VIRTUAL PATHWAYS

Galileo and the Celestial Phenomena

Pre-visit

(High school, age 14-18)

Introduction

This is the support document for the pre-visit phase of the Educational Pathway "*Galileo and the Celestial Phenomena*" aimed at both teachers and students.

Short description
The activity, structured in three phases (pre-visit, visit and post-visit) focuses on the transition from pre-telescopic astronomy to modern astronomy inaugurated by Galileo, with particular attention to his observation of celestial phenomena and in particular sunspots and the Northern Lights.

Target audience
Teachers and students of High school (age 14-18)

Estimated time required for the activity
In school: 5-6 hours (2-3 pre-visit and 3 post-visit)
In the museum (on site or virtually): 1,5 hour

For more information visit:
https://www.virtualpathways.eu/

https://www.museogalileo.it/en/library-and-research-institute/projects/european-projects/2134-virtual-pathways.html

The birth of astronomy and the Geocentric System

How was the sky imagined in antiquity?
Who were the first observers?
Why was the sky observed?

Primitive peoples have always been fascinated by everything related to the sky: stars, planets, and strange celestial phenomena. Sailors oriented themselves at sea by looking at the stars, while farmers used them to decide when to sow. The sky has therefore always represented an important reference point for mankind.

Observing the celestial vault, thanks to a little imagination and creativity, the constellations took shape: groups of easily recognisable nearby stars whose shape and characteristics recalled animals or objects of daily life such as, for example, the constellation Ursa Major or the so-called Orion Belt. Observing them in the sky, people guessed their movements and sought explanations.

Starting from the Mesopotamians and the ancient Egyptians, people began to scrutinise the sky more and more and were able to determine the movements of the planets visible to the naked eye: Mercury, Venus, Mars, Jupiter and Saturn. When they observed the movement of the Moon, they noticed that it had phases that were repeated in well-defined times. Moreover, thanks to their great ability in performing mathematical calculations, they were able to determine the duration of the day, which they divided into 24 hours, and of the solar year.

Their representation of the Universe was, however, strongly linked to mythological elements. For example, for the Assyro-Babylonians, the Earth rested on the Kingdom of the Dead, submerged by the ocean waters, and dominated by the celestial vault, while for the Indian culture the universe was initially enclosed in a gigantic egg from which, once hatched, the sky emerged from the upper half of the shell, and the earth from the lower half of the shell.

The predominant model throughout antiquity was the geocentric one which saw the Earth immobile at the center of the Universe and the other celestial bodies rotate around it with circular and uniform motions.

In the geocentric system all celestial bodies orbit Earth following this order: Moon, Mercury, Venus, Sun, Mars, Jupiter, Saturn, and the fixed stars located on the celestial sphere.
Museo Galileo, Florence

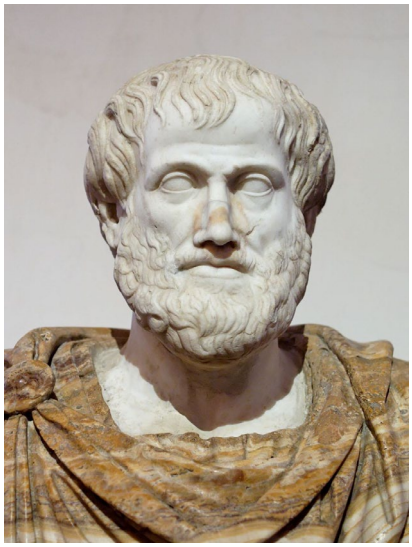
T	*The celestial sphere* https://catalogue.museogalileo.it/indepth/CelestialSphere.html
▶	*Pretelescopic astronomy* https://catalogue.museogalileo.it/multimedia/PretelescopicAstronomy.html
▶	*Arab astronomy* https://catalogue.museogalileo.it/multimedia/ArabAstronomy.html
▶	*Models of the heavens* https://catalogue.museogalileo.it/multimedia/ModelsHeavens.html

Aristotelian cosmology

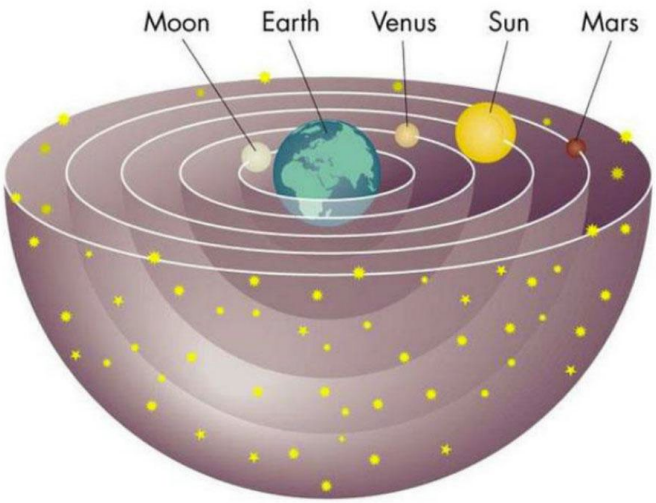
Aristotle, who lived in Greece in the 4th century BC, taking a cue from the ideas of his predecessors, claimed the existence of a clear separation between the terrestrial world, known as the sublunar world, and the celestial world: the former was the realm of instability and imperfection, and was therefore characterised by rectilinear movements, i.e. movements with a beginning and an end, while the latter was the realm of eternity and perfection, and was characterised by circular movements since the circle was the perfect geometric figure by definition.

The Earth was conceived to be motionless at the centre of the Universe, with a series of concentric spheres around it, on which the other visible planets were fixed in succession, that is, in order: Moon, Mercury, Venus, Sun, Mars, Jupiter and Saturn. Finally, there was a last sphere, the Firmament, also known as the sphere of the “fixed” stars, so called because, unlike the planets, they seemed anchored to the celestial vault since they never changed their position. This last sky of the fixed stars was also called the "*Primum mobile*" because it was the first to give the initial movement to all the others.

The stars around the Earth were placed on a particular sky, a sphere made of ether, a transparent, perfect and immutable material, which moved with uniform circular motion. The model thus described was the so-called 'geocentric system'.



Bust of Aristotle. Palazzo Altemps, Rome

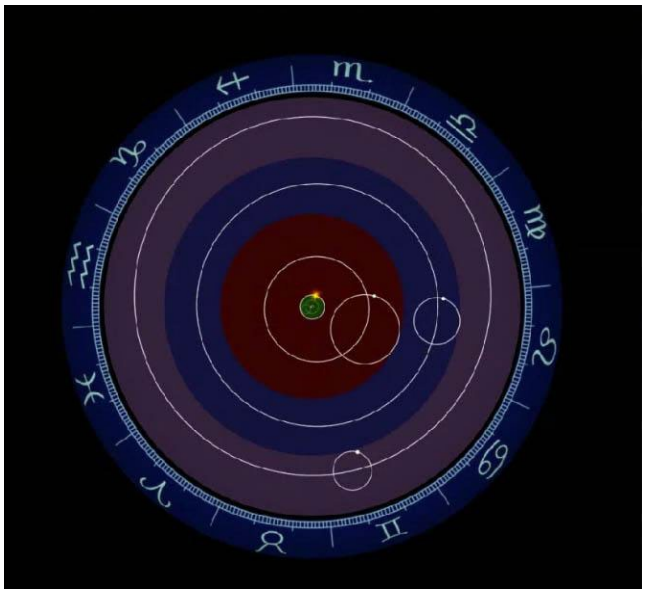


Model of the Universe according to Aristotle

Ptolemaic System

Aristotelian theory, however, could not explain the so-called "retrograde movement of the planets": unlike the stars, which move in a circular pattern on the vault of the night sky, the motion of the planets observed from Earth occasionally form noose-like figures in their trajectories. This did not suit the "circular perfection" of their movements, and therefore in order to try to save the Aristotelian model from this "movement defect", complicated corrections were devised. The Alexandrian astronomer Claudius Ptolemy, who in the second century AD developed and introduced a number of modifications that centuries later would have been in harmony with the Church's geocentric vision, distinguished himself in these laborious operations. In fact, thanks to the cultural synthesis made by the Christian theologian and philosopher Thomas Aquinas (1225-1274) between the Christian tradition and Aristotelian thought, the Ptolemaic model was universally accepted by the Church, which considered it as the official cosmological theory.

This worldview was widely accepted by the Catholic Church because it placed the Earth, and therefore the human race that inhabits it, at the centre of the universe created by God. The geocentric model, supplemented by Ptolemy's, was therefore recognised as the only one possible until the time of Copernicus and Galileo.



Ptolemaic System. Museo Galileo, Florence

Andreas Cellarius, *Atlas coelestis seu Harmonia Macrocosmica*. Ptolemaic System

Ptolemaic System
https://catalogue.museogalileo.it/multimedia/PtolemaicSystem.html

Copernican system

Nicolaus Copernicus, Polish by birth, German by language, Italian by university education, was the scientist who founded modern astronomy between the 15th and 16th centuries.

Despite the Ptolemaic modifications, the geocentric system still did not fully convince scholars. Among them was Nicolaus Copernicus (1473-1543) who, in opposition to the Ptolemaic theory, presented in his most famous work, *De revolutionibus orbium coelestium*, the heliocentric theory of celestial motions: the Sun is motionless in the center of the universe and the planets, including the Earth, revolve around it. Earth is therefore no longer immobile at the centre of the universe, but completes a revolution around the Sun in one year and one rotation on its axis in 24 hours. This was a shocking innovation and his writings became the basis for the study of the greatest astronomers of the modern age, first and foremost Kepler, Galileo and Newton.

The new Copernican conception seemed to finally show the perfect harmony of the cosmos: six planets all revolving around the Sun and always in the same direction.

The Copernican model, however, was for a long time regarded with suspicion by the ecclesiastical authorities because, unlike the Aristotelian-Ptolemaic geocentric system, it placed the Earth in a decentralised position, and therefore not fundamental, in the universe created by God. For this reason in 1616 the first formal condemnation of Copernicanism by the Catholic Church was issued, and four years later, Copernicus' book was included in the Index of Prohibited Books by the Holy Office (*Sanctum Officium*), that is, the books that the Catholic Church forbade to read because their contents were not in line with their theories.

Andreas Cellarius, *Atlas coelestis seu Harmonia Macrocosmica*. Copernican System

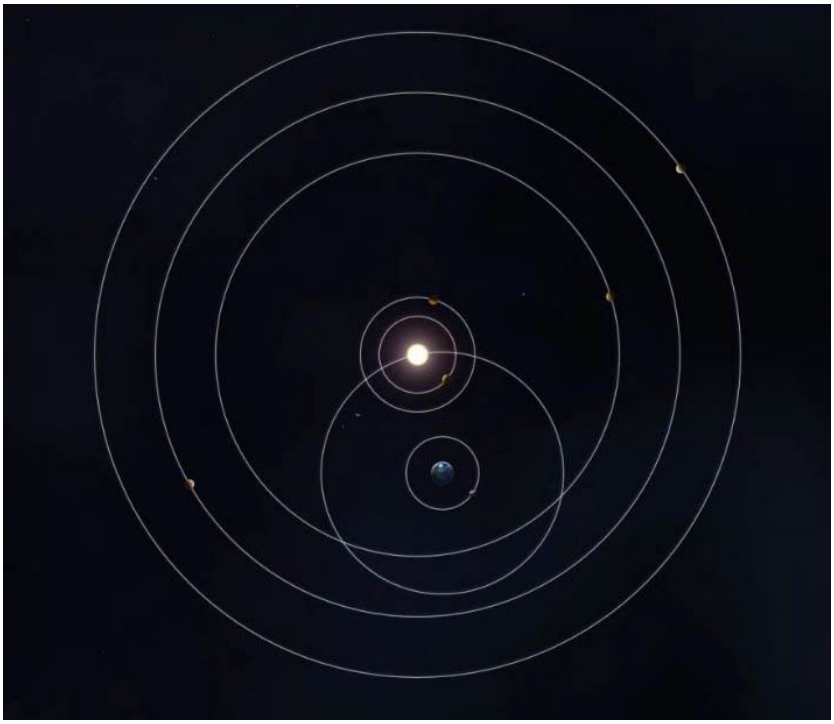
Copernican system
https://catalogue.museogalileo.it/multimedia/CopernicanSystem.html

Tycho Brahe's system

Tycho Brahe (1546-1601) can be considered the greatest naked-eye observer of the sky. Without the aid of the telescope and regardless of economic expenses, in his observatory at Uraniborg in Denmark, he carried out a rich research program, having the most up-to-date equipment of his time and highly trained assistants, including Johannes Kepler who, with his laws of planetary motion, supported Copernicus' heliocentric theory of the solar system.

The Copernican model was not supported by many in the Church. So they preferred to support an alternative and intermediate cosmological model between the geocentric system and the heliocentric system: the so-called Tychonic system.

According to the model developed by the Danish astronomer Tycho Brahe, the Earth is placed motionless at the center of the Universe; the Moon and the Sun orbit around it, while the other planets Mercury, Venus, Mars, Jupiter and Saturn orbit around the Sun.



Tycho Brahe's system. Museo Galileo, Florence

Andreas Cellarius, *Atlas coelestis seu Harmonia Macrocosmica*. Tycho Brahe's System

Tycho Brahe's system
https://catalogue.museogalileo.it/multimedia/TychoBrahesSystem.html

Astrolabe

How did people in the past orient themselves with the stars?

This is an ancient astronomical instrument, apparently known as early as the 2nd century BC. It was used to solve astronomical problems without the need to resort to complex calculations: for example, it was possible to determine the position of the stars and to understand which ones were rising and which ones were setting. It was also important for solving more practical problems such as determining the time of day and calculating the height and distance of objects.

How it is made

It looks like a kind of clock with indexes and rotating disks studded with circles and flame-shaped cusps, but in reality it is simply a perspective representation of the sky visible at a certain latitude. It is composed of several parts, some fixed and others movable, held in place by a central pin.

How to use it

By means of a suspension ring, the instrument is held vertically. In the center there is a rod, called an alidade, which acts as a viewfinder to point a reference star through the two small holes at its ends.

Astrolabe components. Museo Galileo, Florence

Christoph Schissler, Plane astrolabe (1560).
Museo Galileo, Florence

Astrolabe
https://catalogue.museogalileo.it/indepth/Astrolabe.html

Stereographic projection
https://catalogue.museogalileo.it/multimedia/StereographicProjection.html