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Models of the Universe

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Cover: Ptolemy and the astrolabe
After Peurbach, Theoricum Novarum Textus, Paris, 1515

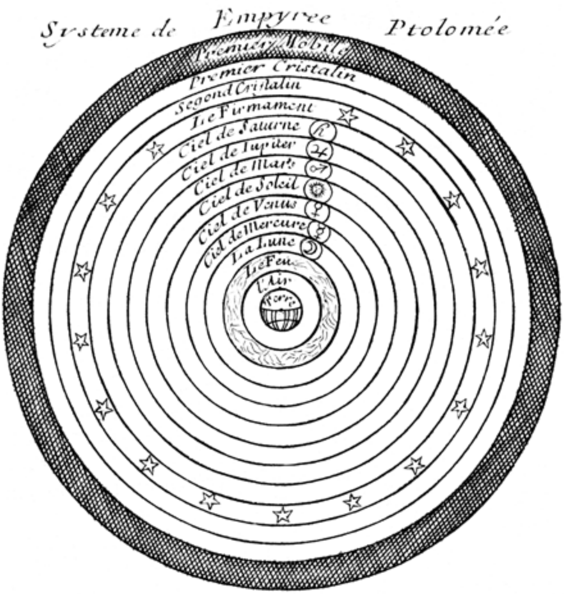
This booklet brings together a number of emblematic objects from the collections of the Musée d'histoire des sciences, designed to represent the world and sky around us. Some of them are simple measuring instruments, while others, richly decorated, evoke the power and might of those who owned them.

Tellurium
MHS 649
Steel, brass, paper, Van Aken, Netherlands, 18th century

The geocentric universe of the ancient Greeks

In the 4th century BC, Aristotle (384-322 BC), whose thought would strongly influence the Western world until the Renaissance, conceived of the Universe as a system of concentric spheres carrying the planets and stars and placed around a central, immobile Earth.

In the second century AD, the Greek geographer Ptolemy (100-168) modernised and updated Aristotle's geocentric vision. He geometrically broke down the movement of the planets into multiple circles. Ptolemy's astronomy was to be the reference for Western scientists until the 17th century. Thanks to this geometric representation of the world, Ptolemy was able to draw up the first truly reliable and accurate astronomical tables.



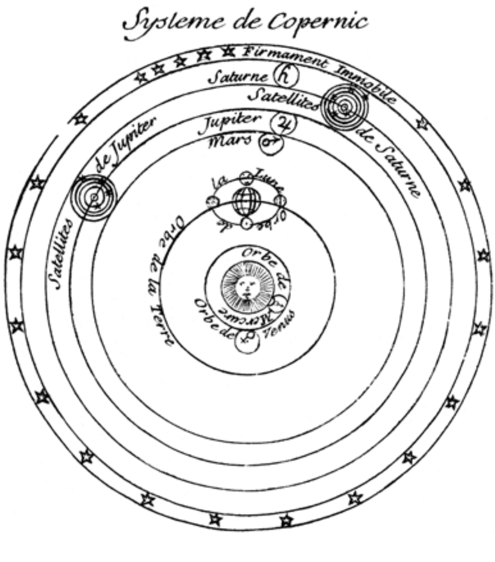
The Ptolemaic geocentric system
Nicolas Bion. L'usage des globes célestes et terrestres et des sphères, suivant les différents systèmes du monde, Paris 1699
Library of the Musée d'histoire des sciences

The sun at the centre

In the mid-16th century, the Polish physician and canon Nicolaus Copernicus (1473-1543) proposed a new system of the world centred on the Sun rather than the Earth, to make it easier to calculate the movement of the planets in the astronomical tables. At this time, astronomy and astrology were closely linked. Working for princes and kings, astronomers had to use these tables to predict certain celestial events (eclipses, alignment of planets, etc.) likely to influence the destiny of their powerful sovereign.

In his book *De Revolutionibus orbium coelestium*, published in the year of his death, Copernicus defended his heliocentric vision by asserting, among other things, that not only did the Earth revolve around the Sun like the other planets, but also that it rotated on its axis like a spinning top (precession).

The astronomical tables derived from Copernicus' model soon proved to be superior to the traditional tables based on Ptolemy's geocentric representation.



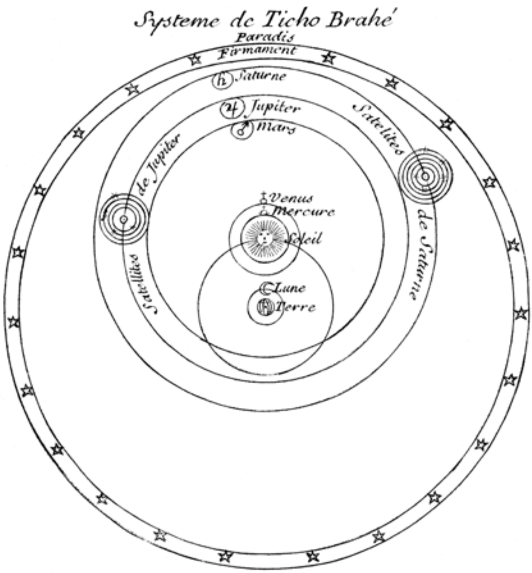
Copernicus' heliocentric system
Nicolas Bion. L'usage des globes célestes et terrestres et des sphères, suivant les différents systèmes du monde, Paris 1699
Library of the Musée d'histoire des sciences

Tycho Brahe’s universe: a mix of geocentrism and heliocentrism

Before the invention of the telescope, the Danish astronomer Tycho Brahe (1546-1601) made his own instruments, based on surveying and topographic tools, to determine the position of the stars and planets.

On the basis of his observations, he devised his own system of the world, which was a sort of compromise between the geocentrism of Ptolemy* and the heliocentrism of Copernicus. The Earth remained immobile at the centre of the universe. Around it orbits the Sun, which drags all the other planets revolving around it.

In 1609, the German mathematician Johannes Kepler (1571-1630) used the measurements of Tycho Brahe, whose assistant he then became, to demonstrate by calculation that the orbits of the planets are ellipses with the Sun as one of their foci. Kepler derived two other laws from this (the law of areas and the law of periods), which the English physicist Isaac Newton used to formulate his famous law of gravitation in 1687.



Tycho Brahe’s geoheliocentric system
Nicolas Bion. L’usage des globes célestes et terrestres et des sphères, suivant les différents systèmes du monde, Paris, 1699
Library of the Musée d’histoire des sciences

The armillary sphere is one of the oldest instruments to represent the universe. It was probably invented by Archimedes (287-212 BC.) in 250 BC. The Greek astronomer Ptolemy* wrote about it in his work *Almagest* in about 150 AD. The armillary sphere made it possible to show both the sky and the earth from wherever the observer was located. In order to keep a clear picture, the instrument is constructed of rings (armilla meaning bracelet in Latin) representing the principal circles of the heavens (ecliptic*, meridian*, tropics*, equator*, polar circles*, etc.) as well as the celestial bodies (sun, moon, planets). There are two types of armillary sphere: Ptolemaic spheres representing a geocentric universe and Copernican spheres which place the sun at the centre of the universe.

In Europe, armillary spheres became very popular at the dawn of the Renaissance in the 16th century. Not only were they able to determine the position of the stars at different times of the year, they were also useful for astronomical demonstrations. Towards the end of the 17th century, the use of armillary spheres as scientific instruments ended and they became luxury decorative objects in copper or engraved gold gracing the salons of princes and emperors.

Geocentric armillary sphere
MHS 1344
Paper, wood, Delamarche, France,
19th century

** see glossary, p. 16*

Astrolabe

This luxurious, beautiful and complex instrument symbolised the power of knowledge. It was invented by the ancient Greeks before being taken up by the Arabs and then by the West at the end of the Middle Ages. Its applications are numerous: measurement of the altitude of stars, determination of the position of the stars according to the day of the year, prediction of sunrise and sunset, surveying, etc.

With regard to astronomy, the astrolabe gives a “flat” representation of the celestial sphere according to the stereographic projection developed by Ptolemy*. The map of the heavens is symbolised by the framework, an intricately engraved and cut mobile trellis on which each point indicates a star. The framework turns above a plate, or tympan, on which the main celestial coordinates* are marked (altitude, azimuth) in relation to an observer at a specific latitude on earth. The rotation of the framework over the tympan reproduces the movement of the sky around the earth (assumed to be stationary) every 24 hours.

Indo-moroccan astrolabe
MHS 1051
Copper, brass, Maroc, India, 14th-19th century

** see glossary, p. 16*

Planisphere

When the production of astrolabes ceased in the 18th century, they were replaced by cardboard celestial charts, which were much simpler and more affordable for amateur astronomers. Also known as star finders or planispheres, these maps are still made today, the only difference being that the original cardboard has been replaced by plastic. They generally consist of two superimposed cardboard or plastic discs. The first, which is fixed, represents the vault of heaven with the main stars of the sky centred on the pole. The second disc - the local horizon - has an eliptical window. The window shows the stars visible from a specific point on Earth at a given time. The celestial vault is graduated around the circumference with the days of the year, and the local horizon with the hours of the day.

To obtain the sky of a particular day, the calendar date must coincide with the time of observation. All you have to do is place the map over your head taking care to align its cardinal directions with those of the Earth. Very easy to use, these maps have one drawback: they can only be used for a given latitude.

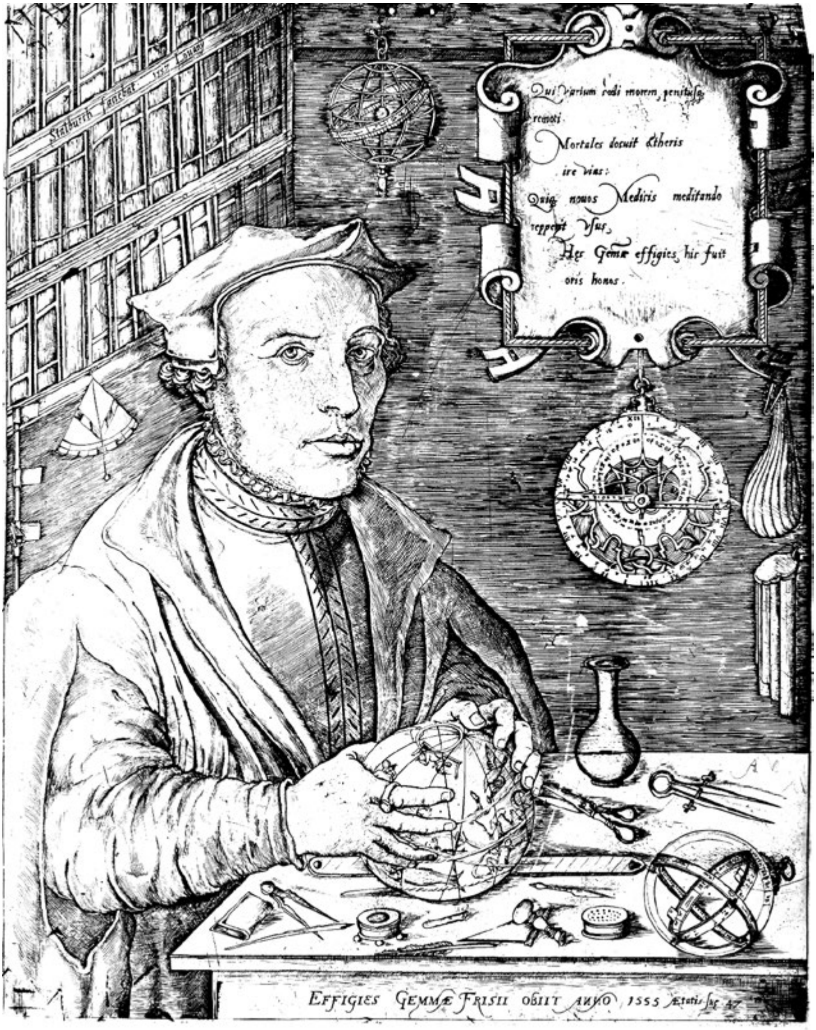
Celestial chart
MHS 2482
Cardboard, Geneva, Burckhardt Library, Geneva, late 19th century

Nocturnal

This instrument indicates the time at night by observing the position of certain stars (usually the pointer stars Dubhe and Merak of the Great Bear constellation, and the two bright stars at the extremities of the Little Bear) around the North Star or Polaris. Because of the earth's movement, the stars give the impression of rotating once every 24 hours around a fixed point: the North Star.

Invented by the Flemish mathematician and maker of scientific instruments Gemma Frisius (1508-1555) around 1530, the nocturnal was part of essential navigational equipment up to the 17th century before being abandoned in favour of mechanical marine chronometers which were much more precise. The nocturnal is composed of two discs one on top of the other and a mobile arm. The largest disc is marked with months while the smaller one has an hour scale. A small hole at the centre of the two discs is oriented to the North Star; the mobile arm is then moved until it is aligned with the chosen stars. The lower part of the arm shows the hour on the time scale.

Nocturnal
MHS 1860
Wood, brass, England, 17th century



Gemma Frisius, engraving by Stalburgh, 1555, Royal Albert 1st Library, Brussels

Gemma Frisius (1508-1554) a Flemish maker of scientific instruments, in his workshop. He is holding a celestial sphere. An astronomical circle lies on the table. Hanging on the wall are an armillary sphere and an astrolabe.

Astronomical ring

The design, shape and construction of this type of sundial are clearly reminiscent of an armillary sphere. In addition to its main function of indicating the time, an astronomical ring is also used to identify the position of certain stars at night.

Astronomical rings were invented in the 16th century and continued to be made until the 18th century. They are usually composed of two or three metal rings. The exterior ring, which is equipped with a suspension loop, serves as the meridian of the observation location. Perpendicular to the meridian ring, the equatorial ring is marked off in hours. Finally, the third and innermost circle, when it exists, pivots and is equipped with a viewer: it represents the solar meridian. In order to determine the time, the mobile meridian must be orientated so that the sun's rays pass through the viewer and strike the graduated hour scale marked on the equatorial ring.

Astronomical ring
MHS 1806
Brass, 16th century (?)

Terrestrial globe

From the 4th century BC, it was thought that the earth must be the most perfect shape in the universe: a sphere. The first terrestrial globe was probably made at that time. In *Geographia*, Ptolemy* gives guidance on their construction.

In the West, it was not until the discovery of America by Christopher Columbus (1451-1506) in 1492 that cartography, and thus the building of globes, became an industry. Like celestial spheres, the first globes were made of metal and engraved wood. With the advent of printing, these were replaced by wooden globes covered in bands of paper. Terrestrial globes showed the earth viewed from outside while celestial spheres show the sky viewed from within.

Pocket terrestrial globe
MHS 1904
Cardboard, galuchat, paper, plaster, Lane, England, 1776

** see glossary, p. 16*

Celestial globe

Celestial globes portray the topography of the sky. The constellations and stars are shown as they appear to an observer on earth in the centre of the sphere.

The first celestial globes date from antiquity. In 150 AD Ptolemy*, following the work of Hipparcos (around 190 - around 120 BC), drew up a catalogue of over 1000 stars and grouped them into 48 constellations. The Greek astronomer explained the rules which should be followed in making globes: stars must be shown in yellow and red on a dark background and stars in the same constellation must be linked to each other with a line and should not be part of the figurative representations used for calculations. Celestial globes were initially made of wood or engraved metal. Following the development of printing, printed paper was glued onto wooden globes. Printed celestial spheres became very popular in the 16th and 17th centuries when they were often made in a matching pair with a terrestrial globe.

Pocket celestial globe
MHS 1454
Wood, paper, plaster, 18th century

** see glossary, p. 16*

The orrery represents the movement of the planets in the solar system. The tellurian simply shows the orbits of the earth and the moon around the sun.

Copernicus and Kepler each tried to make a orrery portraying his own concept of the solar system. In 1682, the astronomer and physicist Huygens (1629-1695) constructed a mechanical orrery at the scale of the solar system and the six planets known at the time (Mercury, Venus, Earth, Mars, Jupiter and Saturn). Orreries were very popular in the 18th century and became indispensable decorative objects in physics laboratories and cabinets of curiosities. They operated through a complex system of gears and pinions and beautifully illustrate Newton's mechanical view of the world described in *Principia Mathematica* at the end of the 17th century.

Orrery
MHS 818
Steel, wood, ivory, brass, bone, Adams, 1770

Glossary

- Polar circles: Imaginary circles parallel to the equator at an angular distance of 23°27′ to the poles which corresponds to the inclination of the ecliptic. The polar circles mark the limits of regions in which on at least one day of winter the sun does not rise and on at least one day in the summer the sun does not set.
- Celestial coordinates: The position of a star in the sky can be identified by an observer on earth by its altitude above the horizon and its azimuth (the horizontal angle between the direction of the object and the geographical north).
- Ecliptic: The circle followed by the sun in the sky in its apparent path around the earth. The ecliptic makes an angle of 23°27′ relative to the equator which corresponds to the angle of inclination of the earth on its orbital plane around the sun.
- Equator: An imaginary line around the earth on which all points are equidistant from the two poles. The equator separates the northern from the southern hemisphere.
- Hipparcos (around 190 BC to 120 BC): a Greek astronomer and mathematician, who drew up one of the first star catalogues. It is possible that he also invented the first astrolabe.
- Meridian: An imaginary line joining the two poles.
- Ptolemy (AD 90 – around AD 168): A Greek astronomer, astrologer and geographer who lived in Alexandria. He is the author, amongst other works, of an astronomical treatise *Almagest* and another on geography, *Geographia* which strongly influenced Arabic and western science.
- Stereographic projection of the sky: A method of projecting the celestial sphere on a plane (the equator) for an observer located at the south pole.
- Tropics: The two imaginary circles parallel to the equator and above or below it where the sun achieves an elevation of 900 alternately during the solstices.

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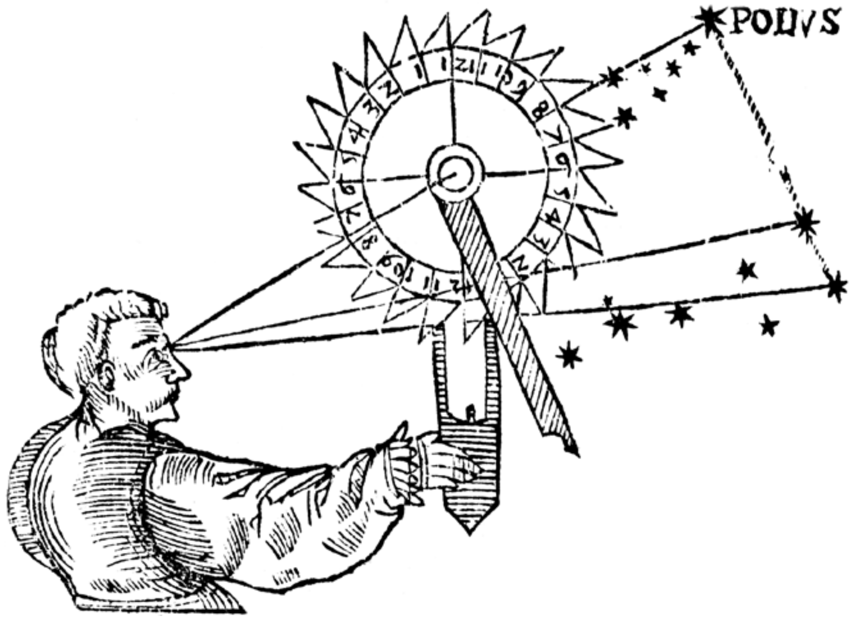

Use of a nocturnal, after Apianus, Cosmographia, Antwerp, 1564

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