Representing the Cosmos

God the Geometer
Bible Moralisée
13th Century CE

This session will consider how science and religion have understood the universe.

The word cosmos means much the same thing as universe. However, it derives from the Greek verb *cosmein* meaning to order or arrange. Thus it means the universe as an embodiment of order. The word *cosmein* was also used to arrange the hair and thus led to the word "cosmetic." Thus cosmos might also meant the universe as an embodiment of order and beauty.

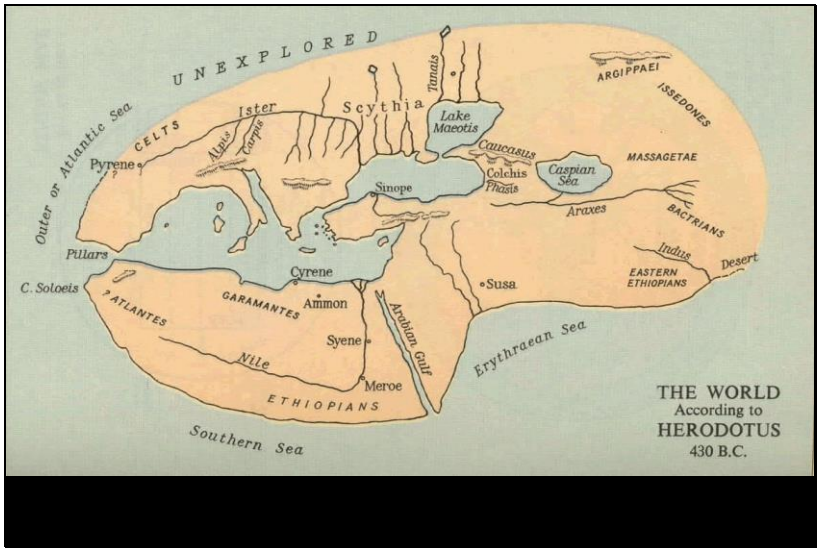
This illustration from a medieval Bible shows God determining the measurements of the cosmos. Everything – earth sun moon stars - is contained in a single geode. Above the illustration is written "Ici crie Dex ciel et terre soleil et lune et toz elemenz" (Here God creates the heavens and the earth, the sun and the moon, and all the elements).

Like the sun and the moon the earth in this medieval illustration is roughly spherical. Although some early human beings may have considered the earth as a flat disc, for more than 2500 years we have thought of the world as a sphere. In the 6th Century BCE, Pythagoras considered the Earth to be spherical because this was the first of the perfect solid shapes.

Nebra Sky Disk

This bronze disk (about 12 inches in diameter) dating back to 1600 BCE was found in Germany. The inlaid gold symbols appear to represent the sun, moon and stars. The cluster of stars in the upper right likely represents the Pleiades. The arc at the right may represent the angle between the rising or setting of the sun in winter and summer. What the lower arc represents is not known.

Human beings have forever wondered about their place in the universe. They paid attention to the sky, watched the phases of the moon, and determined the changes in the sun from winter to summer. This sky disk is but one of many prehistoric representations of the heavens. Monuments such as Stonehenge were built using knowledge of the solstices. Many ancient myths may perhaps be related to how the heavens change with time.



Beneath the heavens was the world wherein we lived. Was this just a flat disk floating on a sea?

This map shows the world as understood by Herodotus (484-425 BCE). The map was put together based on the geographic descriptions in his *Histories.* He was born in Helicarnassus on the Western coast of present-day Turkey and lived much of his life in Athens. Greek maps were made for people who traveled by boat. Thus the rivers are prominent – the Ister is the modern Danube.

In Book IV of the *Histories*, Herodotus recounts the voyage made by some Phoenicians around the continent of Africa:

As for Libya [Herodotus' name for Africa], we know it to be washed on all sides by the sea, except where it is attached to Asia. This discovery was first made by Necos, the Egyptian king, who on desisting from the canal which he had begun between the Nile and the Arabian gulf, sent to sea a number of ships manned by Phoenicians, with orders to make for the Pillars of Hercules, and return to Egypt through them, and by the Mediterranean. The Phoenicians took their departure from Egypt by way of the Erythraean sea [Indian Ocean], and so sailed into the southern ocean. When autumn came, they went ashore, wherever they might happen to be, and having sown a tract of land with corn, waited until the grain was fit to cut. Having reaped it, they again set sail; and thus it came to pass that two whole years went by, and it was not till the third year that they doubled the Pillars of Hercules, and made good their voyage home. On their return, they declared — I for my part do not believe them, but perhaps others may — that in sailing round Libya they had the sun upon their right hand. In this way was the extent of Libya first discovered.

Though Herodotus did not believe the Phoenicians, their report is one of the first pieces of evidence that the earth is spherical rather than flat. In the southern hemisphere the sun is in the north. The sun would be on their right when the traveled westward below the equator.

Small bronze statue of Necho II

Necho II (610-595 BCE)

Necho II was an ambitious king of Egypt. He allied the Egyptians with the Assyrians against Babylon and defeated the Israelites at Megiddo (later to be known as Armageddon). He also tried to make a canal between the Nile and the Red Sea.

He commissioned some Phoenician sailors to journey around the continent of Africa from the Red Sea to the Pillars of Hercules. They reported that as they voyaged westward round the Cape of Good Hope, the noonday sun was on their right, i.e. to the north.

The findings of the Phoenicians could not be explained if the earth were a flat disc floating in the sea. If so the direction toward an object in the sky would be the same wherever one was on the disc. The fact that the direction changed meant that the surface of the Earth had to be curved.

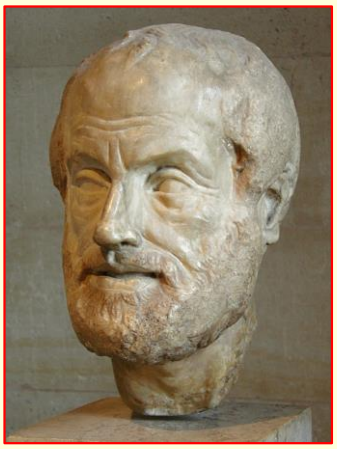
Aristotle's *On the Heavens* (*De Caelo*), 350 BCE

Aristotle (384-322 BCE) concluded that the Earth was spherical for both theoretical and experiential reasons:

(i) the element earth seeks itself and therefore by convergence all portions of the earth will come together to form a sphere.

(ii) there are stars seen in the south that are not seen in the north.

(iii) the shadow of the earth on the moon during a lunar eclipse has a circular edge



Roman marble copy of Greek bronze of Aristotle, Louvre

In order to understand the evolution of our ideas about the place of the Earth in the Universe, we have to understand the physics of Aristotle since this was the dominant theory for almost two millennia.

Aristotle categorized matter into five elements: four terrestrial elements (earth water, air, fire) and a fifth (aether) to explain the heavens. These elements had been identified much earlier in the Hindu Vedas (originating before 1000 BCE). They form the basis of *Ayurveda* medicine which is still in use today. In the West, Aristotle's categories became part of the medical system proposed by Galen (129-200 CE). The four humors were blood (air), yellow bile (fire), black bile (earth), and phlegm (water).

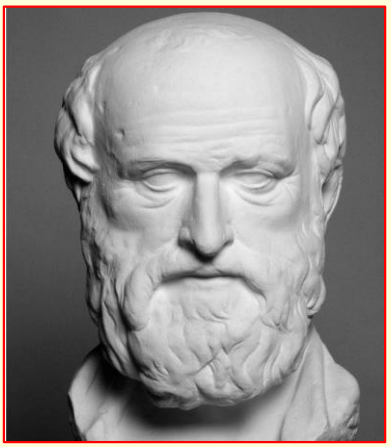
Aristotle's Physics and Astronomy

There are four elements – earth, water, air and fire. Earth and Water tend to fall whereas Air and Fire tend to rise. Thus the universe should contain earth at its center surrounded by concentric spheres of water, air and fire. However, because this system was subject to change, the earth had in part been raised out of the water. The stars were located in the fifth element – the aether.

Two kinds of stars could be observed – fixed and the wandering ("planet" from Greek *planao* wander). Aristotle located these in the aether. To keep them from falling he embedded them in concentric crystalline spheres. The fixed stars were in the outermost sphere. The sun, moon and

all the wandering planets were each located in their own sphere. The sphere of the moon and everything above it were perfect and not subject to change or corruption.

Aristarchus of Samos (310-220 BCE), who worked in Alexandria, suggested that the wandering stars might revolve around the sun. But this did not make sense in Aristotelian physics, and Aristarchus was ignored.

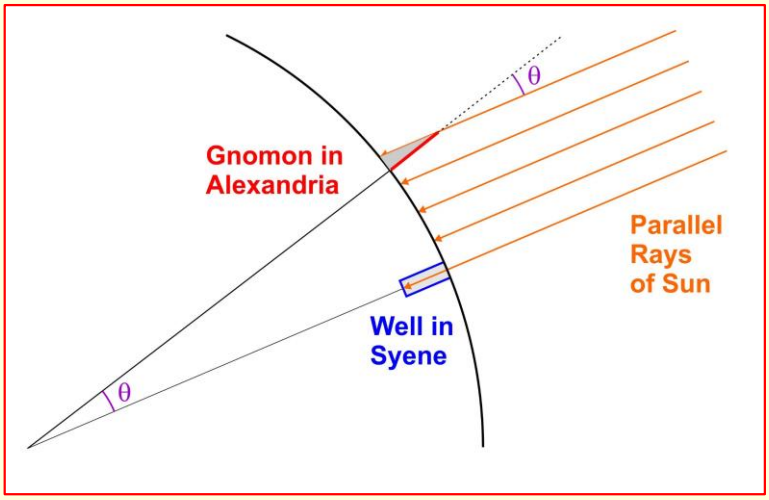


Possible portrait of Eratosthenes

Eratosthenes (276–194 BCE)

Born in Cyrene (part of present-day Libya), Eratosthenes studied in Athens and then became the head of the great Library of Alexandria. As a mathematician he invented a way to discover prime numbers. As a geographer he proposed the idea of longitude. He is most famous for measuring the circumference of the earth.

Late in life he became blind and he is reported to have starved himself to death in despair.



Eratosthenes (276-194 BCE), the chief librarian in Alexandria, heard that at the summer solstice the buildings in Syene (present-day Aswan) cast no shadow, and if one looked down a deep well one could see the sun reflected by the water. Aswan (24.0 degrees latitude) is located very close to the Tropic of Cancer (23.4 degrees). He measured the angle at which the sun's rays cast a

shadow in Alexandria on the summer solstice as 7.2 degrees. This meant that the distance from Alexandria to Syene was 7.2/360 the circumference of the Earth. In order to get the distance to Syene, Eratosthenes is supposed to have employed bematists (Greek *bema*, pace), surveyors who measured distances in paces. Alexander had used these in his various expeditions. The distance was 5000 stadia. A stadion is just less than one eighth of a mile (a furlong). If one takes the distance as 185 meters Eratosthenes' calculation gives 46250 km which is about 15% longer than the actual 40008 km. Also, the North South distance between Alexandria and Syene is less than 5000 stadia since Syene is slightly East of Alexandria.

The results of Erastothenes were replicated using similar measurements by Posidonius about a century later based on the distance between Rhodes and Alexandria. Unfortunately his estimate of the distance was too short and his calculation of circumference gave 29000 km – much shorter than the actual distance. Ptolemy used this measurement in his *Geography*. Christopher Columbus predicted that the distance to the Indies from Spain was therefore about 4000 km. If he had known it was four times this distance he would not have set sail – he could only take provisions for the shorter voyage.

Ptolemy (100-170 CE)

15th Century Florentine map of the world based on the coordinates described in Ptolemy's *Geography*

Ptolemy was an astronomer and geographer who lived in Alexandria.

He described the geography of the known world.

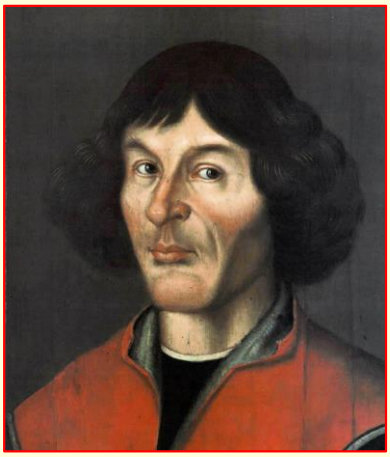
He followed Aristotle's geocentric view of the universe, but made more exact models of the paths of wandering stars, using epicycles to explain their deviances from perfect circularity.

As the map demonstrates, Ptolemy's geography was very accurate. His astronomy was also accurate in its ability to predict the locations and movements of the stars. However, it failed to explain why they moved in the way they did.

The Ptolemaic idea of a geocentric universe with the planetary motions explained by epicycles persisted until the 15th Century

Nicolas Copernicus (1473-1543)

Copernicus studied astronomy and mathematics in Poland. He then spent several years in Italy before returning to the University of Warmia. He decided that a helio-centric model of the universe would better explain the planetary motions than the geocentric model of Aristotle and Ptolemy. However, for fear of being condemned for heresy, he did not publish his book *The Revolutions of the Heavenly Spheres* until he was close to death.



Anonymous portrait in Turun, 1580

Copernicus was a brilliant astronomer. He correctly judged that the Church would not easily agree to his new conception of the universe.

Tycho Brahe (1546-1601)

Tycho Brahe was a Danish nobleman. He lost his nose in a fencing duel during his studies at the University of Rostock. He went on to become the last of the great naked-eye astronomers, accumulating an immense set of data on the motions of the planets. He also observed the sudden appearance of a supernova in 1572. He showed that this was more distant than the moon. This refuted the Aristotelian concept of an unchanging supra-lunary universe. Towards the end of Brahe's life, Johannes Kepler (1571-1630) worked with him in Prague.

If you look closely at the engraving you can see the edge of Brahe's brass nasal prosthesis.

Brahe worked initially worked on an island estate in Denmark called Uraniborg (dedicated to *Urania* the muse of astronomy). After a disagreement with the Danish king, Brahe went to Prague where he was supported by the Holy Roman Emperor. His death has been attributed to a ruptured bladder, when he refused to leave a banquet with the Emperor to relieve himself because he thought that would be impolite.

Johannes Kepler was the astronomer who found that the orbits of the planets were elliptical rather than circular. This phenomenon remained unexplained until the work of Newton.

Giordano Bruno
(1548-1600)

Born near Naples, he entered the Dominican order but was accused of heresy and forced to flee. He taught philosophy at various cities in Europe, supporting the Copernican view of the universe, but having a more mystical view of physics than other scientists of his era. He was arraigned before the Roman Inquisition, found guilty of heresy and burned at the stake in the Campo dei Fiori in Rome.

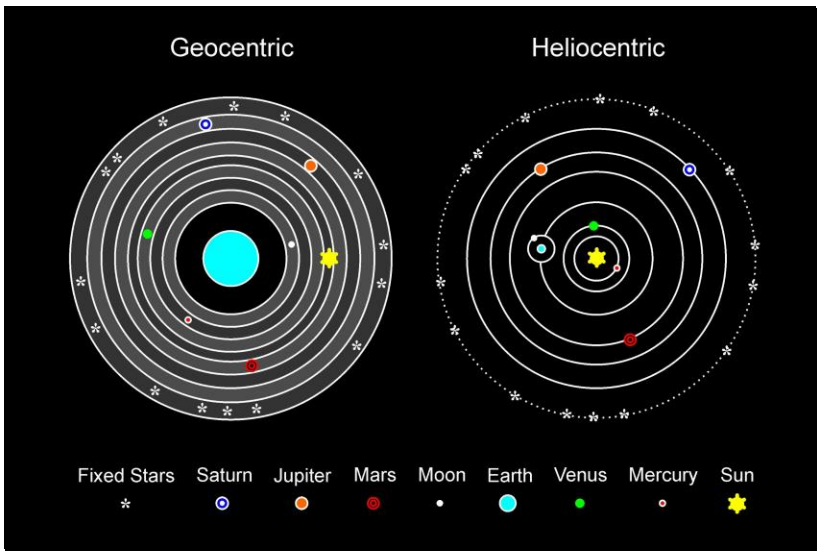
The illustration shows the statue erected in the Campo dei Fiori in 1889 in honor of Giordano Bruno and despite the opposition of the Vatican.

This photograph shows the Campo dei Fiori. The audio clip is from a poem by 1994 Heather McHugh entitled *What He Thought.* The poem recounts an exchange visit of American poets to Italy. Their final dinner is in a restaurant on the Campo dei Fiori. The poem ends:

> For our parting evening then
> our host chose something in a family restaurant, and there
> we sat and chatted, sat and chewed,
> till, sensible it was our last
> big chance to be poetic, make
> our mark, one of us asked

"What's poetry?
Is it the fruits and vegetables
and marketplace of Campo dei Fiori or
the statue there?" Because I was
the glib one, I identified the answer
instantly, I didn't have to think – "The truth
is both, it's both!" I blurted out. But that
was easy. That was easiest to say. What followed
taught me something about difficulty,
for our underestimated host spoke out
all of a sudden, with a rising passion, and he said:
The statue represents Giordano Bruno,
brought to be burned in the public square
because of his offence against
authority, which is to say
the Church. His crime was his belief
the universe does not revolve around
the human being: God is no
fixed point or central government but rather is
poured in waves, through all things. All things
move. "If God is not the soul itself, He is
the soul of the soul of the world." Such was
his heresy. The day they brought him
forth to die, they feared he might
incite the crowd (the man was famous
for his eloquence). And so his captors
placed upon his face
an iron mask, in which

he could not speak. That's
how they burned him. That is how
he died: without a word,
in front of everyone.
And poetry –
(we'd all
put down our forks by now, to listen to
the man in gray; he went on
softly) –
poetry is what
he thought, but did not say.



This slide shows the two competing theories of the universe at the time of Galileo. As well as the different orbits, the geocentric theory proposed that the planets were embedded in crystalline spheres whereas the heliocentric theory had no such spheres. One of the arguments of those opposed to the heliocentric theory was the lack of any explanation for how the planets kept their places if there were no such crystalline spheres.

In addition to these two theories, Tycho Brahe had proposed an additional model wherein the sun and moon revolved around the earth but the rest of the planets revolved around the sun.

Portrait by Ottavio Leoni, 1624

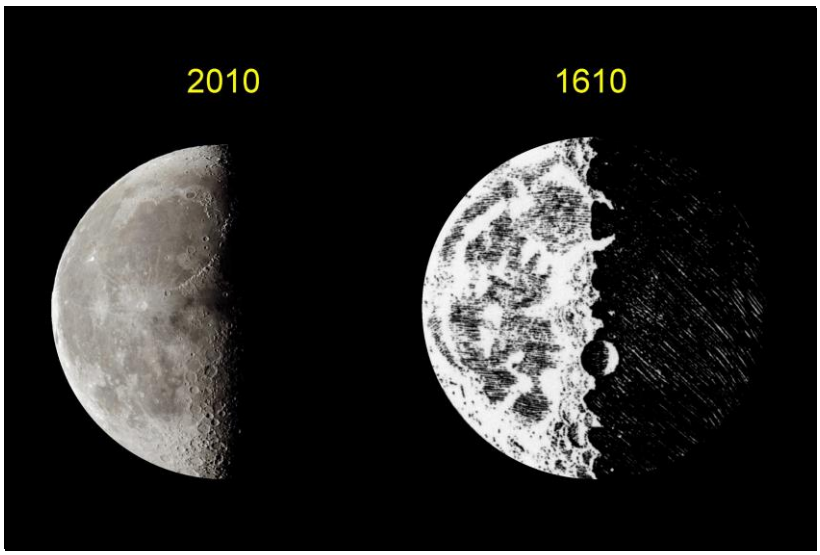
Galileo Galilei (1564-1642)

Galileo was the son of a lutenist in Pisa. He studied mathematics and physics and became a professor in Venice. In 1609 Galileo obtained a telescope which had just been invented in Holland. He was the first to use it to study the heavens. He reported three main findings:

(i) the moon's light is reflected, and its surface has craters and hills.

(ii) four moons rotate about the planet Jupiter

(iii) the planet Venus has phases just like the moon



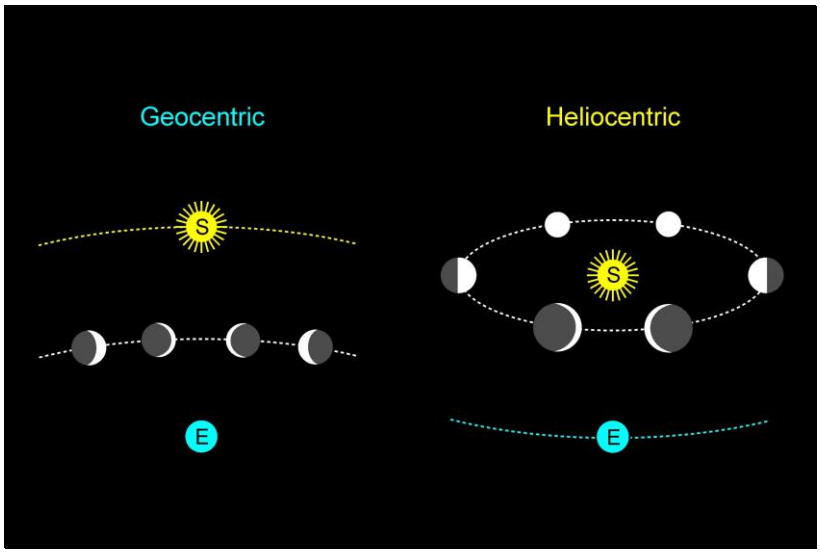
Galileo's description of the moon's surface as being flawed and of moon's light as being reflected contradicted the Aristotelian idea that the moon and everything above it were perfect. Change and deterioration only happened below the moon..

Galileo's drawing of what he saw through the telescope is a little exaggerated from reality. Part of this was likely due to the limited field of view of his telescope, which prevented him from seeing more than a small part of the moon at any one time. His drawing clearly shows the craters and mountains. The shadows demonstrated that the light coming from the moon is reflected.

The 4 main moons of Jupiter were discovered almost simultaneously by Galileo and by Simon Marius, a German astronomer. Galileo called them the Medici stars, in an effort to gain the support of the Medici family in Florence. Marius gave them the names of those seduced by Jupiter – Io, Europa, Ganymede, Callisto.

The orbital times for these moons vary between 1.8 and 16.7 days. Thus Galileo could observe the moons in different positions on successive nights. The clip shows time-lapse photographs from the Juno spacecraft on its way to Jupiter. As the moons go behind the planet (on the left in the photographs) in relation to the sun (located on the right) they are briefly eclipsed. The music is appropriately majestic (Vangelis "Titans" - from the 2004 movie *Alexander).*
This clip is extracted from a longer video:
https://www.space.com/33348-jupiter-moon-s-orbital-dance-humans-have-never-seen-this-video.html
or
https://www.youtube.com/watch?v=zqZEgoJasPQ

The motions of these moons demonstrated that small celestial bodies orbited around larger bodies. This would be impossible if the larger bodies were embedded in a crystalline sphere. Their motion also indicated that some unfixed celestial objects did not orbit around the earth.



If the planet Venus shone with its own light then it would appear circular at all times. Since it changes phase, the light is reflected

In the geocentric theory both Venus and the sun would orbit the Earth. If the light from Venus was indeed reflected from the sun then we should never be able to see a full circular view of the planet. If the planets and the earth both orbited the sun, we should see the planet Venus go through phases just like the moon.

Before the telescope one could not see the phases of Venus. One could only assess its brightness. This did not seem to change – since when the planet was in front of the sun it was closer to the Earth and this compensated for the fact that only part of its surface was reflecting light.

Galileo found that the planet went through a full set of phases just like the moon. Galileo wrote in code to Kepler *Cynthiae figuras aemulatur mater amorum*. The mother of love (Venus) copies the forms of the Cynthia (the moon).

This is a clip form the movie *Galileo* based on the play by Bertolt Brecht. Galileo is played by Topol and his colleague Sagredo by Michael Gough. The episode dramatizes Galileo's discovery of the moons of Jupiter. The importance of the findings is clearly shown, though, after Star Trek's "I am a doctor not a physicist," Galileo's statement "I am a mathematician not a theologian" sounds more comic than insightful.

Sagredo is correct in his fears. A quotation from Machiavelli (a century before Galileo) is appropriate:

It ought to be remembered that there is nothing more difficult to take in hand, more perilous to conduct, or more uncertain in its success, than to take the lead in the introduction of a new order of things. Because the innovator has for enemies all those who have done well under the old conditions, and lukewarm defenders in those who may do well under the new. This coolness arises partly from fear of the opponents, who have the laws on their side, and partly from the incredulity of men, who do not readily believe in new things until they have had a long experience of them.

The eyes of the Lord are upon the righteous, and his ears are open unto their cry. (*Psalms* 34: 15

Dome of the Church of the Holy Sepulchre, Jerusalem

Why were Galileo's ideas found unacceptable by the Church? The key feature of the geocentric system was that it was centered upon the Earth. God looked down from the Heavens upon his special creation. The domes of churches provide a vivid representation of this idea. The faith is human beings as God's special creation was completely disrupted by the Copernican theory.

In Brecht's play *Galileo*, this is expressed by an old cardinal:
I am not just any old creature on any insignificant star briefly circling in no particular place. I am walking, with a firm step, on a fixed earth. It is motionless, it is the center of the universe. I am at the center and the eye of the Creator falls upon me and me alone.

Ecclesiastes 1: 4-5

One generation passeth away, and another generation cometh: but the earth abideth for ever.

The sun also ariseth, and the sun goeth down, and hasteth to his place where he arose.

Joshua 10: 12-13

Then spake Joshua to the LORD in the day when the LORD delivered up the Amorites before the children of Israel, and he said in the sight of Israel, Sun, stand thou still upon Gibeon; and thou, Moon, in the valley of Ajalon.

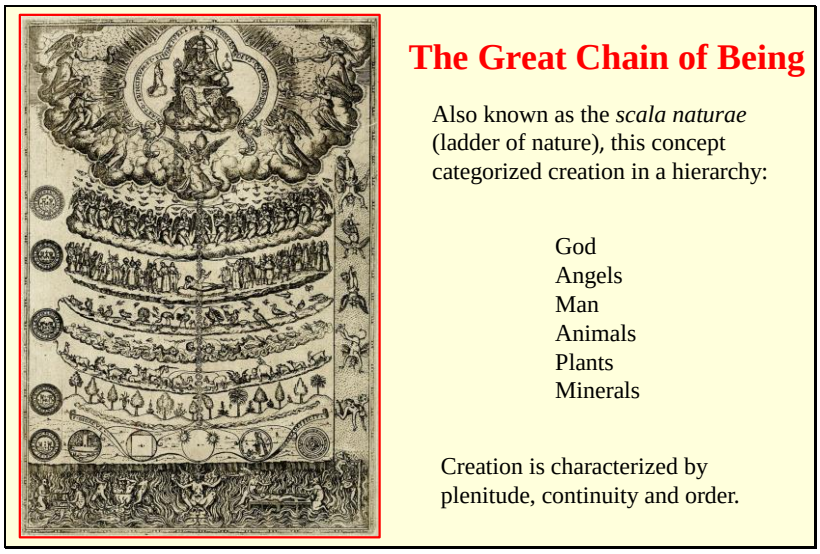
And the sun stood still, and the moon stayed, until the people had avenged themselves upon their enemies.

The Church at the time of Galileo used the scriptures as a means for testing whether something was true or not. The scriptures were acknowledged as the word of God and thus by definition true. And as these verses demonstrate, the scriptures supported the idea that the sun went round

the earth, and that the sun could even be stopped in its tracks by divine order. The argument is complicated – if the sun were stationary at the center of the planets, why should it be commanded to stand still.

Illustration of Joshua commanding the sun to stand still by Gustav Doré, 1866.

Those who interpret the Bible often have difficulty with metaphor. The duration of the killing on the day of the battle seemed to last forever, as though time had stopped.



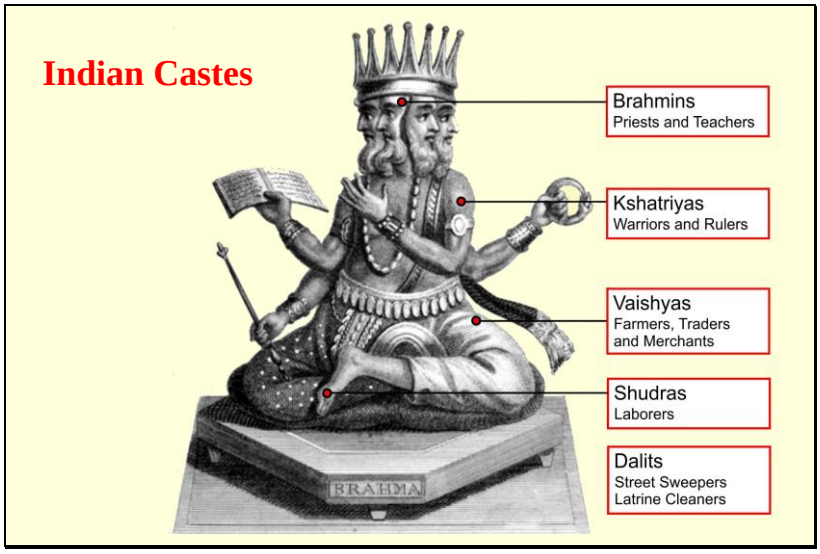
The other argument against the heliocentric theory was that it would disrupt the Great Chain of Being. Without this divinely ordered arrangement, the universe would revert to chaos.

The illustration is from a 1579 book *Rhetorica Christiana* by Diego Valades. The idea goes back to Ancient Greece, and is described in Aristotle's *Historia Animalium.* In the lower right is a representation of the geocentric model of the universe. At the very bottom is Satan. On the right are the falling angels.

The criticism of evolution as having "missing links" probably comes from this "chain" of being.

The great chain also moves from spirit, which is eternal, to matter, which is changeable. Humanity has aspects of both – soul and body.

Within the level of humanity, there is also a hierarchy with the monarch at the top and the peasants at the bottom. Without this hierarchy wherein everyone knows their place, human society would dissolve into chaos.



Social hierarchies have been around as long as human beings have existed. The most striking and persistent of these hierarchies is the caste system of India. This goes back to the Vedas which were initially created before 1000 BCE. Some scholars have suggested that the verses about caste were inserted later to justify the social hierarchies that developed. Even so the hierarchies have a long history.

When they divided Purusa how many portions did they make? What do they call his mouth, his arms? What do they call his thighs and feet?
The Brahman was his mouth, of both his arms was the Rajanya made. His thighs became the Vaishya, from his feet the Shudra was produced.
(*RigVeda* 10: 90: 11-12)

Purusa was the idea of primal creation – the word means "before dawn." The image is that of a God that is sacrificed to make the universe.

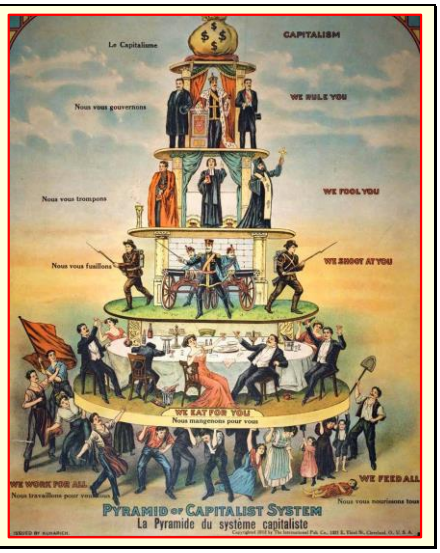
Severe social hierarchies are also supported by other world religions. Slavery was condoned in Judaism and in Christianity:

As for the male and female slaves whom you may have, it is from the nations around you that you may acquire male and female slaves. You may also acquire them from among the aliens residing with you, and from their families that are with you, who have been born in your land; and they may be your property. You may keep them as a possession for your children after you, for them to inherit as property. These you may treat as slaves, but as for your fellow Israelites, no one shall rule over the other with harshness. (*Leviticus* 25:44-46).

Slaves, accept the authority of your masters with all deference, not only those who are kind and gentle but also those who are harsh. For it is a credit to you if, being aware of God, you endure pain while suffering unjustly. (1 *Peter* 2: 18-19).

(These are the New Revised Standard Version translations. Older translations used "bondservant" or "servant" instead of "slave.")

The Pyramid of Capitalism



1911 illustration from *The Industrial Worker*

The established hierarchies are defended by those at the top and attacked by those at the bottom. This shows a socialist view of the social hierarchy

This is another scene from Brecht's *Galileo*. The street balladeer and his wife are played by Georgia Brown and Clive Revill.

When the Almighty made the universe
He made the earth and then he made the sun
Then round the earth he bade the sun to turn
That's in the Bible, Genesis, Chapter One.
And from that time all creatures here below
Were in obedient circles meant to go.

Anonymous Portrait, late 16th Century

Roberto Bellarmine (1542-1621)

In 1615, Galileo travelled to Rome. His findings were confirmed by the Vatican astronomers. However, in 1616, the Vatican decreed that the Copernican theory was "foolish and absurd."

Galileo then met with Cardinal Bellarmine who instructed him to abandon any Copernican beliefs. It is not clear whether Galileo was allowed to discuss the Copernican system in theoretical terms.

Galileo's first interaction with the Church was through Cardinal Roberto Bellarmine. Bellarmine was an expert in heresy and scriptural interpretation. He had been one of the judges in the tribunal that convicted Giordano Bruno of heresy. In 1930 he was canonized as a Saint.

Bellarmine (1615):

For there is no danger in saying that, by assuming the Earth moves and the sun stands still, one saves all of the appearances better than by postulating eccentrics and epicycles; and that is sufficient for the mathematician. However, it is different to want to affirm that in reality the sun is at the center of the world and only turns on itself, without moving from east to west, and the earth is in the third heaven and revolves with great speed around the sun; this is a very dangerous thing, likely not only to irritate all scholastic philosophers and theologians, but also to harm the Holy Faith by rendering Holy Scripture false.

Urban VIII (1568-1644)

Maffeo Barberini, a man educated in both arts and sciences, became Pope in 1623. He had known Galileo in Florence, and agreed that Galileo might write something about the differences between the Copernican and the geocentric theories of the universe. In 1632 Galileo published his *Dialogue Concerning The Two Chief World Systems.* The dialogue was between Salviati, Sagredo and Simplicio. The pope was offended.

Portrait of Urban VIII
Pietro da Cortona, 1627

Bellarmine died in 1621 and Galileo's next interaction with the church came when Urban VIII was pope.

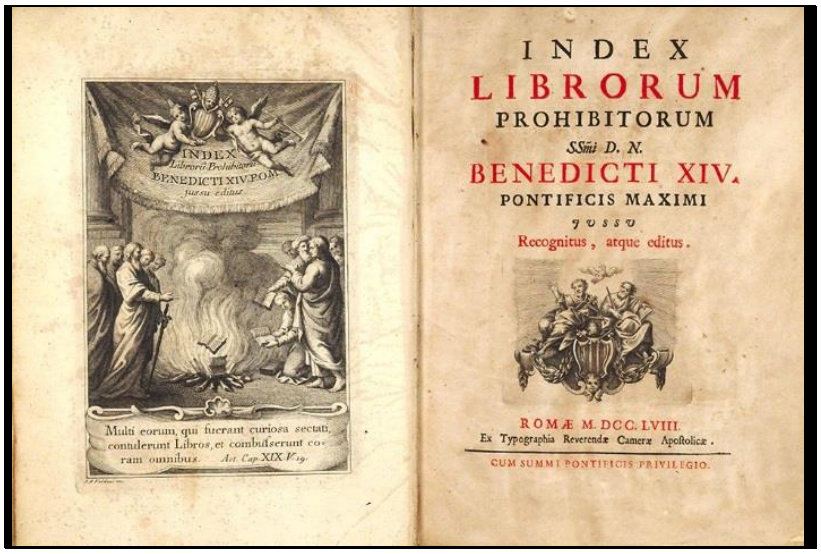
It is not clear why Urban VIII was upset. Perhaps he wished to assert his authority at a time when it was being challenged. Perhaps he thought that Galileo was mocking him. The character Simplicio who defends the Aristotelian ideas in the *Dialogue* was a fool.

The Trial of Galileo (1633)

Galileo was found guilty of "vehement heresy," and his books were placed on the Index. He was forced to publically abjure the idea that the earth moved around the sun. Legend has it that he said *Eppur si muove* (And yet it moves) under his breath after his recantation.

Galileo Facing the Roman Inquisition
Cristiano Banti, 1857

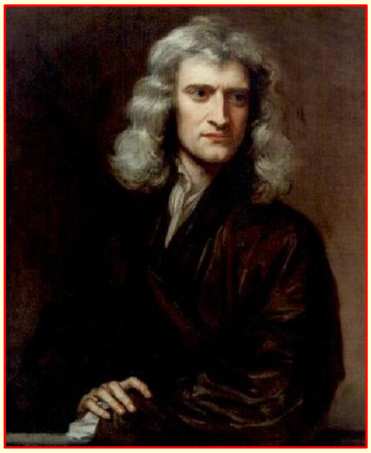
Once Galileo was arraigned before the Inquisition, there was little doubt about the outcome. As pointed out by Giorgio de Santillana (1955), "In a theological state, man is not innocent until proved guilty. Much the reverse, he is presumed guilty and God or the authorities alone can know how much." Galileo was condemned to prison, though this became house-arrest.



Galileo's works were then listed in the *Index Librorum Prohibitorum,* which had been was established in 1559. This slide shows the Index at the time of Pope Benedict XIV (1758)**.**

The scriptural justification for the prohibiting books (illustrated in the frontispiece) comes from: Many of them also which used curious arts brought their books together, and burned them before all men (*Acts* 19: 19)

The Index finally ceased in 1966. This was perhaps because there were just too many books being published. It had become an impossible task to review and prohibit those that were not in keeping with the faith.



Portrait by Geoffrey Kneller, 1689

Isaac Newton (1642-1727)

In 1687, Newton published his *Philosophiæ Naturalis Principia Mathematica,* wherein he proposed the law of universal gravitation: that all masses attract each other with a force that varies directly with the product of their masses and inversely with the square of the distance between them. Newton used the force of gravity to explain Kepler's elliptical planetary orbits and the perturbations that occurred in these orbits as a result of the gravitational attraction between one planet and another. He also explained the diurnal motion of the tides under the gravitational attraction of the moon.

One of the Church's criticisms of the Copernican system was that it was not proven. This fails to understand the process of science wherein nothing is ever proven. Rather science accepts as true that which fails to be disproven when repeatedly tested.

Nevertheless, Galileo's findings did not definitively disprove the geocentric system. Even the phases of Venus might be explained by a the system of Tycho Brahe wherein Venus would revolve around the Sun which itself revolved around the Earth. Why did the planets revolve around the sun? Why were the orbits actually elliptical rather than circular as shown by Kepler? It was not until Isaac Newton that the orbits of the planets around the sun were accounted for by the theory of gravitation. And this theory was itself tested by the idea that planets attracted planets thus slightly perturbing their orbits around the sun.

Gravity also accounted for the tides. Galileo had attempted to explain the tides as caused by the rotation of the earth, but this had completely failed to account for the fact that there were two tides each day.

The world was duly astonished by the genius of Newton. Alexander Pope exclaimed:
Nature and nature's laws lay hid in night;
God said "Let Newton be" and all was light.

Aftermath of the Galileo Affair

Copernicus' *Revolutions* and Galileo's *Dialogue* remained on the Index of Prohibited Books until 1835.

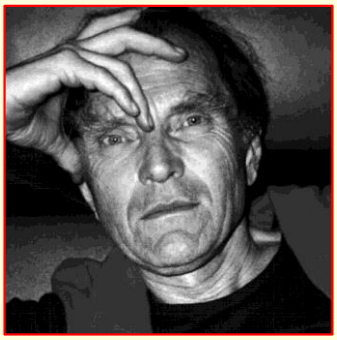
Science continued to investigate the Heavens. However, most of this work went on in the Protestant countries of Northern Europe.

In 1980 the newly elected Pope John-Paul II established a commission to consider the actions of the Inquisition. The commission did not arrive at any conclusion, though the pope issued a statement stating that the conflict between science and religion was more myth than truth.

In 2000, the Catholic Church reviewed the trial of Giordano Bruno for heresy. The Church confirmed that Bruno had been justly convicted but regretted that he had been executed (by civil authorities).

Paul Feyerabend (1924-1994)

Feyerabend was an Austrian philosopher who taught at the University of California, Berkeley. He taught that there was no one-and-only way to gain knowledge – "epistemological anarchism."



"The church at the time of Galileo was much more faithful to reason than Galileo himself, and also took into consideration the ethical and social consequences of Galileo's doctrine. Its verdict against Galileo was rational and just." (*Against Method*, 1975)

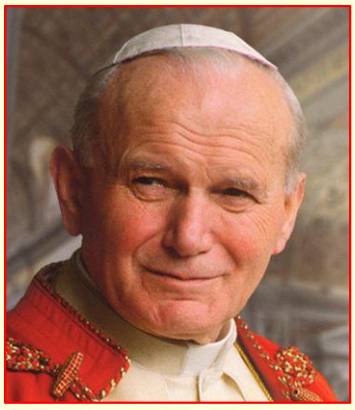
Not everyone has taken the side of Galileo.

Paul Feyerabend delighted in arguing against consensus. As well as considering the ethical justification for geocentrism, Feyerabend also pointed out that accepting the truth of observations made through the telescope itself requires justification. The optical principles underlying telescopes had not been fully worked out at the time of Galileo's *Dialogue*. Descartes *Optics* was not published until 1937.

Feyerabend was quoted by Cardinal Ratzinger (later Pope Benedict XV) in 1994 to support the Church's judgment against Galileo.

St Augustine in His Study, Vitorre Carpacio, 1502

Pope John-Paul II affirmed the teachings of St. Augustine (354-430 CE):
"If it happens that the authority of Sacred Scripture is set in opposition to clear and certain reasoning, this must mean that the person who interprets Scripture does not understand it correctly."



John-Paul II (1920-2005)
elected pope in 1978

From the beginning of the Age of Enlightenment down to our own day, the Galileo case has been a sort of "myth," in which the image fabricated out of the events was quite far removed from reality. In this perspective, the Galileo case was the symbol of the Church's supposed rejection of scientific progress, or of "dogmatic" obscurantism opposed to the free search for truth. … A tragic mutual incomprehension has been interpreted as the reflection of a fundamental opposition between science and faith. The clarifications furnished by recent historical studies enable us to state that this sad misunderstanding now belongs to the past. (John-Paul II, 1981)

The Pope went on to declare:
There exist two realms of knowledge, one which has its source in Revelation and one which reason can discover by its own power. To the latter belong especially the experimental sciences and philosophy. The distinction between the two realms of knowledge ought not to be understood as opposition. The two realms are not altogether foreign to each other, they have points of contact. The methodologies proper to each make it possible to bring out different aspects of reality.

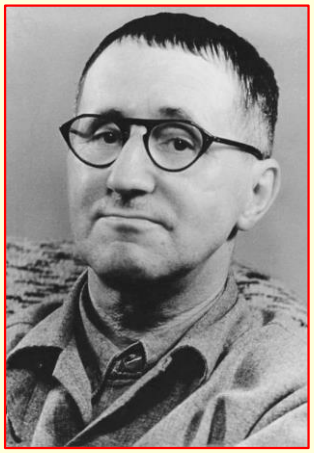
This led Stephen Jay Gould to propose the idea of non-overlapping magisterial (1997, 1999).

Context of Brecht's *Life of Galileo*

Brecht wrote the first version of his play in 1939. The play was clearly related to the rise of Nazism in Germany.

The play was revised for its first English production was in 1947. The context was the recent atomic bombing of Hiroshima and Nagasaki.

A further revision led to a new production in East Berlin in 1955 at the height of the Cold War.



Bertolt Brecht (1898-1956)

As this session ends, we return to Galileo. In his play Brecht was concerned about the role of scientists in society. In the various situations wherein he wrote and revised the play, how should scientists react? Should Galileo have refused to recant? Should the physicists in Germany have refused to work for the Nazi war effort? Should scientists have refused to develop the atomic bomb?

At the end of Brecht's *Galileo*, the old scientist is visited by his student Andrea Sarti (Tom Conti). Galileo (Topol) gives him a new book on his recent researches and asks him to smuggle it out of Italy so that it can be published. Sarti, who had previously thought that Galileo's recantation was wrong, suggests that perhaps Galileo was ahead of his time in ethics as well as physics, that he had saved his life so that he could further the pursuit of truth. Galileo disagrees:

As a scientist I had a unique opportunity. In my day astronomy emerged into the market place. Given this unique situation, if one man had put up a fight, it might have had tremendous repercussions. Had I stood firm, the scientists could have developed something like the doctors' Hippocratic Oath, a vow to use their knowledge exclusively for mankind's benefit. As things are, the best that can be hoped for is a race of inventive dwarfs who can be hired for any purpose... I handed my knowledge to those in power for them to use, fail to use, misuse - whatever best suited their objectives.

Should Galileo have refused to recant?

Representing the Cosmos

Pillars of Creation
Eagle Nebula, 2014
Hubble Space Telescope

The huge trunks of gas and dust are in the process of creating new stars. Is this the hand of God?