STARS IN OUR HISTORY

Galileo and His Times: Some Episodes

• Fr. George Coyne s.j. •

Above *While visiting Italy in the mid 1820s, J.M.W. Turner painted this watercolor of the Moon shining on Galileo's villa outside Florence.*

Galileo's Times

Galileo lived in exciting times, both for himself, for the Church and for humanity in general. His view of the cosmos became a celebrated controversy, to a great extent, because of the times in which he lived. And his view of the cosmos was, to some extent, an inheritance from times gone by, as far back as the ancient Greek, Aristarchus. So the past and the present for Galileo are very much intertwined.

What were some of the ideas that were circulating in Galileo's time? Until Galileo's epoch, discussions as to whether the Earth or the Sun is at the center of what we now know as our Solar System was a topic of placid debate and not of heated controversy, essentially because any claim that one or the other represented the real universe were not at issue. Both proposals were seen as only hypothetical systems, a mathematical expedient to manage what was observed in the heavens.

This sense of the hypothetical had a long history to it, going back to the time of the Pythagoreans five centuries before Christ. There was no thrust to understand how the heavens really worked, as long as we had a mathematical technique to predict where objects that moved in the sky would be found.

To continue this way of thinking, of course, would be a betrayal of what scientists are really trying to do; and Galileo was going to redeem that betrayal. Galileo would completely undermine these ideas. He would provide persuasive, although not conclusive, evidence for a Sun-centered system. And in so doing, he would topple the classical Greek philosophy of nature, which had dominated thinking about the universe for millennia.

Galileo, Teacher and Scientist

What was Galileo's personal life like? After attempts to obtain a teaching position at Bologna, Padua and Florence, in July 1589 Galileo was called to a teaching position at Pisa. He taught the elements of mathematics and astronomy.

What were the sources for Galileo's teaching? Historians working during the past decades have concluded that Galileo relied to a great extent upon lecture notes of Jesuits at the Roman College; that is where Galileo came in contact with the Aristotelian natural philosophy: what today we call physics.

For Aristotle there were only four elements: earth, air, fire and water. Since earth was the heaviest, it was taught, it had to sink down to the center. Furthermore, all heavenly bodies were perfect, so they had to be unblemished spheres that moved in perfect cir-

Above *A portrait of Galileo from a 1699 edition of his controversial book,* On the Two World Systems, *which defended the Copernican theory. (From a copy in the Specola Vaticana library in Castel Gandolfo)*

cular motions. This was the conceptual approach that Galileo inherited and which he would question as his thinking matured. He would eventually completely undermine these ideas.

The Jesuits at the Roman College undoubtedly followed Aristotle in philosophy and they taught an Earth-centered system in astronomy, at least for didactic purposes. But both they and Galileo shared in the growing tensions between an Aristotelian natural philosophy and the new scientific discoveries, especially those of Galileo soon to appear. For the Jesuits this would create an even more significant tension in the realm of theological and doctrinal issues, since the latter relied heavily upon a "Christianized" Aristotelian philosophy.

There is a personal relationship involved in this connection of Galileo, the teacher from Pisa, with the Roman College. In 1587 Galileo took a trip to Rome for his first meeting with the famous Jesuit mathematician, Christoph Clavius, to seek a recommendation from him for a teaching chair in mathematics at Bologna. (He got the recommendation, but not the job.) This provided Galileo with an opportunity to see first-hand the teaching of the philosophy professors at the Roman College. It was then through his regular correspondence with Clavius that Galileo would have obtained the various teaching notes from the Roman College, which he adapted to his own teaching at Pisa.

When Galileo first visited him, Clavius was already at the height of his fame. Clavius was then 50 years old; he had single-handedly founded the world-renowned school of mathematics at the Roman College, and had published various treatises in mathematics and astronomy, which had a wide circulation. He had played an important role in the reform of the calendar under Pope Gregory XIII. Galileo, who was 27 years his junior and had just begun his scientific career, impressed Clavius with his talent both in theory and in practical matters. A personal relationship based upon a deep esteem for one another was born at that time and it lasted, despite some travail, until Clavius' death in 1612.

After Pisa, Galileo began teaching in Padua and, as he himself said, he spent the happiest 18 years of his life there. Padua was part of the Venetian Republic, which at that time found itself on various issues in opposition to Rome. The Jesuits were the defenders of Papal authority and several of Galileo's friends, defenders of the independence of the Venetian Republic, found themselves in opposition to the Jesuits. This, undoubtedly, had some influence on Galileo's attitude to the Jesuits, but it is also clear that Galileo maintained a cordial and productive relationship with Clavius and his disciples at the Roman College.

Galileo's Discoveries with the Telescope

It was during his time in Padua that Galileo carried out his epoch-making telescopic discoveries. In November of 1609, he finally succeeded in making a telescope that magnified twenty times. With it, he observed that the Moon has blemishes, mountains and craters; Venus has phases; there are four satellites going around Jupiter; there are myriads of stars in the belts of light traversing the sky known as the Milky Way.

Before we turn our gaze upon Galileo with his telescope pointed to the heavens, I would like to attempt to recover his state of mind at that moment. He was nearing the end of a relatively long, tranquil period of teaching and research, during which he had come to question at its roots the orthodox view of the known physical universe. But he had as yet no solid physical basis upon which to construct a replacement view. He sensed a unity in what he experienced in the laboratory and what he saw in the heavens. But his view of the heavens was limited, although there was some expectation that, since with his telescope he had seen from Venice ships at sea at least ten times the distance at which they could be seen by the naked eye, he might go a bit beyond that limit when looking into the sky.

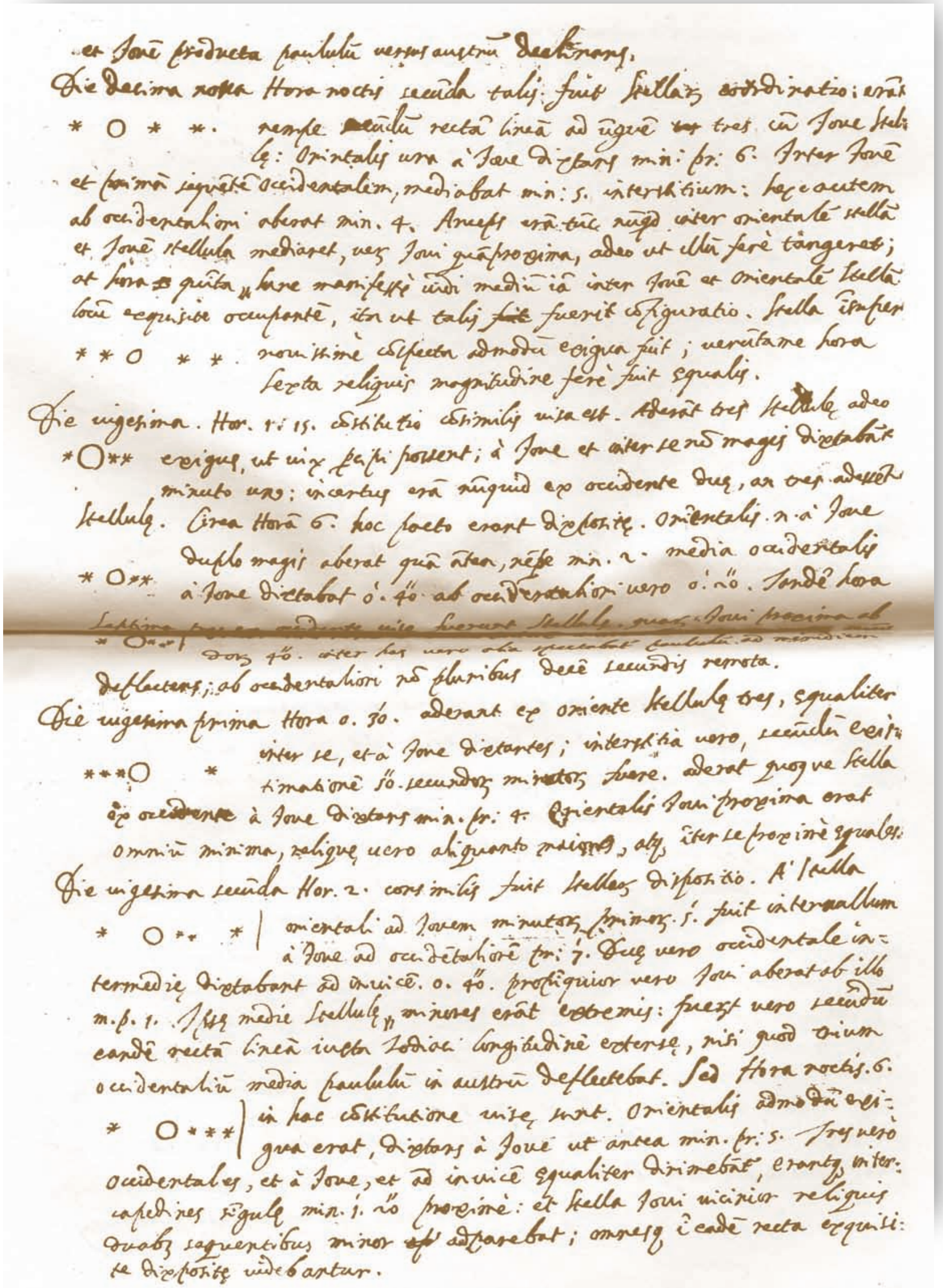
He was uncertain about many things in the heavens. For example, he had seen an object suddenly appear as bright as Jupiter and then slowly disappear (what we now know as an exploding star, a supernova). He had been able to conclude that it must be in the realm of the fixed stars. But he could venture nothing about its nature.

Did he expect that the telescope would let him find out for certain whether the Earth was going about the Sun? Probably not; his expectations were not that specific. He simply knew that the small instrument he had worked hard to perfect, since he had already convinced his patrons of its value for military purposes, was surely of some value for scientific purposes. Although it may seem obvious to us, that in itself was a major discovery: that one could learn more about nature by building artificial instruments like a telescope. For the first time, our knowledge of the universe would be shaped by more than what anyone could simply see with the unaided eye.

In brief, I propose to you a Galileo who was extremely curious, anxious to resolve some fundamental doubts, and clever enough to know that the instrument he held in his hands might contribute to settling those states of mind.

Obviously not everything happened in the first hours or even the first nights of observing. The vault of the heavens is vast and varied. It is difficult to reconstruct in any detail the progress of Galileo's observations; but from November 1609 through January 1610 there is every indication that he was absorbed in his telescopic observations. From his correspondence we learn that he had spent "the greater part of the winter nights under a peaceful open sky rather than in the warmth of his bedroom." They were obviously months of intense activity, not just at the telescope but also in his attempt to absorb and understand the significance of what he saw. His usual copious correspondence becomes significantly reduced during these months but we do learn from it that he continued in his attempts to improve his telescope.

At times his emotional state breaks through in his correspondence. He makes a climatic statement in this regard in a letter of 20 January 1610, some weeks after his observations of the moons of Jupiter, when he states: "I am infinitely grateful to God who has deigned to choose me alone to be the first to observe such marvelous things which have lain hidden for all ages past." For Galileo these must have been the most exhilarating moments of his entire life. The observations were carefully recorded in the *Starry Message* but,



Above Galileo's handwritten manuscript describing his discovery of the moons of Jupiter using his new telescope. This text was prepared in 1610 for his first astronomy book, The Starry Message.
(From a facsimile reproduced in a complete set of Galileo's writings, published in Florence in 1892.)

by necessity, stripped for the most part of their emotional content. What must have been, for instance, Galileo's state of mind when he viewed for the first time the Milky Way in its entire splendor: innumerable stars resolved for the first time, splotches of light and darkness intertwined in an intriguing mosaic? He actually said little of any scientific significance about this in the *Starry Message;* and rightly so, since his observations had gone far beyond his capacity to understand. But he could still marvel. By contrast he showed a very acute insight when it came to sensing the significance of his observations of the Moon, of the phases of Venus, and, most of all, of the moons of Jupiter. The preconceptions of the Aristotelians were crumbling before his eyes.

He had remained silent long enough. Over a three month period he had contemplated the heavens. It was time to organize his thoughts and tell what he had seen and what he thought it meant. It was time to publish!

It happened quickly. The date of publication of the *Starry Message* can be put at 1 March 1610, less than two months after his discovery of Jupiter's brightest moons and not more than five months after he had first pointed his telescope to the heavens. With this publication both science and the scientific view of the universe were forever changed. For the first time in over 2,000 years, new significant observational data had been made available to anyone who cared to think not in abstract preconceptions but in obedience to what the universe had to say about itself.

Did Galileo's telescopic discoveries prove that the Earth went about the Sun? Did Galileo himself think that they had so proven? There is no simple answer to these questions, since there is no simple definition of what one might mean by proof. Let us limit ourselves to asking whether, with all the information available to a contemporary of Galileo's, it was more reasonable to consider the Earth as the center of the known universe or that there was some other center. The observation of at least one other center of motion (moons moving around Jupiter instead of the Earth); the clear evidence (in the crater-pocked face of the Moon and spots on the Sun) that at least some heavenly bodies were "corrupt;" and most of all, the immensity and density of the number of stars which populated the Milky Way; these left little doubt that the Earth could no longer be reasonably considered the center of it all.

Galileo's own convictions are clear, for instance, from his own statement in the Dialogue: " ... if we consider only the immense mass of the sphere of the stars in comparison to the smallness of the Earth's globe, which could be contained in the former many millions of times, and if furthermore we think upon the immense velocity required for that sphere to go around in the course of a night and a day, I cannot convince myself that anyone could be found who would consider it more reasonable and believable that the celestial sphere would be the one that is turning and that the globe would be at rest."

But Galileo was also wise enough to know that not everyone could be easily convinced. In a letter to a friend he wrote: " ... to convince the obstinate and those who care about nothing more than the vain applause of the most stupid and silly populace, the witness of the stars themselves would not be enough, even if they came down to the Earth to tell their own story." While he could not bring the stars to Earth, he had, with his telescope, taken the Earth towards the stars. He would spend the rest of his life drawing out the significance of those discoveries.

Galileo and the Jesuits at the Roman College

Riding on the crest of his telescopic observations, Galileo planned a trip to Rome. Cardinal Bellarmine had heard of Galileo's observations and wished to know if they were true, and what implications they held. Bellarmine turned to his fellow religious, the Jesuits at the Roman College, and asked them to test Galileo's observations.

The day after his arrival on 29 March 1611 Galileo played a long and cordial visit to the Jesuit astronomers and mathematicians. He was honored by an academic assembly at the Roman College with the participation of numerous cardinals and other personages of Roman Society. The official oration, entitled "Starry Message of the Roman College," clearly alluded to Galileo's book of celestial discoveries; it lauded Galileo for his observations and announced that they had been confirmed unanimously by the Jesuit astronomers and mathematicians at the College.

On the other hand, they were cautious about discussing the observations in terms of a Sun or Earth centered system. It is clear from statements of Clavius and those of his Jesuit colleagues at the Roman College at that time that they were hesitatingly approaching Copernicanism, a Sun centered system. The hesitation was shared by the Jesuit philosophers and theologians of the Roman College, who were not pleased with the all-too-positive appreciation of Galileo's discoveries and especially the anti-Aristotelian implications of those discoveries. It was reported that the statements of the Jesuits astronomers on the observations of Galileo were accompanied by murmurings on the part of their philosopher colleagues.

The hesitation on the part of the philosophers was due to their need to maintain "uniformity of doctrine." That persistent requirement of fidelity to Aristotelianism had nothing to do directly with a Sun centered system. It was motivated by the conviction that Aristotle furnished a solid basis for philosophy and, upon adaption, for the so-called "preambles of the faith." But now the natural philosophy of Aristotle was crumbling. Would his whole system of philosophy crumble also—and take with it, the whole system of medieval theology that it supported?

The structure of the Aristotelian system was a unified whole. If the natural philosophy of Aristotle crumbled, would the structure itself give way? How then to maintain "uniformity of doctrine"? There was not, of course, an open, public schism among the philosophers, mathematicians and astronomers of the Roman College. Loyalty to a tradition, reinforced by religious superiors, remained the dominant factor. But the Jesuits astronomers were steadily embracing Copernicanism and thereby threatening Aristotelianism.

The case of the Jesuit Cardinal, Robert Bellarmine, is an interesting one. In his early years of teaching at Louvain he had shown a very independent view of Aristotle. He did not hold, for instance, that the heavens were immutable and incorruptible. As he matured as a Jesuit, it became clear that he was neither a devotee nor an opponent of Aristotelian natural philosophy. With respect to Aristotle he was an eclectic: whatever supported Catholic doctrine in that natural philosophy was fine; what was indifferent to Catholic doctrine was up for grabs. For Bellarmine the issue was that a Sun-centered universe, that of Copernicus and Galileo, appeared to be untenable theologically because it appeared to contradict Scripture.

Above *The frontispiece from a 1699 edition of Galileo's controversial book,* On the Two World Systems. *(From a copy in the Specola Vaticana library in Castel Gandolfo)*

Galileo's Troubles with the Church

And so why did Galileo get into trouble? It is difficult to appreciate the conflict that arose from Galileo's research and writings, unless we also understand the politics and religion of his time. It may be helpful to gather together some dates: Copernicus (1473-1543, *De Revolutionibus* in 1543); Martin Luther (1483-1546); Council of Trent (1545-1563); Galileo (1564-1642); Thirty Years War (1618-1648); Isaac Newton (1642-1727). Religious and political conflicts were very ripe and intertwined, as Galileo and his colleagues in the birth of modern science came on and off stage.

In its opposition to Martin Luther and the Reformers, the Council of Trent had declared that there was to be no private interpretation of Scripture: Scripture was the Book of the Church and only the Church could interpret it authentically. Galileo offered his interpretation of Scripture, whereby he essentially anticipated what the Catholic Church was to propose almost three centuries later; but he did so privately. He said (quoting, by the way, a Cardinal) that the Scriptures were written to teach us how to go to heaven and not how the heavens go. For him there was no scientific teaching in Scripture.

But in 1616 the theologians of the Holy Office declared that the proposition that the Sun is the center of the world and immovable was "absurd in philosophy, because it contradicted Aristotle, and heretical, because it contradicted Scripture and the Church Fathers. Furthermore, the proposition that the Earth is not the center but moves is also absurd in philosophy and erroneous as to Catholic doctrine."

Galileo was not on trial, but he was clearly a target of the Holy Office. This becomes clear when, on the day after this declaration of the theologians of the Holy Office, it was reported at the weekly meeting of the Cardinals of the Holy Office that Pope Pius V had requested Cardinal Bellarmine to have a private meeting with Galileo, in which he was to warn him to abandon his views on Copernicanism. Bellarmine did this, and Galileo acquiesced. Within days of these events the Congregation of the Index published a decree prohibiting or "correcting" a number of writings favoring a Sun-centered system, including those of Copernicus, but Galileo was not explicitly mentioned. These events conclude what is often referred to as the "First Trial."

But with the death of Pope Pius V and the election of Galileo's friend and fellow philosopher Maffeo Barbarini as Pope Urban VIII, it seemed that Galileo would again be free to pursue his ideas. He published several works with Church approval in the 1620s, most notably *The Assayer* (1622), which helped define our modern idea of science. The official church censor, Fr. Nicolo Riccardi, wrote: "I believe our age is to glorified by future ages…thanks to the deep and sound reflections of this author in whose time I count myself fortunate to be born…"

With all this support, why did Galileo's *Dialogue on the Two Chief World Systems* (1632) eventually lead to his trial and conviction?

The episodes of the Thirty Years War clearly had an impact on the ever-changing relationship between Galileo and Pope Urban VIII. Pope Urban had been a close and long-time friend of Galileo through the earlier years of his papacy. But in 1630, at precisely the time when Galileo was seeking an imprimatur for his famous Dialogue, which eventually led to his condemnation, the conflict between the warring factions in the Thirty Years War began to weigh heavily on Urban VIII. Cardinal Richelieu of France was growing ever stronger in his opposition to Rome. And then in 1632 Cardinal Gaspare Borgia openly and violently attacked the Pope in a consistory of Cardinals, with accusations of taking the part of heretics because he had favored an agreement among the King of France, the Duke of Bavaria and the Protestant King of Sweden in opposition to the Hapsburg agreement between Spain and the German Empire. In brief, the Pope was being accused of betraying the Catholic cause in Europe. These were not the best times for Galileo to seek an approving attitude towards his Dialogue from the Pope.

The Trial of 1633, following upon Galileo's publication of his Dialogue in 1632, brought to a culmination the Church's opposition to him. He was declared to have disobeyed the orders given to him in 1616, he was made to abjure his opinions on Copernicanism, and he was sentenced to imprisonment (eventually, house arrest in his home outside Florence).

In the Galileo case the historical facts are that further research into the Copernican system was forbidden by the decrees of 1616 and then condemned in 1633 by official organs of the Church with the approbation of the reigning Pontiffs. Galileo was a renowned world scientist. The publication of his *Starry Message* established his role as a pioneer of modern science. He had provoked anew the controversy about the local universe. Observational evidence was increasingly overturning Aristotelian natural philosophy, which was the foundation of an Earth-centered system. Even if the Sun-centered system in the end proved to be wrong, the scientific evidence had to be pursued. A renowned scientist, such as Galileo, in those circumstances should have been allowed to continue his research. He was forbidden to do so by official declarations of the Church. That was a tragedy for Galileo, for science and for the Church.

The Modern Church and the Galileo Affair

What has happened since then to address that tragedy?

With the condemnation of the Church, the Copernican system could not be used as a basis of natural philosophy. But it could still be considered as a useful "hypothesis" in the Pythagorean sense, as a tool for calculating the positions of the planets. Thus in Jesuit colleges throughout Europe, the study of astronomy – with the idea of a Sun-centered system – quietly moved out of the philosophy classroom and into the mathematics classroom.

The Jesuit theologian and Cardinal, Robert Bellarmine, had played a key role in the events of 1616. Bellarmine was not a dye-in-the-wool Aristotelian, as noted above, but he was profoundly convinced that, contrary to the statement of Cardinal Baronio, replayed by Galileo, that "Scripture teaches us how to go to heaven and not how the heavens go," in some instances the Scriptures do teach a natural philosophy. While the personality and high Church office of Bellarmine might tend to dominate any judgment of the role of the Jesuits, he was not necessarily representative of a Jesuit position, if there were such. Probably most representative was that of the Jesuit astronomers of the Roman College, although simplifications are required even here to be able to speak of a Jesuit position.

The Jesuits astronomers were not ivory tower "pure scientists." They lived and breathed a climate of diversity and intellectual intensity with their philosopher and theologian colleagues. They were devoted with the same fidelity to tradition and Church teaching, but they were also participants in the birth of modern science.

Even the preliminary discoveries of that science were challenging the existing basis of Catholic doctrine and the very meaning of Scripture. There was no philosophy of nature to replace that of Aristotle, which was crumbling under the onslaught of astronomical observations. The position of the Jesuit astronomers in general was one of expectation, and certainly not one of timidity or fear: Jesuits taught the mathematics of the Copernican system from Germany to China, and named the most prominent crater on the Moon after Copernicus.

By the 18th century, a hundred years after the Galileo trials, the Copernican system was well known and well accepted in Catholic circles. Isaac Newton's *Principia* (1687) had finally provided an alternative to Aristotle's cosmology that was compatible with the astronomical observations. But the Church's official condemnation of 1633 was not withdrawn until 1757. Galileo's own writings remained on the Index of Prohibited Books until 1835, even though the ideas in them had long since been accepted by the Church. And during all that time, the personal injustice to Galileo himself had never been addressed.

In a discourse of 10 November 1979, in the first year of his papacy, John Paul II spoke of the fact that "Galileo had much to suffer… at the hands of individuals and institutions within the Church." In 1982 the Pope set up the Galileo Commission so that, in his own words: "theologians, scholars and historians, animated by a spirit of sincere collaboration, will study the Galileo case more deeply…" But in the Pope's discourse of 31 October 1992, which closed the work of the Galileo Commission, the whole Galileo affair is summed up as a "tragic mutual incomprehension" from which a "myth" has continued whereby the Galileo controversy has become a symbol of what some think to be an inevitable contrast between science and faith. Both Galileo and the Church of his time were uncomprehending.

The first discourse seemed to imply that Galileo need not have suffered and that the official Church held some responsibility for his sufferings. In the final discourse the implication is that Galileo's suffering was inescapable ("tragic" in the sense of the classical Greek tragedies) because of the "mutual incomprehension," inevitable if we consider those times… there is no one responsible for Galileo's sufferings; they had to be; they were "tragic"; they were driven by the uncontrollable circumstances of that historical period.

And so does the myth of Galileo continue.

Galileo's telescopic discoveries surely brought us completely new and unexpected information, and it dramatically overturned the existing view of the universe. It looked to the future. Were there other "centers of motion," such as that seen with Jupiter and its moons? Did other planets like Venus show phases and changes in their apparent sizes? And what to make of those myriads of stars concentrated in that belt which crosses the sky and is intertwined with bright and dark clouds? All of these were questions for the future.

Although neither Galileo nor any of his contemporaries had a well-developed comprehensive theory of the universe, Galileo clearly intuited that what he saw through his telescope was of profound significance. His discoveries were not limited to looking; they involved thinking. Henceforth no one could reasonably think about the universe in the tradition of Aristotle, which had dominated thinking for over two millennia. A new way of approaching the universe was required.

The adventure of scientific discovery was only beginning. Eventually all else would accommodate itself to what the universe has to say to us. Modern science was being born and the birth pangs were already being felt. We know all too well how much Galileo suffered in that birth process.

Fr. George COYNE s.j. *(USA)*
is director emeritus of the Vatican Observatory, whose research has centered on the study of circumstellar dust.
He was a member of the Galileo Commission of the Pontifical Academy of Sciences during the papacy of Pope John Paul II.
This chapter was written specially for this book.