

= Dynamics of the celestial spheres =

Ancient , medieval and Renaissance astronomers and philosophers developed many different theories about the dynamics of the celestial spheres . They explained the motions of the various nested spheres in terms of the materials of which they were made , external movers such as celestial intelligences , and internal movers such as motive souls or impressed forces . Most of these models were qualitative , although a few of them incorporated quantitative analyses that related speed , motive force and resistance .

= = The celestial material and its natural motions = =

In considering the physics of the celestial spheres , scholars followed two different views about the material composition of the celestial spheres . For Plato , the celestial regions were made " mostly out of fire " on account of fire 's mobility . Later Platonists , such as Plotinus , maintained that although fire moves naturally upward in a straight line toward its natural place at the periphery of the universe , when it arrived there , it would either rest or move naturally in a circle . This account was compatible with Aristotle 's meteorology of a fiery region in the upper air , dragged along underneath the circular motion of the lunar sphere . For Aristotle , however , the spheres themselves were made entirely of a special fifth element , Aether (?????) , the bright , untainted upper atmosphere in which the gods dwell , as distinct from the dense lower atmosphere , Aer (???) . While the four terrestrial elements (earth , water , air and fire) gave rise to the generation and corruption of natural substances by their mutual transformations , aether was unchanging , moving always with a uniform circular motion that was uniquely suited to the celestial spheres , which were eternal . Earth and water had a natural heaviness (gravitas) , which they expressed by moving downward toward the center of the universe . Fire and air had a natural lightness (levitas) , such that they moved upward , away from the center . Aether , being neither heavy nor light , moved naturally around the center .

= = The causes of celestial motion = =

As early as Plato , philosophers considered the heavens to be moved by immaterial agents . Plato believed the cause to be a world @-@ soul , created according to mathematical principles , which governed the daily motion of the heavens (the motion of the Same) and the opposed motions of the planets along the zodiac (the motion of the Different) . Aristotle proposed the existence of divine unmoved movers which act as final causes ; the celestial spheres mimic the movers , as best they could , by moving with uniform circular motion . In his *Metaphysics* , Aristotle maintained that an individual unmoved mover would be required to insure each individual motion in the heavens . While stipulating that the number of spheres , and thus gods , is subject to revision by astronomers , he estimated the total as 47 or 55 , depending on whether one followed the model of Eudoxus or Callippus . In *On the Heavens* , Aristotle presented an alternate view of eternal circular motion as moving itself , in the manner of Plato 's world @-@ soul , which lent support to three principles of celestial motion : an internal soul , an external unmoved mover , and the celestial material (aether) .

= = = Later Greek interpreters = = =

In his *Planetary Hypotheses* , Ptolemy (c.90 ? 168) rejected the Aristotelian concept of an external prime mover , maintaining instead that the planets have souls and move themselves with a voluntary motion . Each planet sends out motive emissions that direct its own motion and the motions of the epicycle and deferent that make up its system , just as a bird sends out emissions to its nerves that direct the motions of its feet and wings .

John Philoponus (490 ? 570) considered that the heavens were made of fire , not of aether , yet maintained that circular motion is one of the two natural motions of fire . In a theological work , *On the Creation of the World* (*De opificio mundi*) , he denied that the heavens are moved by either a

soul or by angels , proposing that " it is not impossible that God , who created all these things , imparted a motive force to the Moon , the Sun , and other stars ? just as the inclination to heavy and light bodies , and the movements due to the internal soul to all living beings ? in order that the angels do not move them by force . " This is interpreted as an application of the concept of impetus to the motion of the celestial spheres . In an earlier commentary on Aristotle 's Physics , Philoponus compared the innate power or nature that accounts for the rotation of the heavens to the innate power or nature that accounts for the fall of rocks .

= = = Islamic interpreters = = =

The Persian philosophers al @-@ Farabi (c.872 ? c.950) and Avicenna (c.980 ? 1037) , following Plotinus , maintained that Aristotle 's movers , called intelligences , came into being through a series of emanations beginning with God . A first intelligence emanated from God , and from the first intelligence emanated a sphere , its soul , and a second intelligence . The process continued down through the celestial spheres until the sphere of the Moon , its soul , and a final intelligence . They considered that each sphere was moved continually by its soul , seeking to emulate the perfection of its intelligence . Avicenna maintained that besides an intelligence and its soul , each sphere was also moved by a natural inclination (mayl) .

An interpreter of Aristotle from Muslim Spain , al @-@ Bitruji (d. c.1024) , proposed a radical transformation of astronomy that did away with epicycles and eccentrics , in which the celestial spheres were driven by a single unmoved mover at the periphery of the universe . The spheres thus moved with a " natural nonviolent motion " . The mover 's power diminished with increasing distance from the periphery so that the lower spheres lagged behind in their daily motion around the Earth ; this power reached even as far as the sphere of water , producing the tides .

More influential for later Christian thinkers were the teachings of Averroes (1126 ? 1198) , who agreed with Avicenna that the intelligences and souls combine to move the spheres but rejected his concept of emanation . Considering how the soul acts , he maintained that the soul moves its sphere without effort , for the celestial material has no tendency to a contrary motion .

Later in the century , a commentator on the Islamic theologian Adud al @-@ Din al @-@ Iji (1281 ? 1355) rejected non @-@ religious science and astronomy , following the Ash 'ari doctrine of occasionalism , which maintained that all physical effects were caused directly by God 's will rather than by natural causes . He maintained that the celestial spheres were " imaginary things " and " more tenuous than a spider 's web " .

= = = Medieval Western Europe = = =

In the Early Middle Ages , Plato 's picture of the heavens was dominant among European philosophers , which led Christian thinkers to question the role and nature of the world @-@ soul . With the recovery of Aristotle 's works in the twelfth and thirteenth centuries , Aristotle 's views supplanted the earlier Platonism , and a new set of questions regarding the relationships of the unmoved movers to the spheres and to God emerged .

In the early phases of the Western recovery of Aristotle , Robert Grosseteste (c.1175 ? 1253) , influenced by medieval Platonism and by the astronomy of al @-@ Bitruji , rejected the idea that the heavens are moved by either souls or intelligences . Adam Marsh 's (c.1200 ? 1259) treatise On the Ebb and Flow of the Sea , which was formerly attributed to Grosseteste , maintained al @-@ Bitruji 's opinion that the celestial spheres and the seas are moved by a peripheral mover whose motion weakens with distance .

Thomas Aquinas (c.1225 ? 1274) , following Avicenna , interpreted Aristotle to mean that there were two immaterial substances responsible for the motion of each celestial sphere , a soul that was an integral part of its sphere , and an intelligence that was separate from its sphere . The soul shares the motion of its sphere and causes the sphere to move through its love and desire for the unmoved separate intelligence . Avicenna , al @-@ Ghazali , Moses Maimonides , and most Christian scholastic philosophers identified Aristotle 's intelligences with the angels of revelation ,

thereby associating an angel with each of the spheres . Moreover , Aquinas rejected the idea that celestial bodies are moved by an internal nature , similar to the heaviness and lightness that moves terrestrial bodies . Attributing souls to the spheres was theologically controversial , as that could make them animals . After the Condemnations of 1277 , most philosophers came to reject the idea that the celestial spheres had souls .

Robert Kilwardby (c . 1215 ? 1279) discussed three alternative explanations of the motions of the celestial spheres , rejecting the views that celestial bodies are animated and are moved by their own spirits or souls , or that the celestial bodies are moved by angelic spirits , which govern and move them . He maintained , instead , that " celestial bodies are moved by their own natural inclinations similar to weight " . Just as heavy bodies are naturally moved by their own weight , which is an intrinsic active principle , so the celestial bodies are naturally moved by a similar intrinsic principle . Since the heavens are spherical , the only motion that could be natural to them is rotation . Kilwardby 's idea had been earlier held by another Oxford scholar , John Blund (c . 1175 ? 1248) .

In two slightly different discussions , John Buridan (c.1295 ? 1358) suggested that when God created the celestial spheres , he began to move them , impressing in them a circular impetus that would be neither corrupted nor diminished , since there was neither an inclination to other movements nor any resistance in the celestial region . He noted that this would allow God to rest on the seventh day , but he left the matter to be resolved by the theologians .

Nicole Oresme (c.1323 @-@ 1382) explained the motion of the spheres in traditional terms of the action of intelligences but noted that , contrary to Aristotle , some intelligences are moved ; for example , the intelligence that moves the Moon 's epicycle shares the motion of the lunar orb in which the epicycle is embedded . He related the spheres ' motions to the proportion of motive power to resistance that was impressed in each sphere when God created the heavens . In discussing the relation of the moving power of the intelligence , the resistance of the sphere , and the circular velocity , he said " this ratio ought not to be called a ratio of force to resistance except by analogy , because an intelligence moves by will alone ... and the heavens do not resist it . "

According to Grant , except for Oresme , scholastic thinkers did not consider the force @-@ resistance model to be properly applicable to the motion of celestial bodies , although some , such as Bartholomeus Amicus , thought analogically in terms of force and resistance . By the end of the Middle Ages it was the common opinion among philosophers that the celestial bodies were moved by external intelligences , or angels , and not by some kind of an internal mover .

= = = The movers and Copernicanism = = =

Although Nicolaus Copernicus (1473 ? 1543) transformed Ptolemaic astronomy and Aristotelian cosmology by moving the Earth from the center of the universe , he retained both the traditional model of the celestial spheres and the medieval Aristotelian views of the causes of its motion . Copernicus follows Aristotle to maintain that circular motion is natural to the form of a sphere . However , he also appears to have accepted the traditional philosophical belief that the spheres are moved by an external mover .

Johannes Kepler 's (1571 ? 1630) cosmology eliminated the celestial spheres , but he held that the planets were moved both by an external motive power , which he located in the Sun , and a motive soul associated with each planet . In an early manuscript discussing the motion of Mars , Kepler considered the Sun to cause the circular motion of the planet . He then attributed the inward and outward motion of the planet , which transforms its overall motion from circular to oval , to a moving soul in the planet since the motion is " not a natural motion , but more of an animate one " . In various writings , Kepler often attributed a kind of intelligence to the inborn motive faculties associated with the stars .

In the aftermath of Copernicanism the planets came to be seen as bodies moving freely through a very subtle aethereal medium . Although many scholastics continued to maintain that intelligences were the celestial movers , they now associated the intelligences with the planets themselves , rather than with the celestial spheres .