THE LIFE AND TIMES OF GALILEO

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"In this present small treatise I set forth some matters of great interest for all observers of natural phenomena to look at and consider."

Galileo, Sidereus Nuncius, 1610

So began Galileo in his introduction to the Sidereus Nuncius (Starry Messenger) which he published in the year 1610 to describe some of the observations that he had made with his crude telescope -- observations which were literally earth shaking. These observations were the first real evidence that showed that the Earth was not necessarily the center of the universe as many philosophers and scientists had supposed up to that time.

Using a telescope generally much poorer than one might purchase in any retail store today, Galileo observed, recorded, and reported observations of the moon, Venus, Saturn, Jupiter, the Milky Way, star clusters, and many other things. His crude telescope kept him busy for years, providing him with evidence that the prevailing view of the time -- that the Earth was the center of the entire cosmos -- was clearly and demonstrably wrong.

Though Galileo is almost universally known by his first name, he was born Galileo Galilei on February 15, 1564 in Pisa, a town of northern Italy. His father, a poor member of a good family from Florence, was Vincenzo. Vincenzo was distinguished by his abilities as a musician and a mathematician. Galileo was a bright child and at first his father steered his child away from a career in mathematics. He had hoped that Galileo would eventually make his fortune in business. But Vincenzo was wise enough to see that his son had other abilities and interests that would better suit him in some sort of a professional career. In 1581, at the age of 17, Galileo's father sent him to study medicine - a profession that paid much more than one in the academic world - at the University of Pisa.

While at the University Galileo's academic abilities and sharp whit set him apart from his peers. As a student he was noted for his seeming inability to accept statements from his teachers that were based upon the authority of ancient writers who offered no evidence for their conclusions. From a note written in his later years, Galileo indicated that he was particularly incensed by a claim of the ancient natural philosopher Aristotle that heavier objects would fall faster than lighter objects. This offended Galileo's sensibilities because as a youth he had observed a shower of hail stones all of which, large and small, reached the ground at the same time. If the larger, heavier stones fell faster, he argued, then they should have reached the Earth sooner than the smaller, lighter stones. They did not. Bringing contradictions such as these to the fore, Galileo earned nothing but the ire of many of his instructors and deep respect from fellow students who gave him the nickname of "The Wrangler." This skeptical attitude, along with his skill in argument, marked Galileo for a noteworthy, albeit controversial, future.

In 1582, while attending church services at the Cathedral of Pisa, Galileo's attention was attracted to a chandelier set into motion by air currents. He noticed that as the air currents came and went the arc of the swing increased and decreased with one unusual tendency -- the period of the swing appeared to remain unchanged. Using his pulse as a crude clock, Galileo confirmed this observation. Upon arriving home he performed an experiment which showed to his satisfaction that thiswas true for any weight suspended by a string. To test this conclusion with a greater accuracy, Galileo set up identical pendulums and set them into swinging motion. One he swang with a large arc, the other with a small arc. Nevertheless, both swang back and forth at the same rate. Galileo was amazed.

Before long it became clear to Galileo that his life calling was not medicine, a career chosen for him by his father, but rather mathematics and its applications to the physical world. Up to the point of his entry into the University Galileo had not received any formal instruction in the area of mathematics. During his second year at the University, however, he happened to overhear a lesson dealing with geometry. He was so fascinated by what he heard, that he continued auditing the course. Galileo's aptitude for mathematics was immediately apparent. Within a short while he obtained his father's consent to abandon the study of medicine in preference of mathematics.

Interest and ability not withstanding, Galileo was compelled to quit the University in 1585 without completing his course of studies and without obtaining his degree. Galileo was financially strapped and his father, equally strained, could not help. Galileo remained at home over the next four years where he continued to read and to think about matters of math and science.

Fluids and the laws that surrounded them were his primary interest. Within a year of departing the University he wrote and published his first scientific article. In this manuscript he described an instrument which he had invented. The instrument is today called the hydrostatic balance. This article first brought Galileo to the attention of the scientific world.

In 1589 Galileo was appointed to a temporary position as an instructor of mathematics and astronomy at Pisa. The pay was very inadequate and Galileo added to his income by tutoring students and taking private pupils. In this new position Galileo demonstrated his tremendous abilities as teacher and researcher. His many students as evidenced his popularity as a teacher. As a researcher he introduced new methods of scientific investigation which earned him the ire of his fellow professors.

At this time scientific investigation as we know it today was not in the vogue. Scientific investigation consisted largely of interpretation of the writings of Aristotle, Galen, Ptolemy, or other great natural philosophers of the past. Results were reasoned out from general principles which were found in these writings without any appeal to observation. Galileo, who was prone to sharply criticize unsubstantiated statements and theories unsupported by observation, began a new study of the physical world.

He studied falling bodies and "diluted" gravity by rolling balls down inclined planes. According to Aristotle, an object that weighs ten times as much as another should fall ten times faster or go ten times as far in the same interval of time as the lighter object. The typical example was that a ball of lead should fall faster than a ball of wood. Galileo showed by simple demonstration that this wasn't the case and that the two fall at nearly the same rate - the difference being attributed to air resistance.

Rolling balls down an incline, Galileo correctly demonstrated that the ball would continue to speed up so long as air resistance wasn't a factor. If the ball reached the bottom of an incline and then began to climb another ramp upwards, the ball would slow down. If moving downwards meant that an object would speed up and if moving upwards meant that an object would slow down, then, as an object moved along a flat course getting neither nearer nor farther from the center of the Earth it would neither speed up nor slow down -- that it would maintain its speed were it not for friction. Today we call this concept inertia.

The results of experiments such as these shocked the sensibilities of contemporary scholars. Galileo's experimental methods were entirely foreign to scientists of his day and were regarded by most of his colleagues as undesirable if not dangerous innovations. Accordingly, the results derived in this fashion were also suspect.

These studies which upset Aristotelian physicists, as well as Galileo's habit of getting into trouble with persons who did not agree with him, made Galileo far from popular with the faculty at Pisa. Either on this account or on account of his father's death in 1591, Galileo resigned his teaching post at the University several months before it was due to expire and returned to his mother's home in Florence.

After a stay of some few months at Florence, Galileo was appointed to a professorship of mathematics at Padua with the assistance of a friend. The year was 1592. The appointment was for six years and the pay three times that which he had received at Pisa. This situation was much more suited to Galileo's temperament and attitudes as an atmosphere of intellectual freedom prevailed. At this new place Galileo flourished. In addition to enormously popular lectures, he wrote short articles on the subjects of astronomy, physics, and war, and invented a variety of scientific instruments. Following his first year at the University of Padua, Galileo's teaching contract was extended and his salary was increased. This was repeatedly done so and eventually his appointment was for life.

Galileo's first real contribution to astronomy came in the year 1604 with the appearance in the heavens of a "new" star. According to Aristotle, the heavens were perfect and unchanging, for if there was change, then things would have to move from a more perfect state to a less perfect state or visa versa. Since the heavens were absolutely perfect, there could be no change -- or so Aristotle argued. Galileo used this appearance of the "new" star to show that Aristotle must be wrong. (Today we know such a star as a nova, meaning new star, but the star isn't new at old. Rather it's an old star that has exploded.) This observation, along with his previous work in physics, confirmed for Galileo that Aristotle's view of the heavens must be wrong.

Aristotle, a Greek philosopher of the fourth century B.C., taught that the Earth was unmoving and that the heavens turned daily overhead. To Aristotle the Earth was the center of creation and, therefore, all things had to orbit round the Earth. The Earth was necessarily at the center of creation because humans were fallen creatures and their very nature relegated them to a position at the center -- the lowest point in creation.

Aristotle also believed that the heavens and earth were ruled by two completely different sets of physical laws. The very substance of the materials that made up earth and heavens were also different according to Aristotle. On Earth all "elemental" materials were subject to change, decay, and destruction, while in the heavens things were composed of "quintessential" materials which were by definition perfect, unchanging, and eternal. Even the motions of heavenly objects were uniform and planets moved in perfect circles. Indeed, every aspect of the heavens were perfect for how else could they be in heaven?

Astronomers of Galileo's day had accepted Aristotle's view of the cosmos without question. His views, and those scientists whose opinions conformed to these views, were regarded as possessing an almost divine quality. That is, if Aristotle said it was so, it must be so. One set of views that were adopted without question by the astronomers of those days were those of Hipparchus, a Greek astronomer of the second century B.C. His system of the cosmos placed Earth at the center of the cosmos and had the planets moving in orbits round the Earth.

In Hipparchus' view, the heavenly wonderers were in increasing distance from the earth: the Moon, Mercury, Venus, the Sun, Mars, Jupiter, and Saturn. The Moon circled the earth monthly. The Sun did so daily. The motions of the planets were sufficiently complex to require an additional complication.

As one watches the planets over the course of a year, each undergoes an unusual sort of motion. Inner planets such as Mercury and Venus are never seen very far from the sun. The outer planets, Mars, Jupiter, and Saturn, can appear from time to time opposite the sun in the sky. During most of the year these planets move slowly toward the east among the background of stars, but when nearly opposite the sun, they undergo a retrograde motion. For a few weeks the planets stop their eastward motion among the stars and go backward.

Hipparchus originally suggested that the planets went round the Earth, each carried on an invisible crystalline sphere. The planet was not actually part of the sphere; rather, it was rode on a smaller sphere whose center was carried in a circle round the Earth. As the smaller sphere turned within the larger sphere, its path described a circle. This circular motion, along with that of the larger sphere's motion, adequately explained to the ancients the observed looping motions of the planets.

This system was considerably more complicated than another system suggested by Aristarchus. Aristarchus believed that the whole of the observable motions of the sun, moon, stars, and planets could be explained by placing the sun at the middle and then allowing the planets to move in orbit round it. The earth would spin daily upon it axis, and circle annually round the sun. This suggestion was rejected, however, because it was hard to imagine the whole earth flying through space, especially when one doesn't feel the motion, things aren't being flung off into space, neither are they left behind when they are thrown up into the air. Winds don't blow continually from the east as might be expected for a world spinning in that direction. The arguments against a spinning earth were numerous and convincing to those persons unknowledgable of the true laws of motion, laws which Galileo had just begun to understand.

The sun-centered world system was an idea whose time had not yet come and it was soon forgotten. It would, however, be revived centuries later by a Polish cleric known as Nicolas Copernicus and espoused and championed by Galileo.

Hipparchus' system of rotating and revolving spheres, though a cumbersome tool, did an adequate job of predicting the future positions of planets and was widely adopted. A series of improvements were made in the second century A.D. by a Greek Alexandrian astronomer by the name of Ptolemy. Ptolemy refined Hipparchus' system. He dispensed with the crystalline spheres and replaced them with epicycles and deferents. A point known as the deferent would move round the earth. The planet would travel in a circle round the deferent. The combined motions of epicycle and deferent would adequately explain the motions of both inner and outer planets.

The deferents of the inner planets, Mercury and Venus, would lie continually between the Earth and Sun. Venus, moving the slower, would lie farther from the Earth and its epicycle would be the larger. Mercury, moving the faster, would lie nearer the Earth and its epicycle would be proportionately smaller. The moon, the fastest moving of all celestial bodies, would directly orbit the Earth as both common sense and observations indicated.

Outer planets were arranged from Earth as a function of speed among the background of stars. The planet with the slowest motion, Saturn, had the slowest moving deferent. It circled the Earth in just over a year. The planet with the fastest motion, Mars, had a deferent which orbited the Earth in just under two years.

Each planet also moved on an epicycle with the line connecting the planet and the deferent always parallel to the Earth-Sun line. Such an alignment was necessary so that, when the planets appeared opposite the sun in the sky, their retrograde motions were at a maximum and the planets would lie nearest the earth. This would correspond to the time when they were the brightest. The sizes of the epicycles were directly related to the observed sizes of the retrograde loops of the planets. This arrangement for the outer planets adequately explained the observed motions of the outer planets.

Because Ptolemy was a skilled observer of the heavens, he knew that the planets moved somewhat irregularly in their orbits. He realized, too, that the seasons were of unequal length due to the irregular motions of the sun with respect to the background stars. The stars themselves moved at a rate slightly different from that of the sun so that they would circle the earth daily and appear to turn one additional time with respect to the sun annually.

To take these observations into account and to preserve the concept of perfect circular motion, Ptolemy offset the earth from the precise center of the system. The planets and sun each would be perfectly centered on a separate point called the eccentric. He made the deferents move at a uniform rate as seen from a perspective located at yet another set of points known as the equants. Such adjustments made the model marvelously complex and it yielded better - though not perfect - predictions as to the placements and motions of the sun, moon, and planets with respect to the background stars. These corrections to Hipparchus' world system were universally accepted. Today the modified system of Hipparchus is known as the Ptolemaic system.

This was the scheme of things when Galileo began to examine the world system as presented by Aristotle and Ptolemy. Though no record exists as to the exact time that Galileo rejected the earth-centered or geocentric view of the cosmos, he stated in the year 1597 that he had adopted the views of Copernicus who a century before showed that a sun-centered or heliocentric world system could adequately and more simply explain and predict the future motions of the planets.

No one could tell by naked-eye observations alone that the earth and planets revolved round the sun. Others before him had speculated that this might be so, yet Copernicus was the first to prove mathematically that such a system could simply and accurately explain all celestial phenomena - changes in brightness, risings and settings, seasons, length of the year, motion of the sun through the zodiac, speeds and motions of the planets - using only the assumption that the earth moved. Copernicus' herculean effort to show that the sun resides in the center of the world system was published in 1543 and is known simply as "De Revolutionibus."

Copernicus saw the realm of the stars immensely far removed from the orbits of the planets. Inside this spherical shell he placed the orbits of Saturn, Jupiter, Mars, Earth, Venus, and Mercury. At the center of this world system was the Sun. The moon orbited round the earth and the planets moved in perfect circles with perfect uniformity round the sun. (Because Copernicus embraced this latter view, he ultimately was forced to include tiny epicycles in his own system to explain the irregular motions of the planets.)

The system of Copernicus explained the rising and setting of the sun, moon, stars, and planets as a result of the earth spinning on its axis once a day. The retrograde motions of the outer planets were easily explained by the more rapid motion of the earth overtaking the slower outer planets making them only appear to shift westward among the background of stars.

According to Copernicus, the sun's apparent annual eastward circuit among the background of stars resulted from the motion of the earth round it. The annual north-to-south migration of the sun which accounts for our seasons was the result of the earth's axis being tilted 23.5 degrees from a line perpendicular to the plane of the earth's orbit. The system was simple, the system was aesthetically pleasing, and yet it was not capable of making predictions any more accurate than those derived from Ptolemy's earth-centered model.

Though common sense would seem to dictate that it was the sun, moon, planets, and stars that circle the Earth daily, Galileo still found the Aristotelian view of the world system unacceptable. His studies of motion had shown him that Aristotle was not to be trusted. Rather he felt it more appropriate to look for observational tests to decide the issue. The simplicity of Copernicus' helicentric view was appealing. Galileo even went so far as to compile arguments against the geocentric world view and in favor of the heliocentric view. But what Galileo lacked was convincing observational evidence that would decide the argument once and for all. The opportunity for settling the argument was on the horizon.

In 1608 there was a glass worker in Middleburg, Holland, one Hans Lippershey, who ground lenses for spectacles. It's said that one day an apprentice happened to pass one lens in front of another and found that distant objects appeared closer. Amazed, Lippershey mounted the lenses in a tube and attempted to sell the invention to the Dutch government for military applications.

Within a few months Galileo had heard of the invention. True to his nature, Galileo was somewhat skeptical of an instrument that could perform as claimed. Though he immediately grasped such an instrument's significance with regards to scientific inquiry, he was willing to wait for confirmation that such an instrument had indeed been invented. He received that much awaited confirmation from an acquaintance in Paris, who wrote Galileo describing the success of the instrument.

Galileo then set off to study the principles of refraction -- the ability of glass to alter the path of light -- in an effort to create his own instrument. Within ten months of the original report, Galileo had grasped the concept of the telescope and assembled his own instrument.

Galileo's first telescope was a lead tube with a lens fitted at each end. It had an ability to make things appear three times closer. After several more attempts he was able to construct a superior quality instrument which magnified the view some 32 times. Without paying attention to its use for terrestrial objects, he took to the observation of the heavens. What he saw there began a revolution that would not end until the teachings of Aristotle were overthrown and a new system of the cosmos based upon observation sprang up to replace it.

In late 1609 Galileo turned the telescope to the heavens for the first time. He almost certainly was not the first to do so, but he was the first to make definite use out of the observations. He repeatedly examined celestial objects. He used a great independence of thought to interpret his observations. He showed tremendous insight in understanding their astronomical importance. He found that his observations provided those much needed observations to distinguish between the two world systems, sun-centered and earth-centered. By early in 1610 Galileo published his earliest observations in a work entitled "Sidereus Nuncius," The Starry Messenger.

Galileo first turned his telescope on our nearest neighbor in space -- the moon. What he saw there amazed him and helped convince him further that the Aristotelian concept of the heavens was wrong. Up to this time the moon was thought to be perfect and unblemished. As others had reasoned previously, "How else could it be in heaven?" What Galileo saw there both startled and amazed him.

As had others before him, Galileo distinguished two parts of the moon's face - a lighter part and a darker part. But what he observed there was totally new and unexpected by anyone before him. The light regions were mountainous and covered with huge holes or craters. The dark regions were smooth and relatively free of craters. The moon as a whole was not smooth; rather, it was irregular and filled with valleys, mountains, and planes. In reality it was not unlike the surface of the earth. The moon wasn't "celestial" in the deepest sense of the word.

Galileo's observations convinced him that what he was seeing really were mountain peaks and deep valleys. Shortly after new moon, when the moon appeared as a thin crescent in the western evening sky, he noted several bright points of light standing out in the darkness beyond the illuminated portion of the crescent. With the passage of time he noted that these points became more and more illuminated in the same way that mountain peaks on earth first catch the sunlight and their bases become illuminated only later in the day. He also watched the shadows inside of craters shrink before the encroaching sunlight.

Turning his telescope to the stars, Galileo came to the shocking realization that stars must indeed be incredibly distant if they are at all large like the sun. When the telescope was turned to a tree, it appeared several times larger depending on the magnification of the telescope. When turned to the moon, the moon appeared similarly larger. But when turned to the stars, the size of the star image could not be increased appreciably no matter what the magnification of the telescope. Galileo realized that the size of the star image observed in his telescope related only to brightness -- that bright stars had larger images while dim stars had smaller images -- that the size of the pattern had only to do with "adventitious fringes" induced by the air. Stars must be so vastly distant that they show up as only points of light, he concluded.

Galileo also realized that his telescope was able to reveal multitude of stars beyond the sixth magnitude which could not be observed with the unaided eye. As an example of this ability to show fainter stars, Galileo charted all the stars visible in the telescope in one region of the sky. In the belt region of the constellation Orion, where the naked eye could reveal only nine stars in the vicinity of the belt and sword, Galileo observed and recorded an additional eighty. In the region of the Pleiades star cluster in Taurus, in addition to the six stars usually visible, he cataloged an additional forty.

In an attempt to answer the age-old question, "What is the nature of the Milky Way?," Galileo discovered that this hazy path of light in the night sky was nothing but innumerable masses of stars. He found that the fainter stars were by far the more abundant and believed that their number was so large as to be beyond the limit of counting.

One of the most important and damaging observations made by Galileo to counter the earth-centered view of the cosmos, were the observations of Jupiter. Observations of Jupiter revealed that it was surrounded by four heretofore unseen worlds. What is more, they moved to and fro accompanying Jupiter on its path amongst the background of stars.

Up to this point in time Aristotelian scientists argued that one of the reasons that the earth could not be in orbit about the sun was that the moon would be unable to hold its course round the earth. Much to their dismay, Galileo showed in the case of Jupiter this precise phenomenon was happening.

On the evening of January 7, 1610, an hour after sunset, Galileo turned his telescope upon Jupiter. He noted that there were three "stars" next to the planet. In his record of the account he mentions that he was immediately struck by the fact that these objects seemed to line up almost precisely with the planet and seemed to be of an unusual brightness. Though he though the situation peculiar, he failed to recorded his observation.

The next evening Galileo happened to train his telescope on the planet once again, but this time he saw something very different. This time the "little stars" were closer together, all bunched together on the same side of Jupiter. Galileo began to suspect that the predictions of Jupiter's motion was perhaps wrong and that the apparent migration of the "little stars" to one side of the planet was a result of Jupiter's motion among the background stars. He regretted that he had not made an effort to accurately record their relative placement the night previously.

Galileo anxiously awaited yet another view, but on the third night was kept from viewing by cloud cover. On January 10th the planet was again visible, but this time only two of the "little stars" could be seen. Galileo was convinced that the third had moved and was situated behind the planet and that the "little stars" were not really stars at all. Rather, they were satellites - little moons - in orbit round the giant planet. Over the following weeks Galileo discovered yet a fourth moon and became convince that he was observing moons orbiting a planet, moving with that planet round the sun -- something the critics claimed could never happen. Galileo was now in possession of an irrefutable bit of evidence that once and at the same same time crushed the Ptolemaic earth-centered view and supported the Copernican sun-centered view.

By February of 1610 Sidereus Nuncius was in print. The discovery of Jupiter's four moon showed the incorrectness of the old doctrine that all heavenly motions were centered on the earth. This, coupled with the fact that moons could orbit round an object other than the earth, the irregularities of the moon, the nova of six years previous, all served to discredit the infallibility of Aristotle and Ptolemy.

Galileo's report of these four new worlds was met with skepticism by the academic community of his day. Some "scholars" refused even to look through his telescope. How could such a telescope reveal things not visible to the eye? And how could there be more than seven planets? According to the ancient philosophers the world was based on the number seven "as nature and scripture show." There were the seven days of creation and a day of the week named for each planet, there were the seven metals, seven openings in the head, and the seven deadly sins. As the heavens were perfect, so must the number of planets be perfect - Sun, Moon, Mercury, Venus, Mars, Jupiter, and Saturn. To their way of thinking there simply could be no more than seven worlds, the observations of Galileo not withstanding.

To accept the existence of these new worlds and the associated belief that the earth both turned and circled the sun was more than these "scholars" could bear. According to his critics, at best Galileo was only seeing optical illusions produced by the new instrument; at worst he was viewing images of unreal worlds conjured up by the devil himself and the astronomer was Satan's unwitting tool.

Though he was immediately attacked in word and print in Italy, the tide of the intellectual battle began to turn as soon as observers in Rome and northern Europe trained their telescopes on the heavens. With the publication of the "Sidereus Nuncius" Galileo received a worldwide recognition that only added to his reputation as a master scientist and original thinker. The recognition also gave Galileo the impetus he needed to have his teaching duties terminated, allowing him more time for research and writing. This was accomplished by taking a professorship at Pisa and as "First Philosopher and Mathematician" to the Grand Duke of Tuscany. Neither position had any appointed duties. As a result, Galileo chose to take up residence in Florence, the home town of his mother.

Shortly before leaving his position at Padua in late summer, Galileo turned his telescope on Saturn. Unlike the other planets he had observed, Saturn appeared to consist of several parts.

With the passage of time the appendages came and went. Owing to the low power and relatively poor optical quality of the telescope he was using, Galileo was not able to clearly discern the rings of Saturn. The "discovery"of the rings of Saturn would have to wait another 45 years.

In September, observing from Florence, Galileo turned his telescope on Venus. Much to Galileo's delight Venus exhibited a full set of phases not unlike the moon. This too supported the concept that Venus orbited the sun and not the earth. Galileo had observed a full set of phases for Venus and along with it a dramatic size difference that was related to the phase. When the disk of the planet was nearly "full" Galileo saw a very small disk implying that it was far away; when crescent a very large image which implied its relative proximity.

According to the Ptolemaic view of the solar system, Venus moved about its epicycle whose deferent lay on a line directly between the earth and sun. This being the case, Venus would always lie roughly between the earth and sun and would, as a result, show only a crescent phase. Galileo observed Venus going through a complete set of phases just like the moon and increasing and decreasing in size in just the right way as would be expected to happen were it in orbit round the sun.

The observations of Venus' phases was also conclusive proof that the planets merely reflected sunlight and did not glow of their own accord. Previous to Galileo it was believed that when the dark portion of the moon was dimly visible during the crescent phases, the glow was due to starlight streaming through the partially transparent moon. Others held that the moon was slightly phosphorescent. Galileo correctly explained the phenomenon as light reflected off the the earth faintly illuminating the moon.

The observational evidence of the phases of Venus and the phenomenon of Earthshine explained removed one more difference between the earth and the planets. All of these objects, the earth included, were simply worlds basking in the warm glow of the sun. Once again this information confirmed Galileo's conviction that the planets orbited the sun and reaffirmed his belief in the overall truth of the Copernican system.

Toward the end of 1610 Galileo observed and recorded dark blemishes, sunspots, crossing the face of the sun. Sunspots were observed much earlier and these sightings were recorded in the early annals of the Chinese. These and other observers generally believed these blotches to be the silhouetted figures of Mercury or Venus crossing over the face of the sun. But Galileo's observations showed these features to have significant detail and structure; clearly they could not be the planets of Mercury or Venus. This observation, too, helped to destroy belief in the Ptolemaic system.

Galileo argued that these markings were actually features on the face of the sun -- an amazing thing in light of the claim by Aristotle that everything in the heavens had to be perfect, regular, and unchanging.

Galileo believed the spots to lie on or very near to the surface of the sun. This was so, he argued, because the spots moved slowly when near the edge of the sun and much more rapidly when centrally located. The motion was slower near the edge because the motion was mainly along the line of sight (either toward or away from the observer) while the motion was faster near the center of the image because the motion was primarily along the line of sight. To support this view he explained that his observations had shown the spots to be foreshortened when near the edge as well, just as would be expected for a feature on the surface of the sun.

Galileo developed an ingenious proof of the error of the Ptolemaic view regarding these spots that severely angered his critics. He showed via geometrical arguments that either the spots were on the sun and moved across its face as a consequence of its rotation, or that, if these offending bodies were not on the sun, they would necessarily have to orbit the sun moving faster when seen against the center of the sun's disk and slower when near its limb. That is, a body orbiting between the earth and sun would necessarily have to be moving with an irregular motion. The proof was flawless and both conclusions completely unacceptable to the Aristotelian astronomers of his day.

The unrelenting advocacy of the new scientific ideas, the apparent lack of respect which he demonstrated for established and traditional authority, and the biting sarcasm he showed for those who would dare oppose him, no matter how justified, won for Galileo a large company of bitter enemies who opposed the Copernican viewpoint and embraced the Aristotelian standard.

Perhaps as a result of a growing awareness of the potential difficulties that might be raised by members of the academic and ecclesiastical circles, Galileo visited Rome in March of 1611 to secure the approval of the powerful and influential hierarchy of the Catholic Church. He did not seek to obtain support for his views, rather, it was his fervent desire to see to it that the Church not embroil itself in a controversy in which Galileo felt it had not part. At Rome he was warmly received and honored by Pope Paul V, numerous cardinals, and the Jesuit astronomers at the Roman college. Many persons in high places attended the frequent exhibitions of the telescope and viewed sunspots and all such manner of things that might present themselves. Though Galileo was well received, this was not indication that everyone was pleased with Galileo or what he was saying.

Galileo's detractors perceived a growing problem between the question of the validity of scientific observations and reasoning and the authority of both Church and Bible. The claims of imperfect heavens and invisible worlds, the earth displaced from its lowly position at the center of creation, were most unsettling to the theologians of his day. The future battle lines were drawn. Unfortunately, it was not long before Galileo was drawn into this controversy - a controversy which has erupted from time to time in different fields of science and which continues throughout today.

Later that same year Galileo was vehemently attacked in a small work that proclaimed the existence of Jupiter's moons to be in contradiction to the truths of the Bible. A small work by Galileo published in 1612 dealing with floating bodies proved to be immensely popular, but Galileo was once again met with a rousing cry of opposition by a select few who saw in the work the underpinnings of Aritotelianism attacked. And yet, in 1613, Cardinal Barberini (who would later become Pope Urban VIII) warmly thanked Galileo for the presentation of his new work dealing with sunspots in which Galileo, for the first time, publicly proclaimed his unequivocal support for Copernicanism. That same year his friend and follower, Father Castelli, was appointed professor of mathematics at Pisa and was charged not to lecture on the subject of the earth's motion.

A short time after his appointment, Castelli was invited to court breakfast with members of the Medici family present. He was drawn into private discussion of the relative merits of the new astronomical observations and related statement found in the Bible. Of particular note were the moons of Jupiter (which Galileo had named the "Medicean stars" in honor of that house in return for his appointment) was the question relating to the statement of Joshua who bade the sun to stand still. Clearly, this implied that it was the sun that moved and not the earth. When asked to respond to this question as a theologian, Castelli cited several of Galileo's statements in support of his views. Having heard of the interest of his mentors concerning this topic, Galileo expounded at some length on his personal views in a letter which was later widely circulated at court.

For more than a year there was no response from the opposition. And then in December of 1614, suddenly and without warning, a young a Dominican preacher in Florence by the name of Thomas Caccini vehemently denounced from the pulpit mathematicians in general and Galileists in particular. He decried Galileo's claim that the Bible spoke simply in a way that simple people could understand, that the authors of the Bible were not attempting to explain science, that theologians should attempt to understand seeming contradictions in the light of modern science, and that when it comes to the question of scientific inquiry, theologians should allow scientists to deal freely with all matters that could be decided by "sensate experiences and necessary demonstrations." It was Caccini's claim that no contradiction of Holy Scripture could be permitted in science any more than in other things. The text for Caccini's violent sermon was taken from the Acts, "Ye Galileans, why stand you gazing up into heaven?"

Caccini was no stranger to the use of sensationalism. He had been previously reprimanded by his superiors for a similar indiscretion at Bologna. It appears that Caccini was most interested in an appointment at Rome and seems to have believed that this attack was one way to obtain it. A fellow Dominican at Rome even took the pains to write a formal apology to Galileo for the scurrilous attack by one of his order.

Caccini's attack had the effect of stirring up additional trouble for Galileo. A copy of Galileo's letter to Castelli was forwarded to Qualifiers of the Holy Office, the Inquisition, in Rome. After a reading of the letter to the wider Office, a qualified theologian proclaimed that the letter contained nothing of theological significance and that at worst, perhaps some better words might have been chosen here or there. Caccini traveled to Rome to testify against Galileo, and at Caccini's insistence two others were interviewed regarding Galileo's case. For a want of evidence that Galileo opposed the authoritative teachings of the Church, the case was closed. Even though Galileo was found innocent of the charges made against him, enough suspicion had been cast upon him so that he found it necessary to travel to Rome again in 1615 to clear his name and to set aright any wrong.

While in Rome he met and spoke with a number of different groups. Though Galileo won few converts for his own views, he thoroughly demolished the propositions of his opponents. Galileo was not surprised to find resistance to Copernicanism common, but was surprised to find it difficult to arrange appointments with a number of officials in order to discuss theological issues. The whole environment seemed now to be somewhat changed and with good reason.

Seated on the chair of Peter was one Pope Paul V. This pope was, as others before him, most concerned with the breakup of the Church precipitated by Luther a century before. The whole of northern Europe had broken away from the Church of Rome based on the claim of freedom of one to interpret the Bible for himself. If the Catholic Church was now to change its interpretation of the nature of the world system as implied by Holy Scripture, then what was to stop wholesale reinterpretation of any other part of scripture? Pope Paul worked vigorously to nip in the bud any discussion that might raise to the level of controversy which would in turn give the Protestants to the north new ammunition to use against Rome.

Prior to this time proponents of Copernicus' idea of a sun-centered world system such as Carmelite Father Foscarini felt free to publish and debate in Rome. Foscarini had prepared a book reconciling Biblical and Copernican view points by reinterpreting the meaning of selected scriptural passages in light of Copernicanism and the observations of Galileo. Cardinal Bellarmine, a member of the Inquisition who had in fact condemned Giordano Bruno to death by burning in 1600 for his heretical views concerning the mortality of the soul and the eternal nature of the universe, received a copy of the book and warmly congratulated the author. Foscarini was warned in a letter, however, that the Copernican viewpoint was acceptable only so long as it was treated as hypothetical and not real. This was a symptom of the change that was sweeping Rome and would ultimately have disastrous consequences for Galileo.

At the prompting of theopponents of Copernicanism, the Pope was inclined to censure Galileo but, on the advice of Cardinal Bellarmine, submitted the two major theses of Copernicanism -- that the sun was the center of the world system and that the earth did move as a whole and daily upon its axis -- to the Qualifiers of the Holy Office. The Qualifiers found the basic tenets of heliocentric doctrine to be pernicious and further held that both propositions were foolish and absurd (but interestingly enough not false!) and formally heretical inasmuch as they contradicted expressed opinions of Holy Scripture.

On February 24, 1616, these findings were read before the weekly meeting of the Cardinals of the Inquisition. The Pope instructed Bellarmine to inform Galileo that he was not longer to hold or defend the propositions that the sun was at the center and that the earth did move. And that if he should resist this censure, then he would also be instructed that he must also desist from teaching the doctrine which would provide ample opportunity for action by the Inquisition should he persist. The purpose of the twofold order was clear: if he should acquiesce to the command, then there would be no more constraints against him than any other Church member and he would free to discuss the Copernican system as a hypothesis. If he refused, then there were sufficient grounds for the Inquisition to move against him.

Two days later Cardinal Bellarmine summoned Galileo to his residence in order to deliver to him the findings of the Inquisition and the order of the Pope. Just exactly what happened at this meeting is not clear, but it is believed that uninvited officers of the Inquisition made a point of being present with a notary to see to it that the more liberal Bellarmine did not cave in in the face of any protest that Galileo might offer. It is widely believed that Galileo, having been warned by Bellarmine not to resist the injunction of the Pope, accepted the terms neither to hold nor to defend the views of Copernicus but that he might still teach these views as a working hypothesis. It is further believed that one of these uninvited guests, having perceived that Bellarmine had evidently warned Galileo not to resist the injunction, exceeded his authority and informed Galileo that he was neither to hold, defend, or teach the Copernican doctrine. Bellarmine then proceeded to give to Galileo in writing the injunction neither to hold nor defend the views of Copernicus. All this was duly recorded by the notary but the document was signed by neither Bellarmine nor any member of the Inquisition present as it was clear that at least one of them had spoken rashly and had exceeded his authority.

Immediately after the findings of the Inquisition with regards to the tenets of the sun-centered world system hypothesis, three book, including Copernicus' De Revolutionibus, were put on the Index of Prohibited Books until such time as the work was corrected. Following several very minor revisions to make the Copernican thesis appear purely speculative and mathematical, the book was once again being published in Italy by 1620.

On the whole, Galileo appeared to have been reasonably well satisfied with the state of affairs surrounding the controversy. It was clear to Galileo that most of his worries were caused by his detractors and that theologians as a whole were not seeking a pretext to censure him. Neither were they looking to interfere with scientific issues. Rather, they were only concerned with preserving, protecting, and defending the deposit of faith which had been handed down to them and which was now under attack by Protestants to the north.

In the years immediately following these incidents, Galileo was comparatively inactive. He was now more than fifty years of age and he suffered from a good deal of ill health. He continued to delve into the question about how the moons of Jupiter might yet be used as a planet-wide clock for the purposes of navigation. He observed threecomets in 1618 and published a work on these bodies, believed by many philosophers to be elements in the earth's own atmosphere, entitled "The Assayer" which appeared in 1623.

The book, one of Galileo's minor works which contained a thinly veiled support for Copernicanism in accordance with the edict of 1616, was dedicated to Galileo's long-time friend Maffeo Barberini, now Pope Urban VIII. The Pope was so pleased with the work that he had it read aloud to him at mealtime. Galileo's book evidently was used as ammunition against him in Rome as he felt that it was necessary to travel to Rome in 1624 to seek audience with the Pope in the hopes of having the odious restrictions of 1616 lifted.

Though Galileo was warmly received by Pope Urban VIII six times, though the Pontiff gave Galileo several presents and a letter of recommendation to the new Grand Duke of Tuscany who had shown signs of being less friendly to Galileo than had his father, though he promised a pension for his son, he refused to listen to Galileo's request that the onerous decree of 1616 be repealed. Galileo had every hope that the decree would be lifted. Urban knew that the edict of 1616 had lost the Church some prospective converts and Galileo was a close personal friend. The Pope even went so far as to say that if the matter had been left up to him, that the edict would never have been issued, but issued it was and now the Pope felt that he must stand behind it. Galileo consented to this continued restriction but did not give up hope that it would yet be withdrawn.

Galileo explained to the Pope his new theory of tides which he hoped to publish as soon as all the details could be worked out. The explanation depended upon the Copernican proposition that the earth moved. It appears that permission to continue this line of pursuit was granted by Urban, only so long as the motions were treated as hypothetical and not necessarily real. Galileo left the Eternal City with many tokens of the Pope's esteem and affection. He had not, however, told the Pope of the matters which occurred in 1616 at the residence of Bellarmine which Bellarmine had told to Galileo to act as if they never happened. This was to set the stage for tragedy in the coming years as we will see.

Galileo now set to work compiling the work which he anticipated he would call Dialogue on the Tides. From 1624 to 1630 he labored over the work in which he stressed the physical movement of the earth and showed how only this motion could explain the tide raised opposite the moon. He explained how the changing path of sunspots across the face of the sun could only be accounted for by assuming that the earth moved round the sun annually. He detailed his numerous observations of the moon, Jupiter and his retinue, the phases of Venus, and other arguments which supported the sun-centered hypothesis of the world system.

The format of the book was one which was popular in his day, a dialogue between three persons. One was an Aristotelian, the second a Copernican, and the third an intelligent but uninformed individual who weighed the evidence in favor of each theory. In choosing this manner of presentation, not only could Galileo avoid violating the edict of 1616 (for he said nothing himself), but could also write for a wider audience who would come to see the superiority of the Copernican system.

By 1629 the manuscript was nearly complete. At the urging of others, he changed the title to Dialogue Concerning the Two Chief World Systems - the Ptolemaic and Copernican. This title, it was believed, would more clearly indicated the scope of the work. In 1630 Galileo traveled to Rome to obtain the necessary permission to have the work published. The censor made some minor alterations in the work and gave the requested permission for publication in Rome so long as a final draft would be submitted for examination prior to its printing. But shortly after his return to Florence the plague broke out and travels to Rome became impossible because of the quarantines. If the book was to be published then, it would have to be done in Florence. Galileo had considerable difficulty in getting the second approval indicating that the Roman censor was becoming more and more doubtful about the book. Finally, the second license was obtained and the book appeared in March 1632.

The book, a thinly veiled and unanswerable plea for Copernicanism, proved to be immensely popular with the masses and Galileo's enemies were not long in reacting. It appears that the Pope was persuaded to believe that Simplicio - the errant and blundering Aristotelian - was a deliberate and insulting caricature of himself. The Pope was enraged. Further, it is believed that the Pope was shown the unsigned notary statement of 1616 which prescribed Galileo's teaching of the Copernican system in addition to neither holding nor defending the pernicious doctrine. The Pope evidently was angered because Galileo had not informed him of this further restriction. In June, Pope Urban reacted by calling into being a special commission of the Inquisition to examine the matter thoroughly.

By August permission to publish the work was retracted. By September a papal mandate was issued requiring Galileo to appear before the special commission. After making several attempts to avoid appearing in front of the Inquisition by invoking his age, health, and the season of the year, and only after being threatened with arrest, did Galileo make his way to Rome in February of 1633. There he lodged with the Tuscan ambassador who informed him of the Pope's anger and informed him of the nature of the matter before him. It appeared that the meeting of 1616 with Cardinal Bellarmine was the only matter in question. Galileo was confident of the outcome because he was the only living creature who knew of the affidavit provided him by Bellarmine to confirm the substance of that discussion. Galileo did not know of the existence of the contradictory, unsigned notary document.

On April 12, 1633 the trial of Galileo began. Following some initial inquiries regarding the writing and licensing of the Dialogue, the matter of the 1616 Qualifier's ruling was brought up. Galileo detailed what Cardinal Bellarmine had related to him and produced the affidavit in support of his case. It was upon this affidavit that he relied for his memory and upon which he believed himself authorized to discuss the doctrine. He believed himself innocent of violating either the letter of the spirit of the decree of 1616. He argued that the Dialogue treated the Copernican theory as hypothesis and in no other way. He argued that to the best of his memory he had never received even so much as a personal injunction from the Cardinal to avoid teaching the doctrine in any way.

The prosecutor then asked if anyone else beside himself and Bellarmine had been present at that 1616 meeting to which Galileo replied in the affirmative. The prosecutor at that point produced the unsigned document of the notary which contradicted Galileo and upon which, in part, the Inquisition was basing its case. Galileo clearly heard the words, "nor teach in any way." He was dumbfounded.

Before the first and second meeting of the special commission, the Inquisitors examined the Dialogue and found that it did defend and maintain the objectionable doctrine. Because the outcome of the case was in doubt, Galileo was privately advised by the Commissary General of the Inquisition to adopt a more submissive attitude in light of the example provided by Bruno in 1600 who was burned alive for heresy.

Galileo now felt deeply and personally threatened. Had he actually been enjoined to keep from even so much as teaching the sun-centered doctrine? Was his 70-year-old memory failing him? At the second meeting Galileo admitted that perhaps he had been overly zealous in defending and maintaining the doctrine that the earth moved. He even went so far as to offer to make an addition to the Dialogue that would refute as completely as possible the Copernican doctrine.

It was impossible for Galileo to defend himself. No questions of science had actually been raised. The charge was "vehement suspicion of heresy." It was sufficient to show that Galileo had disobeyed an official order. On the only substantive issue of whether or not Galileo had indeed done so, Galileo should have won the case in light of the best evidence, but this was not to be.

At his last appearance before the Inquisition on June 22, Galileo was found guilty by a majority of the judges (with at least three notable exceptions) "of believing and holding the doctrines - false and contrary to the Holy and Divine Scriptures - that the sun is the center of the world, and that it does not move from east to west, and that the earth does move and is not the center of the world; also that an opinion can be held and supported as probable after it has been declared and decreed contrary to the Holy Scriptures." In punishment Galileo was required to "abjure, curse, and detest the aforesaid errors." He was then condemned to the "formal prison of the Holy Office" for an undetermined amount of time which would be served at the pleasure of his judges, and required to repeat the seven penitential psalms once a week for three years.

The condemnation of Galileo was published far and wide. His recantation was circulated in Italy and in Roman Catholic circles else where. His book, the Dialogue, was prescribed to the Index of Forbidden Works. Galileo was crushed by the verdict as it cut him off from the Church he was so much a part of and because no thought of heresy had ever crossed his mind. He perceived this action to be the second major error that the Church had made, the first being the edict of 1616, which would be used by the world to judge the institution once the truth was known. And not the least of the pains came from the knowledge that the entire work of his life had been condemned.

It is most unlikely that Galileo spent more than three days in the prison of the Inquisition, for on June 23 the Pope changed the prison sentence to house arrest in a comfortable country villa near Rome which belonged to the Grand Duke of Tuscany. Galileo moved there on the 24th. Upon the intervention of Archbishop Piccolomini, Galileo was permitted to move to Siena into the custody of the Archbishop whose understanding and compassion helped save Galileo's sanity and even possibly his life. His condemnation by the Church was deeply felt. He wrote to his daughter, a nun, Sister Maria Celeste, that his name was removed from the book of the living. The Archbishop encouraged Galileo to turn his mind to science once again and prompted him to begin work on his long-planned treatise on motion.

By the end of the year Galileo was given permission to retire to his own country home near Florence on the condition that he not leave the house without permission, while his visitors and communications were carefully watched. Several scurrilous attacks on Dialogue were published, but Galileo was forbidden to reply. He was kept from carrying on his studies in the areas he loved most, but he did complete several important works that he had begun much earlier. His telescope was used to study further the motions of the Jovian moons. The observations were cut short, however, by his failing eye sight.

During the final years of his life the now aged Galileo completed work on his book Mathematical Discourses and Demonstrations concerning Two New Sciences. In this final work Galileo detailed techniques and strategies for the solutions of various types of mechanical problems covered today in introductory Physics classes. He also enunciated the first real formulation of what is today known as inertia. The work was complete in 1636 but, because Galileo was prohibited from publishing anything in Italy, it was smuggled out of the country. It first appeared in Leyden in 1638.

In that same year his eyesight failed completely. This proved to be the last devastatingblow and very difficult to accept. Galileo had demonstrated throughout his entire life, he had a special talent for observation which had led him to make marvelous discoveries in both astronomy and physics. Even with weakened vision, Galileo was deeply insightful with regards to his current predicament.

As both Catholic and scientist Galileo had a clear conscience. On one occasion he wrote despairingly that at times he felt as though he should burn all his works, but never once did he feel as though he ought to reject the faith that nurtured him. He realized that his suffering was not due to the Church, but due to a select few who cloaked themselves with her authority. Indeed, he had found many within the Church who supported him personally. Galileo sought not support for Copernicanism, but only for freedom of scientific inquiry without Church intervention -- something that today's modern scientists all too often find themselves contending with.

Galileo, an outcast, a rebel, died at his country estate on January 9, 1642.

Robert Bellarmine

Letter to Foscarini

from Giorgio de Santillana, The Crime of Galileo, Time, Inc., New York, NY, 1962, pp. 104-106

My Very Reverend Father,

It has been a pleasure to me to read the Italian letter and the Latin paper you sent me. I thank you for both the one and the other, and I may tell you that I found them replete with skill and learning. As you ask for my opinion, I will give it as briefly as possible because, at the moment, you have very little time for reading and I have very little time for writing.

1. It seems to me that your Reverence and Signor Galileo act prudently when you content yourselves with speaking hypothetically and not absolutely, as I have always understood that Copernicus spoke. To say that on the supposition of the Earth's movement and the Sun's quiescence all the celestial

appearances are explained better than by the theory of eccentrics and epicycles is to speak with excellent good sense and to run no risk whatever. Such a manner of speaking is enough for a mathematician. But to want to affirm that the Sun, in very truth, is at the center of the universe and only rotates on its axis without going from east to west, is a very dangerous attitude and one calculated not only to arouse all Scholastic philosophers and theologians but also to injure our holy faith by contradicting the Scriptures. Your Reverence has clearly shown that there are several ways of interpreting the Word of God, but you have not applied these methods to any particular passage; and, had you wished to expound by the method of your choice all the texts which you have cited, I feel certain that you would have met with the very greatest difficulties.

2. As you are aware, the Council of Trent forbids the interpretation of the Scriptures in a way contrary to the common opinion of the holy Fathers. Now if your Reverence will read, not merely the Fathers, but modern commentators on Genesis, the Psalms, Ecclesiastes, and Joshua, you will discover that all agree in interpreting them literally as teaching that the Sun is in the heavens and revolves round the Earth with immense speed and that the Earth is very distant from the heavens, at the center of the universe, and motionless. Consider, then, in your prudence, whether the Church can tolerate that the Scriptures should be interpreted in a manner contrary to that of the holy Fathers and of all modern commentators, both Latin and Greek. It will not do to say that this is not a matter of faith, because though it may not be a matter of faith ex parte objecti or as regards the subject treated, yet it is a matter of faith ex parte dicentis, or as regards him who enounces it. Thus he who should deny that Abraham had two sons and Jacob twelve would be just as much a heretic as a man who should deny the Virgin Birth of Christ, because it is the Holy Spirit who makes known both truths by the mouth of the Prophets and Apostles.

3. If there were a real proof that the Sun is in the center of the universe, that the Earth in the third heaven, and that the Sun does not go round the Earth but the Earth round the Sun, then we should have to proceed with great circumspection in explaining passages of Scripture which appear to teach the contrary, and rather admit that we did not understand them than declare an opinion to be false which is proved to be true. But, as for myself, I shall not believe that there are such proofs until they are shown to me. Nor is it a proof that, if the Sun be supposed at the center of the universe and the Earth in the third heaven, everything works out the same as if it were the other way around. In case of doubt we ought not to abandon the interpretation of the sacred text as given by the holy Fathers. I may add that the man who wrote: The Earth abideth for ever; the Sun also riseth, and the Sun goeth down, and hasteth to his place whence he arose, was Solomon, who not only spoke by divine inspiration but was wise and learned, above all others, in human sciences and in the knowledge of created things. As he had all this wisdom from God Himself, it is not likely that he would have made a statement contrary to a truth, either proven or capable of proof. If you tell me that Solomon speaks according to appearances, inasmuch as though the Sun seems to us to revolve, it is really the Earth that does so, just as when the poet says: "The shore is now receding from us," I answer that, though it may appear to a voyager as if the shore were receding from the vessel on which he stands rather than the vessel from the shore, yet he knows this to be an illusion and is able to correct it because he understands clearly that it is the ship that is in movement. But as to the Sun and the Earth, a wise man has no need to correct his judgment, for his experience tells him plainly that the Earth is standing still and that his eyes are not deceived when they report that the Sun, Moon, and stars are in motion.

With this I salute your Paternity affectionately and pray God to grant you all happiness.

From my house, 12 April 1615.

Your very Reverend Paternity's brother,

R. CAR. BELLARMINO

Galileo Galilei

from Discoveries and Opinions of Galileo, trans. Stillman Drake, Masterworks Program, Garden City, NY, 1957, pp. 168-170

Elsewhere in these notes there is a pointbypoint reply to Bellarmine's written opinion. It has the appearance of something intended to be sent to Foscarini for use in the revision and amplification of his book, though its precise date or purpose is not known. In substance it reads as follows:

1. Copernicus assumes eccentrics and epicycles; not these, but other absurdities, were his reason for rejecting the Ptolemaic system.

2. As to philosophers, if they are true philosophers (that is, lovers of truth), they should not be irritated; but, finding out that they have been mistaken, they must thank whoever shows them the truth. And if their opinion is able to stand up, they will have cause to be proud and not angry. Nor should theologians be irritated, for finding such an opinion false, they might freely prohibit it, or discovering it to be true they should be glad that others have opened the road to the discovery of the true sense of the Bible, and have kept them from rushing into a grave predicament by condemning a true proposition.

As to rendering the Bible false, that is not and never will be the intention of Catholic astronomers such as I am; rather, our opinion is that the Scriptures accord perfectly with demonstrated physical truth. But let those theologians who are not astronomers guard against rendering the Scriptures false by trying to interpret against it propositions which may be true and might be proved so.

3. It may be that we will have difficulties in expounding the Scriptures, and so on, but this is through our ignorance, and not because there really are, or can be, insuperable difficulties in bringing them into accordance with demonstrated truth.

4. . . . It is much more a matter of faith to believe that Abraham had sons than that the earth moves . . . For since there have always been men who have had two sons, or four, or six, or none . . . there would be no reason for the Bible to affirm in such matters anything contrary to truth. . . . But this is not so with the mobility of the earth, that being a proposition far beyond the comprehension of the common people. . . .

5. As to placing the sum in the sky and the earth outside it, as the Scriptures seem to affirm, etc., this truly seems to me to be simply . . . speaking according to common sense; for really everything surrounded by the sky is in the sky. . . .

6. Not to believe that a proof of the earth's motion exists until one has been shown is very prudent, nor do we demand that anyone believe such a thing without proof. Indeed, we seek, for the good of the holy Church, that everything the followers of this doctrine can set forth be examined with the greatest rigor, and that nothing be admitted unless it far outweighs the rival arguments. If these men are only ninety per cent right, then they are defeated; but when nearly everything the philosophers and astronomers say on the other side is proved to be quite false, and all of it inconsequential, then this side should not be deprecated or called paradoxical simply because it cannot be completely proved. . .

7. It is true that to prove that the appearances may be saved with the motion of the earth . . . is not the same as to prove this theory true in nature; but it is equally true, or even more so, that the commonly accepted system cannot give reasons for those appearances. That system is undoubtedly false, just as . . this one may be true. And no greater truth may or should be sought in a theory than that it corresponds with all the particular appearances.

8. No one asks that in case of doubt the teachings of the Fathers be abandoned, but only that the attempt be made to gain certainty in the matter questioned.. . .

9. We believe that Solomon and Moses and all the other holy writers knew the constitution of the universe perfectly well, as they also knew that God did not have hands or feet or wrath or prevarication or regret. We cast no doubt on this, but we say that . . . the Holy Ghost spoke thus for the reasons set forth.

10. The mistake about the apparent motion of the beach and stability of the ship is known to us after we have frequently stood on the beach and observed the motion of the boat, as well as in the boat to observe the beach. And if we could stand thus now on the earth and again on the sun or some other star, we might gain positive and sensory knowledge as to which moved. Yet looking only from these two bodies, it would always appear that the one we were on stood still, just as to a man who saw only the boat and the water, the water would always seem to run and the boat to stand still.... It would be better to compare two ships, of which the one we are on will absolutely seem to stand still whenever we can make no other comparison than between the two ships. . .

Besides, neither Copernicus nor his followers make use of this appearance of the beach and the ship to prove that the earth moves and the sun stands still. They use it only as an example that serves to show . . . the lack of contradiction between the simple senseappearance of a stable earth and a moving sun if the reverse were really true. For if nothing better than this were Copernicus's proof, I believe no one would endorse him.