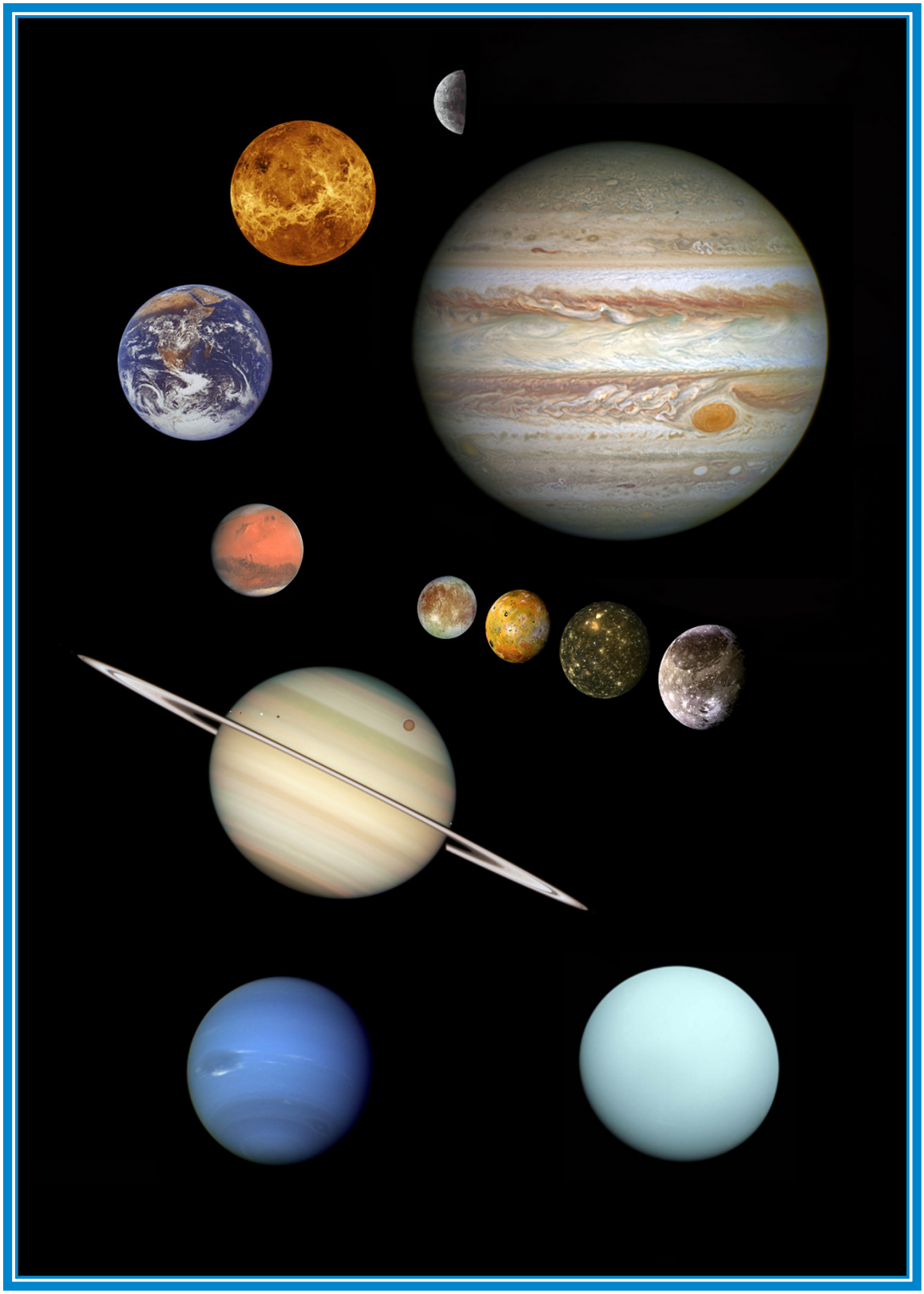
CESAR BOOKLET

General Understanding of the Solar System



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Overview of the Solar System

The system where our planets, asteroids, moons, comets are located is called the Solar System. Basically, the name comes from two words: “solar” and “system”. Solar means “of the Sun” and system is as you may know a collection of objects that act together to form a whole. So, in conclusion, it is a group of celestial objects that act together with one another, the central relations for each object being the on it has with our Sun.

Our Solar System is filled with different types of objects: a star, planets, many moons, dwarf planets, asteroids, comets, gas, and dust. Here is a table of each objects and the number of it that we currently know.

Body	Number
Star (The Sun)	1
Planets	8
Dwarf planets (Pluto, Haumea, Ceres, Eris, and Makemake)	5
Moons	169
Asteroids	566,000
Comets	3100

Table 1: *Approximate number of bodies in the Solar System.*

As you can see, there are many objects out there, just our Solar system. These values are only an approximation. Their masses together are not as much as one might think. The Sun only comprises over 99.8% of the Solar system. Only Jupiter is accounting for most of the mass that is remaining.

All of the mentioned objects orbit the Sun in elliptical paths. Moreover, their orbits lie approximately in the same plane. This plane is called the ecliptic plane. What mechanism causes the objects to orbit the Sun? The answer is one of the central forces in nature, gravity. While the natural tendency of the Solar System objects is to remain in a straight line of motion, the exerting force (gravity) from the Sun on each object “bends” the straight trail into one that is curved. Moreover, other bodies or objects in the Solar System are great enough to apply gravitational forces significant enough to change the orbit of the smaller objects. We can take the Earth as an example. Its gravitational force is strong enough to keep the Moon in orbit around itself.

About the size of the Solar System it is believed that the edge of our Solar System is that of the orbit of Pluto. This is actually far from the truth.

The size of the Solar System

The Solar System has not an actual clear boundary. That is why it is hard to define its size. So, how do define its size?

We can simply state that it extends as far as the effect of the Sun. That effect could mean the influence of the light of the Sun, or the gravitational effect of the Sun, or even the magnetic field of the Sun and the solar winds.

As farther we travel from the Sun, as fainter the light it emits becomes. But there is no boundary where it all of a sudden gets weaker or suddenly stops. It is the same for its gravity; it extends without a border, even if it gets weaker farther away from the Sun.

The solar wind is not the same as the Sun's gravity or light. As it leaves the Sun, it races out in the direction of the space between the stars in our galaxy. The space between them is actually not empty as it may seem, but it contains traces of dust and gas, named Interstellar Medium. The solar wind affects this material by blowing against it, forming a region in this gas that is bubble-like. The entire area (or bubble) inside the boundary of the Solar System is named the Heliosphere. The area where the solar wind slow down and begins to act together with the interstellar medium is named the Heliosheat. The Heliosheat has a small number of parts: the Terminal shock (the innermost part of the boundary), the Heliopause (the outermost part of the boundary), and the part between the inner and outer boundary.

The dwarf planet Pluto is situated about 5,906,376,272 km and the Terminal shock is almost twice as far away as Pluto's orbit. Here is an image of how it actually looks like:

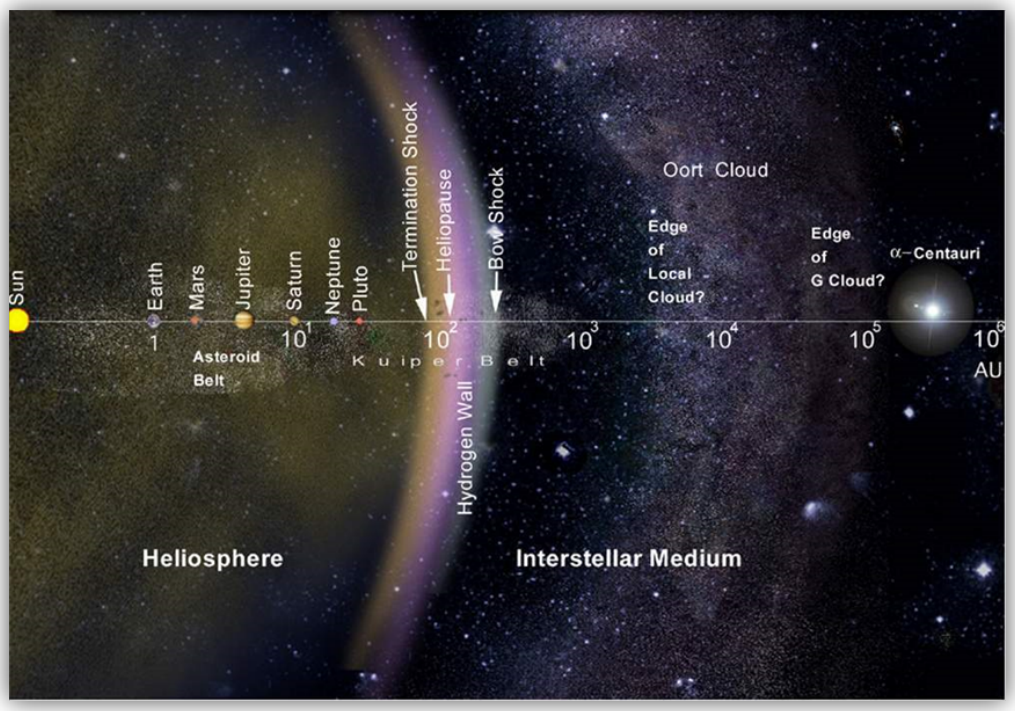

Figure 1: *The approximate distance in our Solar System. The interstellar medium is the space between the bow shock and the nearby stars.* *Credit: NASA*

The planets of the Solar System

The Solar System has eight well known planets and five dwarf planets. These were mentioned in table 1. Each planet has its own features and compositions and rotates in a very different ways. Moreover each one has its own history, for example the gaseous planets were formed by the outer material of the primitive Solar System (i.e. hydrogen and helium) while inner planets were formed by heaviest material that surrounds the primitive Sun. Let us learn a little more about each planet:

Mercury

Mercury is the closest planet to the Sun and is also the smallest among all of the eight ones. According to physics, a body close to a bigger one accelerates faster around it. This is the same for Mercury; it has the fastest orbital period around the Sun. It takes 175,97 Earth days for one orbit.

Since it is so close to the Sun, the temperature of its surface reaches 450 degrees Celsius during the days. Due to this planed has not atmosphere (the solar wind "blows" it away), the temperature can sink to -170 degrees Celsius during the nights. As you can see, the temperature difference is huge and is the greatest in the entire Solar System.

This planet is also the smallest one, only slightly bigger than the Moon (1/3 of the Earth). As it has no significant atmosphere that stop impacts, the planet is scarred with craters. Even if it is close to the Sun, Mercury has water ice at the north and south poles. This was first discovered in 1991, when astronomers used radar observations to learn more about its surface. The ice is to be found inside deep craters that are continually cold and shadowed. A theory is that meteorites or comets might have carried ice there, or water vapour might have outgassed from the interior of the planet and frozen in the planet's poles.

Mercury is also the second planet with the highest density, after Earth that is. It has a big center of metal that is nearly 3,600 to 3,800 km wide, or roughly 75% of the diameter of the planet. Only its outer shell is 500 to 600 km thick. It is also worth to note that Mercury does not have a moon.

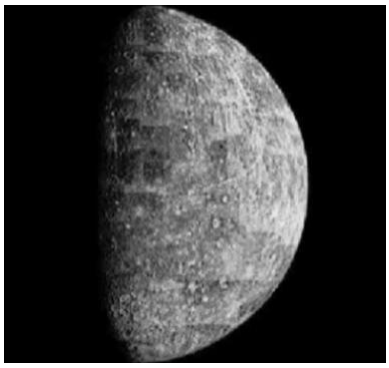

Figure 2: *Mercury* *Credit: ESA*

Venus

Venus is the second planet from the Sun, and also the one with the most number of volcanoes. It is frequently called the Earth's twin because of their similar size, density, composition, gravity and mass. One thing that characterizes Venus is its extremely hot temperature. In fact, it is the hottest planet in our Solar System as the average temperature is around 467 Celsius degrees. Even though it is not the closest planet to the Sun, its thick atmosphere traps heats and is comparable to the greenhouse effect here on Earth (it is extremer there however). As a result, the temperatures on its surface reach 465 degrees, hot enough to melt down lead. Its atmosphere consists mainly of carbon dioxide with clouds of sulphuric acid, and only trace amounts of water has been detected in the atmosphere. Due to its atmosphere, the surface pressure is about 90 times that of the Earth.

Probes have actually been sent to this planet and landed on its surface. But because of the circumstances on it, they have only survived for a couple of hours before being destroyed. They managed to take a few images of its surface which you can see below.

The surface is furthermore very dry. There is no liquid water on it. If there were, the temperature would cause it to boil away.

It was brought up earlier that there are many volcanoes on Venus, actually thousands of them, that ranges from about 0,8 to 250 km. Besides the volcanoes, about 2/3 of the surface is covered by flat plains.

Venus takes 243 Earth days to rotate around its axis, which is the slowest of any of the main planets. Because of this spin rate, its metal core cannot create a magnetic field that is like the Earth's.

Also, while most planets rotate similar way on their axis, Venus does this the reverse way. This also means that the Sun rises and sets on the opposite sides. Lastly, one Venusian year is about 225 Earth days long. As mentioned, it takes 243 Earth days for it to rotate on its axis, which usually would mean that days on Venus would last longer than years. But because of its retrograde rotation, the time from one sunset to the next is "only" 117 Earth days long. Venus does not have a moon, just as Mercury.

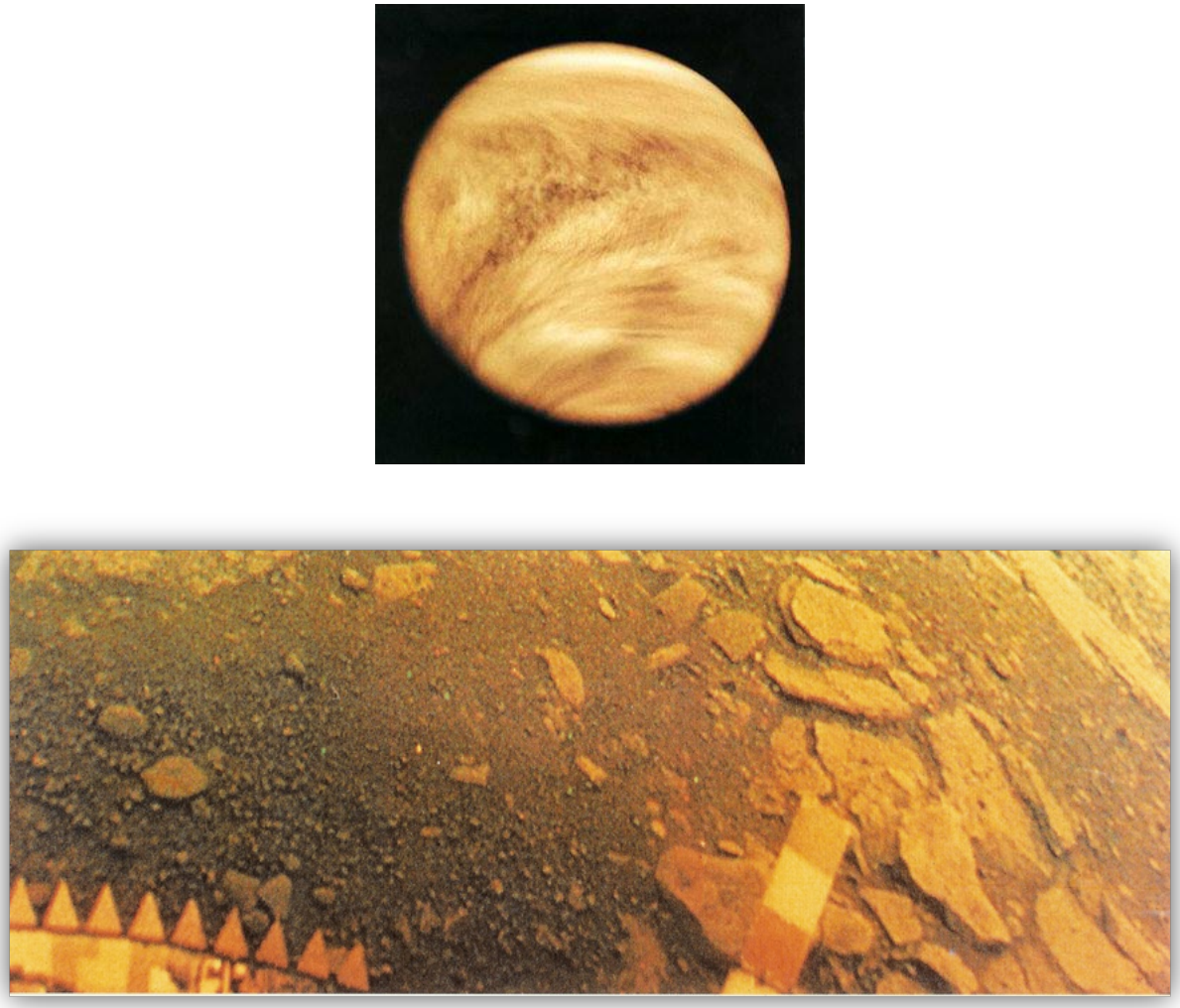

Figure 3: Venus at the top and t*he surface of Venus at the bottom* *Credit: ESA/NASA*

Earth

Earth, our planet, is the third from the Sun and the only known planet that has an atmosphere of free oxygen, liquid water and oceans on its surface, and the only one that hosts life. It´s the closest planet with moon: the Moon.

When it comes to the size of the planet, it is the fifth largest on among the Solar System planets. It has a diameter of roughly 13,000 km and about 71% of the surface is covered by water (most of it in the oceans that is). About 1/5 of its atmosphere is made up of oxygen that the plants has produced.

When it comes to the planet's axis of rotation, it is sloped relative to the ecliptic plane. This means that it will sometimes point toward or away from the Sun, depending on the time of the year. This leads to the varying amount of light they receive and causing the seasons we feel.

Figure 4: *The Earth Credit: ESA*

Mars

Mars, also known as the red planet, is the main planet when it comes for the search of life. Many rovers have being sent to Mars to learn more about its surface. The last rover Curiosity or the Opportunity rover (that still working on Mars since 2004) to see if there is or there were microorganisms on it before Mars' atmosphere mostly disappeared. As seen on the image to the bottom left, it has a rusty colour. The bright rust is known to be due of iron-rich minerals on its regolith.

Mars has also a thin and cold atmosphere, which means that liquid water at present cannot be present on its surface for any long period of time. That is, although this desert planet has just half of the diameter of the Earth, both of them have the same quantity of dry land. Despite that, it is believed that Mars had oceans many million years ago.

Mars is also the planet to the deepest, extended valley (Valles Marineris) and the highest mountain in the Solar System. This mountain, Olympus Mons, is approximately 27 km high. This is almost three times as tall as Mount Everest. Valles Marineris (system of valleys) can be as deep as 10 km and it runs from east to west for nearly 4,000 km. Mars also has the largest volcanoes in the Solar System, including Olympus Mons, which is about 600 m in diameter. It was formed by eruptions of lavas that streamed for long distances before becoming solid.

Channels, ravines, and valleys are to be found all over this planet. This proposes that liquefied water might have run across the surface of the planet not so long ago. Some of these channels can be 2,000 km long and 100 km wide.

Enormous deposits of water ice and dust can be found on its poles. These were most likely deposited by the atmosphere over long periods of time. On top of much of these coated deposits in both hemispheres are caps of water ice that stays frozen all year around. During the wintertime, extra seasonal caps of frost may appear. These are mostly made of solid carbon dioxide (dry ice) which has condensed from its gaseous state in the atmosphere. During the winter, this frost can spread from the poles to halfway to the equator, which is a huge difference compared to where it used to be.

Mars is much colder than our planet, and this is due to its bigger distance from the Sun. the average temperature is around -60 degrees Celsius, although they can change from -125 degrees Celsius near the poles (during the winter) to as much as 20 degrees Celsius at midday near the equator.

Lastly, Mars has two moons named Phobos and Deimos. It is believed that they both were captured by Mars from the asteroid belt helped by the gravitation force of Jupiter. Phobos is four times bigger than Deimos, and its orbit is closer to Mars. It also takes less time to complete an orbit than the rotation period of Mars so it moves from West to East rapidly.

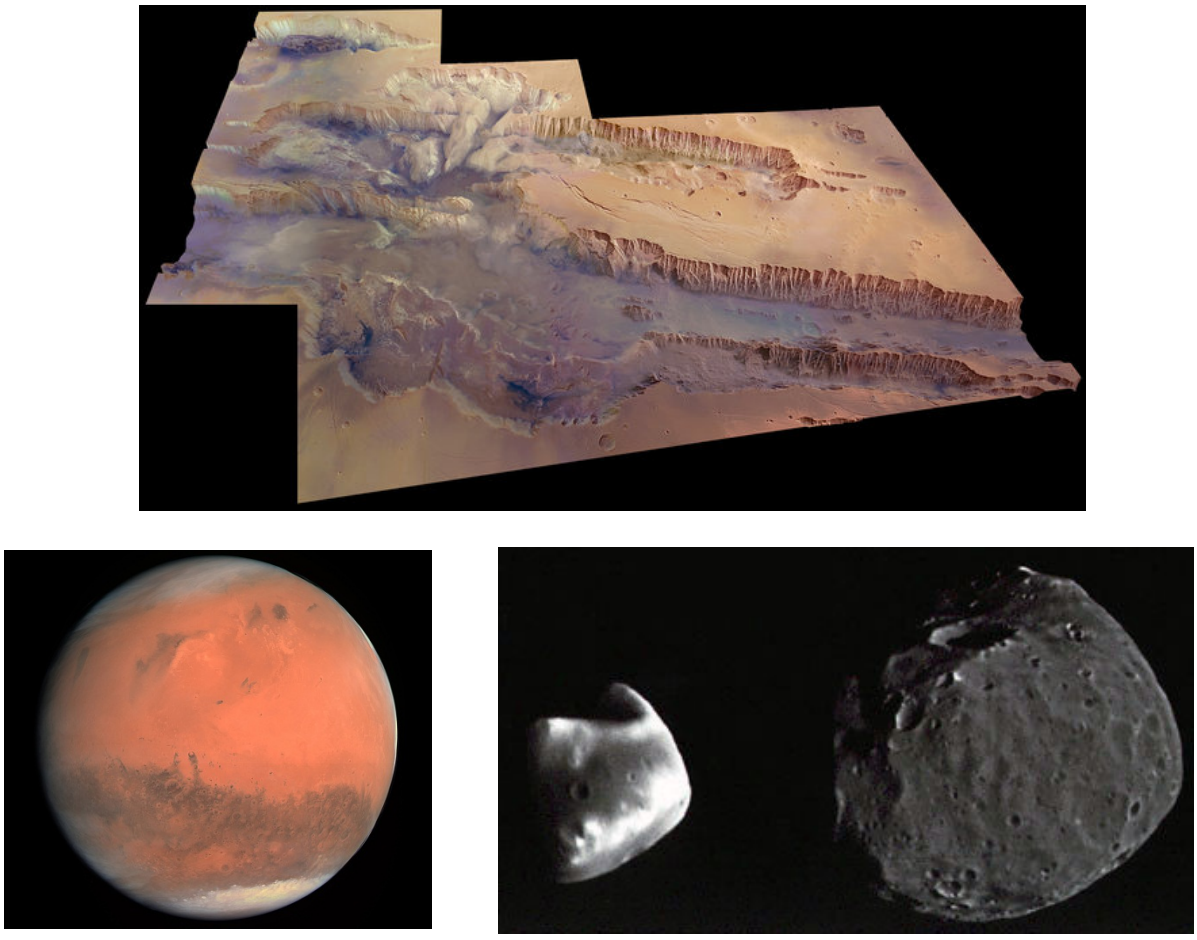

Figure 5: *The top image shows Valles Marineris. The bottom left image shows Mars and its poles and the bottom right image shows Phobos and Deimos.* *Credit: ESA*

Jupiter

Jupiter was first observed by Galileo Galilei in 1609 and its four biggest moons: Europa, Io, Callisto and Ganymede, also known as the Galilean moons. It is worth to mention that Jupiter has at least 63 moons! This was actually the first time celestial bodies were seen as bodies not orbiting the Earth and became the main support of the Copernican view of the Earth not being the center of our universe.

Jupiter is the biggest planet in our Solar System and is twice as huge as all the other planets joined. Only its volume could hold more than 1300 Earths. Had it been around 80 times more massive, we would have a second star.

Its atmosphere is similar to the Sun's, made up mainly of helium and hydrogen. The colourful bands of Jupiter are "divided" in light zones and dark belts. These are formed by strong winds travelling from east-west in the upper atmosphere of the planet. These can reach velocities that are more than 640 km/h! The white clouds (see the figure 6) in the regions are made of crystals of frozen ammonia, while the dimmer clouds are made of other chemicals that are found in the belts. The most amazing feature on the planet is the Great Red Spot. This spot is a hurricane-like storm that has been seen since Galileo's time. At its broadest it is three times the Earth's diameter and its edge turns counter clockwise around its center at a velocity of approximately 360 km/h. The colour of the storm usually varies from a reddish to slightly brown. This may come from small amounts of Phosphorus in the crystals from the Ammonia or Sulphur in the clouds of Jupiter.

Jupiter is also the fastest spinning planet, taking a little under 10 hours to complete a revolution on its axis, in comparison with the Earth's 24 hours. This spin rate actually makes the planet flatten at the poles and bulge at the equator.

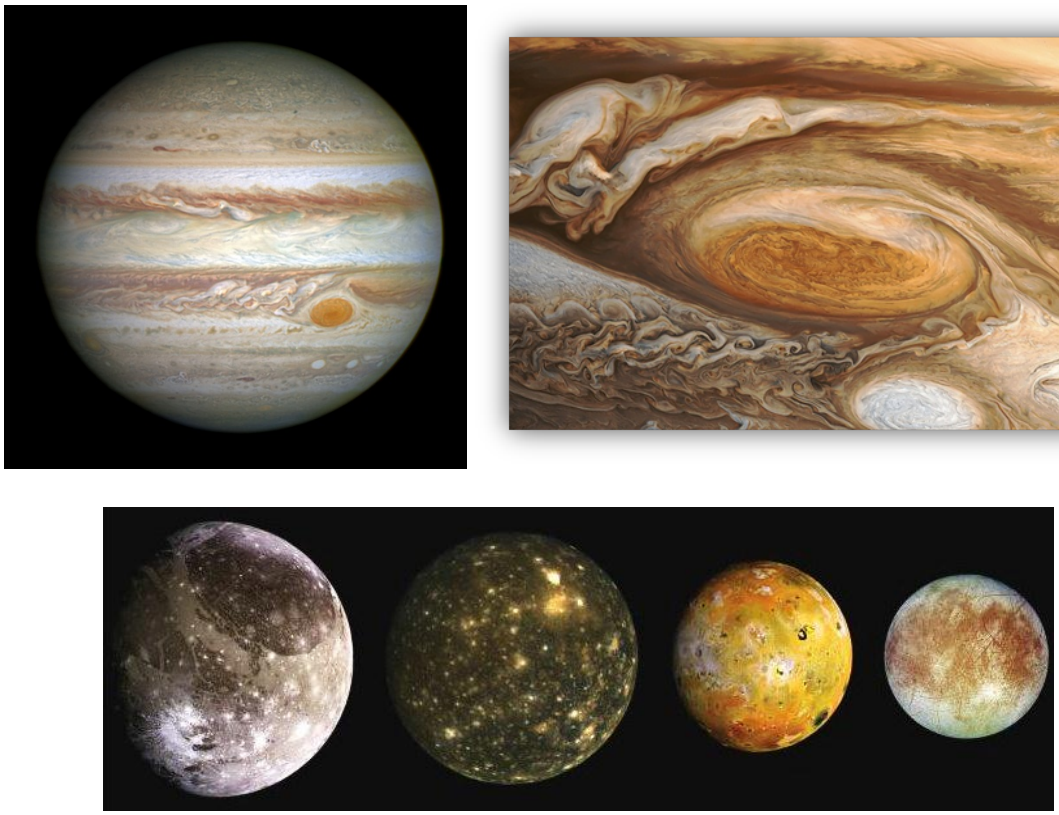

Figure 6: *Jupiter at the top left, Giant Red Spot at the top right and the four Galilean Moons at the bottom. Credit: ESA/NASA*

Saturn

The sixth planet from the Sun and the second largest (after Jupiter) is Saturn. Although the other gas giants in our Solar System (Jupiter, Uranus and Neptune) also have rings, only those of Saturn are the most eye-catching rings.

Saturn is a gas giant that is mostly made up of helium and hydrogen. It is big enough to hold more than 760 planets as big as the Earth and is roughly 95 times the mass of the Earth. However, Saturn is the planet with the lowest density of all the other ones, and is the only one that has a lower density than water.

Among all the planets, Saturn is the one farthest from Earth visible to the naked eye. With this we mean seeing the planet without using an instrument. When it is observed through a telescope, yellow bands seems to appear. These are found in its atmosphere and are the result of very fast winds in the upper atmosphere, which can reach up to 1,800 km/h around Saturn's equator. It is also the second fastest spinning planet after Jupiter, completing a rotation roughly every 10,5 hours. This fast spinning causes Saturn to flatten at its poles and bulge at its equator, just like Jupiter. It is actually around 13,000 km wider at its equator than between its poles.

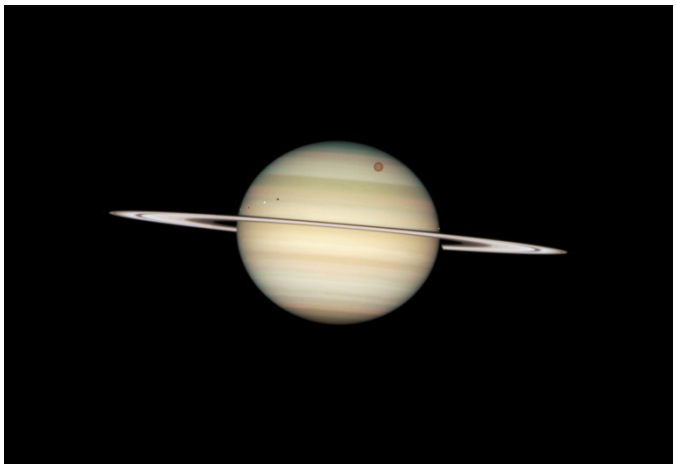

Figure 7: *Saturn with its visible rings and four of its moons.* *Credit: ESA*

Uranus

Uranus was mistaken for a star in many years, although it is visible to the naked eye. This was due to it being so dim and because of its slow orbit. It was also accidentally discovered by the British astronomer William Herschel with his telescope while surveying all the stars down to those about 10 times dimmer than can be seen by the naked eye. Uranus seemed different and within a year, it was shown to follow a planetary orbit.

Uranus's colour is close to a blue-green tone, the result of methane in its atmosphere that mostly contains of hydrogen and helium. 80% or more of its mass is made up of a fluid mix of methane, water, and ammonia ice particles. Not like the other planets, Uranus is tilted so much that it basically orbits the Sun on its side. This means that its axis of spin is almost pointing at the Sun. A theory is that Uranus might have collided with another planet-sized body after it was formed. Due to this, it has extreme seasons not like any other planet in the Solar System. The season are roughly 20 years long, which means that for almost ¼ of its year (about 84 Earth years), the Sun shines directly over each of the planet's poles. This leaves the other half of the planet without any sunlight, causing long, dark, and cold winter.

Not unlike the other gas giants, Uranus too has many moons. Today, there are 27 known moons orbiting it.

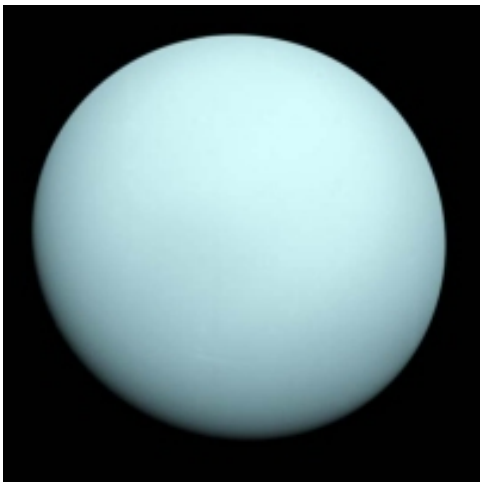

Figure 8: *Uranus and its rings. Credit: ESA*

Neptune

Neptune, the eighth planet in our Solar System, was discovered in 1846. Unlike the other planets, it is the only one that got its existence predicted by mathematical calculations before it was really observed with a telescope. The French astronomer Alexis Bouvard noticed irregularities in the orbit of Uranus and he put forward that the gravitational pull from another body might be the reason for this effect. The German astronomer Johann Galle then relied on successive mathematical calculations to help find Neptune via a telescope. And after many observations, Neptune was detected and a new planet became a part of our solar System.

The cloud cover of Neptune has an especially vivid blue colour that is partly due to an "unidentified (as-yet-unidentified)" chemical compound and the outcome of the red light absorption by the methane in its mainly hydrogen-helium atmosphere. Photos taken of Uranus (see the left image) reveal a blue coloured planet, and it is often called an ice giant, since it retains a thick, sentimental fluid mix or ammonia, methane and water ice particles under its atmosphere. The atmosphere is very thick, roughly 12 times the Earth's mass and almost 58 times its volume!

Neptune too has a core, a rocky one, and it is alone believed to be about the same mass as the Earth: a small one compared with its size. Regardless of its great distance from the Sun that leads to a small portion of sunlight that warms and moves its atmosphere the winds on Neptune can reach velocities up to 2,400 km/h, which is the fastest discovered in the Solar System.

Neptune too has a dark spot, just like Jupiter. This counter clockwise spinning, oval shaped spot is large enough to contain the entire Earth, and it moves westward at almost 1,200 km/h! The Hubble telescope spotted it and it is similar to Jupiter's that is a huge storm.

As mentioned, Neptune is the eighth planet and the most distant one from the Sun. Its oval shaped, elliptical orbit makes it keep an average distance of nearly 4,5 billion km. This is about 30 times the Earth-Sun distance (1 Au, that is 149 597 871 km), making it "invisible" to the naked eye.

Lastly, one year for Neptune equals 165 years, and it completed its first orbit in 2011 since it was discovered. Every 249 years, the dwarf planet Pluto passes "inside" the orbit of Neptune for 20 years more or less, in the course of which time it is closer to the Sun than Neptune. However, Neptune stays the farthest planet from the Sun, since Pluto became a dwarf planet in 2006.

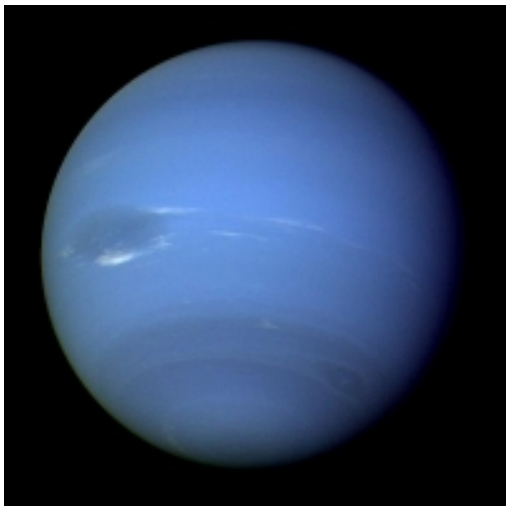

Figure 9: *Neptune and the dark spot Credit: ESA*