

Papers

Galileo's telescopic observations: the marvel and meaning of discovery

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Abstract. 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 both the intellectual climate in Europe and the critical intellectual period through which Galileo himself was passing at the time those observations were made. Through his studies on motion Galileo had come to have serious doubts about the Aristotelian concept of nature. What he sensed was lacking was a true physics. He was very acute, therefore, when he came to sense the significance of his observations of the moon, of the phases of Venus, of the moons of Jupiter and of the Milky Way. 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! In so doing he would become one of the pioneers of modern science. 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.

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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 both the intellectual climate in Europe and the critical intellectual period through which Galileo himself was passing at the time those observations were made.

Galileo was the first true observational astronomer † but he was also an experimentalist. 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.

† 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 telescope 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.

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 this university, he was able to state in a letter to Kepler:

“... already for many years I have come to the same opinion as Copernicus † and from that point of view the causes of many natural effects, which undoubtedly can not be explained by the common hypothesis, have been revealed by me.”

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.

Before we turn our gaze upon Galileo with his perfected telescope pointed to the heavens, I would like to attempt to recover his state of mind at that moment. This is admittedly a very tendentious thing to do, but I think it is important to attempt to do so for the sake of understanding what we might possibly mean by “discovery”. 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. He was uncertain about many things in the heavens. He had seen an object suddenly appear as bright as Jupiter and then slowly disappear; 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 have expectations that he would with the telescope find out for certain whether the world was Copernican? I expect not. His expectations were not that specific. He simply knew that the small instrument he had worked hard to perfect, if he had already convinced his patrons of its value for military purposes, was surely of some value for scientific purposes. That in itself, although it may seem trite to us, was a major discovery ‡. 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

† 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.

‡ It indeed was a major discovery to intuit the importance of the telescope for investigating the universe. In the first note I have remarked that Thomas Digges may have actually been the first to observe with a telescope but it appears that he did so in a rather perfunctory fashion and without an appreciation of its value for science, or at least he did not communicate that science to the world.

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. 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 †. I prefer to leave it as recorded and turn rather to some thoughts about discovery as referred to Galileo's telescopic observations.

I would like to suggest three components contained in the notion of discovery: newness, an opening to the future and, in the case of astronomical discovery, a blending of theory and observation. Discovery means that something new comes to light and this generally happens suddenly and unexpectedly. While I would not exclude that one can plan and even predict what is to be discovered, this is generally not the case. Galileo's telescopic discoveries surely brought us completely new and unexpected information about the universe. Taken as a whole that information was the first new significant observational data in over 2,000 years and it dramatically overturned the existing view of the universe. It looked to the future. Were there other centers of motion such as 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

† 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, 2003) Third English Edition; distributed by the University of Notre Dame Press.

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 theory was required.

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.

Reference

Fantoli, A. 2003, *Galileo: For Copernicanism and for the Church*, Vatican Observatory Publications: Vatican City State, Third English Edition; distributed by the University of Notre Dame Press