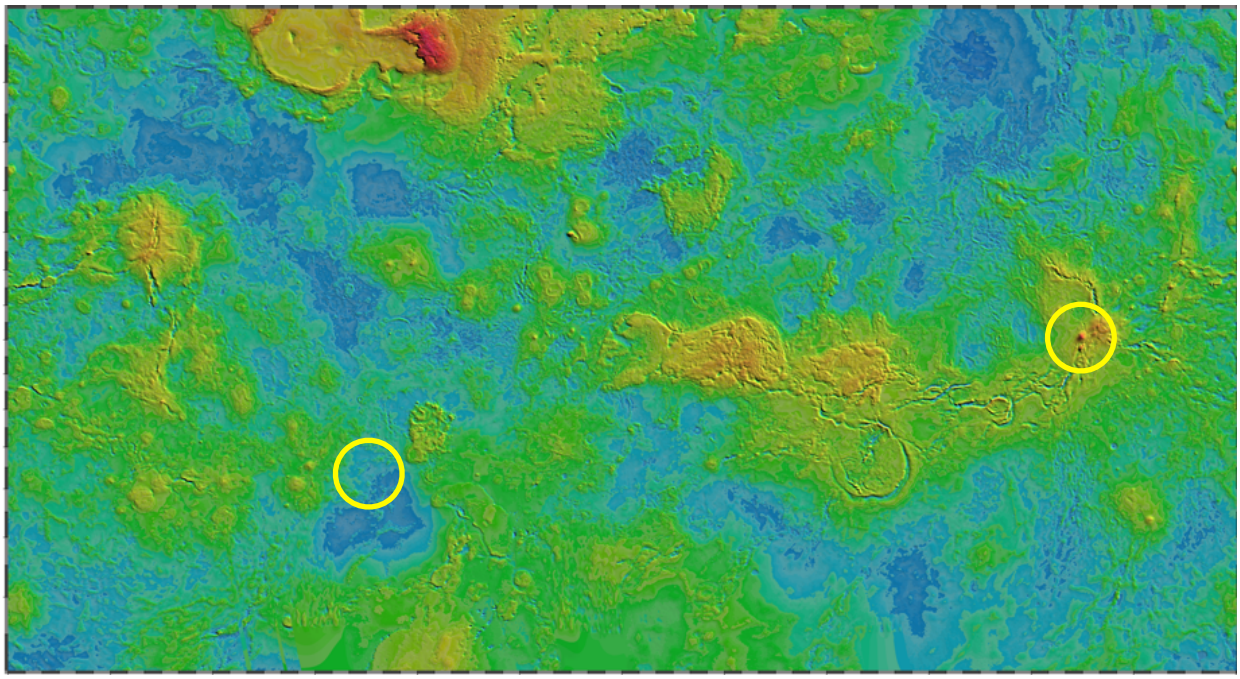
The reason Venus is so bright is not just because it's so close to us but also because it's entirely covered in clouds, which reflect most of the sunlight that hits them. Through a telescope you can't see anything of the surface at all – just clouds. Unlike the clouds of Earth, the clouds of Venus aren't made of water vapour. Instead, they're made of droplets of sulphuric acid, which accounts for their yellowish tinge. They lie at heights of between 45 and 70 km (28 and 43 miles). Circulation patterns in the clouds can be traced in the picture below taken by a space probe in orbit around Venus, but nothing can be seen of the planet's surface.



Yellowish clouds of sulphuric acid completely envelop Venus, obscuring its surface from view. This image was taken by NASA's Pioneer Venus orbiter in 1979.

Astronomers have been able to cut through the clouds of Venus with radar, because radio waves pass through the clouds and bounce back off the surface. Using this technique, a NASA probe called Magellan built up a detailed map from orbit around Venus in the early 1990s (see illustration below). It has found Venus to be a world with continents, rolling plains, canyons, volcanic mountains and meteorite craters.

The highest point on Venus is a mountain range in the northern hemisphere, Maxwell Montes, named after the Scottish scientist James Clerk Maxwell. Its summit towers 11 km (7 miles) above the average surface level of Venus. Maxwell Montes, coloured red on the map below, is part of a continent called Ishtar, the size of Australia.

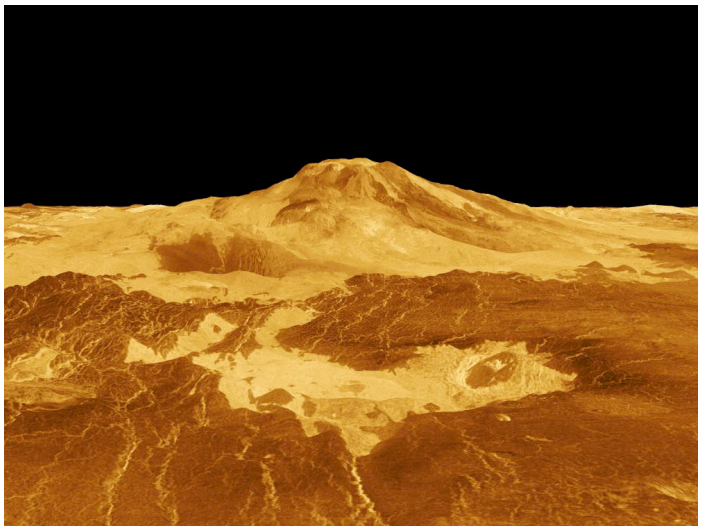


Relief map of Venus from Magellan radar data. The colours are not real – they have been added to indicate the different heights, the reddest parts being the highest and the dark blue ones the lowest. The highest area of all is Maxwell Montes, at top, on the continental area called Ishtar. (NASA/JPL/MIT)

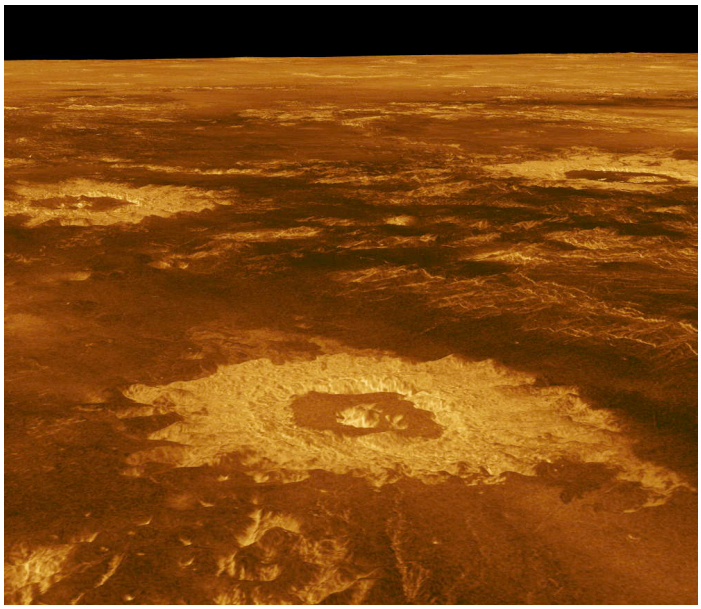
The largest continent on Venus, half the size of Africa, is Aphrodite, on the planet's equator. Aphrodite includes the second-highest peak on Venus, Maat Mons, 8.5 km (5 miles) high, circled at the right of the map above. Maat Mons, seen in the picture on the next page, is believed to be an active volcano, and it is likely that other mountains on Venus were also formed by volcanic eruptions.

As well as volcanoes there are craters where large meteorites hit the planet. In the northern part of the lowland called Lavinia Planitia, circled at left on the map above, is a group of three impact craters imaged by Magellan (see bottom picture on the next page). Even Venus's dense atmosphere is no protection against the largest meteorites.

The atmosphere of Venus consists almost entirely of carbon dioxide which has built up the planet's surface temperature to be hotter than in a kitchen oven. If that weren't enough, the atmospheric pressure is strong enough to crush a submarine. So Venus is not a place where astronauts are ever likely to land.



Left: A simulated view from Magellan radar data of the volcanic mountain Maat Mons, 8 km (5 miles) high. Maat Mons is the second-highest peak on Venus. Lava has flowed down its slopes onto the surrounding plains. The vertical scale on this image has been stretched for clarity – in fact, the surface of Venus is really quite flat, like a rolling plain. For the full-resolution original image, see here.

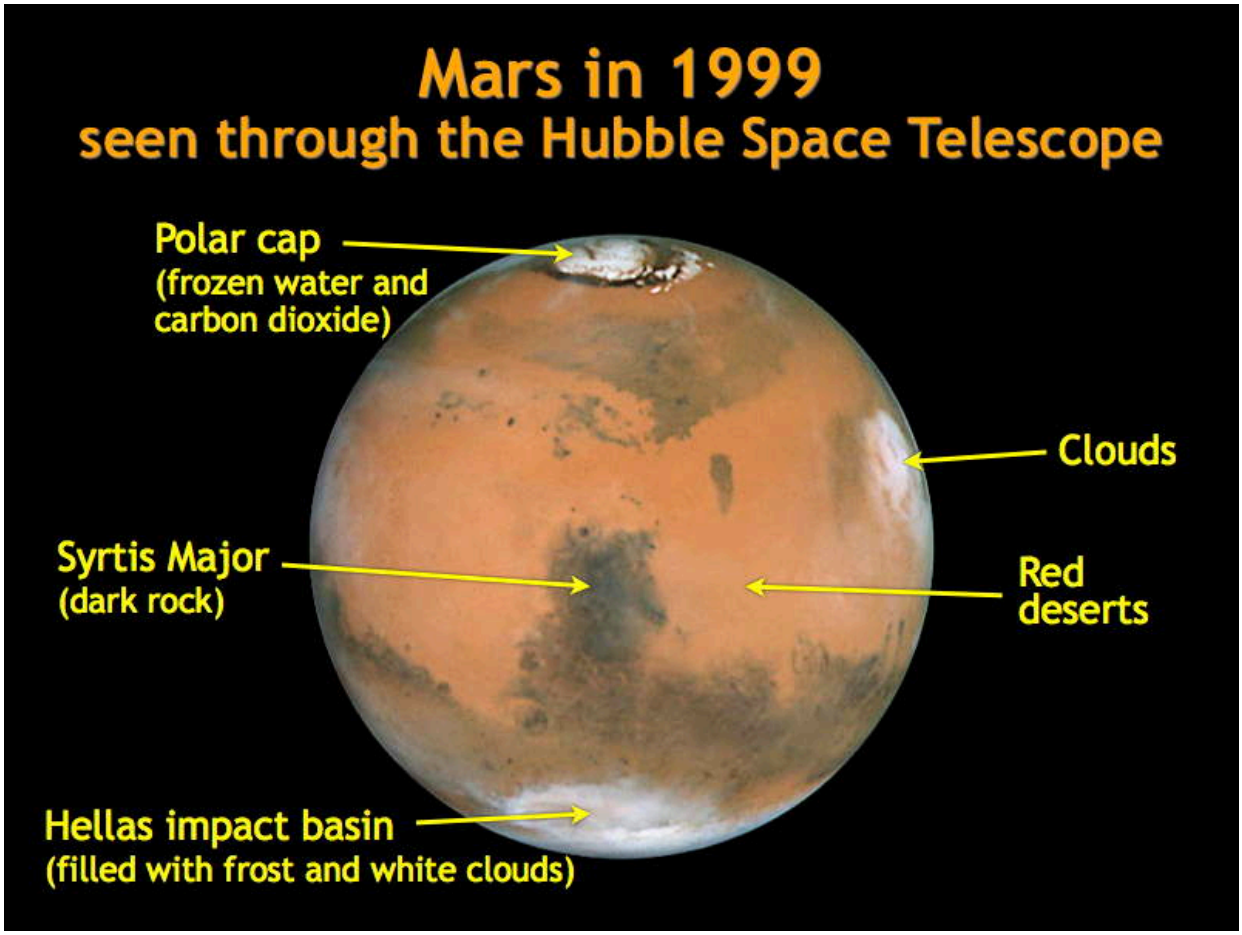


Left: Three impact craters on the lowland area of Venus called Lavinia Planitia from Magellan radar data. They are Danilova (above left), Aglaonice (above right), and Howe (foreground). Their diameters range from 37 km (23 miles) to 63 km (39 miles). As in the picture above, the orange colour has been added to give some idea of what the planet's surface would look like under its dense clouds. For the full-resolution original image, see here.

VENUS DATA	
Diameter	12,100 km (95% that of Earth)
Distance from Sun	108 million km (72% that of Earth)
Time to orbit Sun	225 days (60% that of Earth)
Time to spin on axis	243 days
Mass	0.82 that of Earth
Average density	5.24 times water
Tilt of axis	177°
Number of moons	None

Mars, the red planet

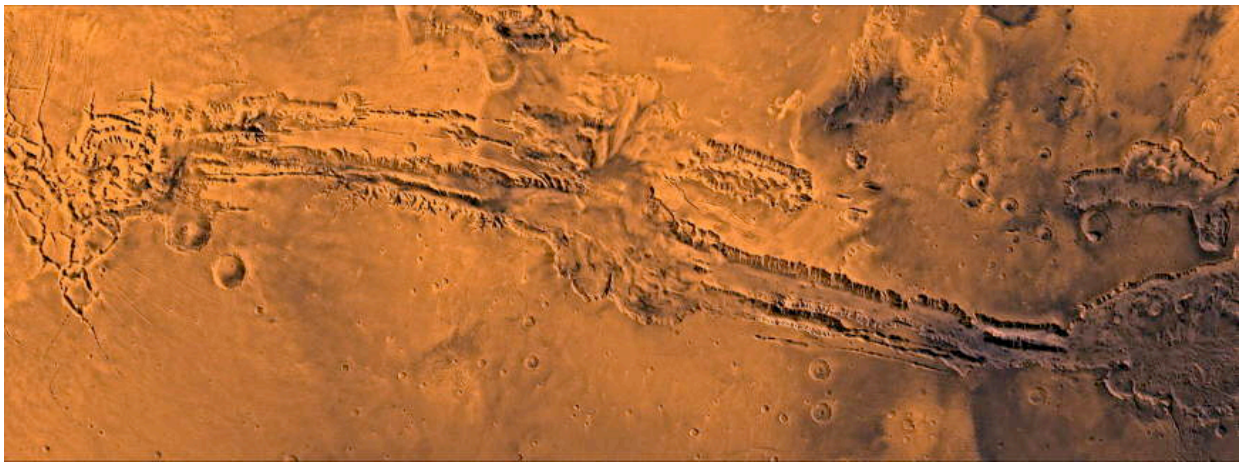
Mars is about half the size of the Earth, and about 50% further away from the Sun than we are, and it has long been of interest as a place where we might find life. Mars is commonly called the Red Planet, although really it's more of a brownish-orange, a colour that comes about because there is a lot of iron oxide in the rocks. Iron oxide is better known as rust, so Mars has literally gone rusty. The picture below of Mars taken with the Hubble Space Telescope shows the main features that can be seen from Earth.



As well as the red deserts there are icy polar caps and also various dark markings that were once thought to be areas of vegetation, but are now known to be only areas of darker rock. The most prominent of them is the one in the centre of the picture above, called Syrtis Major. On the right is a white patch caused by a few wispy cirrus-type clouds in the atmosphere.

Among the major features on Mars is a long chasm near the equator called Valles Marineris, or Mariner Valleys – valleys in plural because it's actually a group of them. The whole complex stretches for 4,000 km (2,500 miles), long enough to cross the United States from Los Angeles to New York. Like the rift valley in Africa, it's where the surface of the planet is being ripped apart by faulting. It is as much as 10 km (6 miles) deep and 600 km (375 miles) wide.

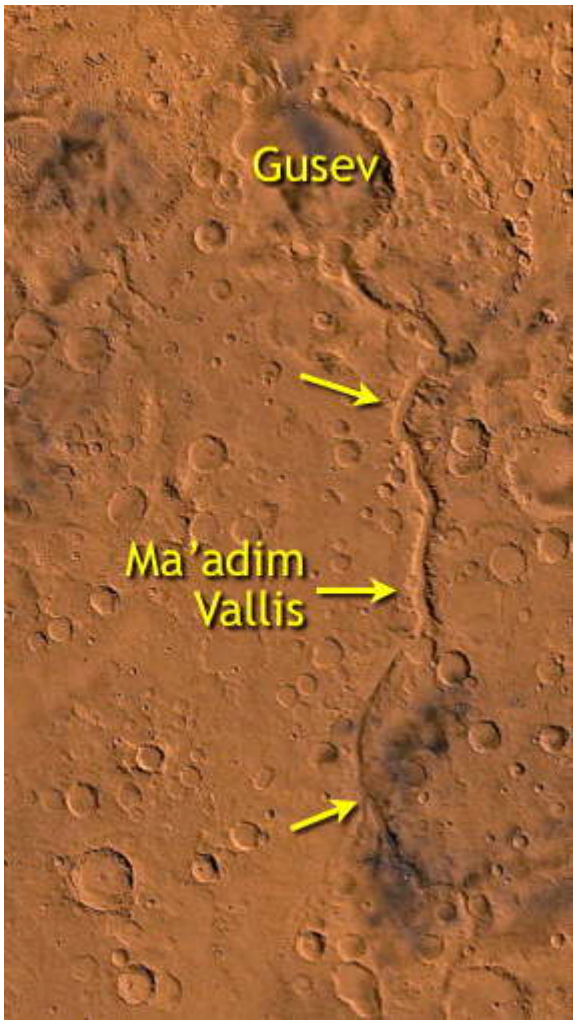
The Mariner Valleys have been been eroded by wind and dust, and there are signs that water has flowed out of them to the right in the past. For an animated flythrough of Valles Marineris, click here.



Valles Marineris (Mariner Valleys), an immense canyon system on Mars, seen in a mosaic of images from NASA's Viking 1 and Viking 2 orbiters.

Mars also boasts the largest volcano in the Solar System, called Olympus Mons (Mount Olympus), 650 km (400 miles) wide at its base and 21 km (13 miles) high. It is seen left in a composite image from NASA's Viking 1 orbiter. At the summit of Olympus Mons is a crater 80 km (50 miles) wide, big enough to swallow several cities.

MARS DATA	
Diameter	6,792 km (53% that of Earth)
Distance from Sun	228 million km (1.52 times Earth)
Time to orbit Sun	687 days (1.88 times Earth)
Time to spin on axis	24.6 hours (1.03 times Earth)
Mass	0.11 that of Earth
Average density	3.94 times water
Tilt of axis	25.2°
Number of moons	2



Although there isn't any liquid water on Mars today, there are signs that water flowed on the surface in the past, so the climate must have been different back then. One area where geologists think that water once flowed on Mars is shown in the image at left. It's a valley called Ma'adim Vallis (arrowed) running downhill from south to north and ending in an impact crater called Gusev. The valley looks like a dried-up river bed, and if it was once a river then there could once have been a lake inside Gusev.

With that in mind, NASA landed a rover called Spirit inside Gusev in January 2004, and it spent five years exploring the crater floor. Among the views it sent back from the surface was this one. The labelling has been added by NASA scientists, who have given names to various rocks, and they have marked out the rover's wheel tracks in the foreground with a dashed white line.

As the rover has gone along it seems to have churned up some white deposit from under the topsoil which is thought to be a kind of salty deposit left behind by evaporated water.

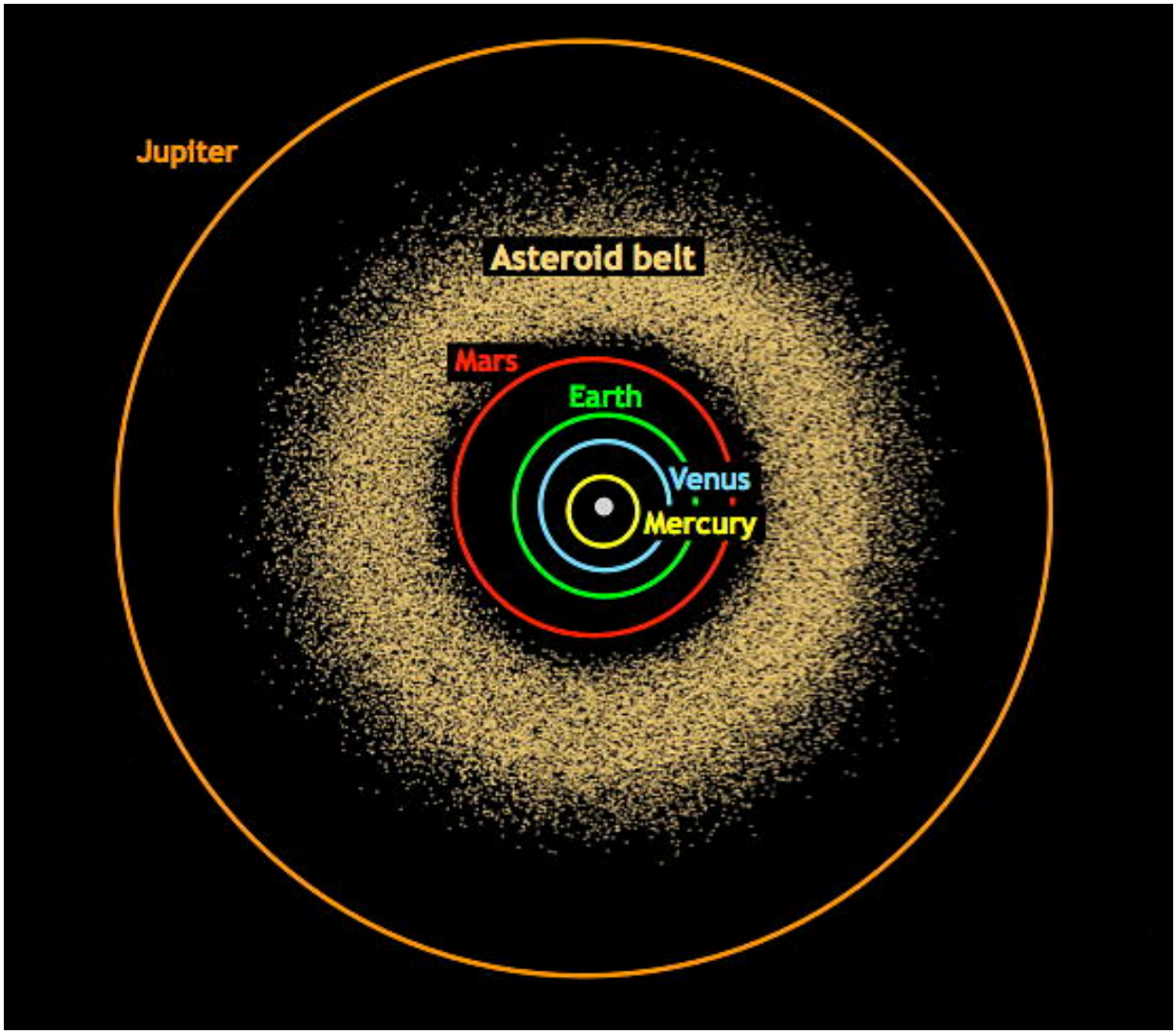
An identical rover called Opportunity landed at the same time on the opposite side of Mars. Opportunity spent a lot of time investigating the area around a small impact crater called Victoria, half a mile or so across, just a bit smaller than the famous meteorite crater in Arizona. Victoria has a beautifully scalloped rim and ripply sand dunes on its floor caused by wind erosion. The rover rolled up to the edge of the crater and took this panorama of the interior.

In August 2012 a larger and faster rover called Curiosity landed in a 154-km (96-mile) wide Martian crater called Gale, another location where water was once thought to exist. Among its discoveries are what appear to be sedimentary rocks, laid down by a river in the distant past. This seems clear evidence that water once flowed over large areas of Mars when the climate was milder. Curiosity has also been drilling into the rocks to take samples for analysis by its instruments on board, and the results confirm that these are sedimentary rocks laid down under water on Mars.

The views from Spirit, Opportunity and Curiosity are pretty typical of Mars as a whole. It's a rocky desert, but it's a cold desert – the air is very thin, so temperatures are sub-zero. There is no sign of life today, but it's possible that some form of microbial life might have got started a long time ago when the climate was milder and wetter, and if so we might one day find signs of it in the soil. And eventually, of course, humans will walk on the planet's surface.

Into the asteroid belt

Between Mars and Jupiter is a swarm of rubble called the asteroid belt. Asteroids are bits left over from the formation of the Solar System. There wasn't much interest in the asteroids until the 1980s when it was realized that some of them stray from this belt and might hit the Earth. An asteroid impact is now blamed for wiping out the dinosaurs 65 million years ago, so they now seem much more important.



The asteroid belt is a swarm of small bodies between the orbits of Mars and Jupiter. There are estimated to be at least a million asteroids of diameter 1 km or larger.

They're very irregularly shaped, knocked about by impacts and collisions. An asteroid called Ida was photographed by a probe on its way to Jupiter, and it turned out to have a little moonlet. They're probably both fragments of a much bigger body that broke up after a collision.

In July 2011 a NASA space probe called Dawn went into orbit around Vesta, one of the largest asteroids. Dawn stayed in orbit around Vesta for a year before moving on to the largest asteroid of all, Ceres, 950 km (590 miles) in diameter, which it went into orbit around in 2015. It is expected to continue studying Ceres into 2016, after which it will remain in orbit as a permanent satellite.

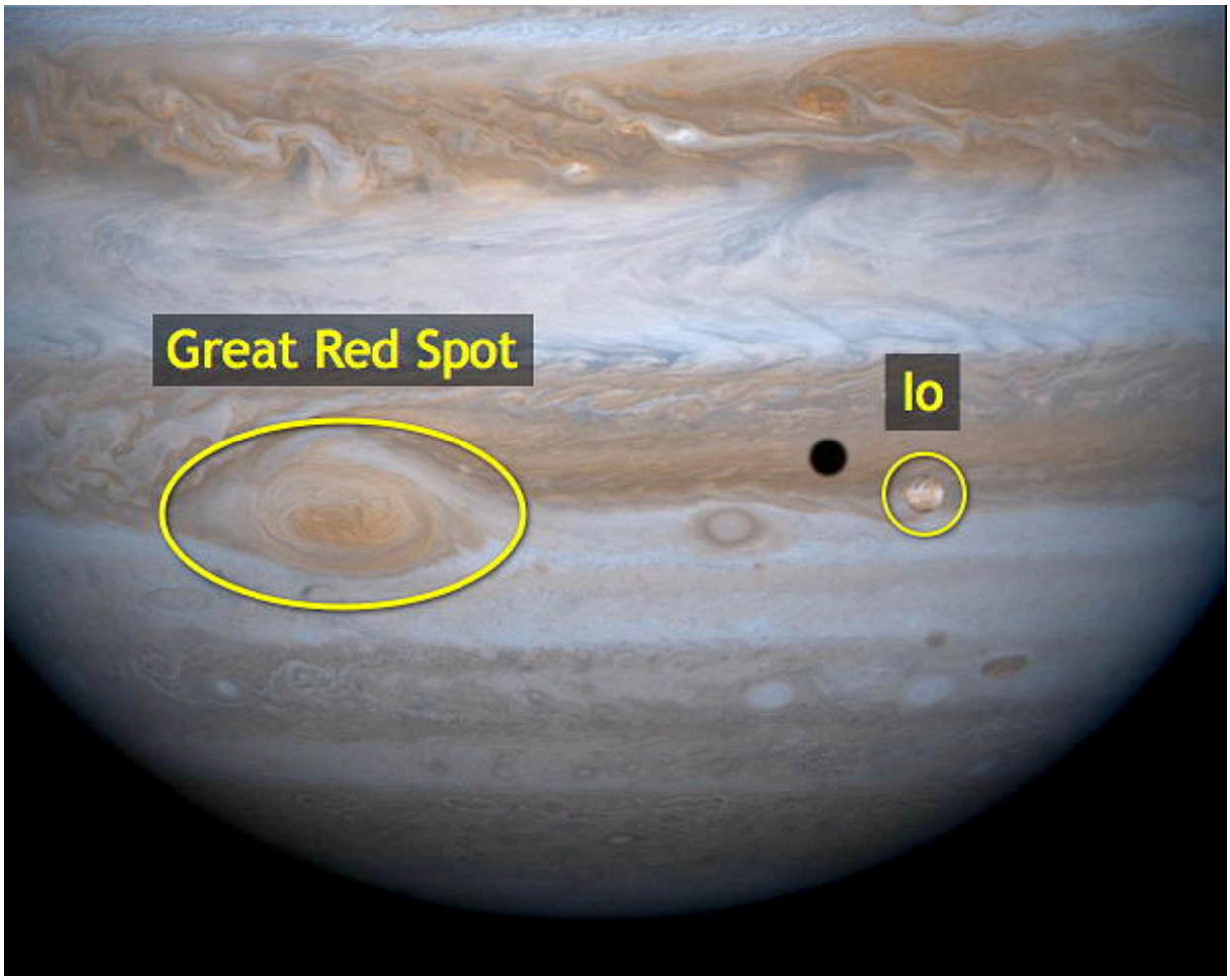
Jupiter, the largest planet

Biggest of all the planets is Jupiter, over 11 times the diameter of the Earth. If you could put it on a set of scales it would weigh twice as much as all the other planets put together. Jupiter is over five times farther from the Sun than we are and it takes nearly 12 years to complete one orbit. It's also very bright, second only to Venus in our skies.

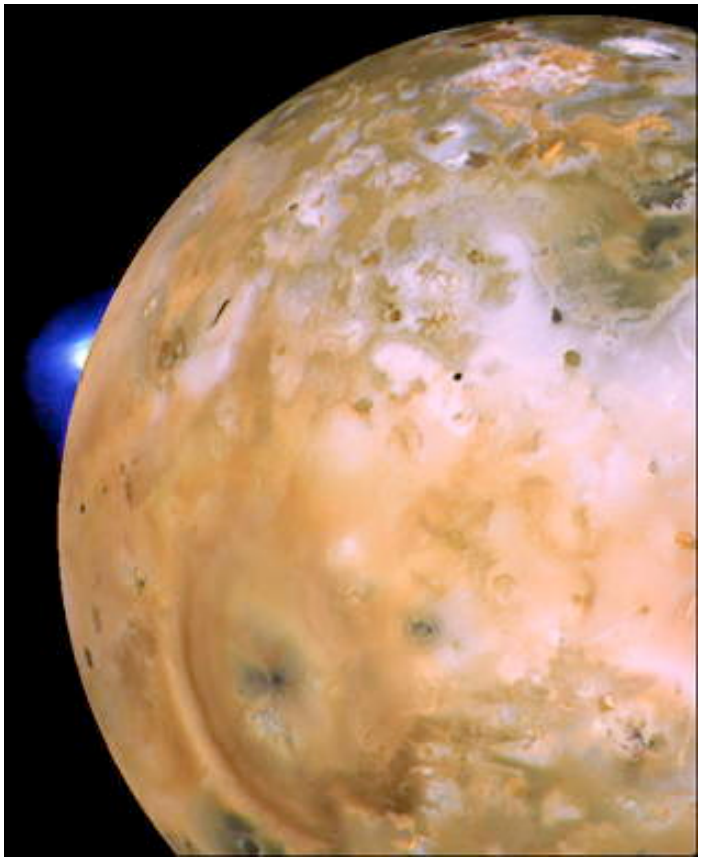
When we look at Jupiter we just see clouds. These are drawn out into horizontal bands by the planet's rapid rotation – it spins once in less than 10 hours, the fastest spin of all the planets. The only persistent feature in the clouds is an oval in the southern hemisphere called the Great Red Spot, which is a spinning storm cloud several times larger than the Earth. The Great Red Spot is about 25,000 km (15,000 miles) long and 12,000 km (7,500 miles) wide, big enough to swallow several Earths, although it changes somewhat in size and shape with time. Its red colour comes from chemical compounds such as phosphorus that are dredged up from lower down in the atmosphere by convection currents.

If you were to dive into Jupiter's clouds, you would find that there is no solid surface beneath. The atmosphere just keeps getting thicker until the gas turns into a liquid and you would be crushed. At the centre there may be a solid core but there's no way we would be able to reach it, so we're certainly never going to land on Jupiter – or any of the outer planets for that matter.

Jupiter's colourful cloud bands, the Great Red Spot and its moon Io (plus Io's black shadow), photographed by NASA's Cassini space probe. For the full-resolution original image see here.

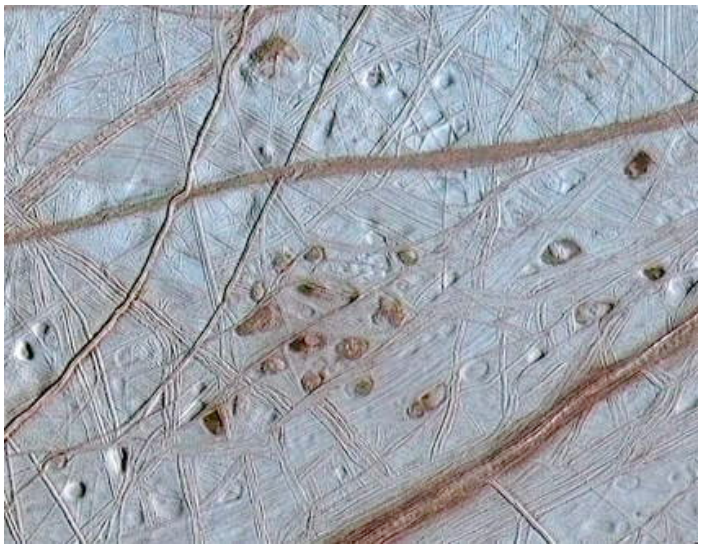


Jupiter is fascinating not just for its atmosphere but also its family of moons, the biggest of which can be seen through a pair of binoculars. This big four are called the Galilean satellites because they were discovered by Galileo 400 years ago. The illustration above shows them lined up in order of distance from Jupiter with our own Moon at the right for comparison. As can be seen, three of them are bigger than our Moon and one is not much smaller, so they're like little planets in their own right.



The innermost moon, called Io, turns out to be the most volcanically active body in the Solar System. When the Voyager 1 probe flew past Jupiter back in 1979 it caught several volcanoes in the act of erupting – one of them was spewing out a plume of material hundreds of miles into space (left). In fact there are hundreds of volcanic vents all over Io.

Io is so active because it's squeezed by the gravitational pull of Jupiter which releases heat, and that makes Io molten inside. What erupts from the volcanoes of Io isn't normal lava but sulphur and sulphur dioxide, which give it a bizarre range of colours that make it look like a giant cheese and tomato pizza. It's one of the most bizarre worlds of the Solar System.



Cracks and spots on the icy surface of Jupiter's moon Europa give the impression of tyre tracks and footprints. See the full-resolution original here.

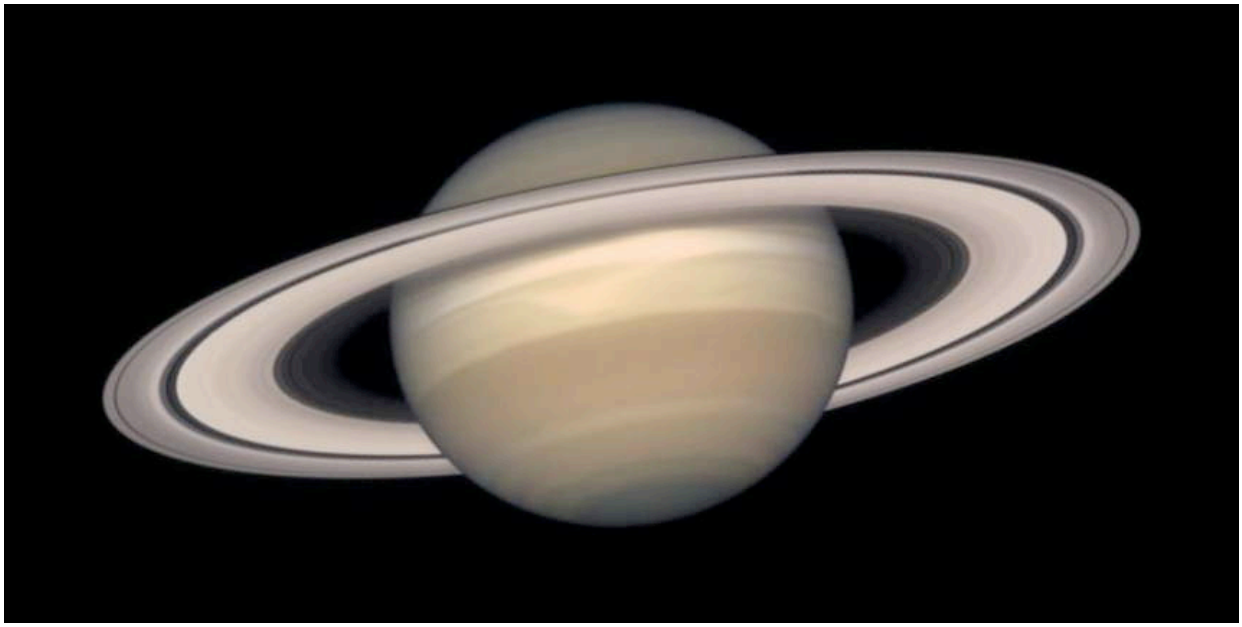
In complete contrast, the next moon out, Europa, is a world of ice. The ice has cracked in places and minerals have oozed out, causing brownish stains. There may well be an ocean under the ice, and it's even been speculated that there could be some form of life in that ocean, by analogy with the weird forms of life that exist deep in the oceans on Earth. You could scarcely imagine two more different moons orbiting the same planet as volcanic Io and icy Europa.

Ganymede is the largest moon in the Solar System, larger than the planet Mercury, while Callisto is only slightly smaller than Mercury. Both Ganymede and Callisto are peppered with craters caused by meteorites. As well as craters, Ganymede has strange grooves on its surface, probably due to movements in the crust. The surfaces of Ganymede and Callisto are not rocky, like our own Moon, but consist of dirty ice.

All the other moons of Jupiter are smaller than the big four. The smallest of Jupiter's moons are only about 3 km (2 miles) across. More are being discovered all the time.

JUPITER DATA	
Diameter (equatorial)	143,000 km (11.2 times Earth)
Distance from Sun	778.4 million km (5.2 times Earth)
Time to orbit Sun	11.86 years
Time to spin on axis	9.84 hours (41% that of Earth)
Mass	318 times Earth
Average density	1.3 times water
Tilt of axis	3.1°
Number of moons	60+

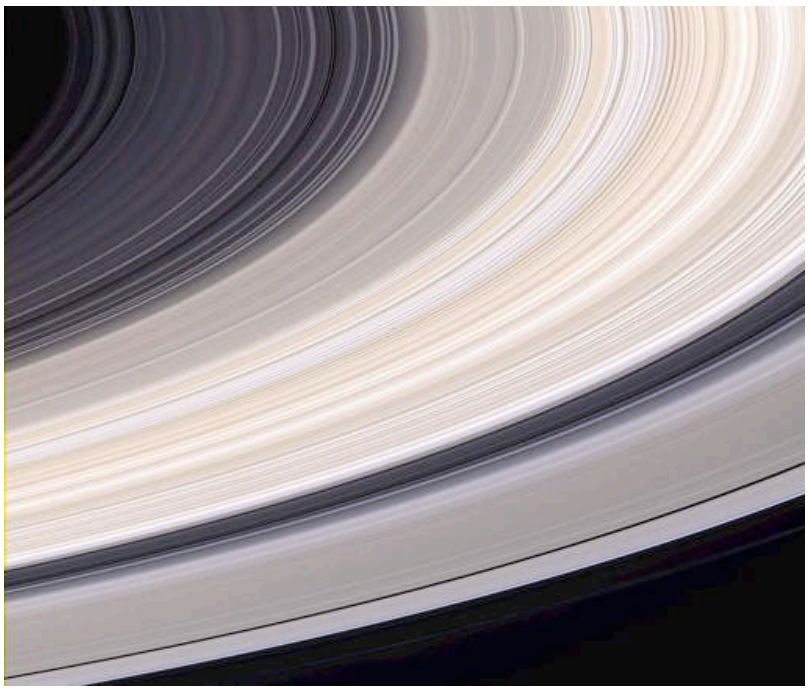
Saturn, the ringed planet



Saturn and its rings seen through the Hubble Space Telescope. The dark line in the rings is the Cassini Division. For a series of Hubble images showing the rings at various angles, see here.

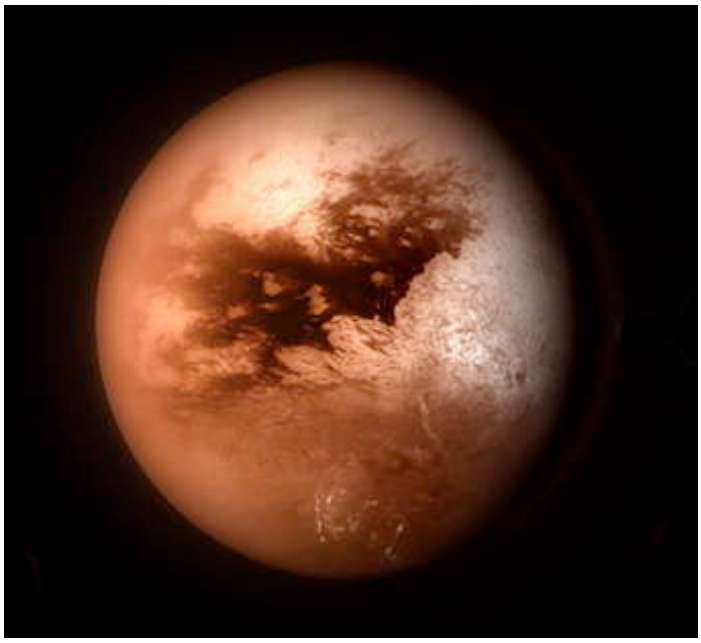
By common consent, the most beautiful planet is Saturn, encircled by its entrancing rings. It's the iconic planet. Saturn's globe is smaller than Jupiter's although the rings make it bigger overall. The Earth would just about fit between the inner edge of the rings and the planet. The dark line in the rings about two-thirds of the way out, as seen in the image above, is a gap the width of the Atlantic Ocean called the Cassini Division. Saturn can be seen through it.

Saturn is over 9 times farther from the Sun than we are and takes nearly 30 years to complete one orbit. Although Saturn is much like Jupiter in structure, it doesn't have anything like the same amount of activity in its clouds. So the main interest is in the rings.



At first they look smooth and continuous but in close-up, as in the image at left taken by NASA's Cassini space probe, they break up into countless narrow ringlets, reminiscent of an old-fashioned vinyl gramophone record.

The rings consist of a swarm of icy chunks ranging in size from snowballs to icebergs, all orbiting the planet like little moons. They might be the remains of a former moon that broke up, or they could be bits that never formed into a moon.

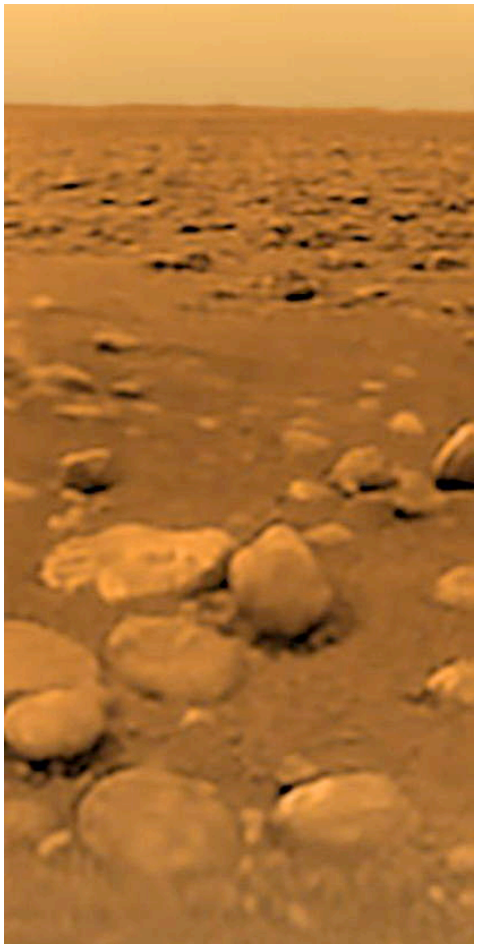


Infrared view from Cassini of the surface of Titan, showing bright uplands and dark lowlands.

Like Jupiter, Saturn has a huge family of moons – over 60 have already been discovered and there are probably more to come. Most of these are very small but the largest, Titan, is the only moon in the Solar System that has an atmosphere. Titan's atmosphere is actually denser than the Earth's and is topped with smoggy orange clouds which hide its surface.

However, we can see through its clouds at infrared wavelengths, as in the image at left, and also with radar. The Cassini space probe is using these techniques to build up a map of Titan.

As well as a continent the size of Australia, Cassini has found signs of erosion on Titan caused by some form of running liquid. This liquid can't be water because the temperature on Titan is way below freezing point. Instead it's thought to be liquid methane – in other words, liquefied natural gas, which falls as an oily rain. And this has been confirmed by the discovery of lakes of liquid methane near the poles of Titan, where it's coldest of all.

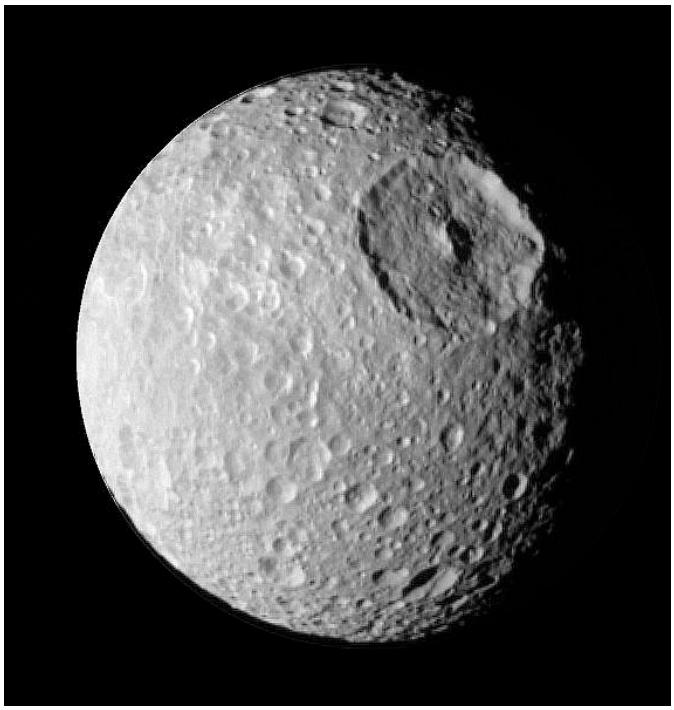


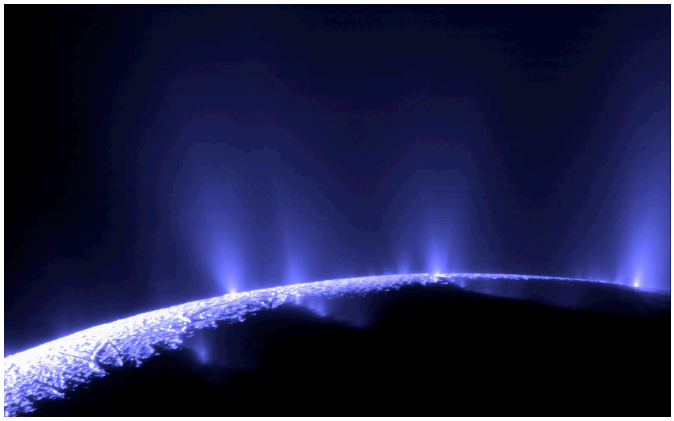
One of the most astounding achievements in the history of the space age happened in January 2005 when a European-built probe called Huygens was released from Cassini and parachuted down through the dense atmosphere of Titan to land on its surface. The image on the left shows what it saw.

At first glance this orange desert might look much like Mars or Venus, but those pebbles in the foreground aren't made of rock – they are actually blocks of frozen water. As well as the ice on the surface, some interesting carbon-based chemistry is going on there, which may hold some clues to the first steps in the origin of life.

In fact, Titan has been referred to as a deep-frozen version of the young Earth. So, under its clouds, Titan is turning out to be a world every bit as fascinating as, say, Venus or Mars. (For an artist's animation of Huygens and its landing site, see here.)

Surface of Titan as seen by the Huygens lander in January 2005. Titan appears orange under its smoggy clouds. The largest pebbles are about 10–15 cm (4 to 6 inches) across.





Before leaving Saturn let us take a quick look at a couple of its other moons. The one in the picture at left is called Mimas, 390 km (240 miles) in diameter. It has a crater on it that is so big the force of the impact that created it must have come close to breaking the moon apart.

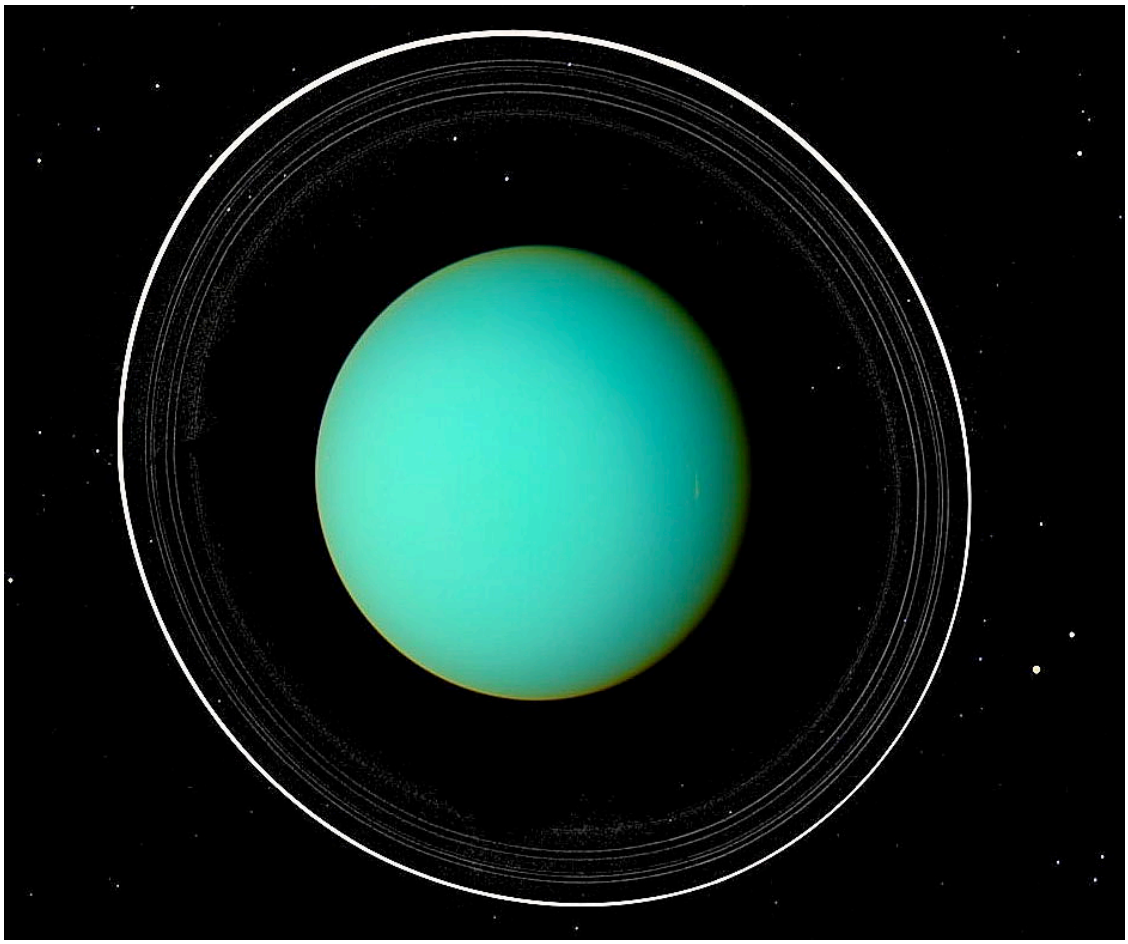
This crater is called Herschel, after the British astronomer Sir William Herschel who discovered Mimas in 1798, and gives the moon the appearance of the Death Star space station from the *Star Wars* films.

Another fascinating moon of Saturn is Enceladus (lower left). At first sight it looks like Jupiter's moon Europa – it's got a bright, icy surface with cracks running across it. Scientists term these cracks 'tiger stripes'.

The Cassini mission has photographed fountains of water vapour and ice spraying out through some of these cracks like geysers on Earth (left), so this is another moon where we might find liquid water under the ice.

SATURN DATA	
Diameter (equatorial)	120,500 km (9.4 times Earth)
Distance from Sun	1,427 million km (9.5 times Earth)
Time to orbit Sun	29.5 years
Time to spin on axis	10.23 hours (43% that of Earth)
Mass	95 times Earth
Average density	0.7 times water
Tilt of axis	26.7°
Number of moons	60+

Uranus, the tilted planet



Uranus and its narrow rings, photographed by the Voyager 2 space probe in 1986. The planet's greenish clouds are almost featureless. (NASA/Erich Karkoschka)

Until the 18th century it was thought that the Solar System stopped at Saturn, which is the most distant planet that can be seen with the naked eye. Then another planet was discovered, the one we know as Uranus. The man who made the discovery was William Herschel, a musician by profession who was passionate about astronomy – he made his own telescopes and observed in his spare time. He stumbled across Uranus completely by chance one night in 1781.

Uranus turned out to be twice as far from the Sun as Saturn, so its discovery doubled the size of the known Solar System. It takes 84 of our years to go around the Sun once. Visually it's somewhat greenish or bluish, due to methane gas in its atmosphere.

Uranus is the least interesting-looking of all the planets, because there are hardly any markings in the clouds. Even the Voyager 2 space probe which flew past it in 1986 didn't show much in the way of cloud features. Uranus has rings, but these are much fainter and narrower than the rings of Saturn and they cannot be seen from Earth except with special techniques.

In the picture above, sent back by Voyager 2, the rings might seem to go over the planet's poles, but they don't – they actually circle the equator, like the rings of Saturn. The difference is that Uranus is tilted on its side, so that its axis of rotation lies almost in the plane of its orbit. Here we are looking at the south pole, which was then pointed towards the Sun.

Why does Uranus have such an extreme tilt? The most likely explanation is that one or more large bodies ran into it while it was forming and literally knocked it over. This is another example of how giant impacts have affected the development of the planets throughout the Solar System. Uranus has 27 known moons, many of which were discovered by the Voyager 2 space probe. The moons orbit Uranus in the same plane as the rings.

URANUS DATA	
Diameter (equatorial)	51,120 km (4 times Earth)
Distance from Sun	2,870 million km (19.2 times Earth)
Time to orbit Sun	84 years
Time to spin on axis	17.24 hours (72% that of Earth)
Mass	14.5 times Earth
Average density	1.3 times water
Tilt of axis	97.8°
Number of moons	27

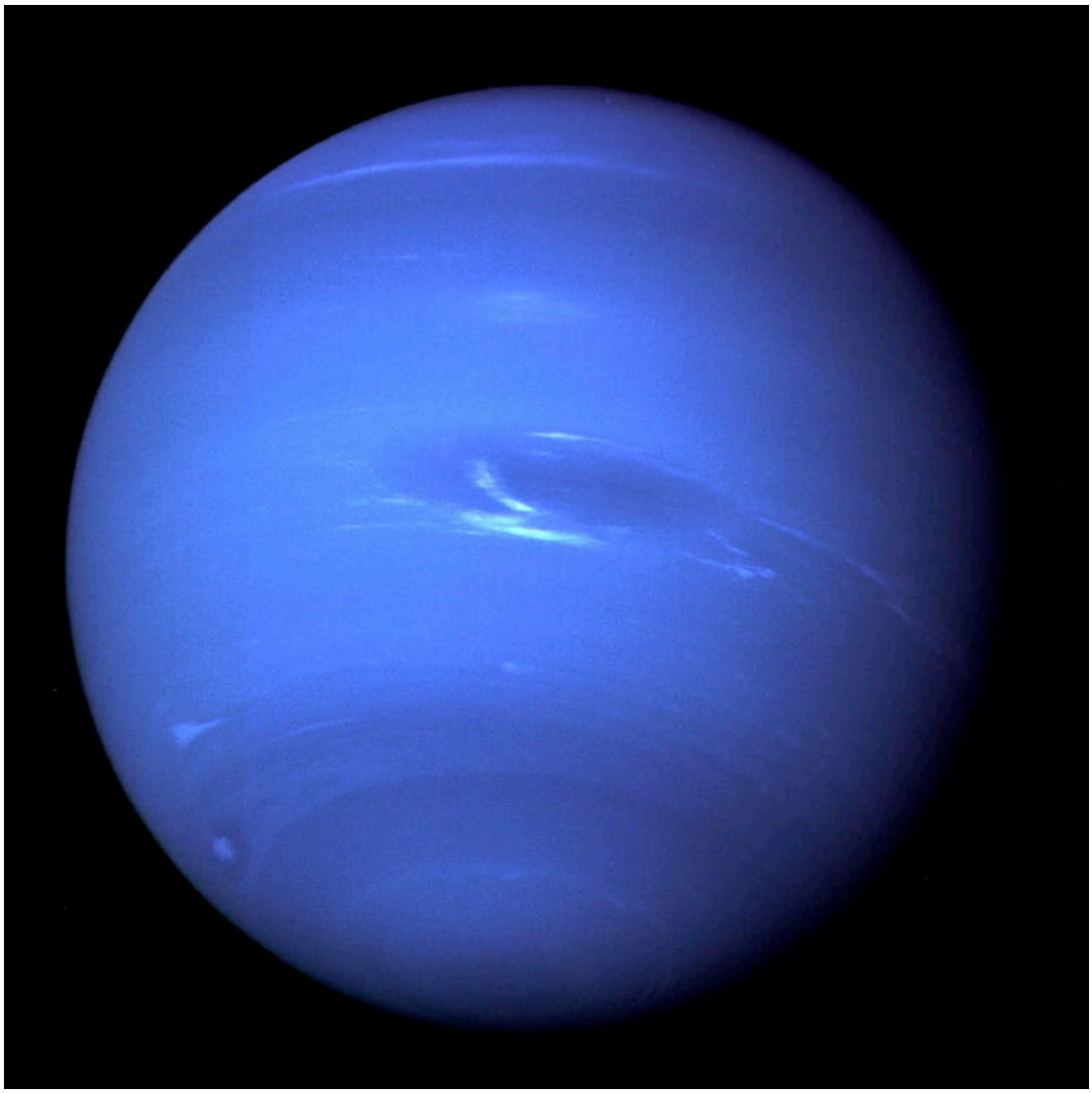
Neptune, the outermost planet

The discovery of Uranus wasn't the end of it. As astronomers followed the movement of Uranus they found that it wasn't keeping to its expected path. They began to suspect that there was another planet, even further out, that was pulling Uranus off course.

A French mathematician called Urbain LeVerrier calculated where this new planet ought to be found. But the French weren't interested in looking for it, so in September 1846 LeVerrier sent his predictions to the German astronomer Johann Galle at Berlin Observatory, who found the new planet the same night he received LeVerrier's letter. This was a great embarrassment to British astronomers, who were looking for the new planet themselves. But their predictions weren't as good, and their search team missed the planet even though they went over the right area. So the credit went abroad and it has been a sore point ever since.

Neptune turned out to be very similar to Uranus in size and composition, and also of similar colour. It takes 165 years to go around the Sun, and it was only in July 2011 that it finally completed one full orbit since it was discovered.

Neptune's atmosphere is more active than Uranus. When Voyager 2 flew past Neptune in 1989 it saw a great dark spot in the clouds, looking like a giant fish basking in a blue lagoon (see the image on the next page). But unlike Jupiter's red spot this dark spot was only a temporary feature. The Hubble Space Telescope looked for it five years later but by then it had gone.



Neptune and its dark spot, rimmed with white cirrus clouds composed of methane ice, as photographed by Voyager 2 in 1989. For the full-resolution original image see here.

NEPTUNE DATA	
Diameter (equatorial)	49,500 km (3.9 times Earth)
Distance from Sun	4,498 million km (30 times Earth)
Time to orbit Sun	165 years
Time to spin on axis	16.1 hours (67% that of Earth)
Mass	17.1 times Earth
Average density	1.6 times water
Tilt of axis	28.3°
Number of moons	14

Pluto, the planet that never was

Pluto is a small, cold world on the edge of the Solar System. Like Neptune, it was found as the result of a deliberate search, in this case by an American astronomer called Clyde Tombaugh working at the Lowell Observatory in Arizona. The observatory's founder, Percival Lowell, had himself looked for a ninth planet early in the 20th century but never found it. Some years after his death, Clyde Tombaugh was appointed to conduct a photographic search for new planets and early in 1930 he struck lucky when he discovered the object that became known as Pluto.

However, there was a problem. It wasn't a large planet like Uranus or Neptune, as had been expected. In fact, every time astronomers tried to measure its size their estimates of it got smaller. They eventually realized that Pluto is actually smaller than our own Moon.

To make things worse for Pluto, since the 1990s thousands of small, icy objects have been found beyond Neptune, like a distant asteroid belt; collectively, these are known as *trans-Neptunian objects*. One of them, called Eris, is near enough the same size as Pluto.

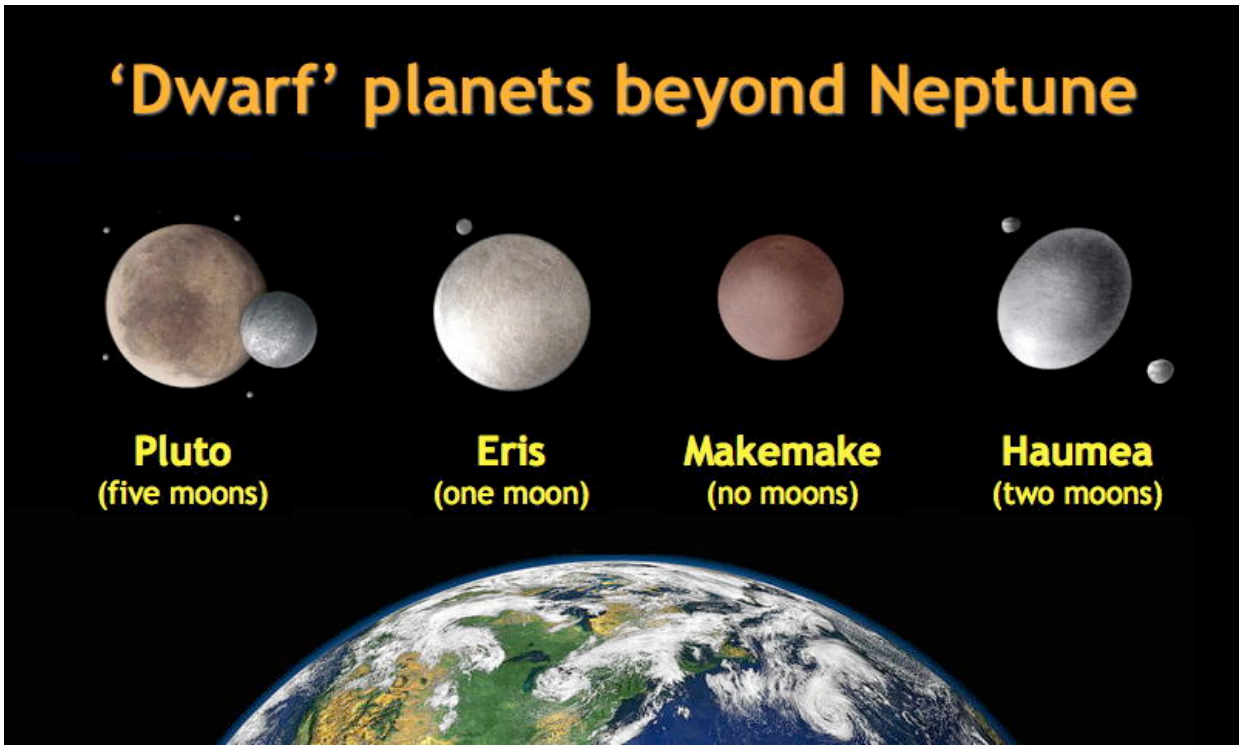
Clearly it was no longer possible to regard Pluto as a major planet, so in 2006 the International Astronomical Union, astronomy's governing body, decided to reclassify Pluto and Eris as dwarf planets. Two more have since been added to the total (see illustration on next page). There could be even larger objects than Pluto and Eris out there that have yet to be discovered.

We got our first close-up views of Pluto in July 2015 when a NASA probe called New Horizons flew past it, *below*. The surface isn't rock, it's ice, and most of the ice is frozen nitrogen. The dark areas are very old and have turned brownish from the long-term effects of sunlight, whereas the bright areas are relatively young. New Horizons also photographed Pluto's largest moon, Charon, which is half the diameter of Pluto.

Pluto as seen by the New Horizons probe in July 2015, in enhanced colour. The largest bright area at centre has been named Tombaugh, after Pluto's discoverer. Bordering it at the lower left are two mountain ranges named Hillary Montes and Norgay Montes, after the first two humans to set foot on the summit of Everest, Edmund Hillary and Tenzing Norgay. These mountains consist of frozen water, which is as strong as rock out in the extreme cold of Pluto. The smoother areas are thought to be composed of frozen nitrogen, which is softer and can flow like a glacier.

Pluto's appearance changes with the seasons as surface ice melts in one hemisphere and refreezes in the other.

Pluto is now classified as a dwarf planet, and is rivalled in size by another such body, Eris, discovered in 2005. In all, four bodies beyond Neptune are currently classified as dwarf planets, shown here with part of the Earth for comparison. Three of these dwarf planets are known to have moons.



Useful links

NASA Solar System Exploration page
http://solarsystem.nasa.gov

NASA planetary fact sheets
http://nssdc.gsfc.nasa.gov/planetary/

NASA Planetary Photojournal
http://photojournal.jpl.nasa.gov/index.html

Gazetteer of Planetary Nomenclature
http://planetarynames.wr.usgs.gov/

Exploring Stars and Planets by Ian Ridpath (mostly for children)

Collins Stars and Planets Guide by Ian Ridpath and Wil Tirion

Source of this document: www.ianridpath.com/solarsystem.pdf