Humanist Masterpieces

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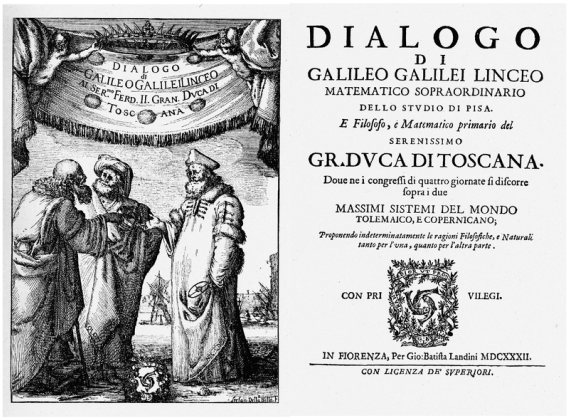
10. Galileo's *Dialogue*



DIALOGO
DI
GALILEO GALILEI LINCEO
MATEMATICO SOPRAORDINARIO
DELLO STVDIO DI PISA.
E Filosofo, e Matematico primario del
SERENISSIMO
GR. DVCA DI TOSCANA.
Doue ne i congressi di quattro giornate si discorre sopra i due
MASSIMI SISTEMI DEL MONDO
TOLEMAICO, E COPERNICANO;
Proponendo indeterminatamente le ragioni Filosofiche, e Naturali tanto per l'una, quanto per l'altra parte.
CON PRI VILEGI.
IN FIORENZA, Per Gio: Batista Landini MDCXXXII.
CON LICENZA DE' SUPERIORI.

AT THE BEGINNING of the 17th century, the cosmology that dominated intellectual discourse was the geocentric model originally formulated by the ancient Greeks. According to Plato, the earth was a sphere, stationary at the centre of the universe. Aristotle agreed and discussed his reasoning in a book written about 340BCE called *On the Heavens*. He saw that eclipses of the moon were caused by the earth's shadow, which was always round. Similarly, ships on the horizon showed their masts and sails before the hull appeared, proving that the earth is a ball.

Aristotle thought that the earth was stationary and that the sun, the moon, the five known planets (from the Greek word for 'wanderer') and the stars moved in circular orbits about the earth. After all, they *appear* to revolve around the earth each day, with the stars circling around the pole, while the earth is a solid substance which *appears* to be at rest.

It was Claudius Ptolemaeus (or Ptolemy), a Roman citizen of Egypt writing in Greek in the middle of the second century CE, who developed what became known as the Ptolemaic model in his book, the *Almagest*. He argued that the earth was in the centre of the universe because we observe that half the stars are above the horizon and half are below at any time. He suggested that eight rotating spheres surrounded the earth, each of which was larger than the one before, like an onion: the moon, mercury, venus, the sun, mars, jupiter, saturn and, on the outer layer, the fixed stars.

Ptolemy had to explain why the motion, size and brightness of the planets varied. So he introduced the idea of epicycles, or little circles, which were smaller orbits around imaginary centres on which the planets moved while describing a revolution around the earth – circles upon circles about the fixed earth. The planets would move closer to and farther from it at different points in their orbit. This Ptolemaic model was generally accepted for the next 1400 years.

It was not treated merely as a matter of opinion but enforced as dogma by Christian authorities, who found it accorded with their own theological position that the earth, as God's special creation, must be the centre of the universe. Heaven could be regarded as lying beyond Ptolemy's eighth sphere, 'the firmanent' in Genesis (1:7), and so the Ptolemaic model was readily absorbed into a Christian cosmology.

In 1514 another model was proposed by a Polish priest and mathematician, Nicolaus Copernicus (1473-1543). He suggested that the sun was stationary at the centre of the solar system and that the earth and planets moved in circular orbits around the sun. This heliocentric model was not completely original: Aristarchus of Samos in the third century BCE presented the first known heliocentric model of the solar system, claiming that the sun, not the earth, was at the centre of the known universe. But his writings on the subject are lost and he had few followers because 'common sense' seemed to refute it. There was also the German Humanist and Cardinal, Nicholas of Cusa (1401-64), who suggested that the earth moved and was not the centre of the universe, but again few paid much notice.

At first, Copernicus (right), who was aware of the views of both Aristarchus and Nicholas, circulated his ideas only to close friends in a manuscript entitled *Commentariolus* ('Little Commentary'). His hesitation may not have been so much a fear of reactionary theologicians as a feeling that his theory was incomplete since he was not really an astronomer and did not carry out detailed observations. It took 30 years before he was persuaded to publish his ideas in *De Revolutionibus Orbium Coelestium (*'Concerning the Revolutions of the Heavenly Spheres'*)* in 1543. According to legend, he received a copy on his deathbed.

Once again, Copernicus had few immediate champions, and the Catholic Church, which accepted the work without any fuss, largely ignored the book for the rest of the 16th century. In 1576 in England, however, Thomas Digges published a work in which he not only included a detailed discussion of the Copernican model but actually went further and suggested that the universe was infinite. Giordano Bruno reached the same conclusion, adding that the stars were suns like our own and even positing life elsewhere in the universe. The Roman Inquisition condemned Bruno to be burnt at the stake in 1600, not so much for his Copernican ideas as for his cosmic pluralism, his pantheistic identification of God and Nature, and his Arianism (the belief that Christ had been created by God and was not God incarnate).

The entire situation changed when it became clear to the Catholic Church that the Copernican theory was espoused by the leading scientist of the day. Copernicus was an obscure Polish priest who made no impact on intellectual discourse, but Galileo Galilei (1564-1642) was a different proposition entirely. By the beginning of the 17th century, Galileo's reputation as an astronomer, physicist and mathematician was

second to none. At the age of 19 he had discovered the isochronism of the pendulum. At 22 he had invented the hydrostatic balance. At 25 he was a lecturer at the University of Pisa. At 28 in 1592 he was Professor of Mathematics at the University of Padua, and his lectures attracted pupils from all over Europe. He was courted by popes and cardinals, who received him with great distinction in Rome and elsewhere.

Yet by the 1590s this respected 'establishment' figure had already concluded that Copernicus was right. In a letter to Iacopo Mazzoni in 1597 he wrote that "the opinions of Pythagoras and Copernicus on the place and movement of the earth' are 'more palatable than the opinion of Aristotle and Ptolemy'. In the same year he wrote to Johannes Kepler: "I adopted Copernicus' opinion many years ago and deduced from it the causes of many natural effects doubtless inexplicable on the ordinary hypothesis" (quoted in J.L. Heilbron: *Galileo*, Oxford, 2010, pp112-3). In 1615 he wrote an open letter to the Grand Duchess Christina: "I hold that the sun is located at the centre of revolving heavenly orbs and does not change place. And that the earth rotates itself and moves around the sun".

He answered her worries that his opinion flew in the face of Biblical teachings by saying that "I do not feel obliged to believe that the same God who has endowed us with sense, reason and intellect has intended us to forego their use and by some other means to give us knowledge which we can attain by them". He added: "in disputes about natural phenomena one must not begin with the authority of scriptural passages, but with sensory experience and necessary demonstrations".

That is exactly what he himself did. Copernicus made the hypothesis; Galileo discovered evidence for it. Until 1609, he had focused mainly on physics, not astronomy. But this all changed when a Dutchman Hans Lippershey invented the telescope. On hearing the news in Venice in August 1609, Galileo set about building one of his own, knowing nothing more than that the instrument involved two lenses in a tube. Within a day, he had built a telescope better than anything else known at the time. By 25th August he had made one with a magnifying power of 10 times, which he presented to the Doge of Venice as a gift. The Doge and the Senate replied by giving him tenure in post at the University of Pisa for life and a doubling of his salary.

By December 1609 Galileo had a twenty-power telescope which he first turned on the moon. He saw that dark areas on the surface grew and shrank depending on where the moon was in relation to the sun. From this he made the correct deduction that these dark areas were shadows cast by craters and mountains, thus disproving the Aristotelian notion of perfect sphericity in the perfect heavens. Early in January 1610 he discovered four satellites revolving around Jupiter, contradicting the Ptolemaic view that the earth was the centre of all celestial motions. previously unseen stars in several constellations were charted, and the Milky Way was seen to consist of myriads of stars.

These discoveries were presented in a little book, *Siderius Nuncius ('*The Starry Messenger*'),* published in March 1610. Curiously, the book and its findings were initially endorsed by the Catholic Church. Galileo was received by Pope Paul V in Rome, and Cardinal Bellarmine, the Inquisitor largely responsible for Bruno's death, appointed a committee to examine Galileo's claims, all of which it accepted. Throughout Italy and beyond, the comparison of Galileo with another Italian pioneer explorer became a refrain – he was hailed as the Columbus of the cosmos. In May he was given the post of Chief Mathematician at the University of Pisa and Philosopher and Mathematician to the Grand Duchy of Tuscany for life.

Later in the year, he also observed the phases of Venus, the only explanation of which is that Venus moves around the sun and not the earth. And when he observed dark features on the face of the sun – sunspots – these blemishes seemed to be yet another nail in the coffin of Aristotelian heavenly perfection.

It was in his *Observations on Sunspots*, published in 1613, that Galileo came out for the first and only time unequivocally in favour of Copernicanism. In the appendix he refers to "the great Copernican system, to whose universal revelation we see such favourable breezes and bright escorts directing us, that we have little to fear from darkness or crosswinds" (quoted in Heilbron, op.cit., p192). The cat was well and truly out of the bag.

Galileo's enemies now moved up a gear. In December 1614 a young Dominican Tommaso Caccini denounced Galileo from the pulpit, and his words reached the ears of the Holy Office in Rome. Caccini was given an interview, in March 1615 in which he reiterated that Galileo's theories and his support for Copernicus were in conflict with Scripture and Aristotle. Other hostile priests were interviewed, and the *Observations on Sunspots* was cited. Another Dominican, Niccolo Lorini, acquired a copy of a letter from Galileo to his former student, Benedetto Castelli (basically a first draft of his 1615 letter to Christina), and sent it to the Inquisition.

Galileo decided to go to Rome himself, and on 26th February 1616 he was invited to Bellarmine's house. What exactly happened is not clear, but it does seem that Galileo promised that he would not teach or write about Copernicanism as anything more than a hypothesis. Eight days later Copernicus' *De Revolutionibus Orbium Coelestium* was declared 'false and contrary to Holy Scripture and placed on the Index, 'suspended until corrected'.

And there, it seemed, the matter rested. But it all changed again after 1623 when Cardinal Maffeo Barbarini was elected pope as Urban VIII. He had been a friend and admirer of Galileo, a Florentine intellectual who had expressed a genuine interest in philosophy and the 'new science'. He had read everything that Galileo had written and the latter in turn had dedicated his book the *Assayer* to him. So Galileo went to Rome in 1624 and was granted no fewer than six audiences with the new pope, in which he discussed his plans to write a book on the tides which depended on assuming the Copernican motions of the earth. It seems that the pope granted him permission, provided he made it clear that the earth's motions were taken to be 'hypothetical'.

This projected book on the tides became a more general work on which Galileo spent 5 years. Eventually, he decided to call it a Dialogue on the Two World Systems. He intended it for educated lay people and so

wrote in Italian rather than Latin and in the dialogue form harking back to Plato and other ancient Greeks which offered a neat way of teaching unconventional ideas without officially endorsing them. By 1629 the work was finished, but Galileo had difficulty getting it past the Roman censorship. The Vatican chief licenser, Niccolo Riccardi, demanded that the preface and conclusion be revised to make it clear that the work was intended only as a 'hypothesis'. Galileo complied but still Riccardi stalled until finally he gave the green light, and in 1632 it was published. The book quickly sold out, not only in Italy but in countries where the Pope had no power.

In the *Dialogue*, the two main world systems are debated between three protagonists. One of them called Simplicio defends the Ptolomaic theory, while Salviati (the name of a former friend of Galileo who had died in 1614) advocates the Copernican view. Sagredo (another old friend of Galileo who had died in 1620) is presented as the supposedly impartial commentator on the debate, but in reality supports Salviati. All the arguments that are offered by Simplicio for the Ptolomaic theory are demolished skillfully one by one by the clever Salviati and Sagredo.

Although Galileo states in the preface that Simplicio is named after a famous Aristotelian philosopher (Simplicius in Latin), the name 'Simplicio' in Italian has the connotation of 'simpleton'. The pope was furious because it appeared that Galileo was deliberately insulting him as the obvious mouthpiece for Simplicio's ideas. So he ordered the Inquisition to summon Galileo, aged 68, to appear before it. He asked that his trial be moved to Florence, a request which was refused. Three physicians then declared that Galileo was too ill to travel to Rome. The Inquistion rejected their statement and declared that if Galileo did not travel to Rome voluntarily he would be arrested and taken in chains.

In February 1633 Galileo arrived in Rome. He was allowed to stay at the home of the Tuscan ambassador, but was forbidden to have social contacts. In April 1633 he was interrogated before the Inquisition. For over two weeks he was imprisoned in an apartment in the Inquisition building. After being shown the instruments of torture, he agreed to plead guilty to a lesser charge in exchange for a more lenient sentence. He declared that the Copernican case was made too strongly in the *Dialogue* and offered to refute it in another book.

In June 1633 Galileo was sentenced to prison for an indefinite term and his book banned. Seven of ten cardinals presiding at his trial signed the sentencing order. Galileo signed a formal recantation. He was allowed to serve his term under house arrest in the home of the archbishop of Siena. In December he was permitted to return to his villa in Florence, where he lived under house arrest.

In January 1638 Galileo, now totally blind, petitioned the Inquisition to be freed, but his petition was denied. On 8th January 1642, aged 77, he died. In 1835 his *Dialogue* was taken off the Vatican's list of banned books. In 1992 the Catholic Church formally admitted that Galileo's views on the solar system were correct.

In *A Briefer History of Time* Stephen Hawking writes: "Galileo, perhaps more than any other person, was responsible for the birth of modern science... Galileo was one of the first to argue that man could hope to understand how the world works and, moreover, that we could do this by observing the real world. Galileo had believed Copernican theory (that the planets orbited the sun) since early on, but it was only when he found the evidence needed to support the idea that he started publicly to espouse it… Galileo remained a faithful Catholic, but his belief in the independence of science had not been crushed (by his trial and recantation). Four years before his death in 1642, while he was still under house arrest, the manuscript of his second major book was smuggled to a publisher in Holland. It was the work, referred to as *Two New Sciences*, even more than the support for Copernicus, that was to be the genesis of modern physics (pp145-146).

Here is Peter Atkins in *Galileo's Finger*: "Galileo marks the turning point, when the scientific endeavour took a new direction, when scientists – an anachronistic term at the time, of course, rose from their armchairs, questioned the efficacy of the preceding attempts to come to grips with the nature of the world by thought in alliance with authority, and took the first faltering steps down the path of modern science... Galileo's finger, then represents the misty concept of the 'scientific method' the centrality of experiment... Galileo also developed the art of simplification, the isolation of the essentials of a problem, the peering in his thoughts through the clouds that in real systems conceal the underlying simplicity, just as he looked through his actual telescope and saw the complexity of the heavens. He set aside the creaking cart pulled through mud; instead, he considered the simplicity of a ball rolling on an inclined plane, a pendulum swinging from a high support. That isolation of the core phenomenon from the creaks and confusions of reality is a key part of the scientific method. Scientists see the pearl in the oyster, the jewel in the crown" (pp2-3).

Jacob Bronowski in *The Ascent of Man* writes: Galileo is the creator of the modern scientific method... he turned it (telescope) on the stars. In that way he did for the first time what we think of as practical science: build the apparatus, do the experiment, publish the results" (p126). And Albert Einstein put it bluntly. "Galileo was the father of modern physics — indeed of modern science altogether".

The Dialogue is not only one of the most important scientific treatises ever written, but a work of supreme clarity and accessibility, remaining as readable now as when it was first published. In it, Galileo Galilei defied the Holy Establishment in defence of a theory which he made clear was not originally his own but a dead man's, because he believed it was true. "In questions of science", he wrote, "the authority of a thousand is not worth the humble reasoning of a single individual". His *Dialogue* is a Humanist masterpiece because it represents the endless struggle against any kind of dogma based on authority. He himself may have lost the fight, but ultimately he has triumphed. The popes and cardinals of his day were the enemy of science, but they lost in the long run and are forgotten, whereas Galileo's work remains a shining beacon in the history of freedom of thought.