UNIT 1:

INNER PLANETS – OUTER PLANETS

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The Planets

Planets are celestial bodies orbiting the Sun in elliptical orbits. Unlike the stars, planets do not have their own light but reflect the sunlight. The brightest ones, like Venus or Jupiter, can be seen perfectly in the sky at first sight shinning more than any night star. However, we need optical instruments to find other planets, such as Uranus and Neptune. Our solar system consists of eight planets (after relegating Pluto to dwarf planet status in 2006), six of which, including Earth, are visible to the naked eye.

Are there planets around other stars? The answer to this question is yes. We call them **exoplanets** or **extrasolar planets**. When a star is born a **proto-planetary disk** is formed around it**,** composed of residual material from the formation of the star which ends up aggregating and forming planets. The great distances of these exoplanets to us and their proximity to the stars around which they orbit make it very difficult to detect them directly. So, how do we detect them? Through various methods of research and the study of light coming from the stars, astronomers have discovered over two thousand planets around other stars (more specifically, 2116 confirmed exoplanets as of May 3, 2016 [1]).

The Inner Planets

The inner planets are those whose **orbits**, that is to say, the paths that they describe around the Sun, are closer to our star than the one described by our planet, the Earth. That means that only Mercury and Venus are inner planets and their paths around the Sun are completed in less than a year, around 88 and 225 days, respectively.

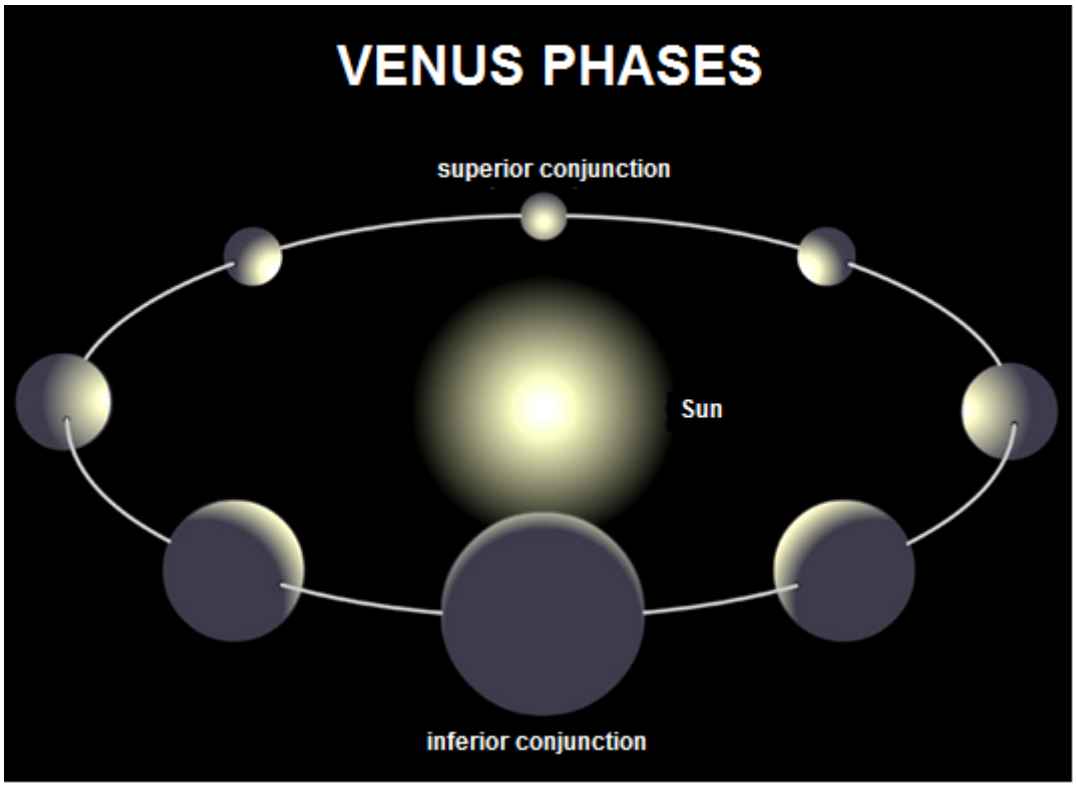
One consequence of being inner planets is that we will always see them in the sky near the Sun but never at midnight. For this reason the observation of Mercury is very complicated due to its proximity to the Sun. Mercury can be observed for only a brief period during either dusk or dawn. On the contrary, Venus is more easily observed than Mercury due to its larger orbit, and it can be observed from Earth with a largest sun separation. Venus can be seen up to 3 hours after sunset or 3 hours before sunrise.

At first glance Venus appears as the brightest object in the sky after the Sun and the Moon. It appears as a very bright and yellow light point. Sometimes it is even visible in sunlight, provided we know where to look.

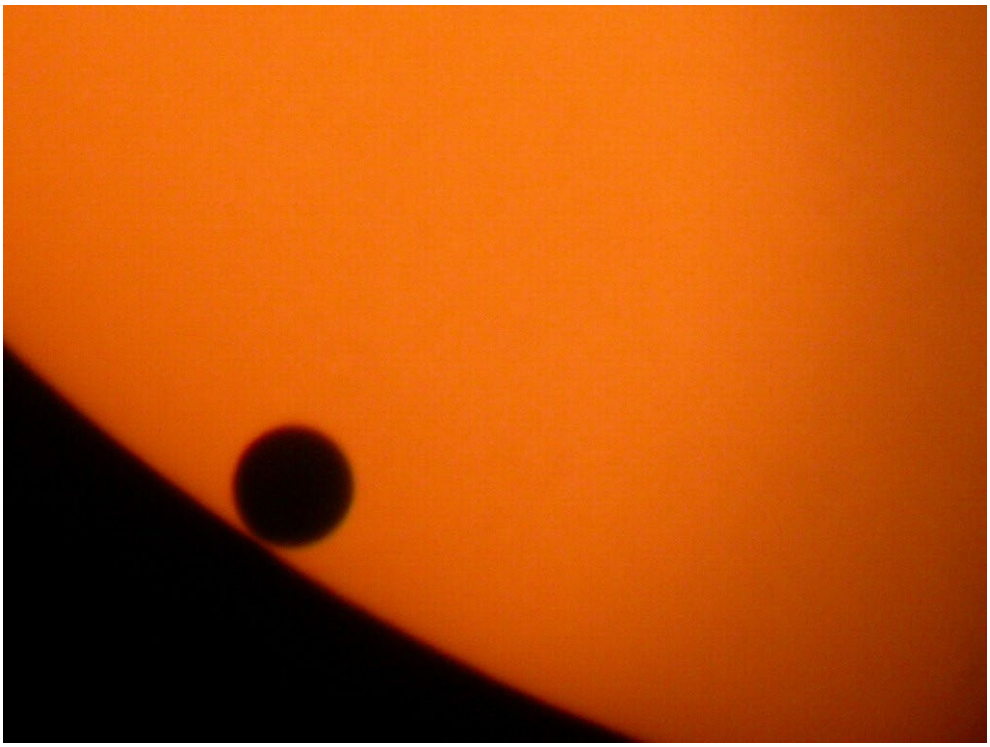
Observing Mercury with a telescope is quite difficult. For example, at dusk when we point with a telescope to that planet, we must do it closer to the horizon, so the atmospheric turbulence prevents us from seeing clearly its surface morphology. However, this is not the case of Venus, which appears higher in the sky once the Sun is below the horizon. Nevertheless, this planet has an atmosphere 90 times denser than the Earth, which prevents from seeing any surface characteristics. At best, some structure in its atmosphere may be observed, but only with the appropriate filters.

Through a small telescope Venus can be easily seen to have phases, which change appearance every week. These phases are similar to those of the Moon, when illuminated by the sunlight as it rotates around our planet.

The Moon is not always equally illuminated. Depending on its position relative to the Sun, the illuminated portion seen from our planet will be larger or smaller. This phenomenon is known as the **phases** of the Moon. With Venus it happens something similar, but it's not only the phase that changes but also the distance that separates us from the planet. This way, in Venus a phase change is accompanied by a change in the apparent size of the planet.



The orbit of Venus is slightly inclined relative to that of Earth. This causes that in **inferior conjunctions**, which means that the planet is between the Sun and the Earth, it goes above or below the solar disc. But sometimes, when Venus crosses the **ecliptic** (orbital plane of the Earth around the Sun), the planet passes in front of the solar disc, and it must be observed by using suitable solar filters. This phenomenon, which is called **transit** of Venus, is very rare; the last transit took place on 5 June 2012 and it was observed from the Pacific, and the next one will be in December 2117.



Transit of Venus in front of the Sun. Author: O. González

The name of Venus comes from the Roman goddess of beauty and love. It is the planet most similar to Earth on certain aspects: both have almost the same size, mass, gravity and density. But there are also significant differences. Venus has an extremely high atmospheric pressure, 92 times higher than the Earth. This high density and elevated concentrations of carbon dioxide in its atmosphere causes what is called greenhouse effect, resulting in an increase of the temperature in its surface, which is almost 480ºC. Its density is so high that solar radiation doesn't reach the surface of the planet, being reflected into space or absorbed by the atmosphere. As we couldn't see the surface of the planet it was impossible to calculate its rotation period. Nowadays and with the help of the radar, it is known that the planet rotation on its axis is carried out in 243 days, and surprisingly retrograde, that is to say, it turns in the opposite direction to the rest of planets in the Solar System.

Sky distances. Angles.

Angles are used in astronomy to express distances in the sky. When we say the Moon is 40 degrees from a given star, what we are really describing is the angle between our arms when we point one to the Moon and other to the star. This way you can describe any celestial object extent and location.

Angles are measured in degrees (°), arcminutes (') and arcseconds ("). A circle has 360° and a right angle 90°. Each grade is divided into 60 arcminutes (60'). For example, 1 Euro coin seen from side to side of a basketball court, has an angular diameter of about 1 arcmin. Every arcminute is divided into 60 arcseconds (60"). A car seen 100 km away would have an angular diameter of 8 arcsec (8").

Some celestial objects can provide angles references that will help us. For example, both the Sun and the Moon have 0.5 diameter degrees (30 arcmin); a large crater on the Moon can reach 1' (1 arcmin) size and a very distant planet as Uranus presents about 3" (3 arcsec) size. To see such a small angle you need to greatly increase the image and that is why we use telescopes.

Outer planets

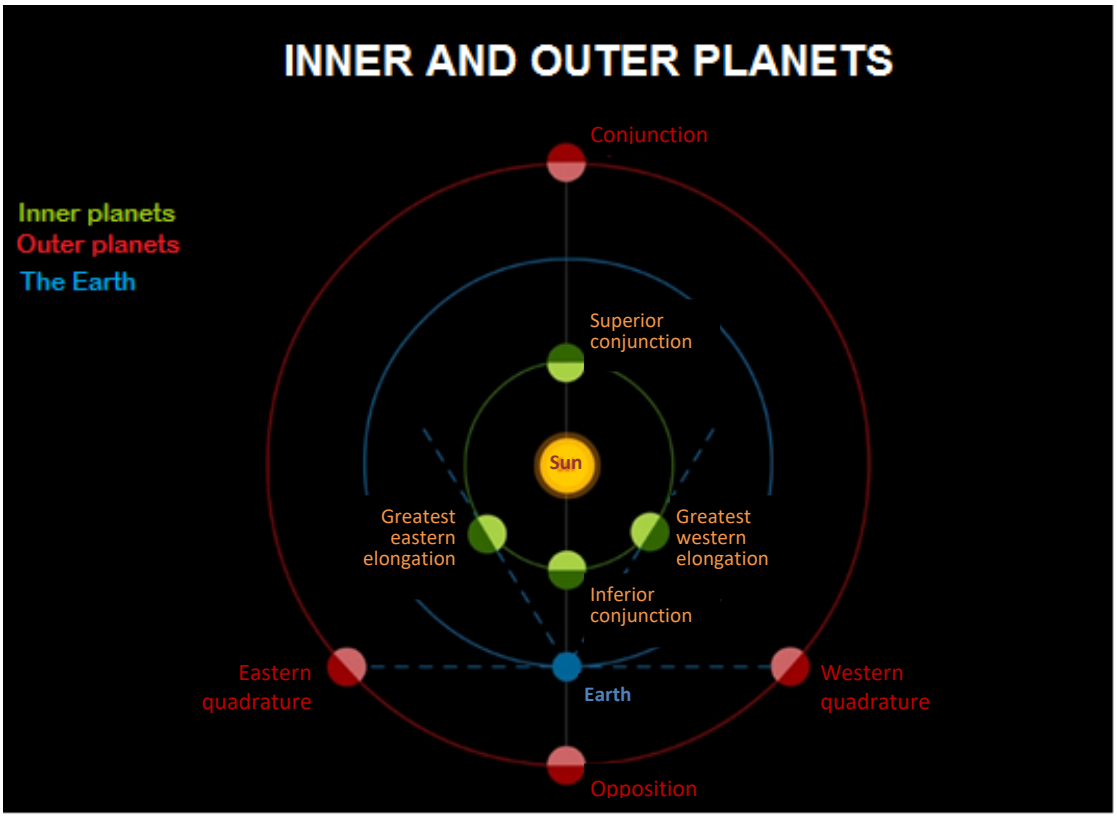
Outer planets are those whose orbits are further to the Sun than the one described by our planet, the Earth. So, Mars, Jupiter, Saturn, Uranus and Neptune are outer planets. The farther they are from the Sun, the longer it takes to them to turn around the Sun, so we can find **translational** periods up to 2 years, as it's the Mars case, and 164 years for Neptune.

Unlike inner planets, we can observe outer planets at midnight, at any height over the horizon and not necessarily near the Sun. Mars, Jupiter and Saturn are bright and easy to see; on the contrary, Uranus and Neptune are much further away and fainter, so we will need binoculars to observe them.

Seen from the Earth, planets can have different positions relative to the Sun, depending on whether they are inner or outer planets. As inner planets, outer planets are not visible during the **conjunction**, when they are moving behind the Sun. This planet disappearance lasts for a few weeks. Outer planets do not have inferior conjunction as inner planets do, because they do not pass between the Sun and us (that's why only Mercury and Venus produce solar transits).

Having a larger orbit than that of Earth, when the planet is in the opposite direction to the Sun we will see it rising on the eastern horizon just after the Sun sets on the western horizon. At that time the planet is said to be in **opposition** – in the opposite direction to the Sun -, and it coincides roughly with the date that the planet is closest to us (it may vary a few days because orbits aren't circular but elliptical).

In outer planets there is a great difference between the distance of the planet to the Earth when it is in conjunction – behind the Sun – or in opposition – in the opposite direction to the Sun -. This big difference between distances makes the planet to be seen through the telescope with very different apparent sizes, especially Mars, the closest to us.



Mars (considered by the Romans as war god) is the fourth planet from the Sun and also known as the “red planet” because of its reddish colour. Mars is about half the size of Earth and it rotates on its axis in 24 h and 37 min. Its rotation axis is tilted 25.2º, which produces a seasonal cycle, similar to the Earth.

Mars mass is 9 times less than Earth and its surface gravity is only about 38% of the surface gravity on Earth. In other words, an individual with a weight up to 75 kilograms on Earth, on Mars would weigh around 28 kilograms. Martian atmosphere is very thin, mainly consisting of carbon dioxide. With a very low density, the planet surface pressure is less than one-hundredth of ours. It has two small satellites, Phobos and Deimos with a diameter of about 22 and 13 kilometres respectively. Interestingly, all outer planets, together with Earth, have satellites, but inner planets don't.

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