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GALILEO'S SCIENTIFIC DISCOVERIES, COSMOLOGICAL CONFRONTATIONS, AND THE AFTERMATH

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INTRODUCTION

Galileo was involved, directly or indirectly, with developments in the major movements of the early modern period: the Scientific Revolution, the great geographical discoveries, even the Protestant Reformation. Recent studies cover mostly specialist aspects of Galileo's activites within his historical context, but not a general or integrative account, as attempted here. The historian Casper Hakfoort writing on "The missing syntheses in the historiography of science"[1] deplored the lack of comprehensive science histories, citing among the most recent works available to him, my 1953 *History of the sciences.* Over recent years, I have been reassessing the formative periods of the natural sciences covered in 1953, from ancient Mesopotamia to eighteenth-century Europe, through the cultures of classical Greece, China, India and Islam. The present article gives the revised and extended treatment of Galileo, based on a selection of recent specialist studies as well as the more-established sources.

1. GALILEO'S EARLY YEARS

Galileo Galilei (1564–1642) came of an old Tuscan family of mercantile and professional patricians, who were prominent in the service of the Florentine Republic, but reduced in standing and affluence under the hegemony of the Medici from the 1520s. His father, Vincenzio Galilei (*c.* 1520–91), gave up the cloth trade in Pisa and became a professional musician in Florence: he published criticisms of the traditional polyphony and the Pythagorean numerology of musical consonance, favouring modern harmony based on a scale of equal temperament.[2] Finding medicine a more rewarding profession than music, he sent his elder son Galileo to study medicine at the University of Pisa, 1581–85. Galileo left Pisa without a degree, for he ran out of funds, and found mathematics a more consuming interest than medicine. Galileo's new interest came from the observation of practical mathematical applications in mechanics and hydraulics, and from studies with Ostilio Ricci (1540–1603), a friend of the family and former student in Venice of the mathematical practitioner Tartaglia (1499–1557). Ricci was then teaching the elements of mathematics and military engineering to the young nobles of the Medici court, and the geometrical principles of perspective and proportion to the aspiring artists and architects of the Florentine Academy of Design.

Galileo taught mathematics and mechanics privately and publicly in Florence and

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Siena from 1585. At this time he was measuring specific gravities with a hydrostatic balance of his own design, and derived theorems on the centres of gravity of solids of revolution. He wrote up these studies as essays, and sent his new theorems to potential patrons who might secure a salaried position for him. Galileo was active in the cultural life of Florence: he was celebrated for lectures he gave in 1588 at the Florentine Academy on the location, structure and dimensions of Dante's *Inferno*, a topic of wide interest in connection with the physical accommodation of the estimated multitudes of lost souls.

The most rewarding patron he found was Marquis Guidobaldo del Monte (1545–1607) of Pesaro, an Urbino military expert and author of an influential book on mechanics (1577), who was appointed Inspector General of the fortresses and towns of Tuscany in 1588. Guidobaldo was impressed by the talented young Galileo, arranging a three-year post for him teaching mathematics at the University of Pisa, 1589–91; then a chair in mathematics at the University of Padua, 1592–1610, at a higher salary, though modest compared to the salaries enjoyed by professors of higher-status subjects, such as philosophy.

Galileo's discoveries in mechanics were made mostly in his earlier years, before 1610, but they were not widely known in any detail until 1638 when his last book was published, *Discourses on two new sciences* (the strengths of materials, and the laws of motion).[3] Students, friends and patrons contributed to these discoveries, or took note of the findings around the time they were made; manuscripts in the Florentine archives preserve the working notes Galileo made during his experiments and the analytical treatment of the results and his conjectures.[4] The late publication of his mechanical discoveries led historians of scientific ideas to suppose that the discoveries Galileo reported in 1638 were the product of thought-experiments, perhaps even to be physically unrealizable in the laboratory.[5] One such "impossible" experiment, the demonstration that the distance of fall is proportional to the square of the elapsed time, using a polished ball rolling down an inclined plane, was found in 1961 to be reproducible using Galileo's own methods, with even greater precision than Galileo himself had originally recorded in his manuscript notes on the experiment.[6]

This kinematic law was recorded in a letter Galileo sent in 1604 to his friend, Paolo Sarpi (1552–1623), the polymath chief adviser to the Venetian senate. Galileo formulated the rule that a body falling from a height traverses, over equal increments of time, a series of distances in the ratio of odd numbers, 1, 3, 5, 7, ..., taking the first spatial interval as the unit. Galileo guessed wrongly in 1604 that the velocity of descent of a body at a given point was proportional to the distance the body had fallen. By 1609 he had arrived at the correct relation, that the velocity of descent is proportional to the time elapsed during the fall to a given point; he noted that the two relationships, taken as equivalent by virtually all commentators in the past, were in fact inconsistent.

Galileo's early work on mechanics at Pisa developed from studies of Archimedes's geometrical statics and measurements of specific gravity with his hydrostatic balance. By 1590 he had composed a Latin text on motion, and a decade later, an Italian text on mechanics for the use of his students.[7] In 1590 Galileo concluded that the fall of a body was accelerated initially, and thereafter fell at a constant speed, which was proportional to the ratio of the specific gravities of the body and the medium through which it moved; basing this on observations of the fall of different heavy bodies and the rise of various light bodies in water. These were the traditional 'natural' motions of Aristotle, towards or away from the centre of the Earth. The Aristotelian 'natural' speed of fall of a heavy body, supposedly proportional to its weight, was still generally accepted around 1600, despite the reports of John Philoponus in the sixth century and Simon Stevin in 1586 that bodies differing in weight by as much as a factor of ten reach the ground at the same time, if dropped simultaneously from a common height.

Galileo rejected the Aristotelian interpretation of 'violent' motions, such as the inrush of air or water to the rear of a moving projectile, to prevent the formation of a void, impelling the projectile forward. He preferred the alternative impetus theory, dating back to Philoponus and Hellenistic precursors, which had been developed during the late Middle Ages. Impetus was regarded as an inner force conveyed to a projectile by its mover. Most impetus theorists had maintained that the acquired inner force gradually decayed over time, just as a hot body cools; the projectile comes to rest, more rapidly if its motion is resisted by the medium. In the minority view of John Buridan, rector of the University of Paris in 1327, God gave the heavenly bodies a perpetual impetus at the Creation, so that the celestial bodies rotate on their axes and move in circles indefinitely, without the need for continuous propulsion by the supposed spirit-motors of tradition (which lack any Biblical sanction).

Galileo initially adopted Buridan's version of impetus theory, and applied the idea to terrestrial bodies to develop a concept of inertia as a state of uniform motion, including the zero-state of rest; thereby rejecting the Aristotelian distinction between the nature and properties of the heavens and the Earth. In his 1590 text on motion, Galileo noted that in addition to the traditional 'natural' and 'violent' classes of motion, there was a 'neutral' kind of motion, exhibited by a polished ball on a smooth horizontal plane, or a body floating in water. They require an arbitrarily small force to set them in motion. The spinning top or a rotating grindstone were similar cases of the persistence of a neutral motion, no medium being displaced to maintain the motion. In a letter to his patron, Mark Welser (1558–1614), banker and chief magistrate of Augsburg, Galileo in 1612 described his principle of neutral motion in terms of a ship which, "having once received some impetus through the tranquil sea, would move continually around our globe without ever stopping; and placed at rest it would perpetually remain at rest, if in the first case all extrinsic impediments could be removed, and in the second case no external cause were added".[8]

The principle of neutral motion enabled Galileo to interpret the parabolic trajectory of a projectile, which he discovered in an experiment carried out with Guidobaldo de Monte in or before 1592. The experiment consisted in the projection of an inked ball, at an angle to the horizontal, over the surface of an obliquely-inclined plane, on which an inked trace of the projectile trajectory remained at the end of the flight.

Guidobaldo recorded the experiment in his notebook for the years 1587–92, remarking that the parabolic trace resembled the shape of a hanging chain. Galileo's Venetian friend, Paoli Sarpi, who hitherto had followed the ideas of Tartaglia on ballistics, recorded in 1592 that the paths of projectiles had a symmetrical shape of parabolic form, resembling a hanging chain, and he made further notes on the symmetry of ascent and descent of the bob in pendulum motion.[9] Galileo informed Guidobaldo in 1602 that the swings of a pendulum were isochronous and that different pendulums of the same string-length had the same period of swing. By 1609 Galileo had discovered that the period of a pendulum is proportional to the square root of the length of the string, and related his pendulum law to his law of descent: the distance fallen is proportional to the square of the time elapsed.[10]

Galileo did not give an account of his analysis of the parabolic trajectory of a projectile until 1638. In his *Two new sciences*,[11] a modified version of his original experiment with Guidobaldo is described during the Second Day. During the Fourth Day he notes that the parabolic trajectory "closely approximates" the shape of a suspended chain (the mathematical form of the catenary was not known before its derivation by Johann Bernoulli in 1693). Galileo considers also the motion of a polished ball across the smooth horizontal plane of a table top. After reaching the edge, it traces a curved path compounded of neutral motion under inertia, covering equal horizontal distances in equal times; while the acceleration of fall results in vertical distances traversed in proportion to the square of the time. The resultant curve is a semi-parabola. In the general case a projectile trajectory is symmetrical, i.e. parabolic, with a maximum range given by the projector inclined at 45°.

The parabolic trajectory of projectiles was known to disciples of Galileo and of Guidobaldo long before 1638, and the 45° angle of inclination for the optimum range of a cannon shot had been known empirically by Tartaglia and the artillery engineers of his time. A second-generation disciple, Bonaventura Cavalieri (*c.* 1598–1647), studied mathematics at Pisa under Benedetto Castelli (1578–1643), who was a former student of Galileo at Padua (1604–6) and professor of mathematics at Pisa from 1613. With Galileo's help, Cavalieri became professor of mathematics at Bologna in 1629 and published a work in 1635 on the geometry of indivisibles, containing an account of the parabolic trajectory of projectiles. Cavalieri replied with apologies, when Galileo reminded him of the inked-ball experiment made forty years earlier, adding that he first learned of the experiment from a former student of Guidobaldo, and had believed that the parabolic trajectory had been published long ago.

While Galileo was slow to publish his discoveries in mechanics, he was more expeditious in defending his rights in the instruments he developed and, in the case of the telescope, the novel results obtained with them. Galileo's laboratory in Padua was a workshop in the lodging house he maintained for some fifteen to twenty well-to-do students he taught privately on extra-curricular topics. He himself lived separately with his companion, Marina Gamba, and their children, Virginia (1600–34), Livia (1601–59), and Vincenzio (1606–49). From 1599 Galileo employed an artisan, Marcantonio Mazzoleni, to construct navigational and various mathematical instruments he sold, the most notable being the "geometric and military compass", based on the principle of proportional magnitudes, with scales on the arms to facilitate rapid calculations. The instrument was widely used until the 1630s when logarithm tables became generally available (produced by Cavalieri and others). Galileo's instrument was not new, but an improved version of an instrument developed by Guidobaldo and other precursors. Galileo wrote out instructions for the use of the instrument from 1599 and improved over the years. In 1606 he published (with his workshop printing press)[12] *The operations of the geometrical and military compass*, in Italian, dedicated to his pupil, Don Cosimo de' Medici (1590–1621), the eldest son of the Grand Duke of Tuscany, Ferdinand I. The work was soon translated into Latin in Padua by Baldessar Capra, who claimed that he had invented the proportional compass, with his teacher, Simon Mayr. Galileo took immediate legal action, securing a public condemnation of Capra for plagiarism from the Regents of Padua in 1607. By this time Mayr had returned to Germany, reappearing with the claim in 1614 that he had observed telescopically the four moons of Jupiter in 1609, before Galileo. Mayr held that Jupiter and its four moons modelled in minature the Sun and five planets of the Tychonian system, which he said he had devised before Tycho Brahe.[13]

2. TELESCOPIC DISCOVERIES

Galileo's telescopes similarly were developments of a previously-known invention. Spectacles for reading were invented in the thirteenth century, and lens-grinding and polishing was a well-developed craft by 1600, requiring hands-on experience and "maker's knowledge"; practised even by scholars, notably the Dutch philosopher, Baruch Spinoza (1632–77). As advisor to the Venetian Senate on all matters of public concern, Paolo Sarpi maintained a wide correspondence network throughout Europe, and he was informed of a patent application in late 1608 by a Dutch spectacle-maker of Middelburg, Hans Lippershey, for a spyglass giving enlarged images of distant objects. When Galileo visited Venice in mid-1609, Sarpi discussed the invention with him and, on his return to Padua, Galileo learned that a Dutchman had passed through the city with a spyglass he was proposing to sell to the Venetian Senate. Galileo soon designed and constructed in his workshop a telescope with a plano-convex objective and plano-concave eyepiece, giving upright images with 3-fold diameter magnification. Galileo immediately informed Sarpi of his new instrument, and Sarpi advised the Venetian Senate to turn down the spyglass offered for 1000 florins by the Dutchman, who allowed only views of distant objects with the instrument, but not an examination of its internal construction.

Galileo returned to Venice in late August 1609 with a set of his better telescopes for demonstration. The Venetian senators were astonished to observe clearly the taller buildings of Padua, some 35 miles distant, and ships approaching Venice were visible two hours before they were seen by the naked eye. The Venetian merchants were much troubled by pirates in the Adriatic and Mediterranean seas, and the telescope offered them an opportunity to evade or attack the pirates. Galileo presented the Doge of Venice with one of his best telescopes, giving 9-fold diameter magnification, and granted the Republic of Venice the rights to manufacture his instrument, in return for a virtual doubling of his annual salary to 1000 florins. This was comparable to the salary of a professor of philosophy, such as his friend and rival, the humanist Aristotelian Cesare Cremonini (1550–1631).

Galileo was concerned to establish that the images oberved with his telescope were real, not optical illusions created by the instrument, as some critics claimed. He worked to minimize the distortion and coloured fringes, arising from spherical and chromatic aberration, inhomogeneities in the glass, and imperfections in the lens-grinding and polishing. His produce instruments were markedly superior to the Dutch telescopes with 3-fold magnification on sale in Paris and elsewhere by late 1609. Galileo selected only the best lenses, one out of every ten made, for his quality telescopes. He also introduced a diaphragm, to mask the edges of the objective, to minimize the optical distortions prominent there. He preferred field-glass optics, giving realistic upright images, rather than the optics of the original Lippershey spyglass, using two convex lenses giving inverted images. The latter arrangement, after Kepler's analysis of 1611, became the basis of the astronomical telescope, capable of much higher magnifications. Galileo showed Sarpi in 1610 one of his telescopes giving 30-fold diameter magnification, but it was too powerful and limited in angular field of view for his purposes; he used telescopes of up to 20× magnification for most of his astronomical studies.[14]

Galileo returned to Padua in the autumn of 1609 to find that the promised salary rise was post-dated for a year, and there were to be no further increments, unlike those enjoyed by Cremonini. Although his prospects had improved, Galileo believed he could do better back home in Florence, where his former pupil Cosimo II had become Grand Duke of Tuscany earlier in 1609. Galileo wished to devote more time to his scientific studies, cutting down his teaching duties: this would be possible, were he appointed to a court position in Florence. Galileo raised the proposition on a visit to Florence, where he donated one of his better telescopes to the court, before returning to Padua for the academic year 1609–10. On most clear nights during the autumn and winter of 1609–10, Galileo viewed the Moon with a telescope of 15× linear enlargement and then the heavens at large with his "discoverer", a telescope of some 20× magnification. He found four satellites around the planet Jupiter, which were regularly eclipsed during their orbital motions around the planet, and many more stars in several constellations than were visible to the naked eye.[15]

Galileo wrote up his first astronomical discoveries, with convincing illustrations of the mountains and plains of the Moon during the successive lunar phases, the sequential line-up of the four moons of Jupiter in the plane of the ecliptic during their motions around the planet, and the new stars now visible in the Pleiades, Orion, and other constellations. His account was published in Venice during March 1610 as the *Sidereus nuncius* (*Sidereal messenger*). He dedicated the work to Cosimo II, and named the four moons of Jupiter the "Medicean Stars"; referring to Cosimo, born when Jupiter was in the ascendant, and his three brothers.[16] Galileo sent copies of his book to influential people across Europe through the regional Medicean ambassador, and one of his better telescopes to a few important rulers, known to be patrons of science, for use by their own experts. In Prague the Imperial mathematician Kepler approved the *Sidereal messenger*, and used the telescope sent to the Elector of Cologne, and later the instrument sent to the emperor, Rudolf II, to confirm Galileo's astronomical findings.

By September 1610 Galileo had resigned from his chair in Padua to go to Florence as philosopher and mathematician to the Grand Duke and principal mathematician at the University of Pisa, with no teaching duties. Galileo was conscious of the higher status of natural philosophy over mathematics in the hierarchy of learning, and had insisted on the inclusion of philosophy in the title of his position at Florence. He was the first and the last to enjoy the full title: his successors were appointed simply as mathematician to the Grand Duke.

Before he left Padua his former pupil and patrician friend, Giovanfrancesco Sagredo, warned him of the dangers of leaving the tolerant Venetian Republic for the more autocratic princedom of Tuscany. This domain bordered on the Papal States, and was ruled by a client of the Hapsburgs, who had restored the Medici as absolute princes after ending the Florentine Republic in 1512. Further warnings came from his Paduan colleague, Cesare Cremonini. He was under investigation by the Inquisition for his Averroist heresy, in following original teachings of Aristotle; that matter is eternal, and that the rational soul at death merges into the universal soul of the world, without the personal rewards or punishments claimed by the Church. Cremonini was safe so long as he stayed in the Venetian Republic, as was Paolo Sarpi. He was excommunicated in 1607 for encouraging the Venetian Senate to resist the intrusion of Rome into the secular affairs of the Republic, and advised the expulsion of the Jesuits when they claimed immunity from civic tribunals. Sarpi was unable to publish his *History of the Council of Trent* (1545–63) in any Catholic country. The Archbishop of Spalato, Marco Antonio de Dominis, who sought an irenic union of the Protestant and Catholic Churches, edited the manuscript in London, where the book was published in 1619. After his return to Rome, de Dominis was imprisoned by the Holy Office, and died under inquisition in 1624.[17]

Others who made astronomical observations with the telescope at this time, and or earlier, included Thomas Digges (1546–95). In his account of the Copernican system (1576), he extended the sphere of fixed stars "infinitely upward", perhaps because he had observed a vastly increased number of stars with an early reflecting telescope, constructed by his father Leonard Digges (*c.* 1520–59).[18] But Galileo was the first to publish his results in detail, and to emphasise the anti-Aristotelian conclusion that the materials and properties of the celestial and terrestrial bodies appear to be similar. The Moon has mountains, craters and plains, as does the Earth. While the Earth has but one satellite, Jupiter has no fewer than four (the term 'satellite', meaning an attendant, was coined by Kepler). Kepler's correspondent in London, Thomas Harriot (1560–1621), made telescopes, "perspective trunckes" as he termed them, and he was the first to observe sunspots telescopically: but his results were known only to a few friends and correspondents, and were not published until 1833.[19]

Harriot, and other observers in Venice and Provence who made their own telescopes, had confirmed the four moons of Jupiter by the end of 1610. Harriot's early illustrations of the lunar surface observed with his telescopes showed less detail than the corresponding drawings of Galileo, but after the publication of the *Sidereus nuncius*, Harriot depicted the lunar craters he had previously overlooked, and with less exaggeration than Galileo had employed. Galileo was an able draftsman, having studied the depiction of highlights, shadows and perspective with Ostilio Ricci at the Florentine Academy of Design, with his artist friend, Lodovico Cigoli (1550–1613). In 1612 Cigoli finished his fresco in the Pauline chapel of the Santa Maria Maggiore in Rome, depicting the Queen of Heaven standing on the Moon as Galileo had found it, cratered and spotted. By 1616, however, Cigoli's Moon had been overpainted to represent the lunar immaculate perfection of tradition.[20]

In 1610 Galileo continued his telescopic studies of the planets at Florence.[21] He first observed the planet Saturn as a large disc with two smaller discs attached, one on either side in the plane of the ecliptic. By 1612 the small orbs had disappeared and he predicted that they would reappear, as they did in the following year. By 1616 they resembled "handles" on the large disc, like a pot. Ultimately Christiaan Huygens (1628–95), with a better telescope, **observed in the mid-1650s** that these appendages are thin flat rings around Saturn, inclined to the plane of the ecliptic but not touching the planet. Between October and December 1610 Galileo discovered that the planet Venus went through a cycle of phases like the Moon, from a small disc, through a larger half-disc, to a thin and relatively large crescent, which then inverted, and went back through an inverse half-disc, to a small disc once again, followed by occultation. These observations suggested that Venus moves around the Sun and shines with reflected solar light, consistent with the systems of Copernicus or Tycho Brahe, but impossible to reconcile with the Ptolemaic system.[22] From the geocentric Ptolemaic viewpoint, Venus should appear only as a crescent if it moved between the Earth and the Sun, or only as a disc if its motions lay beyond the Sun, outwards from the Earth.

In December 1610 Benedetto Castelli wrote to Galileo from Brescia, suggesting that observations of the appearance of Venus would distinguish between geocentric and heliocentric systems of the planetary motions. Galileo replied that telescopic observations of Venus supported a heliocentric system, as he told Kepler and also Father Clavius. In 1596 Galileo had informed Kepler that he supported the Copernican theory, but he was more discreet with Christoph Clavius (1537–1612), chief mathematician of the Jesuit Roman College and upholder of the Ptolemaic system. Clavius had been the chief architect of the Gregorian calendar reform of 1582, and he maintained a friendly correspondence with Galileo on mathematical, and then astronomical questions, from 1587 to the end of his life.[23] When Cardinal Bellarmine of the Congregation of the Holy Office enquired of the veracity of Galileo's telescopic findings in 1611, Clavius replied that the new astronomical observations had been confirmed by the mathematicians at the Roman College, although they did not agree with all of Galileo's interpretations.

In 1611 Galileo visited Rome, where he was feted at the Roman College, and with even greater display at a banquet held in his honour for the discoveries announced in the *Sidereal messenger* by the Marquis of Monticelli, Federico Cesi (1585–1630). In 1603 Cesi had founded the Accademia dei Lincei (the lynx-eyed), devoted to the discovery and publication of new natural phenomena, avoiding politics and worldly pursuits. Cesi conferred membership of the Lincean academy on Galileo at the banquet, and a number of Galileo's correspondents and patrons of the new science then joined, bringing membership of the Lincei to around twenty by 1612. The Linceans coined the name of "telescope" for Galileo's "spyglass", with which he demonstrated the existence of spots on the Sun at Rome in 1611.

On returning to Florence Galileo studied sunspots in detail with Benedetto Castelli. He suggested projecting the telescopic image of the Sun onto a circle inscribed on a white screen so as to determine the positions and motions of the dark spots. Such experiments were not new, for the Dutch astronomers, David and Johann Fabricius, had already published in 1611 their observations of the motions of sunspots, showing that the Sun rotated; others, including Thomas Harriot and friends in London, had made similar, but unpublished, observations. His fellow-Lincean, Mark Welser of Ausburg, sent Galileo in 1612 *Three letters on sunspots* he was publishing on behalf of an anonymous author who used the pseudonym "Apelles hiding behind the painting", a reference to a classical artist who listened to criticism of his picture from behind the work. Galileo soon identified the author as the Jesuit Christopher Scheiner (1573–1650) of Ingolstadt, and was aroused to a critical reply, published in 1613 by the Lincean academy in Rome, by the author's claims; in particular, by the description of sunspots as small planets encircling the Sun, so as to preserve the Sun's "perfection". Galileo pointed out that the sunspots all moved with the same angular speed, and so must be clouds or other solar surface effects, reflecting the rotation of the Sun, with a period of about a month, too slow for any planetary transit across the face of the Sun. The spots were too large to be any planet, and they had irregular and changing shapes, appearing foreshortened on reaching the edge of the Sun's image. These points were illustrated by 38 **figures**, depicting successive images of the sunspots. Scheiner ultimately conceded that the sunspots were solar surface effects in 1630. By this time Galileo and Copernicanism had become targets of criticism by a number of clerics on theological grounds.

3. COPERNICAN CONFRONTATIONS

Galileo advanced Copernicanism only indirectly in his *Sidereal messenger* of 1610, and in his 1613 *Letters on sunspots,* which included corrected tables for the eclipses of the satellites of Jupiter for determining the longitude. The corrections arose from the variation in the direction of the cone of Jupiter's shadow relative to a terrestrial observer over a period of six months or so, and Galileo added the Copernican interpretation: "These differences come about from the annual motion of the Earth."[24] Opposition in Florence to Galileo's Copernicanism, and even to his hydrostatics, arose soon after his arrival, but the controversy did not become serious until late 1613. After prompting by one of the adversaries, the dowager Grand Duchess Christina (mother of Cosimo II) asked Benedetto Castelli, now teaching mathematics at Pisa, was not the Copernican system contrary to the teachings of the Scriptures?

Galileo wrote a letter to Castelli outlining his views on the relationship of the Bible to natural philosophy, subsequently elaborated in his Letter to the Grand Duchess Christina (1615).[25] Broadly, Galileo adopted the principle of St Augustine that the Scriptures were accommodated to the capacity of the popular mind. Copies of the letter to Castelli circulated widely and a garbled version was sent to the Curia in Rome. Galileo's attitude, more Venetian than Florentine, was clear in his 1615 Letter. Theologians, like absolute princes, "should not arrogate to themselves the authority to issue decrees in professions they neither exercise nor study". Otherwise the consequences, in medicine and architecture, for example, will result, respectively, "in serious danger to the unfortunate sick, and in the obvious collapse of structures".[26]

Matters came to a head in 1615 after Florentine Dominicans denounced Galileo as a heretic, locally, repeating the charge to the Holy Office in Rome. At the same time the Holy Office received a book reconciling the Copernican theory to the Scriptures written by the head of the Carmelites in Calabria, Antonio Foscarini (1580–1616). He was professor of theology at the University of Messina, a major centre of resistance to the Spanish occupation of Southern Italy. Earlier an Augustinian friar of Salamanca, Diego de Zuñiga, had advocated replacing the Ptolemaic system by the superior Copernican theory in a 1584 commentary on the Book of Job. The Spanish Inquisition took no interest in this, for Copernicus had been a Catholic and little notice was taken of his book or of Zuñiga's.

Many of the cardinals of the Holy Office at Rome felt their authority under threat, and a Decree of the Congregation of the Index in March 1616 suspended the books by Copernicus and Zuñiga "until corrected", while the book by Foscarini was condemned and banned. Two of the seven cardinals of the Holy Office were said to have opposed the 1616 decree.[27] One, the Roman cardinal Bonifacio Caetani (1567–1617), commissioned the Dominican from Calabria, Tommaso Campanella (1568–1639), imprisoned in Naples, to write a plea for the toleration of unorthodox hypotheses in natural philosophy. Campanella's *Defence of Galileo* (1616) circulated in manuscript, and was banned in Rome when published in Frankfurt (1622).[28] The other cardinal, who was then a warm supporter of Galileo, was the Florentine Maffeo Barberini (1568–1644), subsequently Pope Urban VIII. He rescued Campanella from the Neapolitan dungeons to serve as the Pope's defender against malign astrological prognostications. In 1630 Campanella told the Pope of the difficulties of converting German nobles back to the Catholic faith on account of the prohibition of Copernicanism, to which Urban VIII replied that he himself would never have issued the 1616 decree suspending the work of Copernicus.

Galileo had journeyed to Rome in late 1615 to oppose the impending ban on Copernicanism. He presented his young supporter, Alessandro Orsini (1593–1626), a newly appointed cardinal, with the text of his theory that the tides result from the annual and diurnal motion of the Earth. Galileo's tide theory, first recorded by Paolo

Sarpi in his notebook for 1595, derived from the observation that the water in barges bringing fresh water to Venice from the mainland, tended to surge to the rear when the barges started, and piled up at the front when the barge was retarded by a sandbank or came to a halt in Venice. By analogy, the waters of the oceans were accelerated and then retarded each day as they rotated during the diurnal motion, now in the same direction as that of the annual motion, and then in the opposite direction, alternating every 12 hours. Galileo regarded his tide theory as conclusive proof of the annual and diurnal rotation of the Earth. Urban VIII later reminded him, **that God might well have decided to cause the tides in one of many different ways**.

At the command of Pope Paul V, Galileo was called to appear early in 1616 before the influential Jesuit cardinal, Robert Bellarmine (1542–1621), who warned him to abandon Copernicanism, nor should he teach the theory or support it "in any manner". Galileo agreed, and asked for a certificate from Bellarmine to state that he had not been made to abjure with a penance, nor tried and imprisoned by the Inquisition, as had been rumoured. Bellarmine provided the certificate requested, and Galileo returned to Florence in 1616 with testimonials addressed to Cosimo II from two cardinals, Alessandro Orsini and Francesco del Monte (1549–1626), the brother of Guidobaldo de Monte. They testified that Galileo had left Rome with an intact reputation and in high esteem. The Lincean academicians had supported Galileo's pro-Copernican cause throughout his stay in Rome, except for the professor of mathematics at the Sapienza University, Luca Valerio (*c*. 1552–1618), who was expelled from the Academy in 1616. Valerio's chair at the University of Rome was subsequently filled by Galileo's Paduan pupil, Benedetto Castelli, called from the corresponding chair at Pisa by Urban VIII as the papal consultant on hydraulic enginering.

The Jesuits at the Roman College, founded in 1551 and amply endowed by Gregory XIII (Pope 1572–85), had confirmed Galileo's telescopic findings. After 1616 they mostly adopted the Tychonian system of the world: the Ptolemaic system was no longer tenable after Galileo's discovery of the phases of Venus. Jesuits who adhered to Copernicanism were relocated to remote outposts.[29] Wenceslaus Kirwitzer, professor in the Jesuit College at Graz, on declaring his support for Copernicus in 1615, was sent as a missionary to China, where he died prematurely in 1626. He was replaced in 1617 by Father Guildin, a supporter of Copernicanism exiled to distant Graz from the Roman College.

The Tychonian system had been developed from the Copernican system at Wittenberg from the 1550s, and perfected by Tycho Brahe in 1588. It retained only the heliocentric motions of the five planets and referred the motion of the Sun, with its planetary chorus, to an annual orbit around the stationary Earth at the centre of the universe. Predictions of the positions and motions of the heavenly bodies were wholly equivalent, using the Copernican or the Tychonian scheme. On questions of qualitative physical cosmology, the Tychonian system, but not the Copernican, was consistent with Aristotle. For Galileo the cosmological question was primarily physical. He set out to replace the Aristotelian hierarchy of the constitution of bodies and their movers, terrestrial and celestial, by a uniform equivalence of all bodies in composition and motions. Galileo followed Buridan and Copernicus in maintaining that the unresisted motions of the celestial bodies were uniform and circular. Initially Galileo took the unresisted neutral motions of terrestrial bodies to be effectively circular over the surface of the spherical Earth, as in the idealized case of the ship sailing around the world indefinitely, given an initial impulse, quoted in his 1612 letter to Mark Welser. When he returned to questions of local motion, after being condemned for his cosmological ideas in 1633, Galileo took unimpeded neutral motion to be effectively rectilinear, as demonstrated by the motion of a stone moving tangentially from the circular path of a sling on release.[30] The disciples of Galileo took the state of neutral motion to be rectilinear, and Newton attributed his first law, that of inertial motion, to Galileo.

Galileo had a strong aversion to astrology, which was based on the assumption that the stars are noble rulers governing human and terrestrial affairs at large by action at a distance. Thus he opposed Kepler's theory ascribing the tides to the magnetic attraction of the Moon for the waters of the Earth, which predicted a high tide at a particular terrestrial location once every 25 hours. Like Copernicus, Kepler entertained the notion of an absolute solar imperium, and he regarded the Sun as the residence of God the Father. Kepler extended William Gilbert's concept of magnetic action at a distance, making the Sun the magnetic motor governing the motions of the solar system. But Kepler did not accept Gilbert's notion that magnetic interactions are reciprocal and mutual, requiring the "consentient compact" of both interacting bodies, as in the case of the Earth and the Moon. Kepler's tide theory appeared in his *New astronomy* (1609), which was primarily concerned with establishing his first two laws of planetary motions, assigning a unique elliptical orbit to each planet. Galileo criticized Kepler's tide theory, but ignored the laws of elliptical planetary motion as simply technical refinements of the Copernican system, of little concern to his primary interests. It was the applications of astronomy that interested Galileo, both the practical, in navigation, and the cosmological, in natural philosophy.

Copernicanism was well supported by German scholars, influenced by the work of Kepler; the 1616 ban on *De revolutionibus* appeared to be counterproductive to the Catholic cause, requiring considerable "circumspection", as the German Cardinal Zollern put it. But in Italy Copernicanism had made little headway, and the books of the Lutheran Kepler were largely unknown, proscribed on the Index. The "corrections" to Copernicus issued from Rome in 1620 endeavoured to restore the Aristotelian distinction between celestial and terrestrial bodies by removing the original treatment of the motions of the Earth, and all references to the Earth as a star.[31] The required changes were made mostly in copies of *De revolutionibus* located in Italy, none to copies held in Spain, France or Germany and the Protestant lands, where the majority of copies were held.[32]

After 1616 Galileo was occupied with the observation and the tabulation of the eclipses of Jupiter's moons, incorporating new corrections, for determinations of the longitude. Such tabulations were never used in navigation, owing to the difficulties of telescopic observation at sea; but they were used on land, first by Giovanni Domenico

Cassini (1625–1712), who moved from the chair of astronomy at Bologna to head the Paris Observatory in 1669. Cassini improved Galileo's tables further, enabling his Paris colleague, the Danish astronomer, Ole Rømer (1644–1710), to make the first estimate of the speed of light in 1676. Rømer measured the time taken for light to cross the Earth's orbit, by timing a satellite eclipse when the Earth lay between Jupiter and the Sun and when the Earth was located on the opposite side of the Sun from Jupiter. Cassini himself used his improved tables to determine the longitudes of the principal cities of France in mapping the country. Commenting on the new map, Louis XIV observed that Cassini had robbed France of more land than any foreign invader.

In the autumn of 1618 three ominous comets appeared, claimed by astrologers in retrospect to herald the onset of the Thirty Years War (1618–48) between Catholic and Protestant powers in Bohemia and then in the Germanic lands. The Jesuit father, Orazio Grassi (1590–1654), professor of mathematics at the Roman College, published anonymously on the comets in 1619, claiming that they were astronomical bodies following circular orbits around the Earth above the orbit of the Moon. He quoted Tycho Brahe's observation of the lack of parallax in the motion of the 1577 comet, with the view of reconciling the appearance of comets to the Aristotelian distinction between celestial and terrestrial bodies.

In Florence, Galileo was critical of Grassi's views: the vehicle was an address delivered by his disciple Mario Guiducci (1585–1646) to the Florentine Academy on comets, published in 1619. Galileo and Guiducci asked whether comets could be real bodies, for stars were visible through the comet tails, which were always directed away from the Sun. No complete orbit of a comet had been observed, and they were seen only when near the Sun, apparently by reflected and refracted solar light, rather like rainbows, auroras and haloes, which similarly show no parallax. Galileo never had a theory of comets, his disciple Viviani reported in 1661, no more than he had himself.

Grassi, under the pseudonym of Lothario Sarsi, replied later in 1619, directly attacking Galileo's views as expounded by Guiducci, who issued a moderate reply in 1620. Galileo however prepared a lengthy and polemical reply, in the form of a letter addressed to Cesi's cousin, Don Virginio Cesarini (1595–1624), a member of the Lincean Academy from 1618.[33] The letter was intended for the attention of the Academicians, and the points raised were critically amended and refined prior to publication as *The assayer* (1623)[34] by the leading Roman Linceans, Cesi, Cesarini, and Giovanni Ciampoli (1589–1643), a Florentine supporter of Galileo and the Pope's correspondence secretary. The title referred back to the Grassi (Sarsi) book of 1619, *The balance*, in which Galileo's views were weighed and found wanting. The gross steelyard was now replaced by fine scales of the goldsmith for a more detailed and rigorous assay of current issues in natural philosophy, apart from Copernicanism, banned since 1616.

The assayer was dedicated to the new pope, Urban VIII (1623–44), who as Cardinal Maffeo Barberini had supported Galileo in his disputes with Florentine Aristotelians on hydrostatics. The dispute had culminated in Galileo's *Discourse on floating bodies* (1612), and the future pope had written verse *Adulatio perniciosa* praising Galileo in 1620.[35] Urban VIII appointed Linceans to his staff, Cesarini as Lord Chamberlain and Ciampoli as his correspondence secretary. Ciampoli reported that Urban VIII was delighted with the more polemical passages of *The assayer*, read to him at mealtimes. The new pope's brother Antonio Barberini (1569–1646) and his nephew Francesco Barberini (1597–1679) were made cardinals in 1623, and Galileo's supporter, Francesco, was elected to the Lincean Academy.

In *The assayer*, Galileo rehearsed the history of astronomical discoveries made with the telescope, their plagiarism by others, and their fallacious interpretation by philosophers relying on the authority of Aristotle. The question of comets was a side issue in the book, and Galileo took the opportunity to explain the new method of philosophizing he and the leading Linceans had adopted. For an Aristotelian, the book of nature was written and understood in terms of qualitative features intrinsic to bodies as their substantial forms, perceived directly by the senses. The four terrestrial elements were endowed variously with hot, dry, cold and wet qualities, and combinations afforded complex bodies with new sensible qualities; colour, taste, smell, and so forth.

For Galileo these qualities were subjective and secondary: "I think that tastes, odours, colours, and so on are no more than names so far as the object in which we place them is concerned, and that they reside only in the consciousness." It is the impact of "minute particles" with particular shapes, numbers, and motions from external bodies on the sense organs that produce the sensations of taste, odours, and sound: "I think that if ears, tongues, and noses were removed, shapes and numbers and motions would remain, but not odours or tastes or sounds." The same holds for the perception of heat and light too, both arising from corpuscles in motion. Galileo called for a new philosophy of nature, looking for the corpuscularian mechanisms behind perceived phenomena, based upon geometric and quantitative mathematical concepts. "Philosophy is written in this grand book, the universe, which stands continually open to our gaze. But the book cannot be understood unless one first learns to comprehend the language and read the letters in which it is composed. It is written in the language of mathematics, and its characters are triangles, circles, and other geometric figures without which it is humanly impossible to understand a single word of it."[36]

The assayer was warmly received in Rome by Urban VIII and his circle in the Curia, which included not only Linceans but also Dominicans, at odds with the Jesuits,[37] such as Niccolò Riccardi (1585–1639), the Vatican Secretary in charge of censoring and authorising the printing of books from 1629, as master of the Sacred Palace at the Vatican. A more notable Dominican supportive of Galileo was **Tommaso Campanella (1568–1639)**, extradited to Rome in 1626 from the Neapolitan dungeons in which he had languished since the collapse of the 1599 Calabrian revolt, becoming papal adviser on astrology in 1628 to countermand the malign anti-papal prognostications then prevalent. Galileo came to Rome in April 1624 and stayed for six weeks with his disciple Mario Guiducci, now practising law in Rome and soon to become a Lincean academician. With him Galileo brought examples of his compound microscope with two doubly-convex lenses. One, presented to Cesi as head of the Lincei, was used by the Academician Francesco Stelluti (1577–1646) to pioneer microsopic natural history with a study of the anatomy of bees. Another was given to the German Cardinal Zollern for presentation to the Duke of Bavaria, then neutral during the Thirty Years War.

Galileo had six audiences with Urban VIII during his stay, discussing the scope of the 1616 edict banning support for Copernicanism, raising the question of publishing his theory of the tides, resting on the assumed diurnal and annual motion of the Earth. Urban VIII made it clear that the 1616 edict would remain in force, but that there would be no official objection to a discussion of Copernicanism as a hypothesis among other cosmological hypotheses, nor of his tide theory alongside other views on the tides. No conclusive proof could be asserted, however, **for God could move the heavens or the oceans in a number of different ways**, and it would be presumptious to claim certain knowledge of any one particular mode.

Galileo returned to Florence now confident that he would be able to publish an open discussion of the relative merits of the two main world views: the Ptolemaic system embellished by Aristotelian natural philosophy, versus the Copernican system supported by Galilean physics, provided the discussion was devoid of any personal commitment or of theological implications. Guiducci wrote from Rome in 1625 that Sarsi (Grassi at the Roman College) was replying to *The assayer*, which was under anonymous attack for alleged Copernicanism and other heresies. The reply in question, Sarsi's *Ratio,* appeared in 1626 from Paris, denouncing especially Galileo's atomic view of matter and the doctrine that secondary qualities of colour, taste, touch, and so forth, are subjective, deriving from the contact or impact of minute particles from external objects. Sarsi argued that such a view was contrary to the ruling of the Council of Trent on the Eucharist, whereby the matter of the bread and wine was wholly replaced on consecration by the material of Christ's body and blood, with no change in the sensible qualities of the bread and the wine. The same denunciation had been sent anonymously to the Holy Office in 1624–5, and was repeated in the Naples edition (1627) of Sarsi's *Ratio*, published with the ecclesiastical and financial backing of Cardinal Francesco Boncompagni, the pro-Spanish Archbishop of Naples. Nothing came of these denunciations, save the exile of their author, Orazio Grassi, from Rome to his native Savona in the Republic of Genoa by Urban VIII after the condemnation of Galileo in 1633. Other trouble-makers for the Pope were similarly exiled from Rome.[38]

Galileo in Florence prepared notes with Guiducci answering Sarsi's book, but they remained unpublished: *The assayer* was a wholly philosophical work, and Sarsi was attempting to entice Galileo into a theological dispute, as Castelli, Riccardi, Ciampoli and Cesi in Rome observed. Instead Galileo continued with the preparation of his *Dialogue concerning the two chief world systems*,[39] completed by 1629 when he asked Cesi to see the work through the press as a publication of the Lincean

Academy, for his health was now poor and his eyesight failing. Galileo took his manuscript to Rome in May 1630 for a publication licence and believed that he was well-received by Urban VIII.

Galileo left his manuscript with the Vatican Secretary, the friendly Dominican Riccardi, who assigned the task of reviewing the work to Raffaello Visconti, a sympathetic Dominican mathematician (later exiled from Rome for his association with the astrologers prognosticating the Pope's demise). Visconti approved the publication, subject to the correction of a few minor technical errors. Unusually, Riccardi then reviewed and revised the entire work himself in consultation with Urban VIII, ordering the removal from the title a reference to "the ebb and flow of the seas" as too Copernican in intent. He asked for a new introduction and conclusion making clear the wholly hypothetical character of the theories discussed. Galileo complied with these requirements, and Riccardi agreed that the work now appeared acceptable, but no licence was immediately forthcoming.

In Florence Galileo heard that Cesi had died on 1 August 1630, resulting in the decline of the Lincean Academy and the end of its publication programme. Castelli wrote from Rome, advising publication of the *Dialogue* in Florence in the light of the changed circumstances. Riccardi procrastinated further, but under pressure from the Tuscan ambassador in Rome and the assurance of Ciampoli that the Pope had sanctioned the transfer, he finally agreed to leave the granting of a licence for publication in the hands of the Florentine Inquisitor, who provided the required imprimatur in July 1631. Printing of 1000 copies of the *Dialogue* began immediately, and was completed by February 1632, bearing the ecclesiastical licence of both Rome and Florence, and the secular sanction of the government of the Grand Duke of Tuscany to whom the book was dedicated.

The *Dialogue* covered four days of discussion between three interlocutors, in the Venetian palace of Giovanfrancesco Sagredo (1571–1620), Galileo's former student and his closest friend at Padua, who featured as the common-sense spokesman. The other two were Filippo Salviati (1582–1614), a merchant-banker noble of Florence and one of the Lincei, who acted as spokesman for Galileo (termed "the Academician"); and the genial Simplicio, a resilient and informed Aristotelian, like his sixth-century namesake. The book was primarily an instructive polemic against the hierarchical Aristotelian cosmology, introducing the reader to a more uniformitarian heliocentric and mechanical world view, which was developed further during the seventeenth century. There was virtually no technical astronomy in the *Dialogue*, but Galileo's telescopic discoveries and their qualitative interpretation in terms of the material equivalence of the heavens and the Earth were extensively discussed, laced with Galileo's mechanics, and presented in an entertaining form, comprehensible to a wide sector of literate Italians.

The introduction and conclusion had been heavily censored in Rome. The preface, written by Riccardi, opens with a restatement of the 1616 decree, and the comment that the edict had led to complaints that the Vatican advisers had been unskilled in astronomy. It was now proposed to serve the Church by showing "foreign nations" (notably the Germans) that the scientific arguments for and against Copernicanism were well understood in Italy, for the 1616 decree had been directed against unauthorized biblical interpretations purporting to demonstrate the motion of the Earth (Foscarini and Protestant writers).

The First Day opens with a critique of Aristotle's sole law of nature, the Pythagorean ruling that perfection resides in the number three, governing salient features of the cosmos and society, explaining why extended bodies and space have three dimensions, and why we worship the gods in sets of three.[40] Are three legs better than two or four, asks Salviati? The discussion continues with an extensive criticism of the Aristotelian division of the cosmos into the unchanging heavens, with their perfect circular motions, and the imperfect Earth, subject to generation and corruption and ruled by rectilinear motions. What of the new stars of 1572 and 1604 that came into being and passed away, asks Salviati, the mountains, craters and plains of the Moon, or the spots on the Sun? Indeed, it is generation that makes the terrestrial globe noble, adds Sagredo, for earth and water give rise to trees and fragrant flowers, of more worth than unalterable gold or diamond, valued only for their scarcity (as William Gilbert had observed, in contrast to the abundant and useful iron). Those who exalt incorruptibility are moved "by their great desire to go on living and by the terror they have of death".[41]

The Second Day continues in the same vein, with the question of whether the Earth rotates daily on its axis, or the planets and vast sphere of fixed stars rotate around the celestial poles once every 24 hours. Objections to the rotation of the Earth are met by the principle of the relativity of all motions. A stone dropped from the top of a ship's mast hits the deck at the same point whether the ship be at rest in port or moving under sail. A cannon shot has the same range whether aimed due east or due west; aimed vertically, the ball on falling back returns to the cannon. Contrary to Aristotle, the rate at which the cannon ball falls is independent of its weight, be it one pound or 100 pounds, and it is an accelerated motion, such that the distance of fall is proportional to the square of the time elapsed from rest.

The Third Day is devoted to the question of the annual motion, either of the Earth around the Sun, or of the Sun around the Earth. Simplicio advances the Aristotelian argument that it is more reasonable to have the container, the sphere of the fixed stars, and the contained bodies of the planets, move round a common centre, the Earth, than round a diversity of centres, as Copernicans hold. On the contrary, Salviati replies, it is more reasonable to place the Sun at the centre of the circular orbits of the Earth and the planets, for such an arrangement explains why the planets appear so much larger when on the same side of the Sun as the Earth in its orbit, than when on the opposite side, by a factor of 60 in the case of Mars; and why the planets display apparent stations and retrogressive motions. Moreover the phases of Venus show that this planet must orbit the Sun in a circle, resembling the phases of the Moon in its circular orbit around the Earth. Our Moon is carried by the Earth in an annual orbit around the Sun, just as the four moons circulating round Jupiter move with their parent body around the Sun. On the composition and motions of the Earth, Salviati and Sagredo discuss the magnetic philosophy of William Gilbert at some length, approving his experimental method, but regretting his lack of mathematics, while doubting the conjecture that a sphere of lodestone spontaneously rotates on its magnetic axis once every 24 hours.

The discussion of the Fourth Day covers the theory of the tides, which Galileo regarded as establishing conclusively the diurnal and the annual motions of the Earth. Three tidal periodicities are observed in the Mediterranean, with local modifications in regions adjacent to the various islands. The principal periodicity is diurnal, giving high tide twice a day, with monthly and annual variations. If the Earth were motionless, Salviati observes, there would be no tides at all, and Aristotle concedes that the causes of tides are incomprehensible. Salviati then recalls Galileo's account to Paolo Sarpi of the behaviour of the water in the barges bringing fresh water to Venice, how the water piles up at the stern on starting and then at the prow on ending. The great intercontinental basins containing the seas are accelerated and then decelerated once each day as the diurnal spin of the Earth has a direction, now parallel and then contrary, to the direction of annual motion round the Sun. This mechanism would give high tide once each day in a particular region, and the two high tides a day observed in the Mediterranean must arise from secondary geographical causes. The lengthy Red Sea is devoid of tides, for example, because it runs from north to south, rather than from east to west. Simplicio concludes the discussion with the observation of Urban VIII that God could generate the tides in many different ways, some unthinkable to our minds, and it would be presumptious to limit Divine power to any particular fancy of our own. Salviati solemnly agrees with this piety, and Sagredo takes the opportunity to close the discussion.

In the spring of 1632 copies of the *Dialogue* reached Rome, exacerbating the furore already raging at the Vatican. Urban VIII exiled from Rome the most active supporter of Galileo within the Curia, his own correspondence secretary, Giovanni Ciampoli, by appointing him governor of a remote district within the Papal States in April 1632. Riccardi, on the instructions of the Pope, ordered the Florentine Inquisitor to sequester all remaining copies of the *Dialogue*, and to discover the significance of the book's colophon of three dolphins. The Florentine printer, Landini, replied that the edition was now sold out, and that the colophon was his trade mark, appearing in all the books he printed. The Grand Duke protested to the Vatican through his ambassador at the Tuscan embassy in Rome, who reported back that the Pope was much enraged against Galileo, and his patron, dismissed as a vassal of the Hapsburgs.

Urban VIII suspected that the colophon might be an indirect reference to the three nephews he had made cardinals and enriched, following a heated consistory of March 1632, at which the Spanish ambassador, Cardinal Gaspare Borgia (1589–1645), had accused him of nepotism, and of supporting Lutheran heretics. The Pope protested to Madrid, and was then threatened by direct intervention from Naples, governed by Spain. Urban VIII had long favoured France as a more enlightened Catholic power than Spain: he owed his election to the French cardinals, led by Maurizio of Savoy. As Pope he was opposed to the pact between Spain and the Holy Roman Emperor, aiming for Hapsburg hegemony in Europe, and he supported French policy during the Thirty Years War, pressing for the neutrality of Catholic Bavaria, and agreeing to the entente established early in 1631 between France, Bavaria, and Lutheran Sweden, where there were fears that the Baltic ports would be lost to the Hapsburgs, following their military gains in 1630.

The armies of the Swedish king Gustavus Adolphus (1594–1632), financed by the French Cardinal Richelieu, swept through Germany to the Alps by April 1632, expelling all Jesuits on their way. This was followed by a political crisis in the Vatican. Cardinal Maurizio of Savoy changed his allegiance from France to Spain, and the Pope followed suit in May 1632, perceiving enemies and traitors everywhere. In December 1632 Urban VIII conducted a Papal Mass in Rome at the Church of the German Nation, Santa Maria dell'Anima, giving thanks for the death of the Protestant king, Gustavus Adolphus, at the battle of Lützen earlier in the year.

Galileo became a political scapegoat during the Vatican disarray, as the worldly Florentine and liberal French influence in the Curia was replaced by that of the conservative pro-Spanish Jesuits. Urban VIII set up a commission of experts in August 1632 to determine whether Galileo, in his *Dialogue*, had infringed the edict of 1616, forbidding the defence or teaching of Copernicanism. All of the chosen experts were theologians, none versed in mathematics, Campanella told Galileo, and they decided that Galileo had indeed contravened the edict of 1616. The Pope's younger brother, Cardinal Antonio Barberini, one of his subsequent inquisitors, ordered Galileo to Rome for trial in October 1632, and when Galileo procrastinated, on the grounds of ill-health and the prevalence of plague in Italy, he was told that unless he came voluntarily, he would be brought to Rome in chains and imprisoned at his own expense. The protests of the Grand Duke were similarly brushed aside, and Galileo was accommodated at the Tuscan embassy in Rome on arrival in February 1633. The Tuscan ambassador, Francesco Niccolini (1584–1650), told him that the principal charge would be violation of the 1616 edict, and advised Galileo simply to submit, and relinquish his programme to bring cultural enlightenment to the Curia and the Catholic world.

Galileo was obliged to appear before his prosecutors and inquisitors of the Holy Office a number of times from April to June 1633, during which he confessed that some passages in the *Dialogue* did indeed appear to support the heresy of Copernicanism, which he abjured on his knees. Finally he was condemned to formal imprisonment at the pleasure of the Holy Office, and to recite the penitential Psalms once a week for three years, being vehemently suspected of heresy. The *Dialogue* was placed on the Index of prohibited books, but pirated editions were already appearing, and a Latin translation by Mathias Bernegger of Strasbourg was published at Leiden in 1635 for the European market at large.

Of the ten cardinals responsible for the verdict and sentence in 1633, three abstained. These included the Pope's nephew, Francesco Barbarini, a former fellow Lincean, who supported Galileo's programme for cultural enlightment, and the Spanish ambassador, Gaspare Borgia, who may have felt that Galileo was worth saving from imprisonment in the Spanish interest, for his proposed method of determining the longitude.[42]

The Tuscan ambassador and Francesco Barbarini arranged for the formal imprisonment of Galileo not far from home, in the palace of the Archbishop of Siena, Ascanio Piccolomini, an old friend of Galileo. Piccolomini came of a Sienese family of prelates and academic cultured connoisseurs. His cathedral was embellished with a mosaic pavement of Hermes Trismegistus and two Sybils;[43] and a fresco of the legendary Pope Joan (853–5?) adorned the Piccolomini library of the Duomo at Siena.[44] Galileo, now near the end of his seventh decade, found himself in a congenial environment, discussing his views with Tuscan notables. Encouraged by his host, he started to write again.

But Galileo and the Archbishop were denounced anonymously to the Holy Office, and in December 1633 Galileo was transferred to his villa at Arcetri near Florence, with the restrictions that he had no visitors, nor ventured himself beyond Arcetri, even to visit his eye-specialist physician in Florence. In 1613 Galileo had placed his daughters in the Convent of San Matteo at Arcetri, and he was able to see them daily. The elder daughter, Virginia, now Sister Maria Celeste, had taken an active and sympathetic interest in her father's work and the calamities that had befallen him, but she died in the spring of 1634. The younger daughter Livia, now Sister Arcangela, had declined into chronic melancholy, with little interest in the outside world.[45] Galileo's son, Vincenzio, married into a well-connected Florentine family in 1629, shortly after graduating in law from Pisa. The brother of his daughter-in-law, Geri Bocchineri, an official in the secretariat of the Grand Duke Ferdinand II, attended to Galileo's interests, weeding his papers of material that might concern the inquisitors during his call to Rome for trial in 1633, and then conveying uncensored correspondence to and from Galileo on his return to Arcetri.

Former students of Galileo at Padua, notably Comte François de Noailles (1584–1645), French ambassador to Rome from 1634 to '36, and Nicole Fabri de Peiresc (1580–1637), counsellor of the Parlement of Aix, interceded with Urban VIII for Galileo's release, but to no avail. Thanking Peiresc for his intercession in 1635, Galileo suggested he was being used as a scapegoat. He wrote "when a man is wrongly condemned to punishment it becomes necessary for his judges to use the greater severity in order to cover their own misapplication of the law".[46] Galileo could see that he had become a political whipping-boy, and also that Copernicanism had now been associated with the Protestant Reformation by the Jesuits. On the eve of his departure for Rome in 1633 Galileo wrote to his old friend Elia Diodati (1576–1661), an eminent jurist of the Parlement of Paris, telling him of the summons to appear before the Inquisition, adding; "I hear from well-informed parties that the Jesuit fathers have insinuated in the highest quarters that my book [*Dialogue*] is more execrable and injurious to the Church than the writings of Luther and Calvin".[47] The Jesuits insinuated, also, that the simpleton (Simplicio) in the discussion of the tides on the Fourth Day of the *Dialogue*, supposedly represented Urban VIII.

Galileo had been forbidden in 1633 to publish any further writings, but the prohibition could not be enforced in Protestant Europe. Towards the end of the *Dialogue*, Galileo mentioned a discourse on local motions, natural and violent, in preparation, and he started writing his *Two new sciences* at Siena after his trial in 1633. The first draft was virtually completed by the end of 1634, when he began negotiations for publication abroad. In 1636 Galileo was visited at Arcetri by Louis Elzevir, representing the Dutch publishers of Latin translations of the *Dialogue* and *Letter to Madam Christina*. The Dutch visitor left Italy with the manuscipt of the *Two new sciences*, which emerged from the Leiden press of the Elzevirs in 1638.

The *Two new sciences* took the form of a discussion, over four days, with the same three interlocutors as in the *Dialogue*, but now located in the Arsenal of Venice. Salviati and Sagredo observe at the beginning of the First Day, discussing the strength of materials, how the practical wisdom of the skilled artisans at the Arsenal stimulates and instructs the natural philosopher. Large ships are not constructed as simple copies of small vessels, scaled up in strict geometrical proportion: the timbers are much thicker in cross-section in the larger vessels, relative to their lengths. Similarly, large animals have disproportionately thicker legs than small creatures, and the largest creatures are the sea animals, their weight supported by the water. Bones are essentially hollow tubes, which are much stronger than solid cylinders of the same length containing the same amount of material. Geometry is a guide to *discovery*, but a theory of the constitution of materials is needed for *understanding*. Matter consists of particles which cohere by minimizing the voids between them. Material bodies fracture because the abhorrence of a vacuum by nature is limited: thus, engineers find that water cannot be drawn up into a column higher than 18 cubits by a suction pump.

Contrary to Aristotle, all bodies would fall at the same speed in a vacuum. In a fluid medium the rate of fall is inversely proportional to the relative specific gravity of the medium, and light bodies, which fall in air, rise in water. Aristotle's theory leads to the paradox that if two stones were loosely linked by a cord, the lighter stone would delay the fall of the heavier, but if they were tightly bound, the two stones would fall faster than either of them individually. The law of fall is illustrated by the isochronous swings of the pendulum, with a period proportional to the square root of the cord-length. The shorter Second Day continues the subject in Archimedean style, using the principle of the lever to treat the strengths of beams of various materials and cross-sections, including the hollow tube.

The Third and Fourth Days cover Galileo's studies of local motion, made decades earlier. He now starts from formal definitions of uniform motion and acceleration; and then derives, from postulates, sequential theorems and problems in an Archimedean form, with numerous corollaries. These demonstrations are all most reasonable, Simplicio observes, but does the acceleration that is discussed correspond to the acceleration found in Nature? A good question, Salviati replies, and relevant "for all those sciences where mathematical demonstrations are applied to natural phenomena". He goes on to give a detailed account of the timed descent of a bronze sphere down an inclined plane, with elaborations and repetitions to ensure consistency. The demonstration of the parabolic motion of a projectile gives a result long known to gunners in the field, a maximum range for a cannon elevation of 45°. Discovery of the *causes* allows the mathematical demonstration of "what has perhaps never been observed in experience", that cannon elevations which exceed, or fall short, of 45° by equal amounts have equal ranges.[48] The Fourth Day ends with the hint that the discussion will continue; but Galileo's eyesight deteriorated further throughout 1637 and he was wholly blind by the end of the year. He left an incomplete Fifth Day, discussing the Euclidean theory of proportion, and fragments for a Sixth Day on the role of the speed and the weight of hammers in percussive actions; he noted that large resistances are ultimately overcome by repeated small percussive impacts.

After Galileo became wholly blind, he was allowed in 1639 the assistance of his young disciple, Vincenzo Viviani (1622–1703), who came of a well-to-do Florentine family. For the last months of his life, Galileo had the additional help of Evangelista Torricelli (1608–47), the son of a textile artisan of Faenza, who had studied in Rome with Galileo's Paduan student, Benedetto Castelli, and became his secretary. When Galileo died in 1642, Torricelli succeeded him as court mathematician to Grand Duke Ferdinand II, but the position of court philosopher came to an end. Torricelli died in 1647, probably of typhoid fever, and he was followed as court mathematician by Viviani.

4. CONTINUING THE GALILEAN TRADITION

In 1630 Galileo was asked by Giovanbattista Baliani (1582–1666), a Genoese administrator of public engineering works, why a siphon designed to carry water over a rise of some 60 feet had failed. Galileo replied that suction pumps failed to raise a column of water higher than 30 feet, since this height represented the limit to the cohesion of water and the avoidance of a vacuum. Baliani suggested that suction pumps work from the pressure of the atmosphere above the water surface, and he doubted that the total weight of many miles of a column of air above a water surface would support a column of water only 30 foot high.

Viviani and Torricelli investigated the problem by measuring the column heights attained by other liquids in vertical tubes closed at the upper end. In 1644 Torricelli informed his friend in Rome, Michelangelo Ricci, that mercury, with a density more than 13 times that of water, attained a height of some 28 inches in such a tube. The vertical height was maintained when the tube was inclined from the upright position, or when the tube carried a bulb at the upper end. The effect supported the view of Baliani that the height attained by a liquid in a closed vertical tube above an open dish of the liquid, was balanced by the pressure of the atmosphere standing above the dish. Moreover, the height of the liquid column varied a little, dependent upon the weather conditions. The news soon reached Marin Mersenne in Paris, who visited Florence to view the experiment and discuss its implications. Mersenne conducted an international scientific correspondence, and it was not long before Torricelli's experiment was repeated across Europe, and extended to other studies of atmospheric pressure.

Both Ferdinand II, Grand Duke from 1628 to 1670, and his youngest brother, Prince Leopold de' Medici, had been Galileo's pupils, and they maintained well-equipped laboratories, and gardens with collections of animals and plants. After the death of Galileo they held informal scientific discussions at the Medici court, with Torricelli and then Viviani taking a leading role, joined by the chief court physician and head of the court pharmacy, Francesco Redi (1626–97), the Medici engineering experts, and by professors of medicine and mathematics at the University of Pisa. Prince Leopold, with the approval of Ferdinand II, placed the discussions on a formal footing with the foundation in 1657 of the Accademia del Cimento, devoted wholly to experimental studies, avoiding the theoretical disputes which had led to Galileo's condemnation and problems for his Medici patrons.[49]

The Academy of Experiments was closed down in 1667 when Leopold became a cardinal, and had to spend time in Rome; he ordered the secretary, Lorenzo Magalotti (1637–1712), who had made notes at the meetings, to write an account of the decade's studies.[50] Magalotti did not record the names of the nine academicians; he presented their work as collaborative and empirical, improving scientific instruments, and extending earlier non-controversial physical studies. The more notable academicians published independently, reluctant to accept the purely empirical and anonymous presentation of the official record. In 1668 Redi showed that insect larvae were not generated spontaneously from decaying organic material, since this putrefied without the appearance of visible animal life if screened from insects. Using the microscope, he discovered the egg-laying organs of insects, producing morphologically-distinct eggs from different species. These were laid after coitus in decaying organic matter, becoming larvae and then the next generation of the insect species.

Marcello Malpighi (1628–94), professor of medicine at Pisa from 1656 to 1659, returned to Bologna, for reasons of health. He brought with him Redi's microscopic techniques of dissection and vivesection, and the iatromechanical-atomic philosophy of his colleague, Giovanni Alfonso Borelli (1608–79), who was professor of mathematics at Pisa over the decade of the Cimento's activities, 1656–67. Malpighi was the first to observe, with the microscope, the capillary network linking the arteries to the veins around the air vessels in the lungs of the frog, and the individual red blood corpuscles, the red "atoms" of the blood, as he termed them. Malpighi published his work in the *Philosophical transactions* of the Royal Society of London from 1667, to avoid clerical censorship in Italy.

Giovanni Borelli was the most notable and independent of the Cimento academicians. He was the eldest of five sons and a daughter born to Laura Porello (or Borelli) of Naples and a Spanish father, Miguel Alonso, an infantryman guarding the Castel St Elmo, where Tommaso Campanella was imprisoned. Campanella probably taught some of the Borelli brothers, passing on his ideas. In Rome, around 1628, he introduced Giovanni Borelli to Benedetto Castelli for the study of mathematics. Castelli subsequently sponsored the appointment of Giovanni to the chair of mathematics at Messina in 1635. Another brother Filippo Borelli became Campanella's amanuensis in Rome and accompanied him to France in 1634. Giovanni Borelli had studied medicine in Naples, and had learned of Galileo's ideas while in Rome with

Castelli. He extended Galileo's views of animal structures to animal motions, and began in Pisa his iatromechanical study *De motu animalium*. This work was finally published in two volumes in Rome (1680, 1681), financed by the eccentric Queen Kristina of Sweden, who had become a Catholic convert and patron of natural science in Rome.[51]

While at Pisa, Borelli set up an observatory in a fortress on a hill just outside Florence to track the motions of the moons of Jupiter and of a comet seen for a few months from December 1664. He concluded from parallax measurements that the comet lay at varying distances from the Earth above the Moon's orbit. He told Prince Leopold that the comet appeared to follow a parabolic trajectory, which was consistent with none of the then-current astronomical systems. In 1666 Borelli published his *Theory of the Medicean Planets deduced from physical causes*, in Florence, dedicated to the Grand Duke, assigning elliptical orbits to these bodies from his observations, and ascribing their motions to the interplay of three actions, developed from Kepler's model with Galilean additions. The central body of a planetary system sent out rays which rotated in the equatorial plane, owing to the spin of the central body on its axis. The rays swept round the planets, and their natural rectilinear motion became a closed orbit: this resulted from the balance set up between the centrifugal action, due to the deviation from their natural rectilinear tangential path, and the centripetal attraction of the central body on each planet. If the initial balance were not exact, self-correcting fluctuations led from a circular path to the observed elliptical orbits of the planets, just as a perturbed plumb line becomes a pendulum. Later, Newton quoted Borelli for the concept of a balance between centripetal and centrifugal forces in planetary motion. The Copernican implications of Borelli's scheme were clear: to avoid censure, he confined the details of his analysis to the motions of the four moons of Jupiter.

When the Cimento closed in 1667, several academicians left Florence. Carlo Rinaldi, an engineer and professor at Pisa, moved to Padua. Antonio Olivia, a hydraulics expert, went to Rome, where he died the following year, falling from a window of the Inquisition prison. Borelli returned to his chair of mathematics at Messina, but his tenure was brief. In 1674 there was a popular revolt in Messina against the Spanish overlords, who put a price on the heads of the republican rebels, including Borelli. He fled to the uncertain patronage of Queen Kristina of Sweden in Rome, lecturing at her newly founded Accademia Reale in 1675. Giovanni Cassini (1625–1712), who had left Bologna to head the Paris Observatory, invited Borelli and Viviani to join him in Paris, but Borelli felt he was now too old to move abroad, and Viviani considered himself well placed in Florence to promote the achievement of his master Galileo.

Viviani started to write his *Life of Galileo* in 1654, but he encountered continuous setbacks, and the book was published posthumously in 1717, when the work appeared to be safe from clerical censure. Praise of Galileo was strongly discouraged by the Vatican, after his death in 1642, and there were fears in Florence that burial with his ancestors in the Basilica of Santa Croce would be forbidden by Rome, on account of his suspected heresy. Urban VIII banned the erection of a monument to Galileo in Santa Croce, proposed by Grand Duke Ferdinand II and Prince Leopold. Viviani was as cautious as his Medici patrons. He promoted the reductive experimentalism of the Accademia de Cimento, to boost the standing of the Medici as patrons of science, with one eye on the antipathy of Rome, and the other on the Protestant image of Galileo as a martyr of science. John Milton in his *Areopagitica — Speech for the liberty of unlicensed printing* (1664) reported his meeting with Galileo in 1638 at Arcetri, blind and old, a prisoner of the Inquisition. The image was extended in Catholic France by the anticlerical *philosophes* of the eighteenth-century Enlightenment, and amplified by the anticlerical politicians of the Italian Risorgimento during the nineteenth century, with the addition of Bruno and Campanella as fellow hero-martyrs.

Viviani found himself in a delicate position, endeavouring to promote Galileo's scientific studies while conciliating the Vatican authorites and blurring the conflict with Rome. With Medicean support, Viviani published the collected works of Galileo at Bologna in 1656, without the banned *Dialogue*, and flawed by many errors. In 1673 he wrote to the former secretary of the Cimento, Lorenzo Magalotti, then in Flanders, asking him to stop the impending publication in Amsterdam of the letters exchanged between Galileo in Padua and Paolo Sarpi in Venice, with allusions to their common opposition to clerical intervention in secular affairs. Viviani requested Cosimo III, Grand Duke from 1670 to 1721, to implement his father's plan for a monument to Galileo in 1674, with no response. Cosimo III had none of the concern of his father and grandfather to enhance Medicean standing by the patronage of Tuscan science. In 1691 Cosimo III meekly agreed to ban the teaching of the atomic philosophy in Florence. The ban followed a demand of the Jesuits who had warned students at their Florentine College against atomism, denouncing the associated doctrine of the vacuum, which was supported by the barometric experiments with the mercury column made in Florence by Viviani and Torricelli in 1643. The decline of the State of Tuscany led to its incorporation into the Austrian empire in 1736, shortly before the death of Gian Gastone de' Medici, the childless son of Cosimo III.

With the end of the Medicean dynasty, the monument to Galileo in Santa Croce was finally built, in 1737, with funds bequeathed by Viviani for the purpose, and constructed mainly to his design. Viviani believed that Galileo had been born on the day that Michelangelo Buonarroti had died, expressing the continuity of Tuscan creativity, and designed a monument to Galileo modelled on the one erected to the memory of Michelangelo in Santa Croce. The memory had been sanitized by orthodox chroniclers. Michelangelo had defended the Florentine Republic against the Hapsburg army restoring the rule of the Medici, and his earthy images and sensual nudes flouted the artistic canons of the Counter-Reformation, requiring the arts to serve Tridentine doctrine.

Michelangelo's monument in Santa Croce carried three statues, representing the three arts he had revived, Painting, Sculpture, and Architecture. Viviani designed three statues for the monument to Galileo, to represent his contributions to the disciplines of Mathematics, Astronomy, and Philosophy. Only two statues, those representing

Mathematics and Astronomy, appeared in Galileo's monument unveiled in 1737: his natural philosophy was still suspected of heresy, of Copernicanism and atoms in the void. No ecclesiastical authorities attended the ceremony for the inauguration of Galileo's monument, but most secular notables did, along with the recent recruits to Freemasonry in Florence, regarded by the Holy Office as immoral and atheistic Copernicans.[52]

By the time that Galileo's monument was installed in Santa Croce the Curia had become more defensive and softer on the Galileo case. The liberal Pope Benedict XIV (1740–58) sanctioned the publication of most of Galileo's works, including the *Dialogue*, and reformed the Congregation of the Index to include experts in "profane" learning, alongside the traditional theologians, to examine new publications. Benedict XIV corresponded with Pierre de Maupertuis (1698–1759), a member of the Paris Academy of Sciences, who measured the length of a meridian degree in Lapland in 1738, for comparison with the corresponding measures near Paris and in tropical regions, to show that the Earth is an oblate spheroid, flattened at the poles and bulging at the equator, due to the Earth's plasticity and diurnal spin. Newton had surmised this shape of the Earth in his *Principia*[53] from the variation of gravitational attraction between the arctic and tropical regions. In addition to the firm evidence for the diurnal rotation of the Earth, there was now an indication of the Earth's annual motion round the Sun from the discovery of the aberration of starlight. In 1729 James Bradley (1693–1762), Savilian professor of astronomy at Oxford, found that prominent stars appeared to trace out a small elliptical motion annually, due to the finite velocity of starlight combined with the terrestrial motion of the observer in an annual elliptical orbit around the Sun. These developments had little immediate impact on the Curia, who left Galileo's *Dialogue* and the *De revolutionibus* of Copernicus on the Roman Index of Prohibited Books until 1835.

CONCLUSION

Galileo started out as a mathematical practitioner, teaching and developing a trade with a lowly social status and modest reward. His developments included new technical inventions and improvements of useful instruments, along with the critical reappraisal of generally accepted principles of mechanics. His reappraisals were carried forward into natural philosophy, a subject of higher academic standing and financial reward. The major step of his entry into natural philosophy came with his improvement of the telescope and the introduction of systematic telescopic observations of the heavens from 1610. Doubtful of traditional Aristotelianism from the start, he now aimed to construct an alternative world view: a coherent and uniformitarian physical science, covering both the heavens and the Earth. To this end Galileo contributed his new quantitative kinematics of terrestrial motions, which he tested experimentally earlier, before 1610. Most of the telescopic studies were qualitative and exploratory. He repeated them for consistency and for the detection of new regularities, such as the phases of Venus, to provide evidence directed to his anti-Aristotelian and pro-Copernican cosmological aims.

One such telescopic project was quantitative, the extensive observation and tabulation of the eclipses of Jupiter's four moons. This project arose from the need to measure longitude with precision, in order to exploit the major geographical discoveries of the period by making the sea voyages involved more exactly reproducible. Telescopic observation of the Jovian moons was not practicable at sea, but was not difficult on terra firma: Galileo's method for determining the longitude was first employed successfully in the mapping of France during the late seventeenth century. The quest for the longitude was of particular concern to the Atlantic maritime nations, Spain and the Dutch Republic especially. Both of these powers entered into negotiations with Galileo for his method of longitude measurement, Spain through its ambassador to Rome, Cardinal Gaspare Borgia, until Galileo's condemnation in 1633, and the Dutch during his subsequent exile at Arcetri.

Galileo became a victim of the Counter-Reformation in 1632 during the Thirty Years War (1618–48), when Urban VIII switched from his former pro-French and Florentine allegiance to support for the Spanish and Hapsburg interest. The armies of Lutheran Sweden, allied to France and Bavaria, swept down from the Baltic to the Alps, driving members of the Jesuit Order before them. Rome was purged of French and Florentine supporters, along with others whom Urban VIII found troublesome. Galileo's *Dialogue*, printed in Florence, arrived at Rome in the middle of the furore. As Galileo observed in his correspondence with Diodati and Peiresc, he became a scapegoat for the papal disarray, and his *Dialogue* was judged by the Jesuit fathers as injurious to the Roman Church as the writings of Luther and Calvin.

Galileo himself had none of the Renaissance interest in Pythagorean and Hermetic notions. He jested in the *Dialogue* with Aristotle's Pythagorean "law of nature" that all entities in the universe come in sets of three. He was more inclined to the mentality of the Enlightenment, critical of theologians and other authorities who meddled with professions they did not practise; to the jeopardy of the sick, in the case of medicine, and of the safety of buildings, in the case of architecture. Galileo anticipated the anti-clericalism of the Risorgimento in his last will and testament, in which he specified that any beneficiary who might join a religious Order would forfeit his bequest.[54]

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