

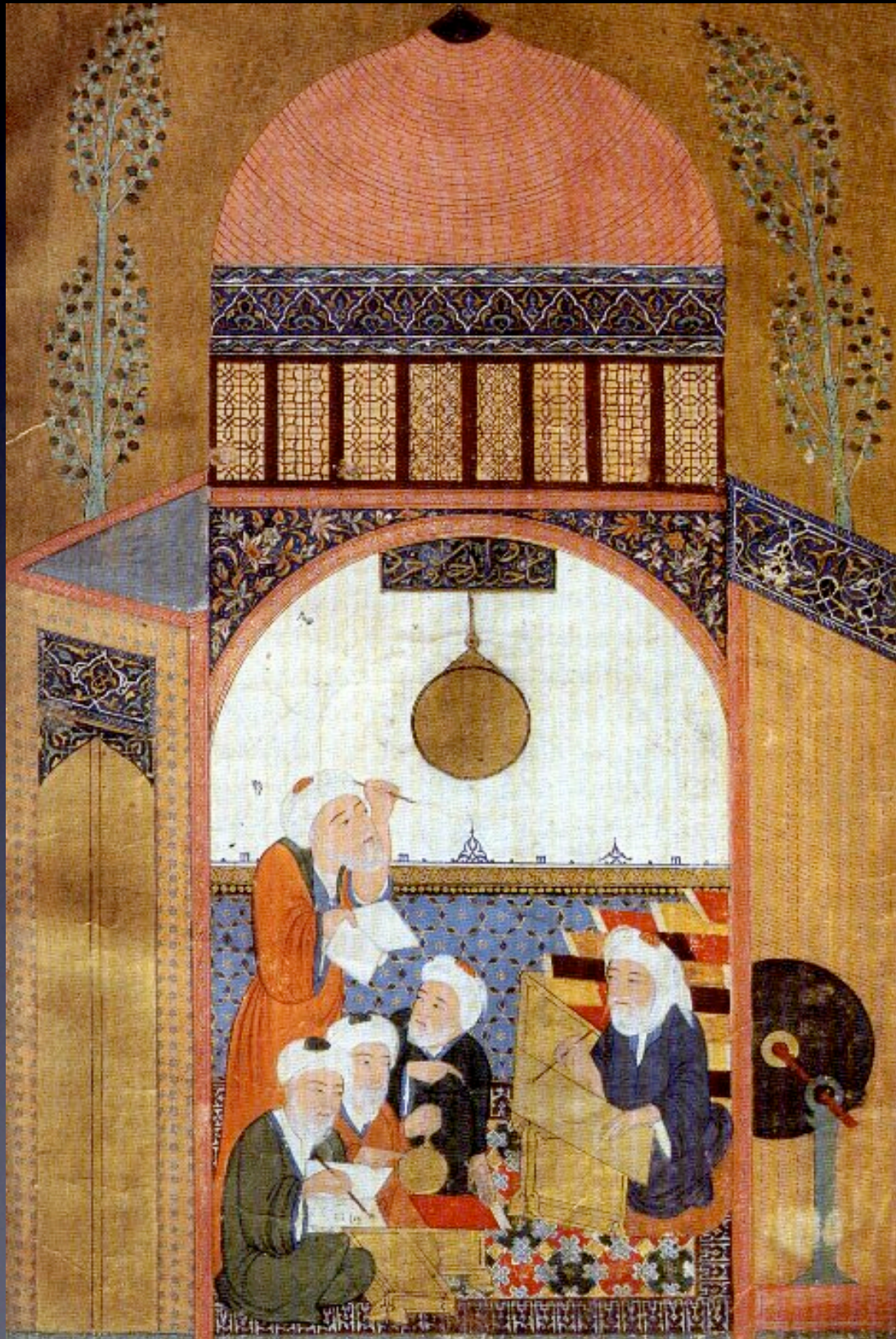
COPERNICUS: REVOLUTION IN ASTRONOMY

- Brief history of Europe
- Copernicus: biography
- Heliocentric model
- Seasons
- Eclipses

History's timeline

- 200s AD Crisis in Roman Empire: 285AD Empire is split into East (Byzantine) and West (Rome)
- 476 AD end of the (West) Roman Empire
- 570 - Muhammad born at Mecca. 632 - death of Muhammad. 635- Muslims begin conquest of Syria and Persia. By 10th century arabs rule from Spain to Egypt to India.
- 1096- first Crusade

During medieval times development of astronomy and preservation of knowledge of ancient greeks was mostly done by the arab civilization.



The Andromeda constellation, from a medieval Islamic copy of drawings by the tenth-century Persian astronomer Abd al-Rahman al-Sufi, who revised the star catalogue in Ptolemy's *Almagest*. The drawing shows (directly above this caption), very remarkably, the Andromeda Nebula, which is visible to the naked eye only under very favourable conditions and which had to be rediscovered telescopically in the West in the seventeenth century. The fish represents an alternative depiction from pre-Islamic Arabia.

History's timeline

- 1390- Turks conquer all of Asia Minor. 1453- fall of Constantinople and end of Byzantine
- 1338-1453 Hundred Years' war between England and France
- 1348-1351 Black Death ravages Europe. 25 million people - 1/4 of the whole population is dead. Increase in labor productivity.
- 1209- Cambridge University is founded in England
- 1492- Christopher Columbus discovers the West Indies. 1519- Magellan sails for the round-the-globe trip
- 1500s- Renaissance in Italy. It spreads to France, Germany, England.
- 1517- Reformation begins in Germany (Martin Luther). 1560- Catholic Church introduced its own reforms. 1572- St.Bartholomew's Day massacre of huguenots (protestants) in Paris.
- 1618-1648 Thirty Years' War in Germany. Catholics against protestants. Foreign troops: Spain, France, Sweden ... 1/3 of population is dead

Revival of science in Europe

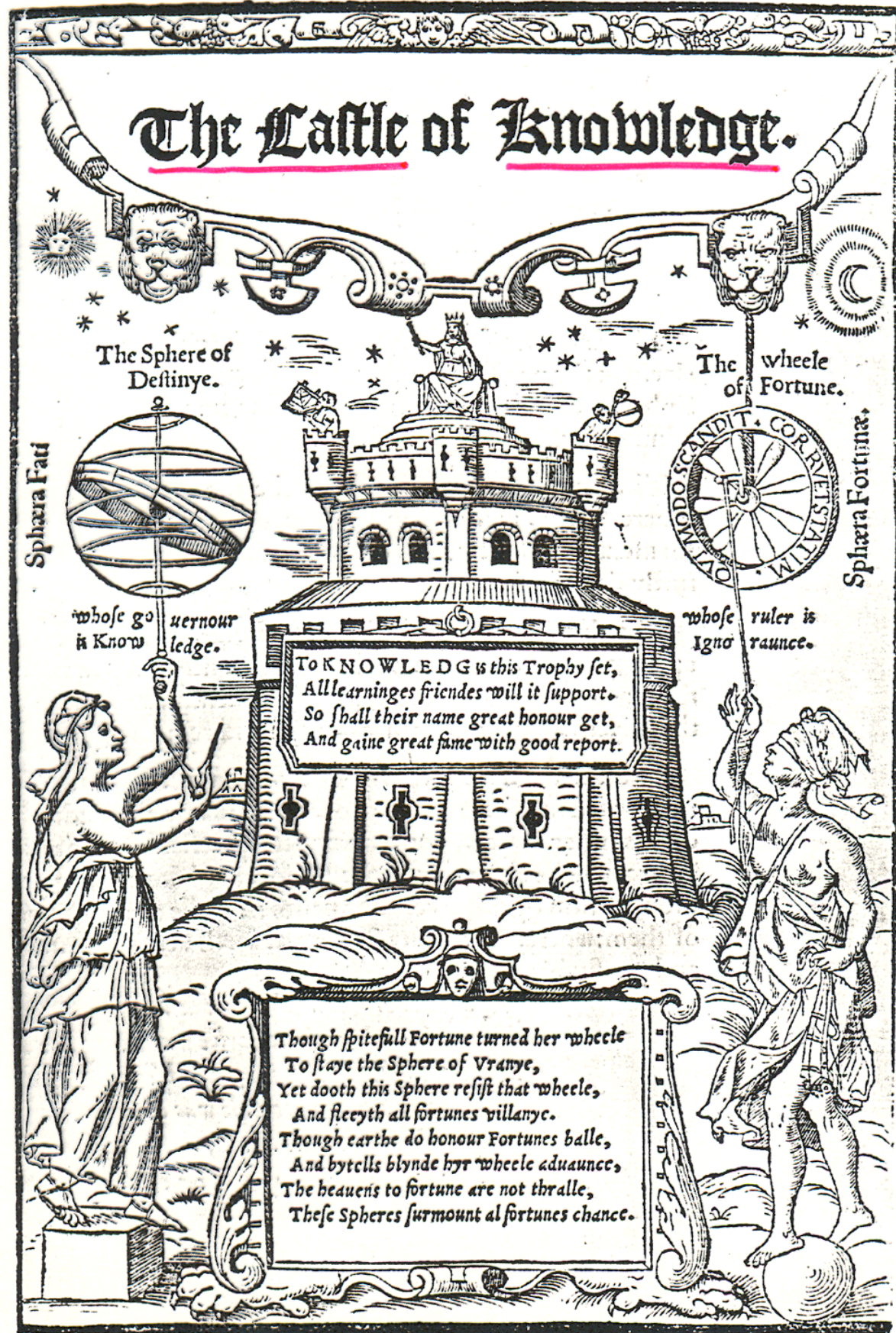
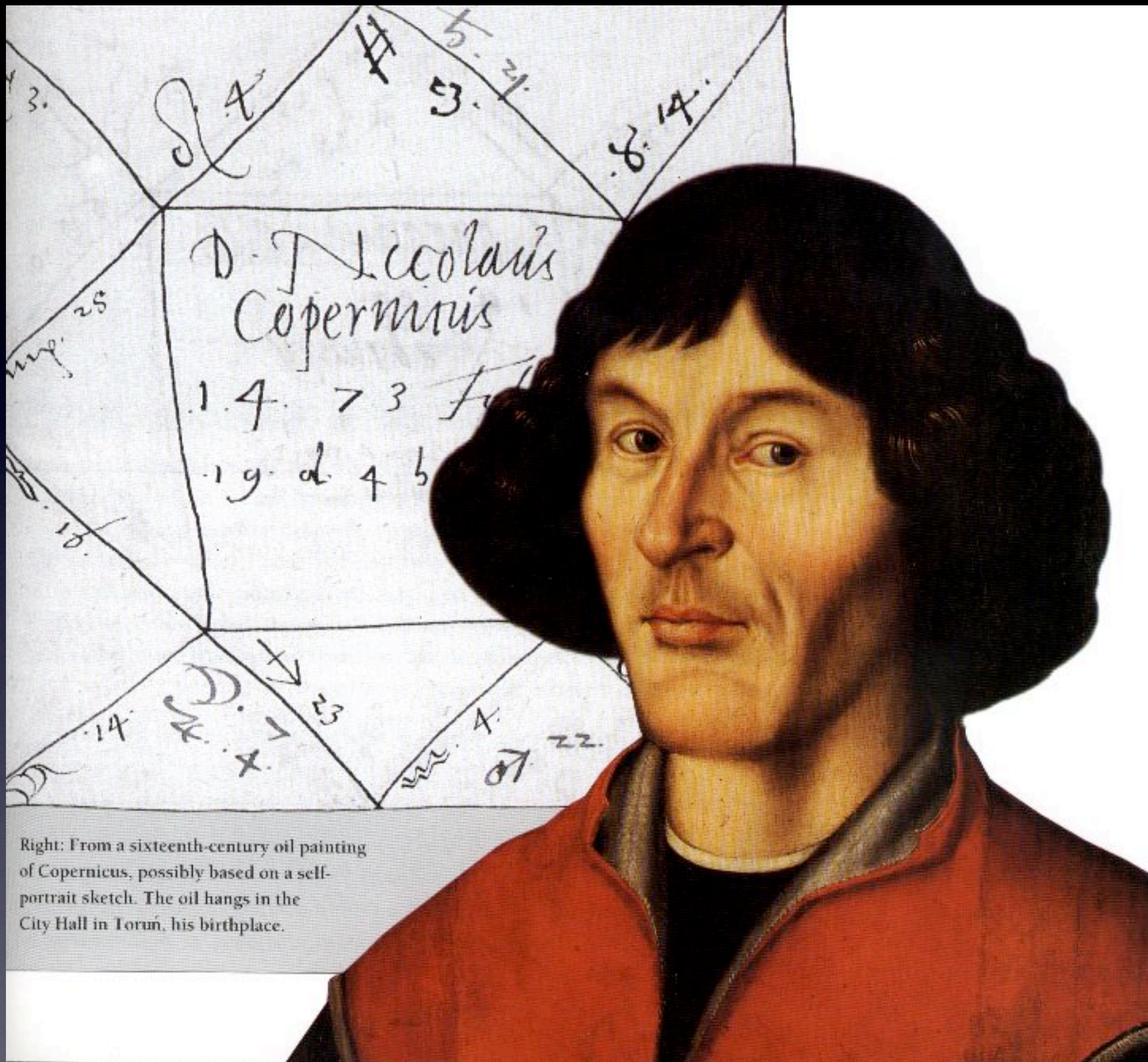


Fig. 7. The Christian philosopher, who reads both the Holy Scriptures and the book of nature.

ca. 1590



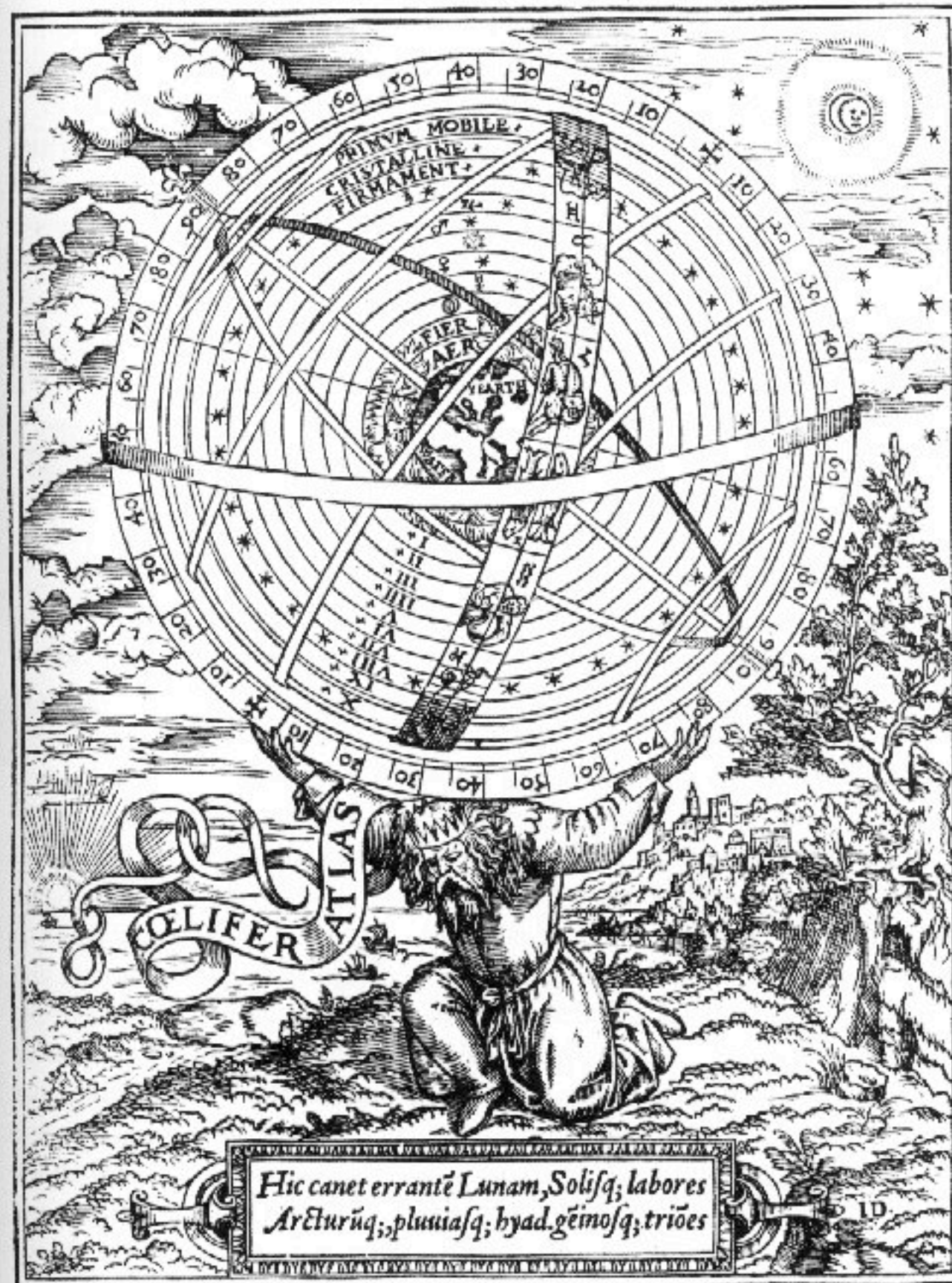
Right: From a sixteenth-century oil painting of Copernicus, possibly based on a self-portrait sketch. The oil hangs in the City Hall in Toruń, his birthplace.

Copernicus: revolution in astronomy

- Born: 19 Feb 1473 in Torun, Poland
Died: 24 May 1543 in Frombork, Poland
- Nicolaus Copernicus came from a middle class background and received a good standard humanist education, studying first at the university of Krakow (then the capital of Poland) and then traveling to Italy where he studied at the universities of Bologna and Padua. He eventually took a degree in Canon Law at the university of Ferrara. At Krakow, Bologna and Padua he studied the mathematical sciences, which at the time were considered relevant to medicine (since physicians made use of astrology).
- In 1513 he wrote a short account of what has since become known as the Copernican theory, namely that the Sun (not the Earth) is at rest in the centre of the Universe. A full account of the theory was not published until the very end of Copernicus's life, under the title “*On the revolutions of the heavenly spheres*” (*De revolutionibus orbium coelestium*, Nuremberg, 1543).



Aristotelian system:
Earth is at the center.



Atlas carrying the world, as portrayed in 1559. At the centre are the elements earth, water, air, and fire, after which come the celestial spheres in the order established in the second century AD by Ptolemy: Moon, Mercury, Venus, Sun, Mars, Jupiter, Saturn, and the fixed stars. Outside the fixed stars (the 'firmament') are two additional spheres invented in the Middle Ages for theological reasons (see page 78). Also shown is the band of the zodiac, together with the celestial equator, the tropics of Cancer and Capricorn, and other circles.



Geocentric model of ancient greeks

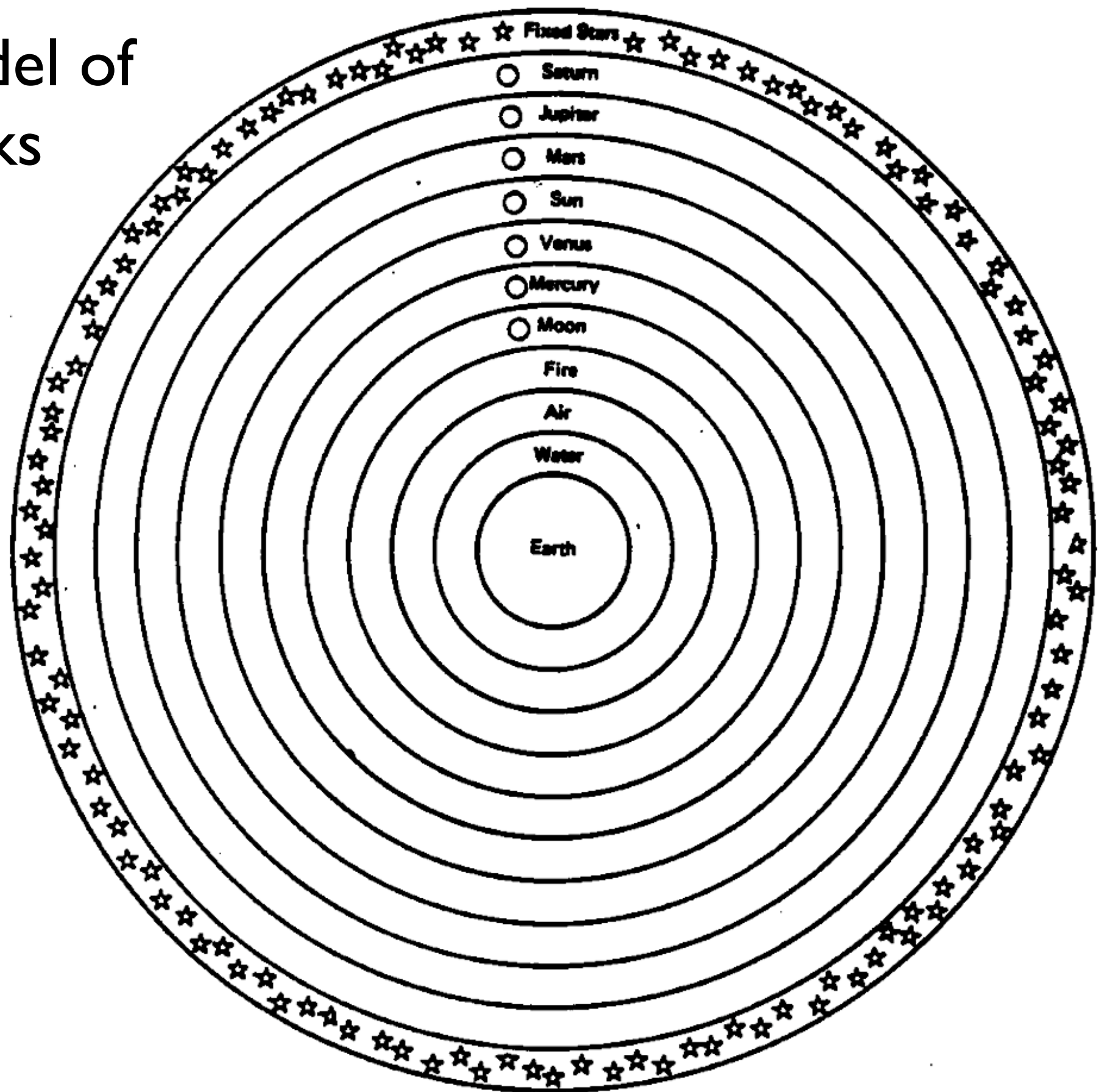
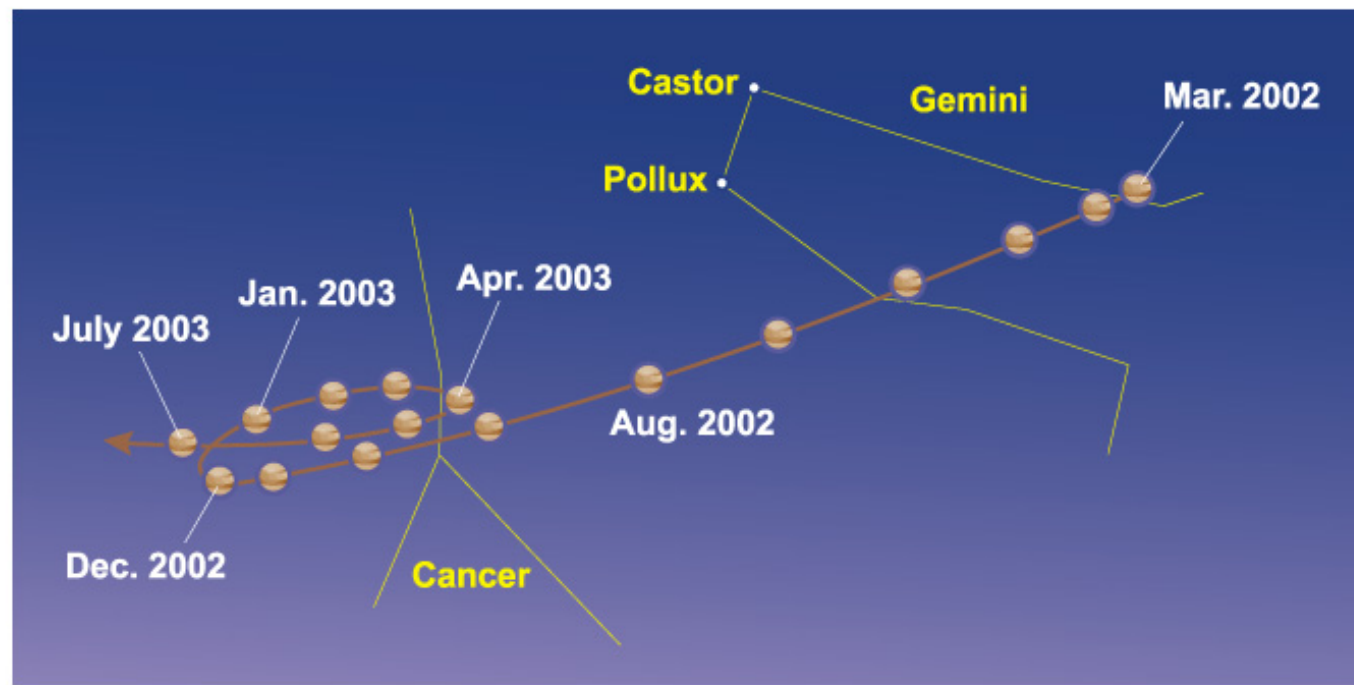


Figure A. The universe according to Aristotle (a section through the spheres).

Copernicus

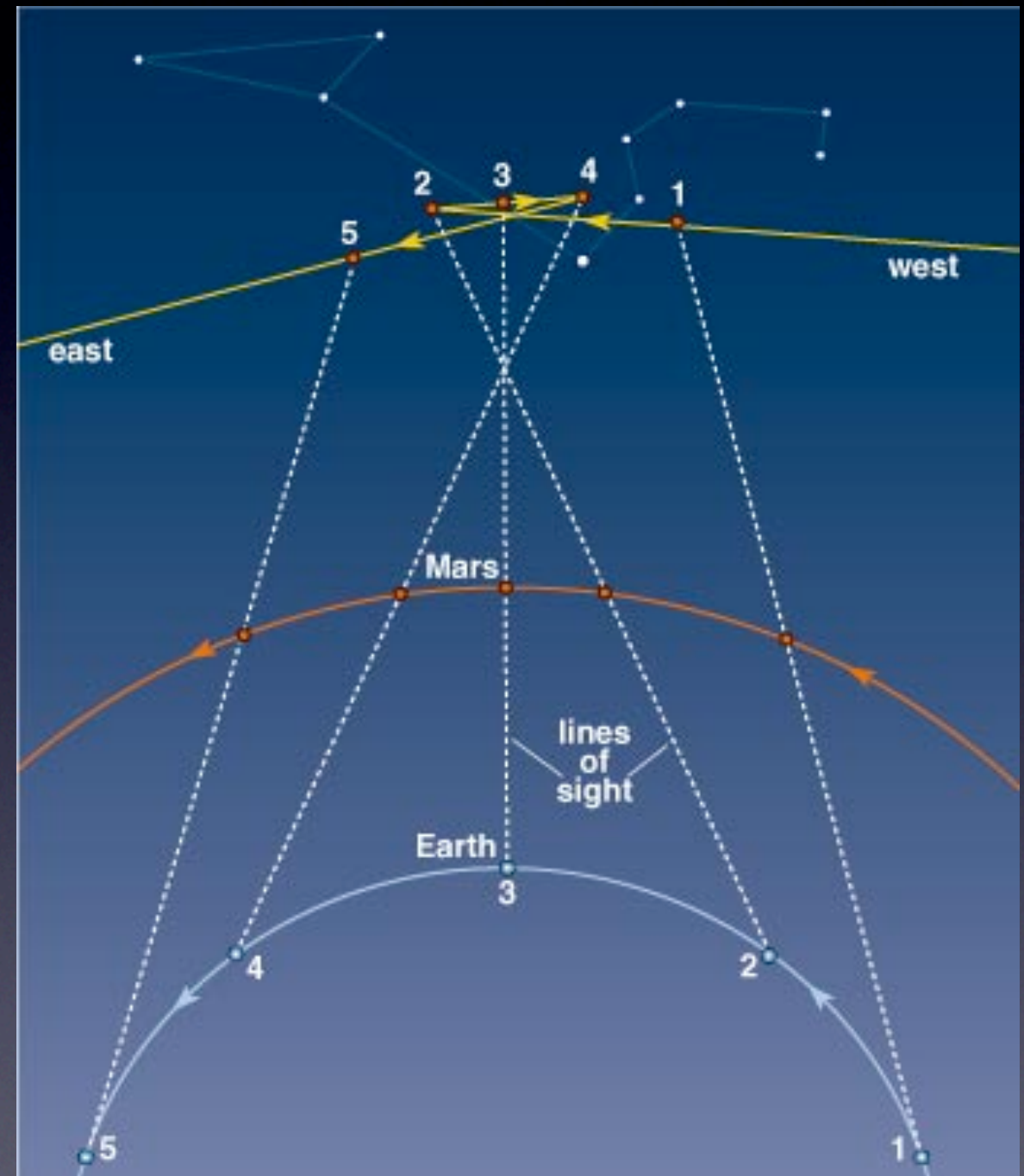
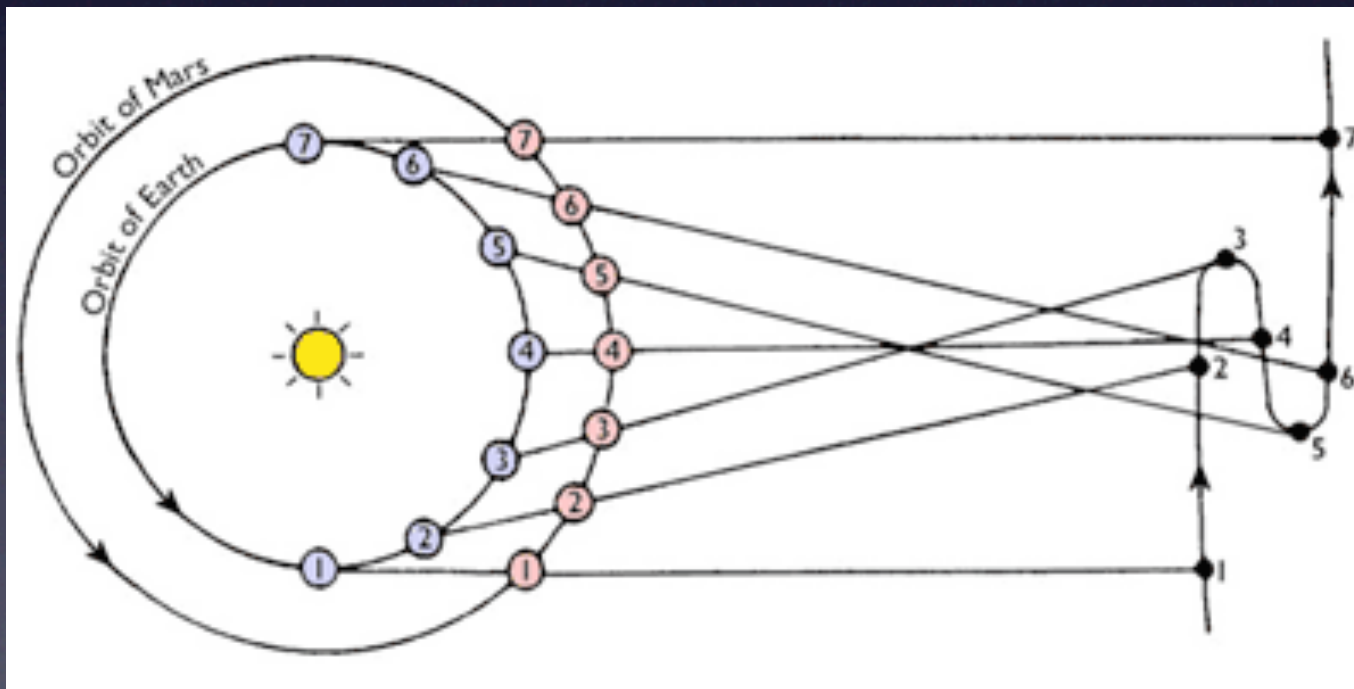
- Stars do not have parallaxes because they are too far away.
- Earth is not at the center: the Sun is.
- Planets move around the Sun on circular orbits.
- Retrograde motion is an illusion. There is no physical backward motion of planets.
- Retrograde motion is explained by faster motion of inner planets as compared with outer planets.

Retrograde Motion of Planets



Dots represent Jupiter's approximate position at 1-month intervals.
(Jupiter not to scale.)

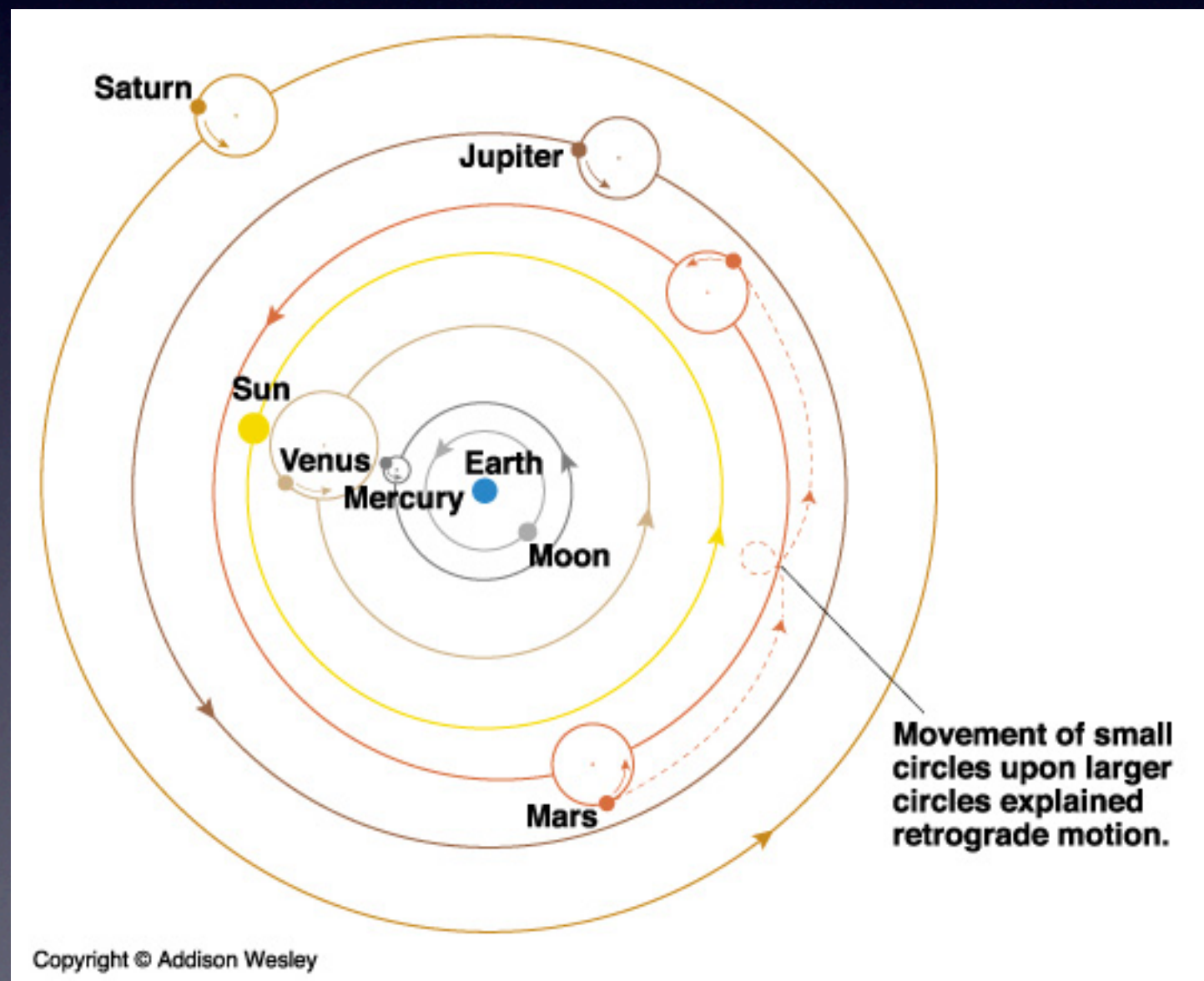
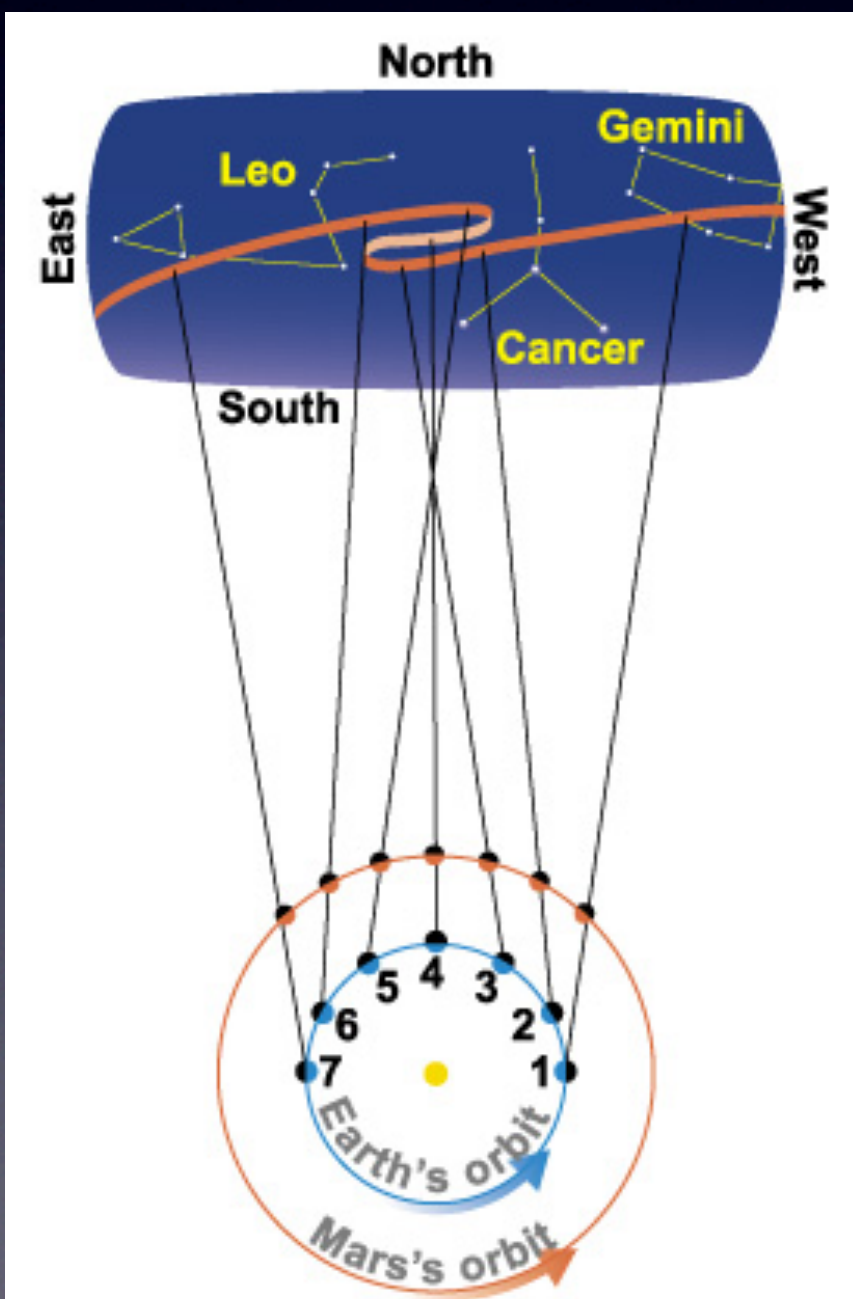
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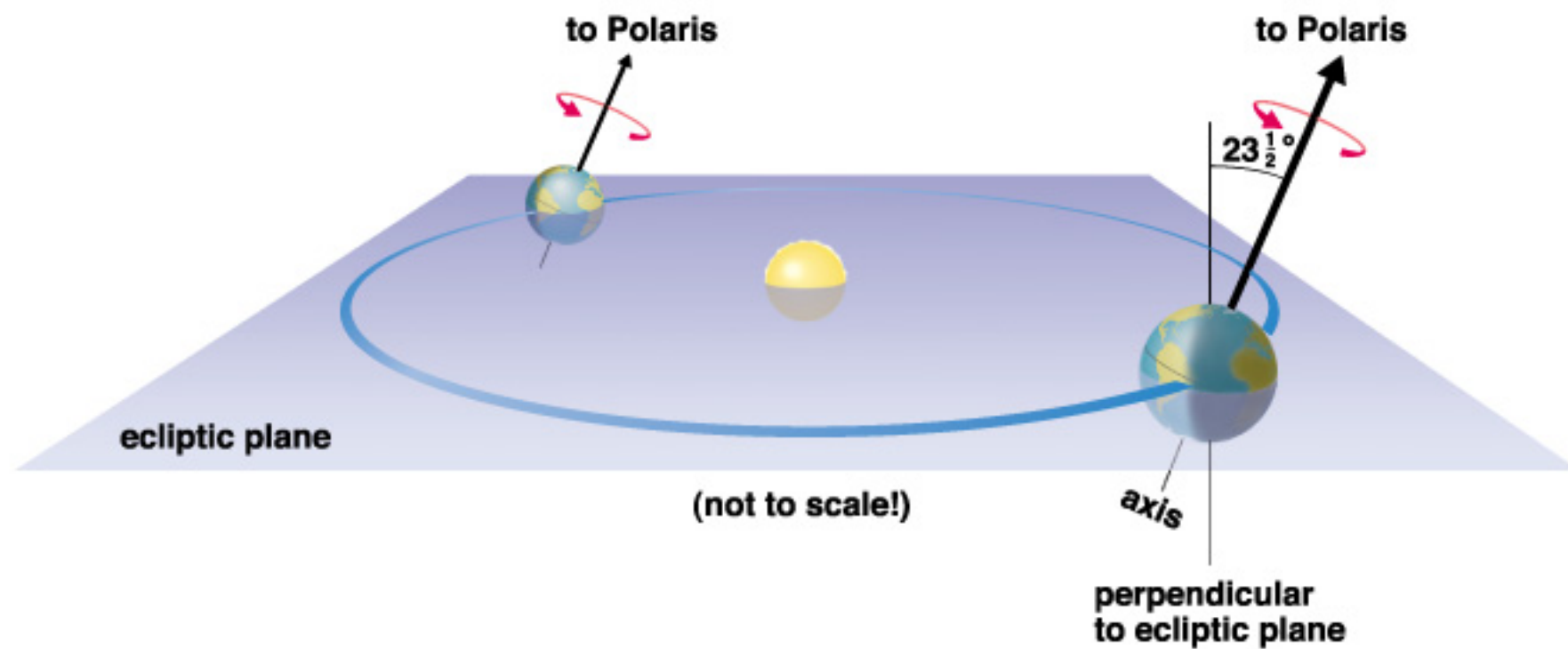
Retrograde Motion of Planets

Copernicus

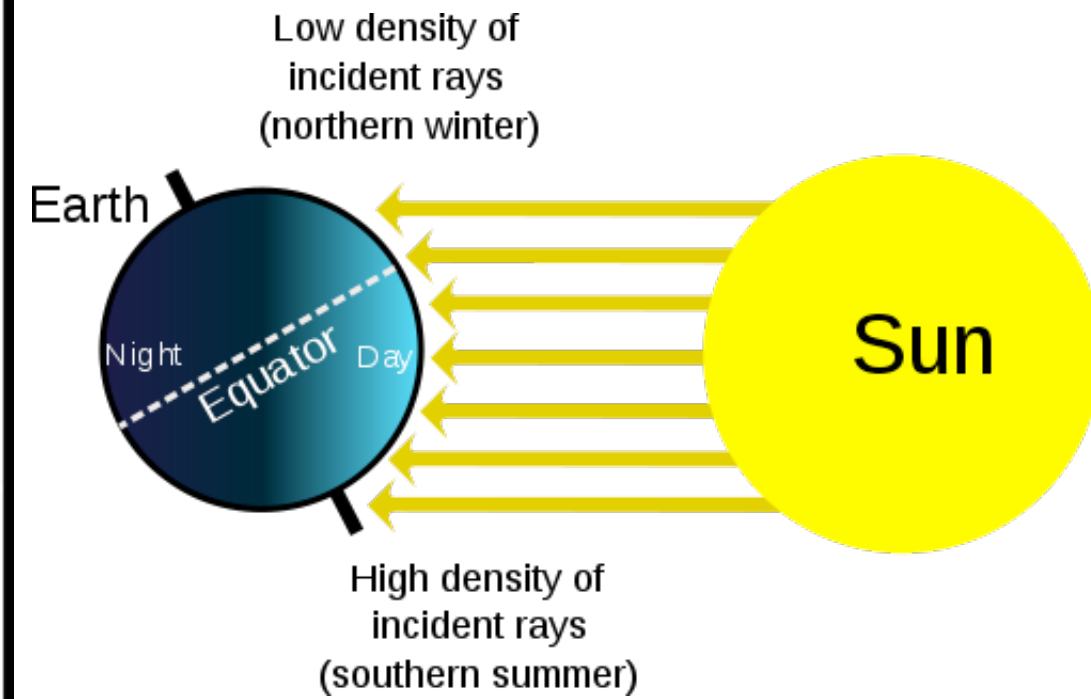
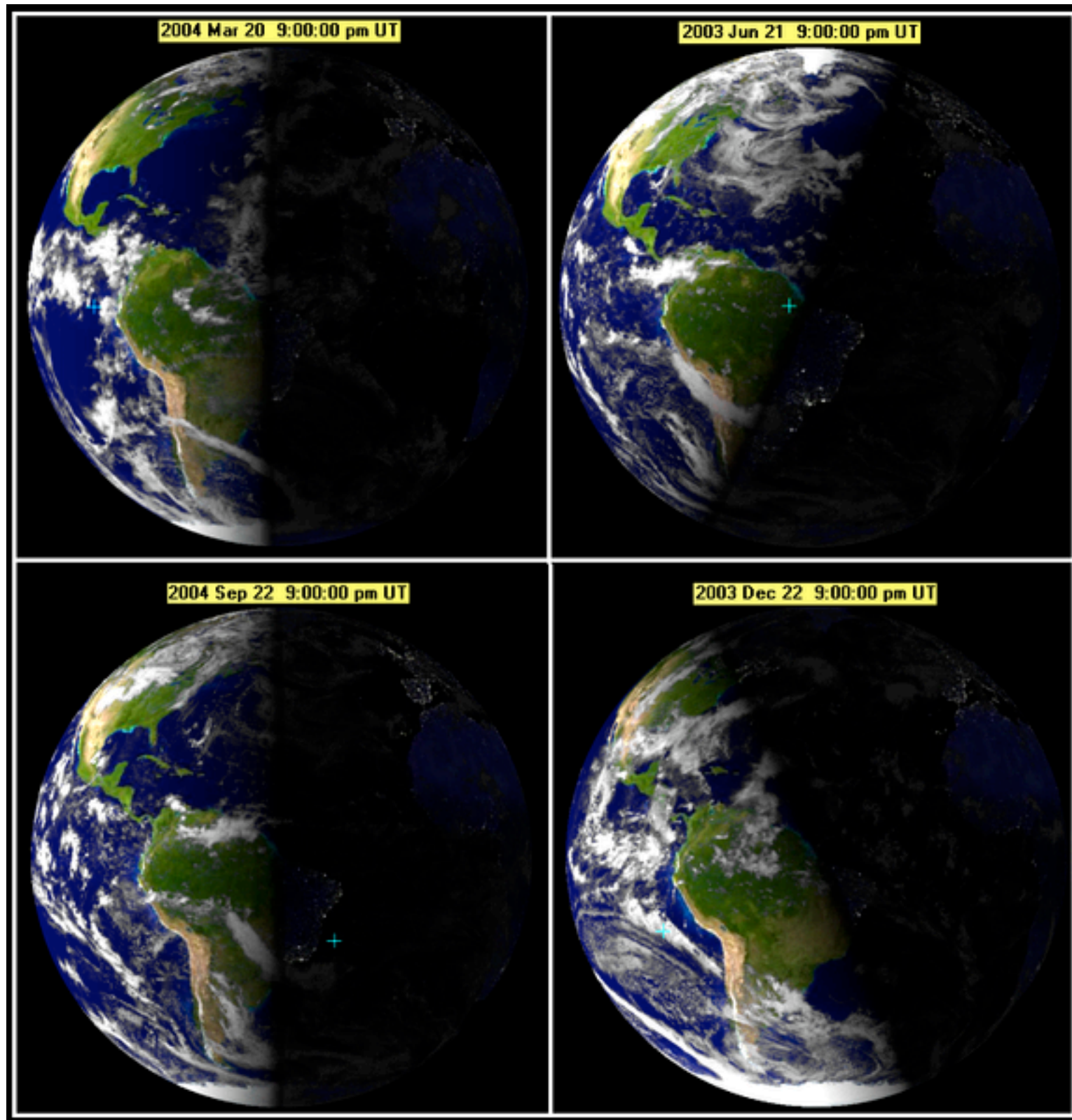
Aristotel



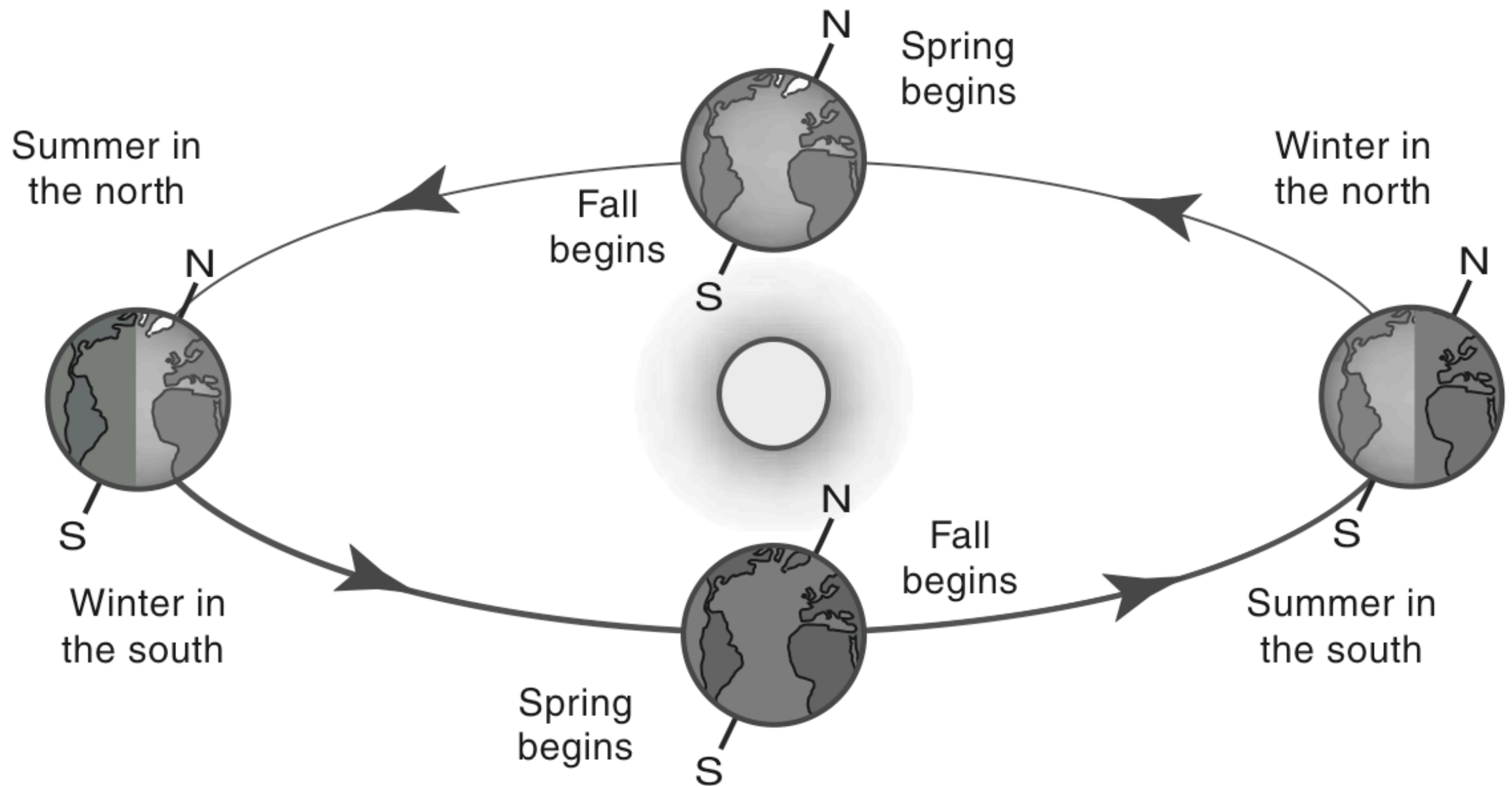
Seasons



Illumination of the Earth



Seasons



Seasons

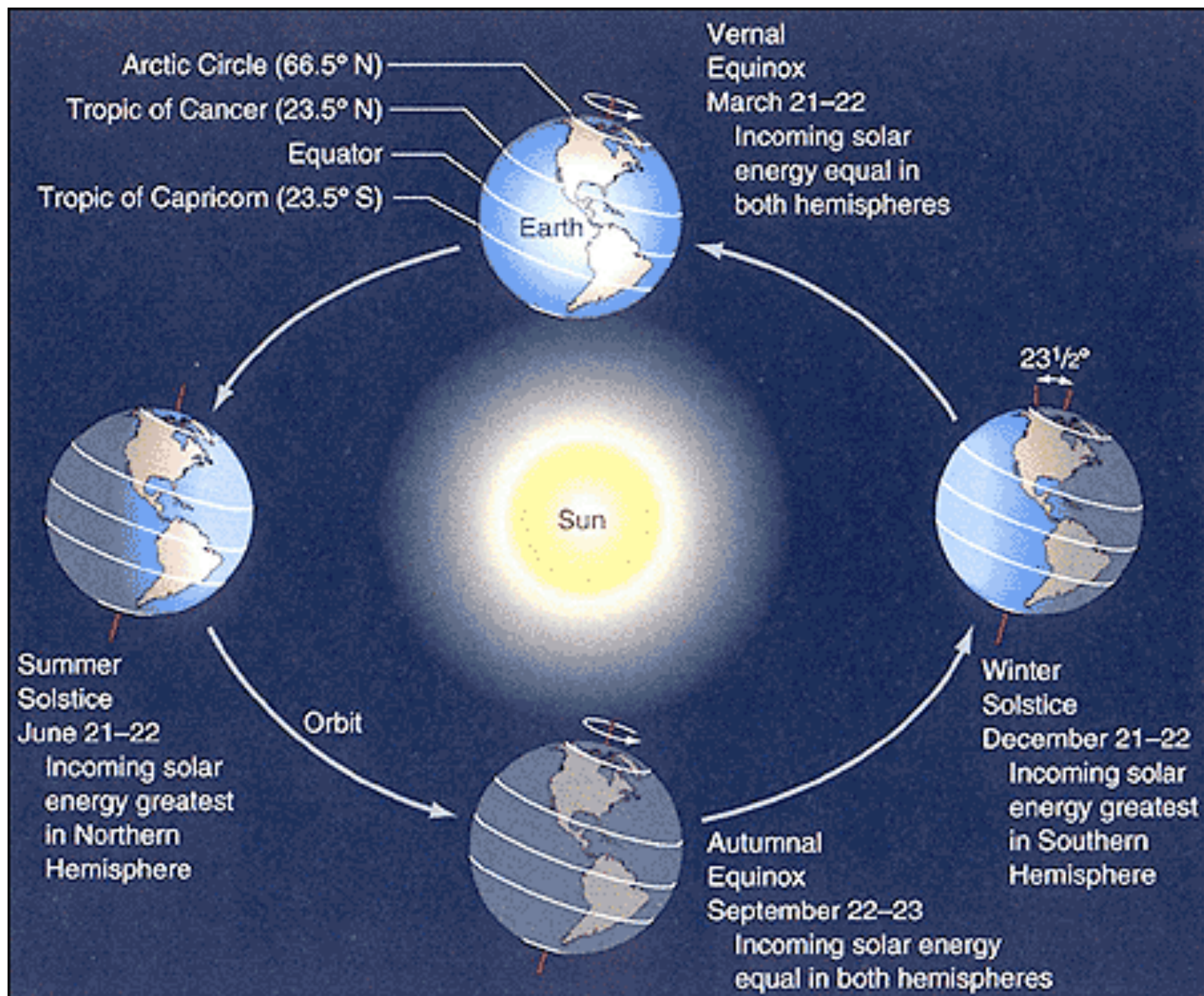
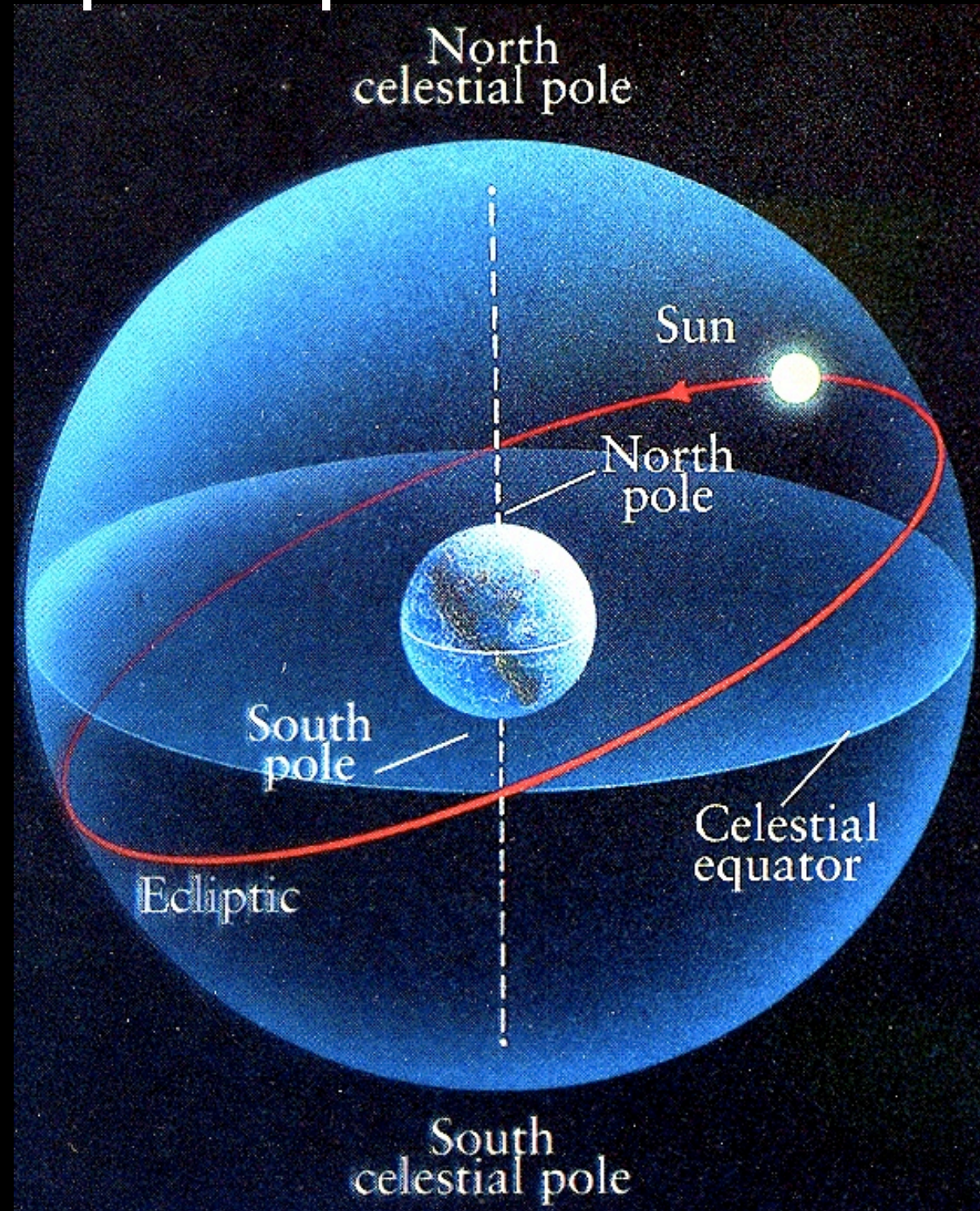
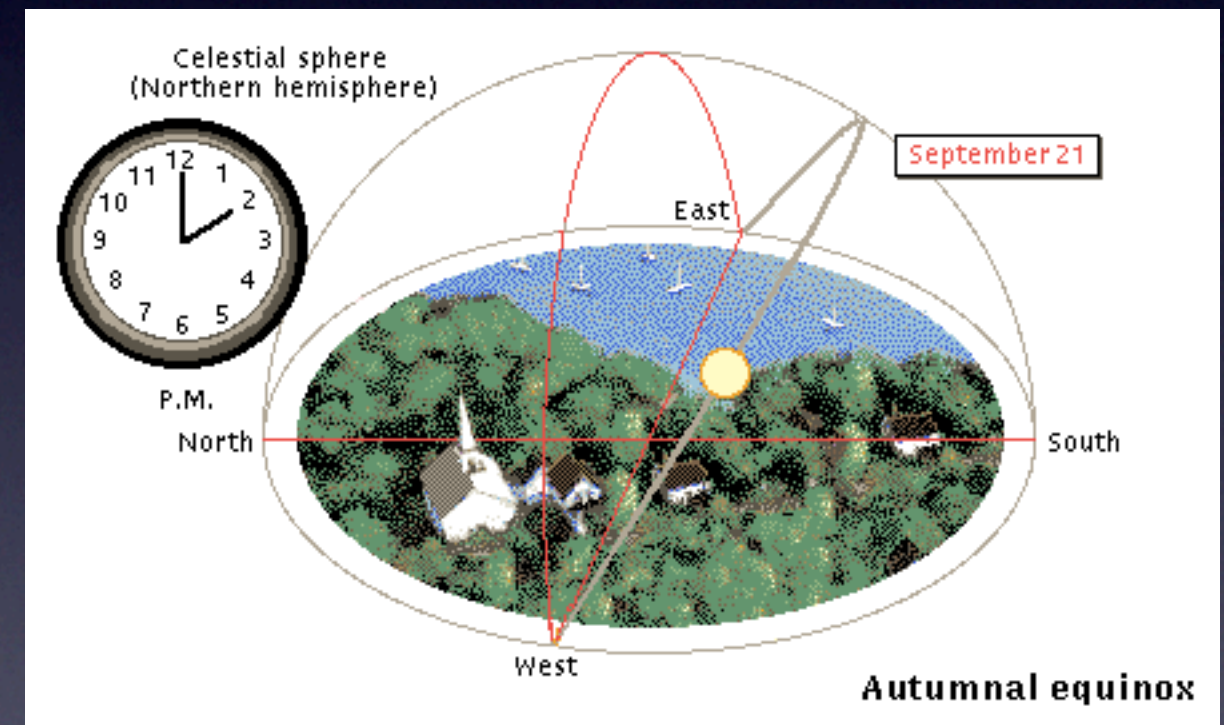
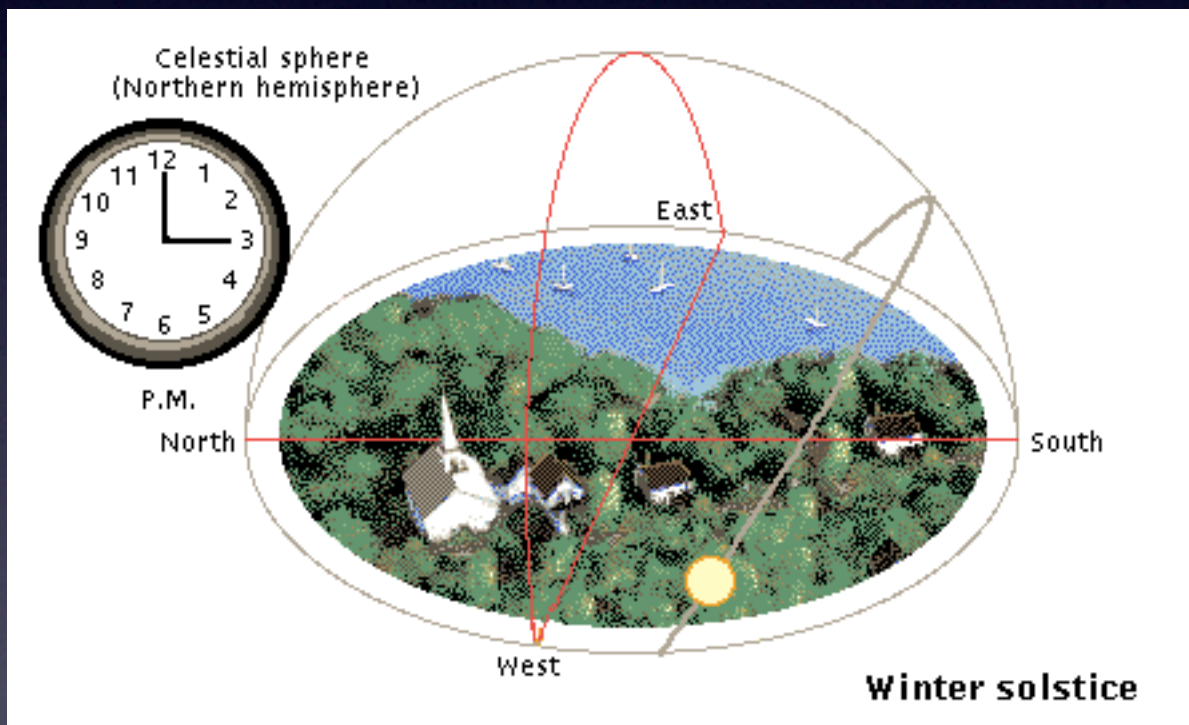
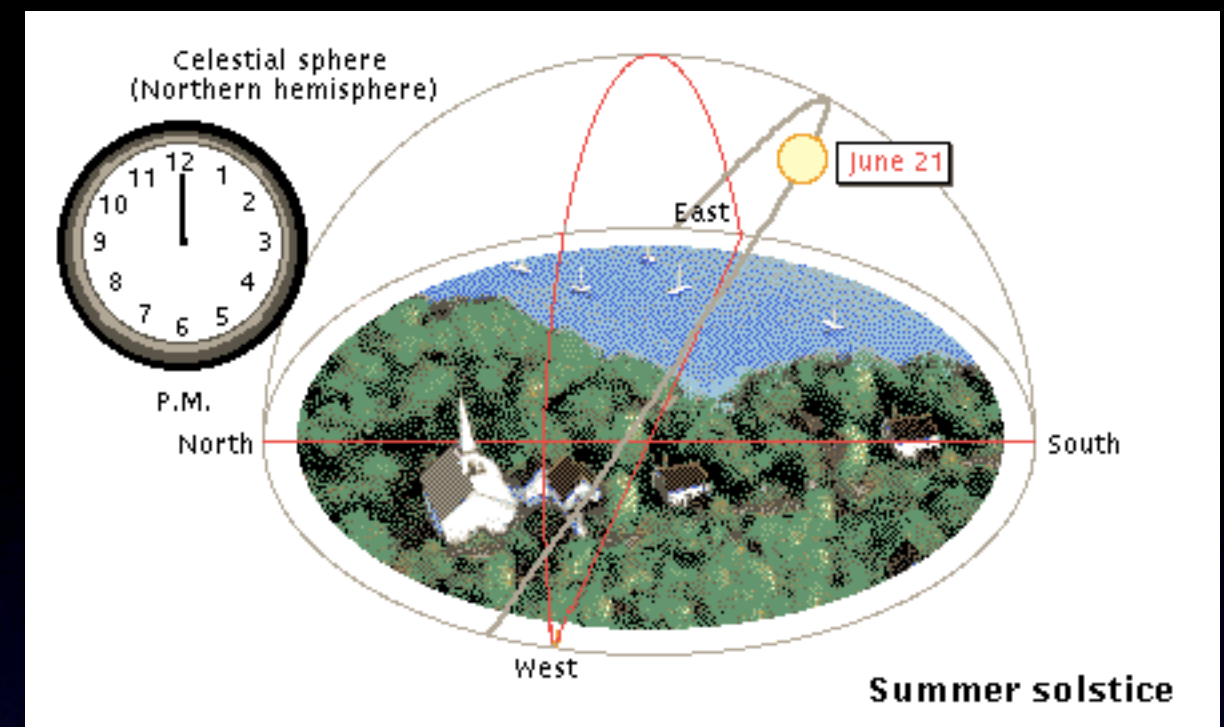
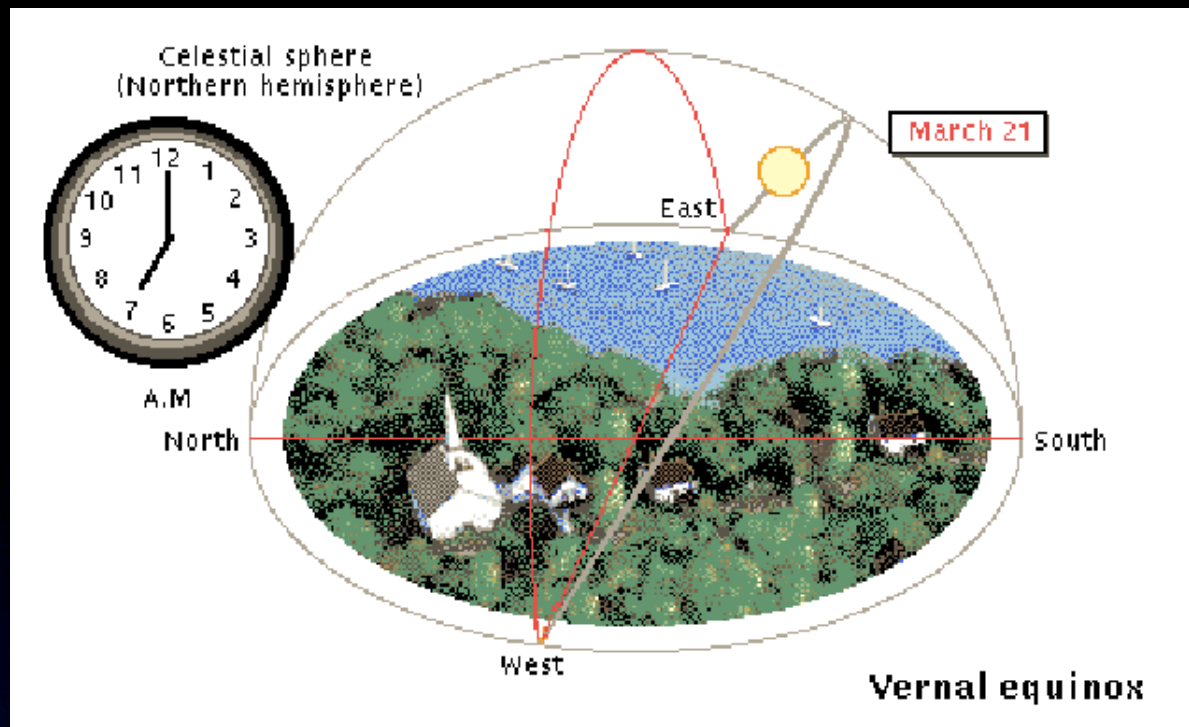


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Ecliptic is path of the Sun on the sky





East

South

West



During the summer:

Day is longer and the sun is higher in the sky.

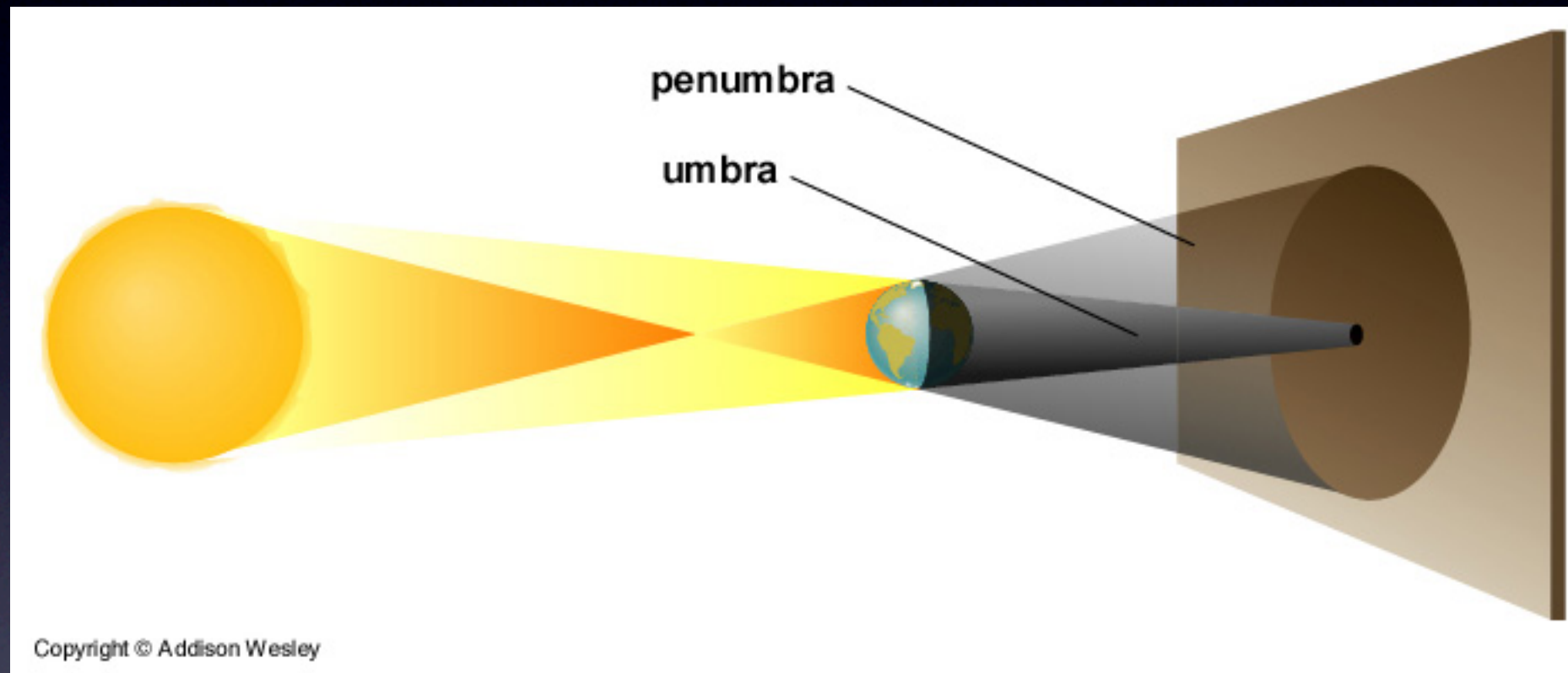
The sun rises in north-east and sets in north-west

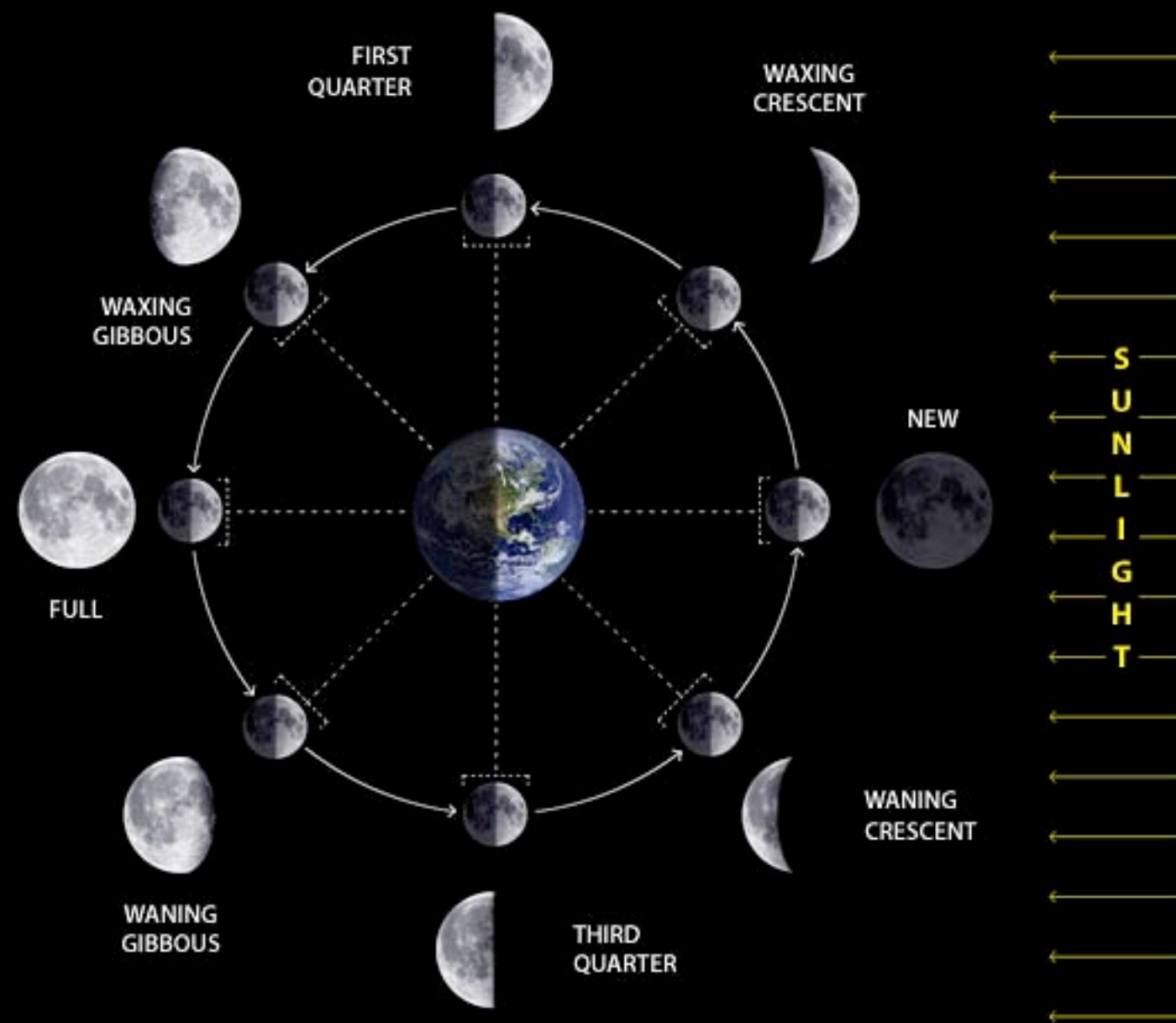
During the winter:

Day is shorter and the sun is lower in the sky.

The sun rises in south-east and sets in south-west

Eclipses

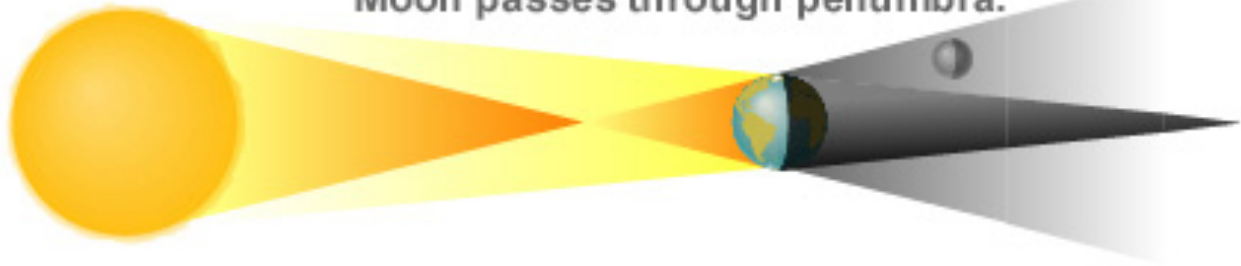




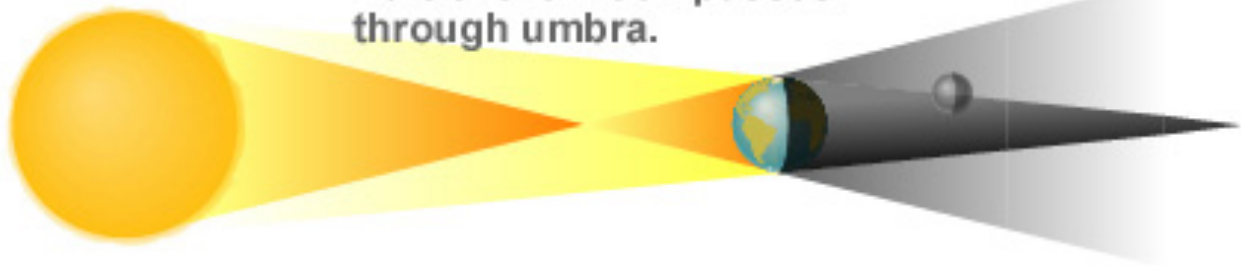
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Lunar Eclipses

Penumbral Lunar Eclipse
Moon passes through penumbra.



Partial Lunar Eclipse
Part of the Moon passes through umbra.



Total Lunar Eclipse
Moon passes entirely through umbra.



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Total Lunar Eclipse Victoria BC
August 28 2007



1:31 AM PDT
Moon before entering penumbra

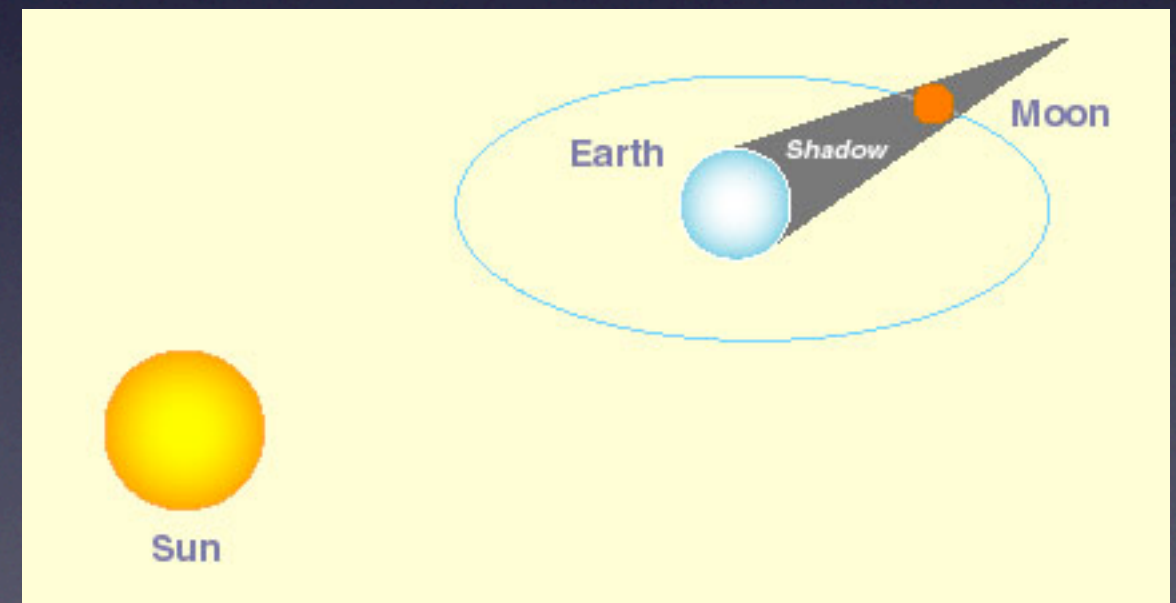


2:54 AM PDT
Moon entering the umbra

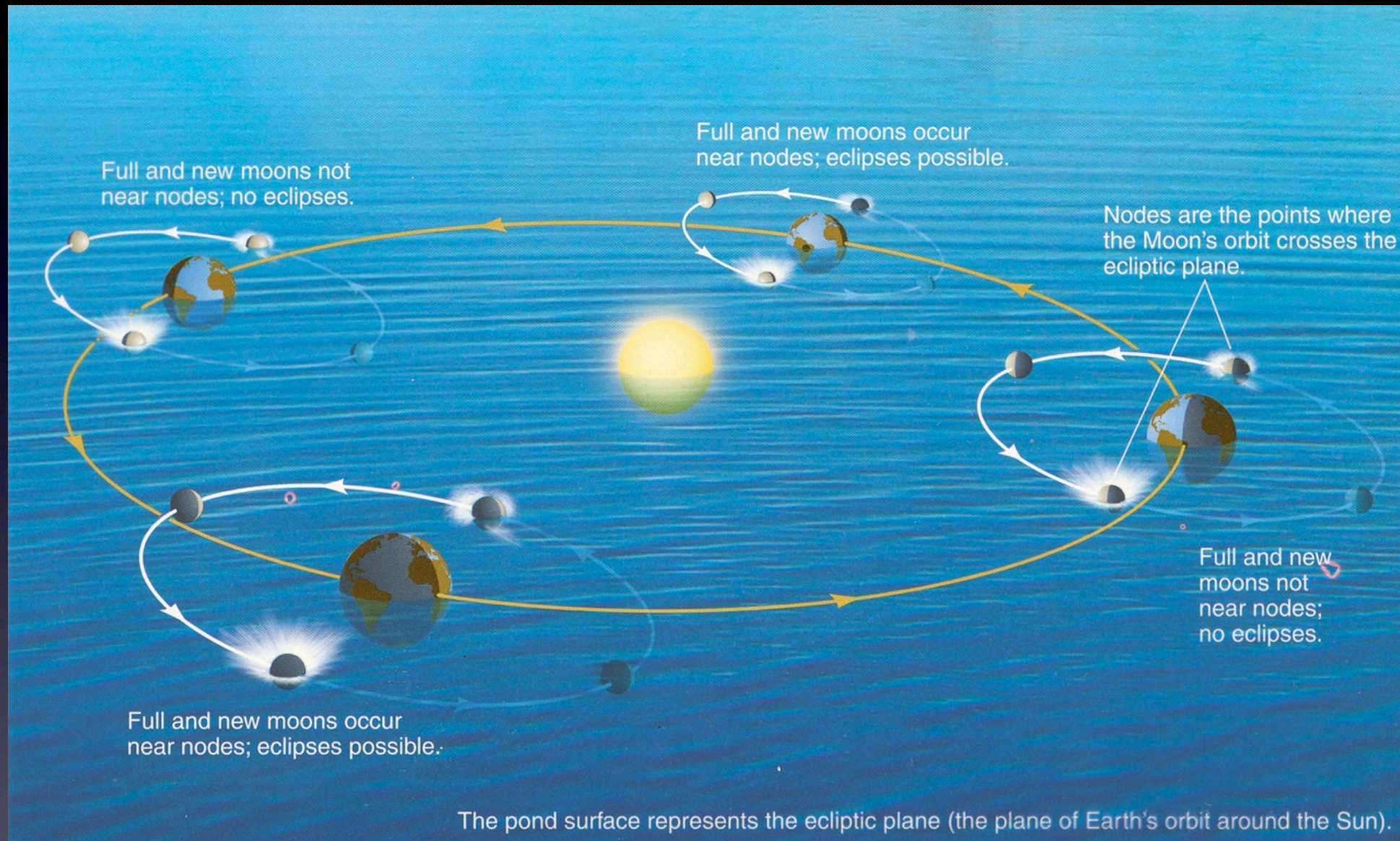


3:41 AM PDT
Total eclipse of the Moon

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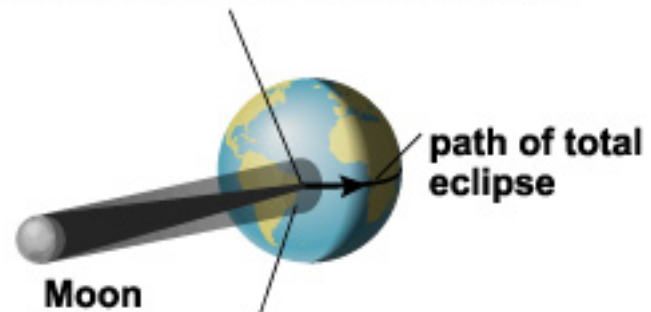
Lunar Eclipses: Full Moon is in the ecliptic



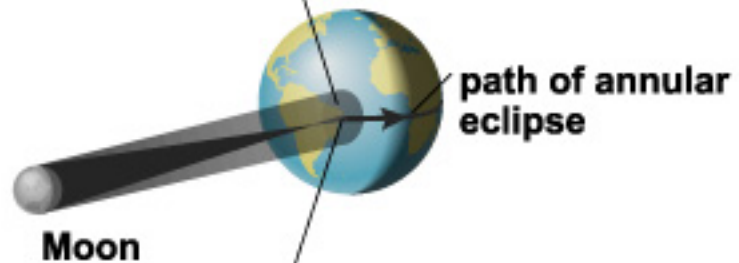
Solar Eclipses



A **total solar eclipse** occurs in this region.



A **partial solar eclipse** occurs in the lighter area surrounding the area of totality.



If the Moon's umbral shadow does not reach the Earth, an **annular eclipse** occurs in this region.

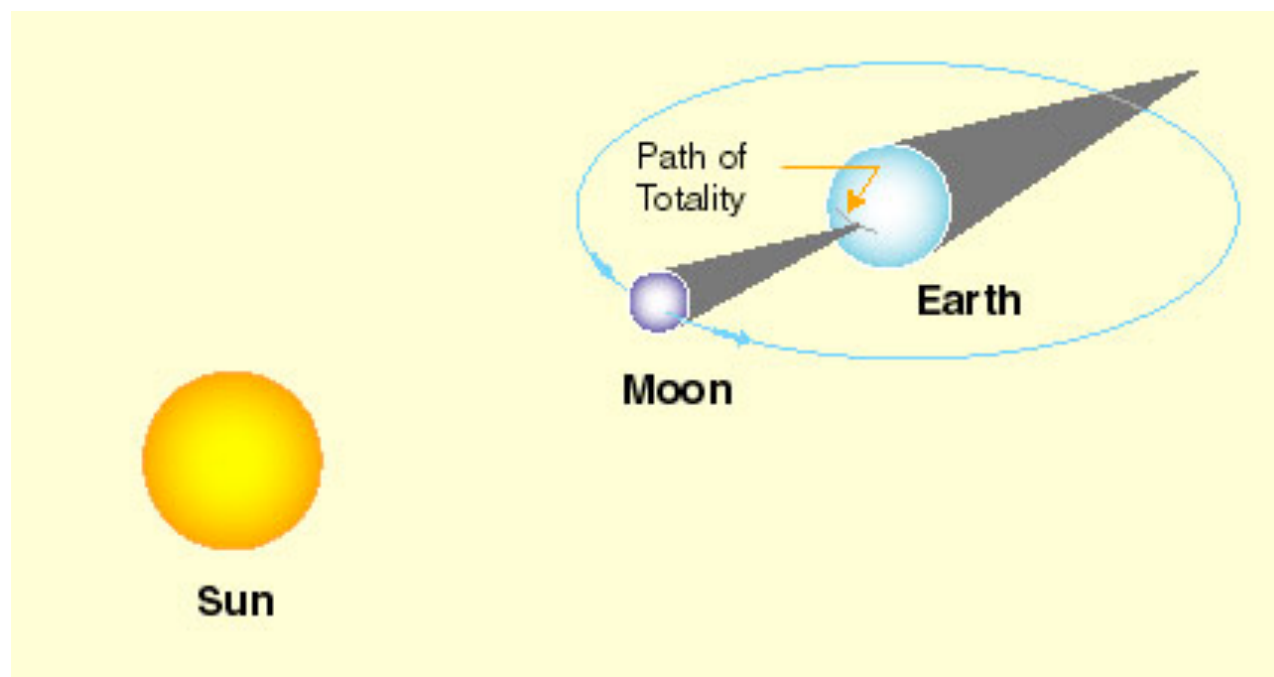
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New Moon is in the ecliptic

Solar eclipses



This can only happen during the new moon phase
and when the Moon is in the plane of ecliptic



Copernicus: Beginning of a Revolution

- The problems & complexities of the geocentric model caused Nicholas Copernicus (1473-1543) to examine an alternative sun-centered or *heliocentric* model of the solar system.
 - His model proposed that:
 - The Sun is at the center of the Universe.
 - The distance between the Earth and the stars is much greater than the Earth-Sun distance. This would explain the lack of observed stellar parallax.
 - The east to west daily motions of stars, planets, the Moon, and the Sun are caused by the rotation of the Earth on its axis.
 - The Earth and all the planets revolve around the Sun on circular orbits. This produces the change in constellations observed from one time of year to the next.
 - Retrograde motion is an illusion caused by the fact that we are observing other planets on the planet Earth which itself is moving around the Sun.
- Although Copernicus' idea of a heliocentric solar system is correct, his assumption of circular orbits made his model no more accurate than that of Ptolemy.

Implications of Heliocentric Model

- The Heliocentric Model offers additional explanations for some of the basic observations of the sky and the Earth environment made for thousands of years.
- *Seasons:*
 - Seasons are produced by the fact that the Earth's rotation axis is inclined by 23.5 with respect to the line drawn perpendicular to the Earth's orbital plane. Seasons are NOT produced by the varying distance to the Sun as the Earth makes its elliptical orbit about the Sun.
 - The sunlight intensity (or amount of heating) depends on the angle that the Sun's light rays make with respect to the ground. When the Sun is highest in the sky at noon during the summer in Las Cruces, the Sun's rays are nearly perpendicular to the ground - this produces the greatest heating of the year. This is caused by the fact that the northern hemisphere is pointing most directly at the Sun. The opposite occurs during the winter.
 - What other terrestrial planet has seasons?
- *Eclipses*
 - Eclipses occur when one astronomical body moves into the shadow cast by a second astronomical body.
 - A *Lunar Eclipse* occurs at Full Moon when the Moon moves through the shadow of the Earth.
 - A *Solar Eclipse* occurs at New Moon when the Moon's shadow falls upon the Earth.
 - *Question:* Why isn't there a total solar eclipse at each New Moon?