Galileo in Rome

The Rise and Fall of a Troublesome Genius

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INTRODUCTION

Galileo is the father of modern science and a major figure in the history of mankind. He belongs to the small group of thinkers who transformed Western culture, and his clash with ecclesiastical authorities is one of the most dramatic incidents in the long history of the relations between science and religion.

In 1633 the Roman Inquisition condemned Galileo for teaching that the earth moves. The trial was the outcome of a series of events that are described in this book and are usually referred to as the Galileo Affair. It extended over a period of several years, during which different popes, cardinals, and civil personalities entered the scene and made their exit. We can even speak of two Galileo trials, one in 1616 and the other in 1633, although only the second was a trial in the legal sense. The new science, which today pervades our entire life, was just emerging, and very few were able to realize what was happening at the time. Most people were not ready to abandon cherished traditional ideas for daring hypotheses that had yet to be proved.

Galileo made six long visits to Rome, totaling over five hundred days, during which he met the pope, high-ranking members of the Church and the nobility, as well as leading figures of the literary and scientific establishment. His career can be seen in a novel and fascinating way when studied from the vantage point of the city where he was most anxious to be known and approved. This is what our work does for the first time. Each chapter corresponds to one trip, thereby providing a clear framework for the main events of Galileo's life and allowing a fresh insight into the nature of the problems that he faced.

Galileo was deeply influenced by his close contacts with members of the ecclesiastical and the scientific community in Rome and, as time went on, he changed his agenda to fit new circumstances. He sometimes met with success, but he ultimately overplayed his hand and the outcome was dramatic. On the short term, his strategy was a failure; on the long term, he clearly emerged the winner.

The six trips occurred over a period of 46 years. The first took place in 1587, when Galileo, then 23 years old, went to Rome to meet scientists who might help him obtain a university appointment. With the assistance of Christopher Clavius, a Roman Jesuit professor, he got his first job at the University of Pisa in 1589 and, in 1592, he moved to the University of Padua, where he spent the next 18 years. After the publication of his astronomical discoveries had transformed him into a celebrity, Galileo returned to Florence, where he became the mathematician and philosopher of the grand duke of Tuscany. The next year, in 1611, he undertook a second and triumphal trip to Rome. He was made welcome by top-level members of the Church and the teaching profession. Unfortunately, his celebrity also gave rise to jealousy and opposition, especially when he began defending in public the Copernican view that the Earth is in motion and revolves around the Sun. This went against the commonsensical view that the Earth (and therefore humanity) is at the center of the universe, a belief that current scientific shared with tradition and Christian doctrine.

The opposition first arose among Aristotelian professors, but they soon managed to involve clerics who did not relish having to reinterpret Scripture in the light of new ideas. Galileo found out that he had been denounced to the Holy Office, and he traveled to Rome for the third time in December 1615 in order defend himself and avoid the condemnation of the heliocentric theory. He was brilliant in discussion, but to no avail. Copernicus's book on the motion of the Earth was banned in 1616, and Galileo was admonished not to teach it. He returned to Florence and was silent on the matter until his friend and admirer Maffeo Barberini was elected pope in 1623, taking the name of Urban VIII. A year later Galileo made his fourth trip to Rome, where he was received six times by the pope. This trip was another triumph, and Galileo felt he could now publish his ideas as long as they were presented as conjectures. This is how his celebrated *Dialogue on the Two Chief World Systems* came to be written, and in 1630 Galileo made a fifth trip to Rome to request permission to print the book. A number of complications arose, and the work only appeared in Florence in 1632. A loud outcry was raised and Galileo was summoned to Rome, where he was put on trial in 1633. His book was censored, and he was condemned to prison, a sentence that was immediately commuted to house arrest.

The Galileo Affair remains as fascinating as ever, and it has much to teach us that is relevant to our own day. We believe it is the first step in a proper assessment of the relations between science and religion, and we hope that our account will help readers come to grips with the issue and enable them to answer for themselves questions that often arise concerning the affair. We have avoided technicalities, but the book is based on first-hand research and the reader will find the sources of our quotations at the end of the book. We have carefully checked out the slightest details and have been able to correct inaccuracies that are found in the best books on the subject. We have combined our respective knowledge of science and religion (one of us teaches history of science, and the other is a philosopher who is also a physicist and a Roman Catholic priest). The priest often saw Galileo's point before the historian; the historian frequently reminded the priest that the Church had sound arguments.

CHAPTER ONE

Job Hunting and the Path to Rome

FIRST TRIP • 1587

In the autumn of 1587, a young man of 23 arrived from Florence on his first trip to the Eternal City. His name was Galileo Galilei, and, in accordance with an Italian custom of calling great men by their first name, we shall continue to refer to him as Galileo. In an age when class consciousness was on the rise in Italy, Galileo was proud of the fact that he descended from a noble family. Originally called Bonaiuti, they had exchanged that name for Galilei in the fourteenth century, although they kept their coat of arms unchanged, a red stepladder on a gold shield, forming a pictograph of the word *buonaiuti,* which literally means *good help*. The first Galileo Galilei, the older brother of the young Galileo's great-grandfather, was a successful doctor and an influential professor at the University of Florence. He also held high office in the Republic and was elected *gonfaloniere* or chief magistrate in 1445. He died around 1450 and was buried with public honors in the church of Santa Croce in

Florence, where visitors to this day can admire his full-length marble figure in the floor of the nave, near the main entrance door. The second Galileo Galilei, the scientist who is the hero of our story, could not know in 1587 that he would one day become even more famous, and that his tomb would be erected in the same church, just a few meters away from the effigy of his ancestor.

Vincenzio, the father of our Galileo, lived in reduced circumstances but enjoyed a distinguished reputation as a lute player and a musical theorist. By his wife, Giulia Ammannati, Vincenzio had three sons, Galileo, Michelangelo, and Benedetto (who died in infancy), and four daughters of whom only two, Virginia and Livia, survived. The children were all given a musical training, and Galileo became a good organist as well as an outstanding lute player. He continued to play throughout his life, and he derived great solace from the instrument in later years, especially when blindness was added to his other afflictions. His younger brother, Michelangelo, became a music teacher and spent most of his professional career at the court of the Duke of Bavaria in Munich.

Galileo's father supplemented his meager income as a musicologist by dealing in cloth and textile fabrics in the maritime city of Pisa, which was part of Tuscany. It is in this city that his eldest son, Galileo, was born on 15 February 1564, just three days before his celebrated countryman, the great artist and sculptor Michelangelo Buonarroti, closed his eyes in Rome.

Galileo received his early education in Pisa, but the family returned to Florence when he was ten years old. He was then sent to the Benedictine school of Vallombrosa, near Florence, but had to be removed because of an inflammation of his eyes, a problem that recurred later in life. He enrolled in the Faculty of Arts at the University of Pisa in September 1581 but left after three and a half years without taking a degree. This practice was not uncommon at the time, and it was not held against him when he later applied for a university post. Publications and good references were more useful than a piece of paper that said "Master" or "Doctor."

The pages of the grand duke were given courses in mathematics by Ostilio Ricci and Galileo was allowed to attend them. He soon discovered that his real interest was not medicine, as he had thought, but mathematics, which was enjoying a great revival with the publication of the original writings of Euclid and Archimedes. This does not mean that Galileo neglected literature and the arts altogether, for around this time he drafted essays on some of the great Italian writers such as Dante, Ariosto, and Tasso. He also showed considerable skill in drawing and, had circumstances permitted him to choose his own career, he would have elected to become a painter. His talent as a draftsman and colorist later won him the admiration of some of the most famous artists of his day. Ludovico Cigoli, perhaps the best-known painter working in Rome at the beginning of the seventeenth century, used to say that Galileo had been his teacher in the art of perspective and that whatever reputation he enjoyed as an artist was due to his advice and encouragement.

EMPLOYMENT BECKONS

When he left the university in the summer of 1585, however, a career as a painter was out of the question. With his growing family and small means, Vincenzio expected his oldest son to get a job. Galileo agreed, and he began to give private lessons in mathematics to students in Florence and the neighboring city of Siena. However, he realized that this would not get him far. What he needed was a permanent job and, in mathematics, this meant a position in a university. Galileo decided to apply for the next vacancy that occurred, and in the meantime he knew what he had to do. First, he had to produce an original piece of work and, second, he needed good references. The first was a condition for the second, and while Galileo was casting about for a suitable topic he heard, perhaps from the lips of Ostilio Ricci, the famous story about Archimedes and the goldsmith who had been given a certain amount of gold to fashion a crown for Hiero, the ruler of Syracuse. When the work was finished, Hiero suspected that the goldsmith had swindled him by mixing the gold with some baser metal, and he applied to Archimedes in the hope of detecting the imposture.

The goldsmith had made sure that the crown weighed as much as the quantity of gold that had been supplied, but since silver, weight for weight, is of greater bulk than gold, if silver had been added, the crown would be bulkier. So much was certain, but the problem was to measure the bulk (and therefore test the purity of the metal) without destroying the work of art by melting the crown into a regular figure. Archimedes was almost driven to distraction by this conundrum, and he decided to take a break and go to the public baths. As he stepped into the pool, which was full to the rim, he realized that a quantity of water of the same bulk as his body must overflow before he could immerse himself completely. In a flash, he saw the solution to his problem and rushed out of the public bath, stark naked, calling out in Greek, "Eureka! Eureka!" (I have found it! I have found it!). Having calmed down somewhat, he returned to his house, procured two masses of metal, one of silver and the other of gold, each of equal weight as the crown. He filled a vessel with water right to the top and placed it in a larger container. He then plunged the mass of silver into the vessel and carefully collected the water that overflowed. He repeated the same procedure with the mass of gold and found that a smaller quantity of water had overflowed. Next he plunged the crown into the vessel and observed that it displaced more of the fluid than the gold had done but less than the silver. The crown was clearly neither pure gold nor pure silver but a mixture of both! This experiment made Galileo think as furiously as Archimedes himself. He realized that a more massive body such as gold is more closely compacted than a less massive one such as silver and, hence, weighs more per volume. He felt that Archimedes's method, though correct in principle, was not rigorous enough, and he built an ingenious precision balance, what we now call a hydrostatical balance, to measure the respective weights of the metals more accurately.

The chair of mathematics at the University of Bologna was vacant and Galileo decided to try his chance. But practical skills, however important, were not enough to secure a position in a university. Original mathematical work was required, and Galileo decided to investigate geometrical problems related to the center of gravity of solids. The result was a paper that was not published in a journal because there was as yet no mathematical review, but it was put in circulation and sent to several eminent mathematicians including Giuseppe Moletti, the professor of mathematics at the University of Padua, and the Marquis Guidobaldo del Monte, the author of influential works on mathematics and mechanics. Both replied very graciously and congratulated the young man.

THE LEADING JESUIT MATHEMATICIAN

In Italy of the Counter Reformation, ecclesiastical support was not something to be neglected, and Galileo took steps to secure it by submitting his work to the Jesuits, who were considered the most learned and up-to-date order in the Catholic Church. Their main institution of higher learning was the Roman College, founded in 1551, and the professor of mathematics, Christopher Clavius, was celebrated all over Europe. A letter of recommendation by him would be worth its weight in gold.

The Society of Jesus was founded by Ignatius Loyola and approved by Pope Paul III in 1540. By 1581 there were over 5,000 members, and, in 1612, when a census was taken, they numbered 13,112 members. They excelled in teaching and by 1580 had opened 140 colleges, a number that rose to 245 at the beginning of the following century. They specialized in theology and philosophy, but they did not neglect mathematics and the natural sciences. Several Jesuits made important contributions to the advancement of learning, but the most successful was Christopher Clavius, who had left his native Bamberg in Germany to join the Society in Rome in 1555 when he was only 17. The years 1555 to 1557 were particularly difficult for the Jesuits because the election of Pope Paul IV created hostility between the papacy and Spain. The young Society, almost destitute, could not afford to maintain all their recruits in Rome, and for this reason many were dispersed to other Jesuit colleges. Thus Clavius was sent to study in Portugal in 1556 and returned to Rome four years later. He was ordained to the priesthood in 1564, the year of Galileo's birth. Shortly thereafter he was appointed professor of mathematics at the Roman College, a post he was to occupy until his death in 1612.

CALENDAR REFORM

One of the highlights of Clavius's career was the role he played in reforming the calendar as part of a commission that was instituted by Pope Gregory XIII in the mid-1570s. The Church saw this as a pressing matter because Easter, the main Christian feast, does not fall on a fixed date like Christmas but is celebrated by Western Christians on the first Sunday after the full moon that occurs upon or just after the vernal equinox. In practice this means between 22 March and 25 April. The Julian calendar, introduced under Julius Caesar in 46 B.C., was sorely out of step with the seasons and the equinoxes. This calendar, which assumed that the year contains exactly 365 days and a quarter, added an extra day every fourth year. Since the length of the year is actually a little less than 365 days and a quarter, this led to an error of about 3 days in every 400 years. The commission of Gregory XIII set matters right by omitting three leap years in every four centuries. Under the old scheme, any year was a leap year if its number was divisible by four. Under the new one, years whose numbers are divisible by 100 but not by 400 are not leap years. Hence 1800 and 1900 were not leap years, but 2000 was and 2400 will be. This reduces the error to about 1 day in 4,000 years. The Gregorian reform that was introduced in 1582 caught up with the real year by omitting ten days. Thus the day following 4 October 1582 was 15 October, 1582. Saint Theresa of Avila, the great Spanish mystic, died on the night of 4–15 October 1582.

The reform may seem straightforward or even trivial to us but it gave rise to acrimonious debates. Workers feared that they would lose paydays, and riots erupted in many cities. Clavius had to spend a considerable amount of time explaining the bases and applications of the new calendar, with very limited success outside Catholic countries. The Gregorian calendar was not adopted in England until 1752 and in Russia only in 1918.

THE LEADING JESUIT THEOLOGIAN

Clavius may have been the leading mathematician at the Roman College, but the most prestigious professor was the theologian and future cardinal Robert Bellarmine, who came from a noble Tuscan family. His uncle had been elected pope with the name Marcel II in 1555 but had died shortly thereafter. In 1560, when he was 18, Bellarmine went to Rome to join the Jesuits. He became a member of the staff of the University of Louvain in 1569, and in 1576 he was appointed professor of theology at the Roman College. A generous and saintly person, he was also a man of discipline and order who disliked the doctrinal confusion that followed in the wake of the Reformation. It appeared to him that the task of theology was chiefly to systematize and clarify the faith, conceived as a body of coherent intellectual propositions, in such a way as to maximize its certainty and finality.

Bellarmine articulated Catholic doctrines into systems so that they might be directed, in their most unequivocal and effective form, against doubt and heresy. Indeed, to make confrontation easier he even systematized the views of his opponents. His best-known works are the four volumes of *Controversies*, which had run through 30 editions by the end of the seventeenth century. They were so popular that when the second volume was published in 1588, all the copies at the Frankfurt Book Fair were sold immediately. They included Bellarmine's lectures at the Roman College and consisted of a clarification of Catholic doctrine by contrasting it with Protestant theology. This is not to say that Bellarmine and his Protestant adversaries were totally at odds, as is shown by the fact that one of Bellarmine's devotional works, *The Art of Dying Well,* was translated into English by an Anglican priest and went into at least two editions.

Galileo may have met Bellarmine in 1587 but they would have had little in common at the time. Bellarmine, who was 45, was a major representative of Catholic thought, Galileo a mere unemployed mathematician trying to attract attention to his first paper. Bellarmine became rector of the Roman College in 1592 but his administrative skills were soon needed elsewhere, and he was sent to Naples to head the Jesuit Province in 1595. The pope then decided that his services were even more urgently required in Rome, summoned him back, and appointed him cardinal. Bellarmine's name was mentioned at the two conclaves he attended, but he did not wish to be considered a candidate for the papacy. In 1606, when Cardinal Camilo Borghese became Pope Paul V, Bellarmine agreed to handle the controversial issues that arose with Venice (1606), the Anglican Church (1607–1609), and the French Gallicans (1610–1612). Bellarmine had examined the dossier of the Italian thinker Giordano Bruno, a one-time Dominican friar who ended up being burnt at the stake in Rome in 1600. Bruno was condemned for his unorthodox views in theology, but he had also embraced the Copernican system, which may have made the motion of the earth suspect. In 1587, Galileo was not committed to the new theory, but he was probably aware of its existence and may have already begun toying with its possibilities.

THE COUNCIL OF TRENT

To understand Bellarmine's role we have to say something about the Council of Trent and the Catholic Counter Reformation, of which he was one of the most prominent spokesmen. The Church had held general or ecumenical councils at various times since antiquity. The Council of Trent, named after the city in northern Italy where it was held, was convened in 1545 in the hope of reuniting Protestants and Catholics. The Protestants were skeptical of Roman intentions and refused to come, with the result that the Council of Trent was mainly attended by Italian bishops. Of 270 bishops present at one time or another between 1545 and 1563, 187 were Italian, 31 Spanish, 26 French, and 2 German. The growing Italian influence can also be seen at the level of the Sacred College of Cardinals, which, at the beginning of the sixteenth century, numbered 35 of whom 21 (68 percent) were Italian. By 1598, when the number had risen to 57, 46 (more than 80 percent) were from Italy.

Of the many doctrinal issues that were discussed at Trent, two were to become important for Galileo, namely the interpretation of Scripture and the doctrine of the Eucharist. At the Fourth Session of the council, on 8 April 1546, the following declaration concerning Holy Scripture was approved:

> Furthermore, to check unbridled spirits, the council decrees that, in matters of faith and morals pertaining to the edification of Christian doctrine, no one, relying on his own judgement, shall distort the Holy Scriptures in accordance with his own conceptions, and presume to interpret them contrary to that sense which holy mother Church, to whom it belongs to judge of their true sense and interpretation, has held and holds, or even contrary to the unanimous teaching of the Fathers, even though such interpretations should never at any time have been published. Those who act contrary to this shall be made known by the ordinaries [i.e., bishops] and punished in accordance with the penalties prescribed by the law.

The Catholic Church wished to stress the importance of tradition and the magisterium against the Protestants who downplayed their relevance. The key words in the decree that we have just quoted are "in matters of faith and morals." The council operated in this theological context, and no one at the time seems to have thought that science in general, and much less the specific hypothesis that the Earth moves, recently put forward by Copernicus, could be a religious issue.

If scriptural exegesis was a sore point between Catholics and Protestants, the doctrine of the Eucharist was equally controversial. The crux of the matter was the interpretation of Christ's words at the Last Supper: "This is my body; this is my blood." Some Protestants favored a purely spiritual or symbolic interpretation while Catholics and other Protestants insisted on a *real* presence of Christ in the consecrated bread and wine. This latter position was upheld by the Council of Trent and, to emphasize that the bread and the wine were changed into the body and blood of the

Savior, they used the technical term "transubstantiation," which became a bone of contention with the Protestants. The decree was also to cause problems for scientists, like Galileo, who favored atomism. Some theologians claimed that the atomic theory was incompatible with the teaching of the Council of Trent because it did away with the distinction between substance and accidental properties. These theologians believed that the distinction was required to render intelligible the doctrine whereby the substance of the consecrated host becomes Christ's body while the appearances remain those of bread. We will see how this issue became serious when we consider Galileo's fourth trip to Rome in 1624.

The Papal Bull with which Pope Pius IV approved the decrees of the Council of Trent was signed on 26 January 1564, a few days before Galileo's birth. These decrees provided the *doctrinal background* against which the relations between science and religion would henceforth be discussed in Catholic countries. The *administrative background* was shaped by the development of the pontifical government, or the Roman Curia, as it was usually called. Two new Congregations (what we would today call ministries) of the Curia are of special significance. One is the Holy Office, the other the Congregation of the Index.

The Holy Office was the third, modernized version of two earlier Tribunals of the Inquisition. The first was the medieval Inquisition created in the twelfth century to combat heretical and social movements such as the Albigenses in the south of France and northern Italy. The second was the Spanish Inquisition, which operated independently but had been recognized by the pope and lasted until the nineteenth century. The third, the Holy Office, was established by Pope Paul III in 1542 as a bulwark against the spread of Protestantism and was later raised to the rank of the first of the Congregations and installed, in 1566, next to St. Peter's in a building with which Galileo was later to become only too well acquainted.

The Congregation of the Index, whose job was to censor books, was created after the Holy Office. An index of proscribed books existed since the Fourth Lateran Council of 1515, but it had been administered locally by bishops or universities. Paul IV thought it should be handled from

Rome, and in 1559 he issued the first official Index of Prohibited Books, a list that included all the works of Erasmus, the complete productions of sixty-one printers, and all the translations of the Bible into vernacular languages. It was so harsh that it was actually mitigated by the Council of Trent in 1562. Shortly thereafter, Pius V (1566–1572) changed the nature of the index, intending it no longer as a fixed list of condemned writings but as a continuous action of vigilance and censorship. In order to oversee this enterprise he set up the Congregation of the Index in 1572.

THE NEW ROME OF THE COUNTER REFORMATION

When Galileo arrived in Rome in 1587 he could not have failed to be impressed by the urban renewal that had unexpectedly been set in motion a couple of years earlier when a mild-mannered and soft-spoken Franciscan became Pope Sixtus V. At 64, and with a reputation for indifferent health, Sixtus V had been seen as a "transitional" pontiff who would not live long and would not upset anyone. Events were to show otherwise. During the five years of his pontificate, Sixtus was more active than any pope within living memory. He was convinced that a shabby Rome was a disgrace and that Christendom needed a symbol of victory over paganism and heresy. He was also indignant at the fact that Rome's 140,000 inhabitants lived huddled close to the Tiber, which often flooded and caused severe hardship and disease. Sixtus asked the simple question, Why should they not live on higher ground? The Roman hills of the Quirinal, the Esquiline, and the Viminal had been settled in ancient times, and Sixtus V made this possible again, laying out new streets and constructing a major aqueduct to solve the city's recurrent shortage of drinking water. He also rendered the streets of Rome safer than they had been for decades. He remodelled the Lateran and the Vatican palaces, and, two weeks before his death on 27 August 1590, he was able to admire the completed dome of St. Peter's from his residence on the Quirinal, which is now the residence of the president of the Italian republic. Indeed, he turned Rome into an open-air museum.

Sixtus carried his reforms to the heart of the pontifical administration. In 1588 he enlarged the Curia to 15 permanent Congregations, composed of several cardinals, and he confirmed the priority of the Holy Office. To remind everyone of the triumph of Christianity he had the ancient columns of Trajan and Marcus Aurelius crowned with the statues of Saint Peter and Saint Paul. He also fitted with crosses four huge obelisks that had been brought to Rome under the Romans. He had one erected on the Piazza del Popolo, and the others in front of the Lateran, Santa Maria Maggiore, and St. Peter's. The most spectacular of these engineering feats consisted in moving the very heavy obelisk that had stood in the Circus of Caligula and Nero. Renaissance popes had considered moving the 25-meter-high column, but Michelangelo and Sangallo had dissuaded them. Sixtus V persuaded his architect, Domenico Fontana, that it was feasible. After six months of preparation, the obelisk was carried on a specially designed oak carriage to the center of St. Peter's Square, and, on 10 September 1586, it was raised by 800 workers and 140 horses. The crowd had been asked to remain silent but suddenly a loud yell of, "Water! Water!" was heard. A worker had noticed that the dry ropes were getting too warm and might burst in flame, and he had the courage to disobey orders and sound the alarm. The foreman grasped the urgency of the situation, and the ropes were immediately drenched with water. The day was saved and the worker was handsomely rewarded by the pope.

Galileo, like any visitor at the time, was struck by the dynamism of the papacy. Rome was important, and Galileo took this lesson to heart. He never forgot that the approval of the Church was crucial, and he was to return to the Eternal City on five more occasions with this in mind: in 1611, to have his telescopic discoveries approved; in 1615–1616, to try to vindicate Copernicanism; in 1624, to find out whether he could write about the motion of the Earth; in 1630, to secure permission to publish his *Dialogue*; and in 1633, to face the wrath of the Roman authorities. But, in 1587, all these trips were unforeseeable. What struck people that year was not unpredictable in itself, but it took everyone by surprise: on 19

October 1587 the grand duke of Tuscany, Francesco I, died at the untimely age of 42.

A CARDINAL BECOMES GRAND DUKE

The grand duke was childless, and the succession passed to his younger brother, Ferdinando, who had not envisaged this outcome and had become a cardinal as many members of his family had done before him. The Medici had even had two popes. Some of the most dramatic events of the Reformation had occurred under their pontificates: Luther nailed his theses on the door of the cathedral of Wittenberg under Leo X (Giovanni Medici, 1513–1521), and Henry VIII severed ties with Rome under Clement VII (Giulio Medici, 1523–1534). These two popes also intervened in local Tuscan politics. After Rome was sacked by the mercenaries of Emperor Charles V in 1527, Clement VII agreed to support his rule and crowned him emperor in Bologna. In exchange, Charles marched against the Republic of Florence to reinstate the Medici.

Some years later Cosimo I de Medici, who came to power in 1537, persuaded the pope to crown him grand duke of Tuscany. When his successor, Francesco I, became grand duke in 1574, he had already followed the family tradition of marrying out of political interest and had wed Joan of Austria, the sister of the future emperor Maximilian. When she died, Francesco married his Venetian mistress, Bianca Capello. The only son from his first marriage died in 1582, and, because he had no child from Bianca, his brother Ferdinando was next in line of succession. But Ferdinando had been destined for a very different career. His powerful father had convinced the pope to make him a cardinal when he was only 13 years old. Ferdinando went to Rome to receive his red hat in 1565 and the next year, at the age of 16, he took part in the conclave that elected Pope Pius VI. From 1569 onward Ferdinando lived in Rome, close to the Pantheon, in the Palazzo Firenze, which is now the headquarters of the Dante Alighieri Society. It should be noted that a cardinal in those days was not required to be ordained, and Ferdinando never intended to take holy orders. His role was largely political and diplomatic, and he behaved like a prince, not a priest. With a personal staff of 130 persons, his aim was to impress visitors with the wealth and power of Florence. He even convinced his father, Cosimo I, to increase his annual stipend from 28,500 to 36,000 scudi, and, after his father's death in 1574, this rose to 80,000 scudi. In order to have an idea of what this amount represented, we can mention that at the height of his career Galileo was paid 1,000 scudi, a huge salary for a professor. Ferdinando received eighty times as much, but it must be said that out of his allowance he was expected to pay the wages of his staff and maintain a huge building that was in constant need of repairs.

When Galileo arrived in Rome in 1587, Ferdinando had probably already left for Tuscany to see his brother, Francesco I. Relations between the brothers had cooled after Francesco's marriage to Bianca Capello. Their meeting took place in the Medici villa of Poggio a Caiano some fifteen kilometers to the northeast of Florence in a lovely wooded area where the grand duke was fond of hunting. This was his way to escape from the pressure of work and pains in the stomach from which he increasingly suffered. Upon returning from hunting on October 8, he felt worse than usual and took some medication of his own devising. His condition quickly deteriorated and he passed away on October 19, to be followed by Bianca Capello on the very next day. The untimely and coincidental deaths of the granducal pair made tongues wag. To preclude any suspicion of wrongdoing, Ferdinando ordered an autopsy. The physician found that Francesco I had died of cirrhosis of the liver and Bianca of a tumor. In all likelihood Francesco, who dabbled in alchemy, hastened his own demise with one of his exotic potions. Nonetheless, the circumstances were hardly pleasant for Ferdinando, although he was never accused of having a hand in the deaths of his brother and his sister-in-law.

The Florentines again made a show of respecting republican forms and duly "elected" Ferdinando grand duke. He was by then 38 years old. He resigned his cardinalate and asked the pope to allow him to marry. Spain and Austria declared themselves willing to provide the bride, but

Ferdinando preferred Christina of Lorraine, who was reputed to be a devout Catholic. She was also the niece of Catherine de Medici, the queen of France, who was fond of her and had seen to her education. This strengthened ties with France and paved the way for a second wedding, that of Maria de Medici, the daughter of Francesco I, to Henri IV.

The wedding of Ferdinando and Christina was celebrated with great festivities in Florence. The new grand duchess was known not to have arrived empty handed but with a dowry of 60,000 crowns and the duchy of Urbino to boot. Christina was to play a crucial role in Galileo's career by inviting him to come from Padua to give private lessons in the summer to the young Prince Cosimo, the heir to the grand duchy. Years later, Christina was also responsible for stimulating Galileo's interest in the relations between science and religion, and his most important utterance on the topic will take the form of a letter to her in 1615.

THE MEETING WITH CLAVIUS

When Galileo called on Clavius at the Roman College in the autumn of 1587, he brought with him an essay on the centers of gravity of solids that was both original and ingenious. Clavius was impressed but raised a number of questions, and the two mathematicians carried on a friendly correspondence after Galileo returned to Florence. Early in 1588, Clavius even promised to send him a copy of his new book on the reform of the calendar as soon as it appeared.

Galileo now had the Jesuits on his side. They were not the only allies he had cultivated in Rome. He had also managed to win the approval of Cardinal Enrico Caetani, who had recently been papal legate to Bologna and was about to become the pope's envoy to Paris. The cardinal sent a warm letter of recommendation to the University of Bologna in which he said that he would view it as a personal favour if Galileo was awarded the chair of mathematics.

Did Galileo discuss Copernicanism with Clavius, Caetani, or other scholars? There is nothing to indicate this in the correspondence, but we know that Galileo had composed in 1586–1587 a manuscript, *Treatise on the Sphere, or Cosmography,* that he used for his private teaching in Florence and Siena. It is a conventional discussion of climatic geography and spherical astronomy following the thirteenth-century *Sphere* of Sacrobosco (John Holywood) that had been a standard undergraduate textbook for over three centuries. It contained no discussion of planetary astronomy, but it did outline arguments to show that the Earth was at rest at the center of the universe. So it may be assumed that in 1587 Galileo took the geocentric system for granted. After all, the Earth does not seem to move, and we *see* the Sun rise in the morning and set in the evening. The Ancients had devised two main astronomical models to account for celestial observations. These went under the names of Aristotle and Ptolemy, and we must say a few words about them.

TRADITIONAL ASTRONOMY

The great majority of stars do not appear to change position in relation to one another but form an unchanging pattern in the sky. The Babylonians gave names to the more conspicuous groups of fixed stars, called constellations, which appear to rotate in circles about a point called the pole of the heavens. Those near the pole can be seen to perform a complete circle, and those farther from it dip below the horizon. The time they take to make one complete turn is called a sidereal day. The pole is closely marked by the bright star Polaris, easily found from its relation to the conspicuous constellation Ursa Major.

There are, however, seven celestial bodies visible to the naked eye whose positions vary in relation to the fixed stars. These are the Sun, the Moon, Mercury, Venus, Mars, Jupiter, and Saturn. The movement of the Moon among the stars is so rapid that it can be noticed in a few hours. That of the planets can be detected if they are observed on successive nights, but the path they follow is not straight, nor is it always covered at the same speed. For instance, the planet Mars can be seen approaching from the west in April, slowing down in June, and then moving backward against the background of fixed stars until mid-August, when it resumes its eastward progression. The apparent stops are called *stations,* and the backward motions *retrogradations*. The retrogradations of Mars are always of this general form and duration, but they do not always occur at the same time or in the same part of the sky.

In the fourth century B.C. in ancient Greece, an astronomer named Eudoxus invented a system to explain how the planets move. Each planet is attached to a sphere whose axis is connected to the inside of another sphere, whose own axis is attached to a third, and so on. The system of Eudoxus gave a rough approximation to the position of the planets, but it suffered from an inherent weakness: It did not allow the distance of the planets to vary, which meant that they could neither approach the Earth nor recede from it. How, then, does one explain the variations in their brightness and apparent size, as well as the fact that solar eclipses are sometimes total and sometimes partial?

Without departing from the assumption that the Earth was at rest and the Sun in motion, the second-century Alexandrian astronomer Claudius Ptolemy found a better way to explain the apparent path of the planets by placing each planet on a circle, called an *epicycle,* attached to another circle called the *deferent* or "carrying" circle. Thus the Ptolemaic system is often described as based on epicycle and deferent. The result is that the planet traces out a curve with a series of loops or cusps. It is clear that this curve, which results from the combination of epicycle and deferent, sometimes brings the planet nearer the center than at other times. Furthermore, when the planet is on the inside of each loop, an observer can see it move with retrograde motion. It is only necessary to choose the relative size of the epicycle and the deferent, and the relative speed of rotation of the two circles in order to make the motion of the planet conform with observation.

Ptolemy's systems gave results that are surprisingly good, but he went about his work in what is for us a curious way. He tackled each construction piecemeal; that is, he took up each problem one by one, and dealt with it as though other aspects of the planet's motion were irrelevant to what he was doing. This raises the question of what Ptolemy was trying to achieve. He was certainly not attempting to devise a unified cosmology. Rather he seems to have assumed that his job as an astronomer was "to save the appearances," as the phrase went, namely, "to account for the way heavenly bodies appeared," not to offer a *physical explanation* of their motion. If a planet showed an irregularity in speed, and another in size, some astronomers took the liberty of explaining the first by an epicyle and the second by two epicycles or vice versa! The question of the reality of these constructions was never raised by Ptolemy.

Copernicus was dissatisfied with this arbitrary way of doing astronomy and he proposed a radically different system by moving the Sun to the center and locating the Earth among the planets. Galileo had probably heard of this innovation before 1587, but it is only after his first trip to Rome that he will start asking himself whether it really made sense.