



UNIT 1:

INNER PLANETS – OUTER PLANETS

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The Planets

Planets are celestial bodies that revolve around the Sun in elliptical orbits. Unlike stars, planets do not emit their own light but reflect the light that reaches them from our star, the Sun. The brightest ones, such as Venus and Jupiter, can be seen perfectly in the sky with the naked eye as very luminous stars (brighter than any star in the night sky); others, such as Uranus and Neptune, require optical instruments to locate them. Our Solar System consists of eight planets¹, six of which (including Earth) are visible to the naked eye. In 2006, Pluto and other similar planets that had been discovered recently were classified as **dwarf planets**.

Are there planets around other stars? The answer is yes. To differentiate them from the planets in the Solar System, we call them **exoplanets** or **extrasolar planets**. When a star is born, a **protoplanetary disk** forms around it, composed of leftover material from the star's formation, which eventually aggregates and forms planets. The great distances between us and these planets, and their proximity to the stars around which they orbit, make it very difficult to see them directly, so we currently have very few images of exoplanets obtained with very powerful telescopes.

¹ Official number recorded as of June 2025.

So how do we detect them? Thanks to a variety of research methods and the study of light from stars, nearly six thousand planets have already been found orbiting other stars (there are exactly 5,976 confirmed exoplanets as of June 4, 2025 ²).

The Inner Planets

The inner planets are those that have **orbits**, or paths around the Sun, that are closer to the Sun than Earth's orbit. This means that only Mercury and Venus are inner planets, and they complete their orbits around the Sun in less than a year, in about 88 and 225 days, respectively.

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One consequence of being inner planets is that we will always see them in the sky near the Sun and they will never be visible at midnight. This is why Mercury is so difficult to observe, as it is so close to the Sun that we have to wait until it is far enough away from it (as seen from Earth) to be able to observe it at twilight, just after the Sun sets on the western horizon, or at dawn, shortly before the Sun appears on the eastern horizon. Venus, on the other hand, can be seen much better than Mercury because it has a larger orbit and can be observed from Earth at a greater distance from the Sun. Venus can be seen up to 3 hours after sunset or up to 3 hours before sunrise.

At first glance, Venus appears to be the brightest object in the sky after the Sun and the Moon, and it looks like a very bright, yellow point of light. When it is at its brightest, it is visible in broad daylight even to the naked eye, as long as we know where to look.

Observing Mercury with a telescope is quite difficult. When we point a telescope at this planet, for example at sunset, we are pointing it very close to the horizon, so atmospheric turbulence prevents us from seeing the morphology of its surface clearly. This is not the case with Venus, which appears much higher in the sky once the Sun is below the horizon. However, this planet has an atmosphere about 90 times denser than Earth's, which blocks our view of its surface features. At best, we can observe some structures in its atmosphere with the appropriate filters.

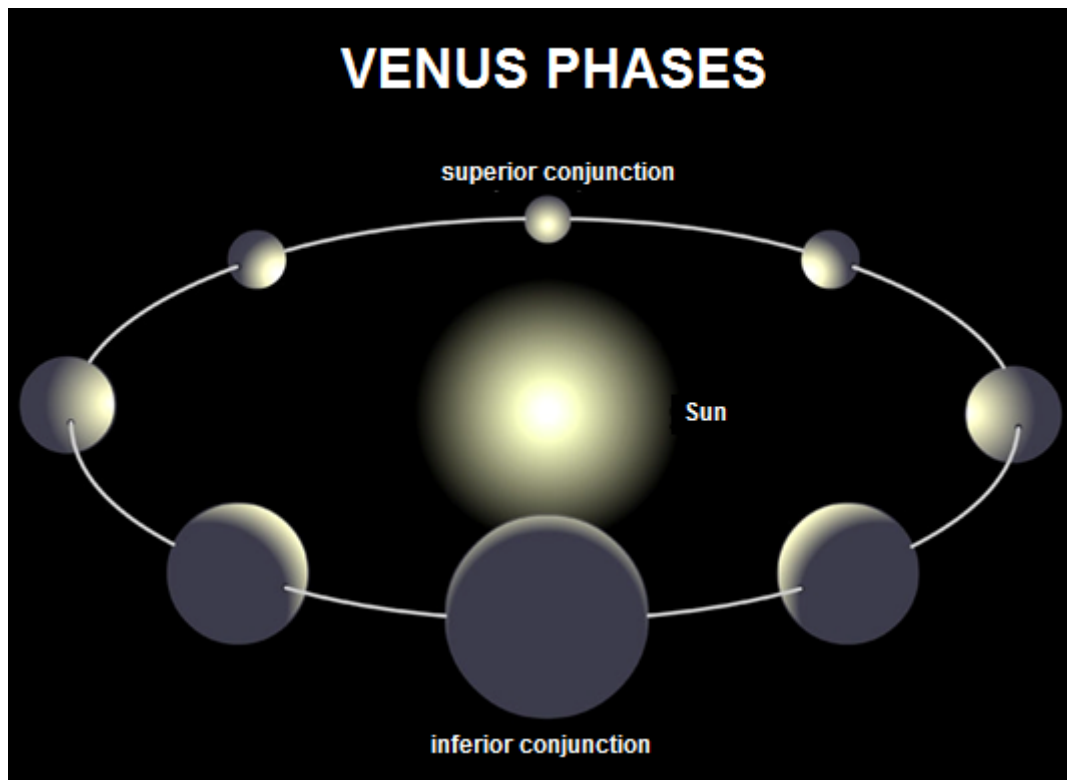
One thing that is easily recognisable on Venus, even with a small telescope, are the phases that this planet presents, which change its appearance from week to

² *The Extrasolar Planets Encyclopedia* (<http://exoplanet.eu/>).

week. These phases are similar to those shown by our satellite, the Moon, when illuminated by the Sun during its cycle.

We do not always see the Moon illuminated in the same way. 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. Something similar occurs with Venus, but in addition to changing phases, the distance between us and the planet also changes considerably. Thus, on Venus, a change in phase is accompanied by a change in the apparent size at which we see the planet.

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Venus' orbit is slightly tilted from that of Earth. This causes it to pass above or below the solar disc during **inferior conjunctions**, which is when the planet is between the Sun and Earth. However, on certain occasions, when Venus crosses the **ecliptic** (the plane in which the Earth orbits around the Sun), the planet passes in front of the solar disc and can be observed using appropriate solar filters.

This phenomenon, known as the transit of Venus, is very rare. The last one occurred on 5 June 2012 and was seen from the Pacific, and the next one will be in December 2117.



Transit of Venus across the Sun. Author: O. González

The name Venus comes from the Roman goddess of beauty and love. It is the most Earth-like planet in some ways: both have roughly the same size, mass, gravity and density. But there are also notable differences. The atmospheric pressure on Venus is 92 times greater than that on Earth. This high atmospheric density and high concentration of carbon dioxide cause what is known as the greenhouse effect, with a consequent increase in surface temperature to around 480 °C. Its density is so high that solar radiation barely reaches the planet's surface, as it is reflected back into space or absorbed by the atmosphere. As the planet's surface could not be seen, it was impossible to calculate its rotation period, as the only thing that could be observed was the rotation of its atmosphere, which varies from the equator to the poles. Today, thanks to radar, we know that the planet rotates on its axis in 243 days and, surprisingly, in a retrograde manner, i.e. it rotates in the opposite direction to the other planets in the Solar System.

Sky distances. Angles.

In astronomy, we use angles to indicate distances in the sky. When we say that the Moon is 40° from a certain star, what we're actually describing is the angle formed by our arms when we point one towards the Moon and the other one towards the star. This way, we can describe the size and location of any celestial object.

Angles are measured in *degrees* ($^\circ$), *arcminutes* ($'$) and *arcseconds* ($''$). A circle has 360° and a right angle has 90° . Each degree is divided into 60 *arcminutes* ($60'$). For example, a 1 euro coin seen from one end of a basketball court to the other has an angular diameter of approximately 1 *arcminute*. Each *arcminute* is divided into 60 *arcseconds* ($60''$). A car seen from 100 *km* away would have an angular diameter of 8 *arcseconds* ($8''$).

Some celestial objects can provide us with reference angles that will be helpful. For example, both the Sun and the Moon have 0.5° in diameter (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

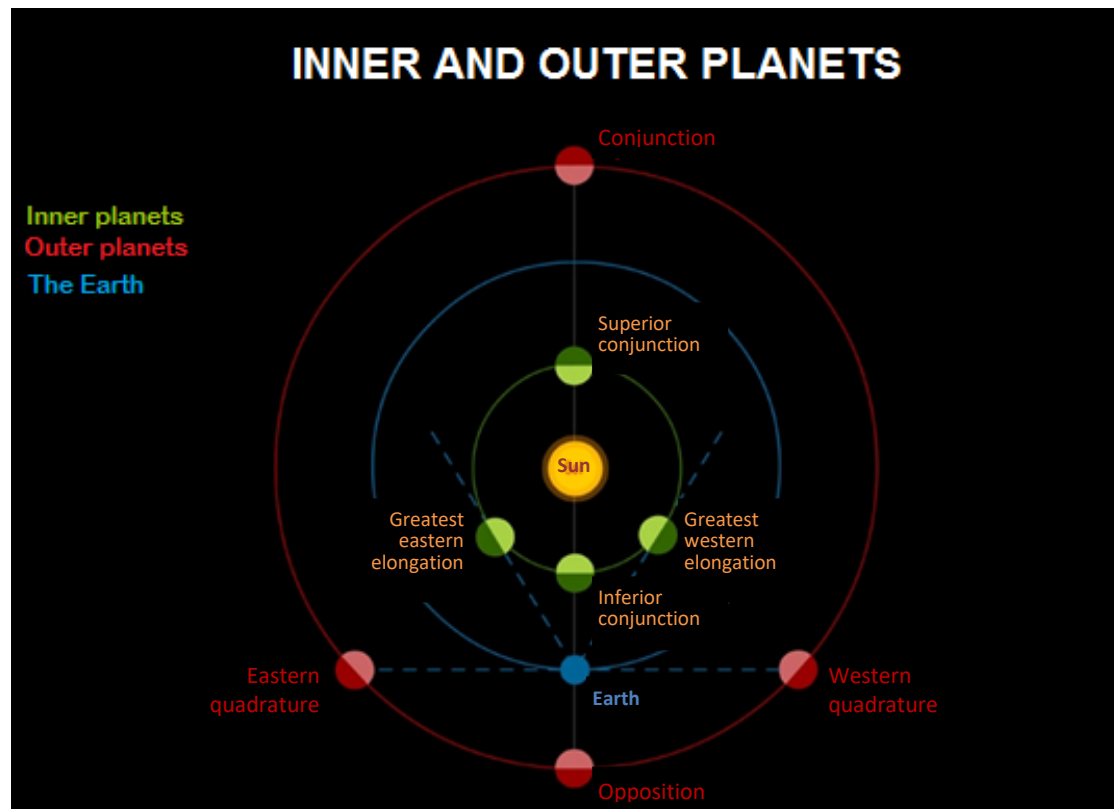
Outer planets are those with orbits that are further to the Sun than the one described by our planet, the Earth. So, Mars, Jupiter, Saturn, Uranus and Neptune are outer planets. The farther they are from the Sun, the longer it takes to them to revolve around the Sun, as a consequence, we can find **translational**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

Unlike inner planet, outer planets can be observed 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 and fainter, so we 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.



Representation of the orbits of the outer and inner planets, not to scale.

Mars (the god of war for the Romans) is the fourth planet closest to the Sun and, as it appears reddish in the sky, it is often called 'the red planet'. It is slightly larger than half the size of Earth and rotates on its axis in 24 hours and 37 minutes. This axis of rotation is tilted by 25.2° , which produces a seasonal cycle similar to that of Earth, as we can see by observing how, throughout the Martian year, its two polar caps vary in size as the seasons pass.

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.

For further information, visit our website: www.iac.es/peter

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INNER AND OUTER PLANETS