GALILEO AND HIS TIMES

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Historical Precedents

During the very last year of what he himself described "as the best [eighteen] years of his life" spent at the University of Padua Galileo first observed the heavens with a telescope. In order to appreciate the marvel and the true significance of those observations we must appreciate the historical precedents which will have important repercussions on the intellectual climate in Europe at the time of Galileo and, therefore, on the critical intellectual period through which Galileo himself was passing at the time those observations were made.

The natural philosophy of Aristotle (384 -321 BC) was an attempt to understand the true nature of the world and it was not just a mathematical expedient, as it had been for the Pythagoreans. Ptolemy's (130 AD) *Almagest* , one of the greatest astronomical works of antiquity, presents, however, a pure mathematical reconstruction of the universe with the earth at the center. Moreover, Aristotle proposed that everything in the sub-lunar universe was made of a combination of four elements: earth, air, fire and water and that the heavenly bodies, as compared to sub-lunar bodies, were perfect in shape and in their motions. Galileo's telescopic observations will challenge both Aristotle and Ptolemy as they present the first truly new data about the universe in about 2,000 years. To explain them a new physics would be necessary. The Aristotelian view of the universe was crumbling. Contrary to the Pythagorean inheritance of Ptolemy the word hypothesis would no longer signify a mere mathematical expedient. It would come to mean primarily, as it did for Galileo, the best available scientific explanation of how the universe really worked from an interpretation of observations of that same universe. His accusers would claim that he did not accept Copernicanism, a sun centered universe, as hypothetical. He did, but not in the Pythagorean sense. He would become one of the first modern scientists as he observed the universe and tried to interpret what he observed in an attempt to understand how the universe really worked. Copernicus in his *De Revolutionibus Orbum Coelestium* (1543) had, of course, already proposed a sun-centered universe, as had Aristarchus (310-230 BC) long before him, but he did not have at hand the telescopic observations which Galileo presented to the world in his *Sidereus Nuncius*.

Martin Luther's break with Rome in 1519 set the stage for one of the principal controversies to surface in the conflict of the Church with Galileo, the interpretation of Sacred Scripture. In the 4th Session of the Council of Trent, the reformation council, the Catholic Church in opposition to Luther solemnly declared that Scripture could not be interpreted privately but only by the official Church:

> Furthermore, to control petulant spirits, the Council decrees that . . . no one, relying on his own judgment and distorting the Sacred Scriptures according to his own conceptions, shall dare to interpret them according to his own conceptions, shall dare to interpret them contrary to that sense which Holy Mother Church . . . has held and does.

As we shall see, Galileo interpreted Sacred Scripture privately which contributed to his condemnation, even though he essentially anticipated by some 300 years the official teachings of the Church on the interpretation of Scripture.[i]

From this brief review of historical precedents we can identify several issues which are lurking in the wings and which will come on stage as the confrontation of the Church with Galileo goes forward. A sun-centered universe in the eyes of the Church threatened both Sacred Scripture and Aristotelian natural philosophy. As to Scripture the conflict was obvious, since to the Church of those days Scripture taught in many verses that the Sun moved. As to Aristotle the earth had to be at the center since it was the heaviest of the elements. Furthermore, the philosophy of Aristotle was fundamental to Catholic theology at that time. If his natural philosophy was wrong was all of his philosophy, and therefore Catholic theology, menaced? Another lurking issue was the ambiguous meaning of hypothesis, the contrast between the view inherited from the Pythagoreans and that which was coming to light at the birth of modern science. Galileo will be accused of not accepting Copernicanism as a hypothesis. While he did not in the first sense, as a pioneer in the birth of modern science he certainly did in the second sense.

The Views of Aristotle and Ptolemy

For Aristotle all sub-lunar bodies were made of a combination of four elements: earth, water, fire and air. Since earth was the heaviest and water the next heaviest element, the planet Earth which consisted principally of these two elements had to be at the center as its natural place. Furthermore, there was a distinction between earthly elements and heavenly elements. Heavenly bodies by their nature were perfect in shape and in appearance: spheres, therefore, and smooth. They had to move in perfect geometrical trajectories, i.e., circles. There were at increasing distances from the Earth a series of real transparent rotating spheres on which were fixed all of the then known celestial objects. This natural philosophy, based on pure theoretical considerations, dominated the view of the universe for about 2,000 years. It presented a natural philosophy, a depiction of the universe as it truly was. It would eventually collapse under the weight of observations, especially those of Galileo.

Ptolemy, on the other hand, in his *Almagest* some five hundred years after Aristotle presented not a natural philosophy but a purely geometrical construction to explain the distances and the movements of the celestial bodies. His earth-centered universe with circles upon circles (technically called deferents and epicycles) to explain the motions of the planets against the background of the fixed stars would be considered today a much too complex explanation as compared to any sun-centered system. But Ptolemy's system, proposed as a mere mathematical construct but sustained by the natural philosophy of Aristotle, will dominate thinking on the universe up until the 16th century.

The Interpretation of Sacred Scripture

One of the first indications that Scripture was to play an important role in the Galileo affair occurred over lunch in 1613 at the palace of the Grand Duke of Tuscany when the Duke's mother, Christina, became alarmed by the possibility that the Scriptures might be contradicted by observations such as those of Galileo which might support a sun-centered universe. Since Galileo was supported by the Grand Duke and Duchess and in general by the Medici family, this episode was of acute interest to him. Although he was not present, it was reported to him by his friend, Benedetto Castelli. Galileo hastened to write a long letter to Castelli in which he treats of the relationship between science and the Bible.[ii] In it Galileo stated what has become a cornerstone of the Catholic Church's teaching:

> I would believe that the authority of Holy Writ had only the aim of persuading men of those articles and propositions which, being necessary for our salvation and overriding all human reason, could not be made credible by any other science, or by other means than the mouth of the Holy Ghost itself. But I do not think it necessary that the same God who has given us our senses, reason, and intelligence wished us to abandon their use, giving us by some other means the information that we could gain through them - and especially in matters of which only a minimal part, and in partial conclusions, is to be read in Scripture.

Galileo was encouraged and supported in his thinking about Scripture by the publication of a letter by the Carmelite theologian, Antonio Foscarini, which favored Copernicanism and introduced detailed principles of the interpretation of Scripture which removed any possible conflict.[iii] The renowned Jesuit Cardinal, Robert

Bellarmine, who will play an important role in the Galileo affair, responded to arguments of Foscarini by stating that:

> . . . I say that if there were a true demonstration that the sun is at the center of the world and the earth in the third heaven, and that the sun does not circle the earth but the earth circles the sun, then one would have to proceed with great care in explaining the Scriptures that appear contrary; and say rather that we do not understand them than that what is demonstrated is false. But I will not believe that there is such a demonstration, until it is shown me.

However, in the end Bellarmine was convinced that there would never be a demonstration of Copernicanism and that the Scriptures taught an earth-centered universe.[iv]

Finally in June 1615 Galileo completed his masterful Letter to Christina of Lorraine[v] (the same Christina, Duchess of Tuscany of the Medici family) in which he essentially proposes what the Catholic Church will begin to teach only about three centuries later, i.e., that the Books of Scripture must be interpreted by scholars according to the literary form, language and culture of each book and author. His treatment can be summed up by his statement that:

> . . . I heard from an ecclesiastical person in a very eminent position [Cardinal Baronio], namely that the intention of the Holy Spirit is to teach us how one goes to heaven and not how heaven goes.[vi]

In the end, however, the Church's Congregation of the Holy Office will declare that putting the sun at the center of the world is "foolish and absurd in philosophy, and formally heretical since it explicitly contradicts in many places the sense of Holy Scripture."[vii] The Church had declared that Copernicanism contradicted both Aristotelian natural philosophy and Scripture. This sentence will over time come home to roost!

Galileo, The First Observational Astronomer

Galileo was the first true observational astronomer[viii] but he was also an experimentalist. It is impressive, indeed, to visit the *Istituto e Museo di Storia della Scienza* in Florence where one sees the many broken lenses from Galileo's attempts to make ever better telescopes. He himself stated that "of the more than 60 telescopes made at great effort and expense [in his home here in Borgo de' Vignali] I have been able to choose only a very small number ... which are apt to show all of the observations". In that museum one also sees a display showing Galileo's application of the pendulum to a clock and his experiments with an inclined plane in search of the law of falling bodies. Before he pointed his finest telescope to the heavens he had done his best to show experimentally that there were no serious "instrumental effects". Again, in his own words: "In so far as I can truthfully state it, during the infinite, or, better said, innumerable times that I have looked with this instrument I have never noticed any variation in its functioning and, therefore, I see that it always functions in the same way".

In fact, it was precisely through his dedication as an experimentalist, and in particular through his studies on motion that he had come to have serious doubts about the Aristotelian concept of nature. What he sensed was lacking was a true physics. The world models inherited from the Greeks were purely geometrical and the geometry was based upon preconceived philosophical notions about the nature of objects in the universe: all objects had a natural place in the universe and consequently they had a natural motion. But there was no experimental justification for these preconceptions. They were simply based upon a philosophical idea of the degree of perfection of various objects.

But, in addition to his attachment to experiment and the sense for physics that derived from it, Galileo also nourished the idea that the true physical explanation of things must be simple in the richest meaning of that word. To be more specific, among several possible geometrical models the nature of the physical world would see to it that the simplest was the truest. Thus, as early as 1597, at the age of thirty-three and only five years after the beginning of his teaching career in Padua, he was able to state in a letter to Kepler:

> ... already for many years I have come to the same opinion as Copernicus[ix] and from that point of view the *causes of many natural effects*, which undoubtedly cannot be explained by the common hypothesis, have been revealed by me. (italics mine)

One senses in such statements as this by Galileo that, although he did not yet have the physical explanation, he realized that it must be a simple and unifying one. For Galileo, the motion of falling bodies and the motion of the planets had something in common and geometrical explanations were not sufficient. Physics was required.

Let us now turn our gaze upon Galileo with his perfected telescope pointed to the heavens. 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 October 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 and even to introduce "some other invention". He finally succeeded in November of 1609 to make a telescope which magnified twenty times.

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 Medicean 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 will be carefully recorded in the *Sidereus Nuncius* but denuded for the most part, and by necessity, of their emotional content. What must have been, for instance, the state of mind of Galileo when for the first time he viewed the Milky Way in all of its splendor: innumerable stars resolved for the first time, splotches of light and darkness intertwined in an intriguing mosaic? He will actually say little about this of any scientific significance; and rightly so, since his observations had gone far beyond the capacity to understand. He could, nonetheless, be ignorant and still marvel.

But he will be very acute and intuitive when it comes 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, in his contemplations of 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 *Sidereus Nuncius* 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, although Galileo would suffer much before this was realized. For the first time in over 2,000 years new significant observational data had been put at the disposition of anyone who cared to think, not in abstract preconceptions but in obedience to what the universe had to say about itself. Modern science was aborning and the birth pangs were already being felt. We know all too well how much Galileo suffered in that birth process. That story has been told quite well even into most recent times.[x]

Did Galileo's telescopic discoveries prove the Copernican system? 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, the clear evidence that at least some heavenly bodies were "corrupt", measurements of the sun's rotation and the inclination of its axis to the ecliptic and most of all the immensity and density of the number of stars which populated the Milky Way left little doubt that the Earth could no longer be reasonably considered the center of it all. Of course, a more definitive conclusion will be possible in the coming centuries with the measurement of light aberration, of stellar parallaxes and of the rotation of the Foucault pendulum. As to Galileo, his telescopic discoveries, presented in a booklet of fifty pages, the *Sidereus Nuncius*, will become the substance of his Copernican convictions lucidly presented in his *Dialogue on the Two Chief World Systems*, a work which he promised would appear "in a short while" but which actually appeared only twenty-two years later. His 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 Benedetto Castelli 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 and he would spend the rest of his life drawing out the significance of those discoveries.

The Future

Could the Galileo affair, interpreted with historical accuracy, provide an opportunity to come to understand the relationship of contemporary scientific culture and inherited religious culture? In the Catholic tradition there is what Blackwell calls a “logic of centralized authority” required by the fact that revelation is derived from Scripture and tradition which are officially interpreted only by the Church.[xi] In contrast, authority in science is essentially derived from empirical evidence, which is the ultimate criterion of the veracity of scientific theory. In the trial of 1616 Blackwell sees the defendant to be a scientific idea and the authority which condemned that idea to be derived from the decree of the Council of Trent on the interpretation of Scripture. What would have been the consequences if, instead of exercising its authority in this case, the Church had suspended judgment? But, having already exercised that authority over a scientific idea, the Church then applied that authority in the admonition given by Bellarmine to Galileo in 1616. That admonition would go on later to play a key role in the condemnation of Galileo in 1633 as “vehemently suspect” of heresy.[xii]

There is a clear distinction here between authority exercised over the intellectual content of a scientific idea and that exercised over a person in the enforcement of the former. This results in the fact that, as Blackwell so clearly puts it, the abjuration forced on Galileo in 1633 “was intended to bend—or break— his will rather than his reason.” Could this contrast between the two authorities result in other conflicts? It is of some interest to note that in the third part of the same discourse whereby he received the final report of the Galileo Commission John Paul II says:

> And the purpose of your Academy [the Pontifical Academy of Sciences] is precisely to discern and to make known, in the present state of science and within its proper limits, what can be regarded as an acquired truth or at least as enjoying such a *degree of probability that it would be imprudent and unreasonable to reject it*. In this way unnecessary conflicts can be avoided.[xiii]

Would that the Congregation of the Index in 1616 had displayed such wisdom regarding the degree of probability for Copernicanism! Would that this wisdom may guide the Church’s action in times to come!

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[i] On 18 November 1893 Pope Leo XIII issued his encyclical *Providentissimus Deus* which called for the study of the languages, literary forms, historical settings, etc. of Scripture so that a fundamentalist approach to Scripture could be avoided. On 7 May 1909 Pope Pius X founded the Pontifical Biblical Institute which is dedicated to such studies.

[ii] A. Favaro, Edizione Nazionale delle Opere di Galileo Galilei (Florence: Giunti Barbera, 1968) V, 282-288.

[iii] See an English translation of this letter in R. Blackwell, Galileo, Bellarmine and the Bible (Notre Dame: University of Notre Dame Press, 1991).

[iv] See an English translation of Bellarmine's letter in M. Finocchiaro, The Galileo Affair (Berkeley: University of California Press,1989).

[v] A. Favaro, Edizione Nazionale delle Opere di Galileo Galilei (Florence: Giunti Barbera, 1968) V, 309-348.

[vi] A. Favaro, Edizione Nazionale delle Opere di Galileo Galilei (Florence: Giunti Barbera, 1968) V,319.

[vii] A. Favaro, Edizione Nazionale delle Opere di Galileo Galilei (Florence: Giunti Barbera, 1968) XIX, 321.

[viii] My claim that Galileo was the first true observational astronomer requires some justification. Galileo did not invent the telescope; he improved it for the precise purpose of astronomical observations. Nor, it seems, was he the first to use the telescope to observe the heavens. There is evidence that Thomas Digges of England, using a rudimentary reflecting telescopic invented by his brother Leonard, saw myriads of stars about thirty years before Galileo's first observations. Even if this is true, the observations of Digges did not become known and had no scientific impact. Galileo not only observed; he intuited the great importance of his observations and he communicated them rapidly to the whole cultured world of his day. It is for that reason that I feel justified in naming him the first true observational astronomer.

[ix] Historians debate endlessly as to when Galileo first became personally convinced of the correctness of Copernicanism. Judging from his statement of "already for many years" and from other indications he must have certainly been leaning towards Copernicanism during the first years of his teaching at Pisa, which began in 1589.

[x] An excellent up-to-date study of the Galileo affair up until the most recent statements of John Paul II is: A. Fantoli, *Galileo: For Copernicanism and for the Church* (Vatican Observatory Publications: Vatican City State, 1996) Second English Edition; distributed by the University of Notre Dame Press.

[xi] Blackwell, "Could there be another Galileo case?," in *The Cambridge Companion to Galileo*, ed. P.Machamer. (Cambridge: Cambridge University Press, 1998), 348-66.

[xii] Fantoli, "The disputed injunction," in this volume.

[xiii] John Paul II, "Discourse to the Pontifical Academy of Sciences," *Origins* 22 (12 Nov. 1992): 370–75, English trans.; original in *Discorsi dei Papi alla Pontificia Accademia delle Scienze (1936-1993)* (Vatican: Pontificia Academia Scientiarum, 1994), 271 ff.