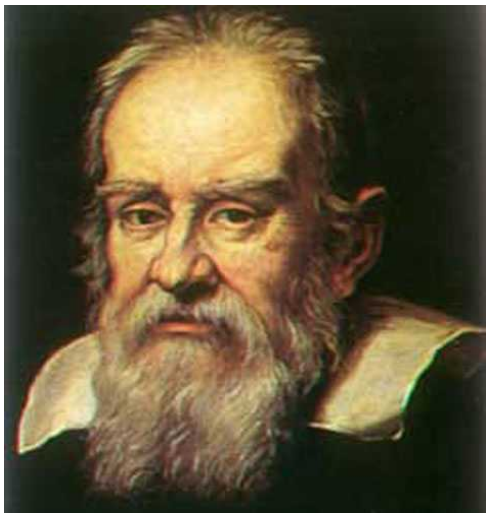
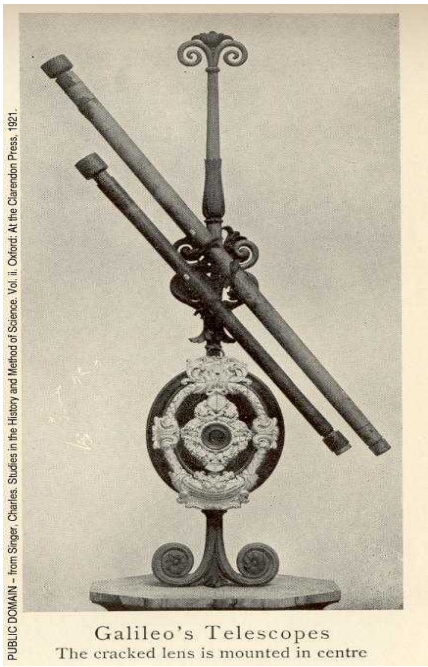
GALILEO GALILEI

On October 18, 1989, The Galileo Spacecraft, launched from the cargo bay of Space Shuttle Atlantis, began a 14-year odyssey that came to an end when it passed into Jupiter's shadow and then disintegrated in the planet's dense atmosphere on September 21, 2003. During its journey the spacecraft traveled about 2.8 billion miles. It was purposely put on a collision course with Jupiter because the onboard propellant was nearly depleted. This meant it could not point its antenna toward Earth or adjust its trajectory, making it impossible to control the spacecraft and it was feared that the spacecraft might impact with Jupiter's moon, Europa. The spacecraft was named in honor of **Galileo Galilei** (February 15, 1564 – January 8, 1642), the first modern astronomer, who made the initial heavenly observations using a telescope in 1610.





Galileo did not invent the telescope, but he was the first to use it effectively in the study of the heavens. The son of an impoverished nobleman Vincenzo Galilei, well known for his musical studies, and his wife Giulia degli Ammannati, Galileo was born in Pisa, the first of six (perhaps seven) children. When he was six, the family moved to Florence. In 1581, Galileo was sent to the University of Pisa to study medicine. One day, while attending services in the cathedral, he became aware of a huge lamp suspended from the ceiling. As he watched the lamp sway back and forth, he used his pulse as a timekeeper to measure the oscillations. To his surprise, the time required for the lamp to make a small oscillation was the same as to make a large one. That is, the

period of the swing of a pendulum is independent of its amplitude, a discovery that would have important implications for the measurement of time intervals. Wishing to account for this phenomenon, Galileo abandoned the study of medicine for science. He learned the physics of Aristotle, but questioned the ancient Greek scientist's approach to the subject.

After tutoring mathematics in Florence, Galileo was appointed a professor of mathematics at Pisa in 1589, where he remained for eighteen years. During this period he made his discovery about falling bodies and set his steps on a lopsided conflict with the church. Galileo used the Archimedean approach to motion: "the speed of falling bodies is proportional to their density, not their weight." To prove this, legend has it that Galileo dropped two pieces of metal, one of which was ten times heavier than the other from atop the Leaning Tower of Pisa. The two struck the ground at practically the same time. To Galileo this experiment refuted Aristotle's teaching that a heavier body will fall faster than a lighter one. It is certain that Galileo performed various experiments in which he dropped objects from a certain height, but historians doubt the Tower of Pisa experiment, which was reported by Galileo's first biographer, Vincenzo Viviani. This approach, however, illustrates how Galileo pioneered the "experimental scientific method."

To churchmen, Galileo's assertions were viewed as sacrilegious insolence. Galileo had worn out his welcome in Pisa, and resigned his professorship to accept a similar position in Padua, where freedom of thought was encouraged. His lectures were so successful, with people coming from all over Europe to hear them, that the university was forced to provide him with a lecture hall that accommodated 2000 people. During his time at Padua, Galileo built a thermoscope, an instrument for indicating changes in temperature of a substance without accurately measuring them, by observing the accompanying changes in volume. He devised and constructed a geometrical and military compass and wrote a

manual describing how to use the instrument.

About 1607, Hans Lippershay, the apprentice of a Holland spectacle maker, accidentally discovered that by holding a pair of spectacles in a certain way objects were magnified. His master put the two lenses in a tube and displayed it as a toy. By 1609, Galileo had heard of the "toy," called a spyglass, and made an instrument far more powerful. He presented it to the Doge of Venice, who immediately saw the immense possibilities it could play in naval and military operations. Galileo proceeded to make more powerful telescopes, as they were now called, from *tele*, Greek for "far" and *skopos*, "watcher."

Galileo scanned the sky with a telescope on January 7, 1610 and saw what he thought were three fixed stars, two to the east of the planet Jupiter and one to the west. The next night, he found all three were to the west of Jupiter. Over the next week Galileo observed that the little stars never left Jupiter, but seemed to be carried along with the planet. In addition, as they were carried along they changed their position with respect to Jupiter and each other. He also discovered that there were not three but four little "stars." By January 15, Galileo realized that he had uncovered a miniature Copernican system in the satellite system of moons of Jupiter.

For Galileo this was substantiation of the Copernican theory, and he began to contend that the sun-centered arrangement was not just a hypothetical mathematical theory but was the way things really were. Galileo described his discoveries and his interpretations in a short book called *Sidereus Nuncius* (Message from the Stars), which he dedicated to Cosimo II, the Grand Duke of Tuscany and his Medici family. The book caused a sensation and made Galileo famous. He was not able to prove that the Copernican system was the correct one, but he offered evidence that made it appear increasingly

probable. The book was provocative, for in it he claimed to have seen mountains on the Moon and to have proved that the Milky Way was made up of tiny stars. In July 1610, Galileo made a new discovery, which he shared with his patron:

> "I discovered another very strange wonder, which I should like to make known to their Highnesses …, keeping it secret, however, until the time when my work is published ….The star of Saturn is not a single star, but a composite of three, which almost touch each other, never change or move relative to each other, and are arranged in a row along the zodiac, the middle one being three times larger than the lateral ones, and they are situated in this form: oOo."

To preserve his priority in his discovery until he could publish it in a book, Galileo circulated an anagram, *smaismrmilmepoetaleumibunenugttauiras,* and sent its solution "I have observed the highest planet tri-form" to his correspondents. It would take the investigations of numerous scientists and the passage of many years before the actual nature of Saturn was known, namely that it was surrounded by a ring made up of particles no larger than a few inches. Meantime, Galileo's discovery was acclaimed far and wide.

Soon afterwards, Galileo became "Mathematician and Natural Philosopher" to the Grand Duke of Tuscany. He continued his work on mechanics and became more and more involved in disputes over which system accurately described the solar system. With his telescope he discovered that the planet Venus showed phases like Earth's moon, and therefore must orbit the Sun and not the Earth. This was not in conflict with the compromise system of Danish astronomer Tycho Brahe, who maintained that,

everything but the earth and its moon revolves around the Sun, which in turn revolves around the Earth. However, by now Galileo was a fervent Copernican. Churchmen attacked Galileo for questioning the system of Ptolemy, which was based on the teachings of Aristotle, who accepted the view that the sun revolved around the earth. Not all clergy opposed Galileo's interpretations of his observations. Cardinal Barberini, later to become Pope Urban VIII, confirmed Galileo's discoveries by looking through the telescope. Unfortunately, reactionaries convinced the Pope that Galileo unfavorably represented the pontiff in his book.

In 1632, Galileo published his *Dialogue concerning the two greatest world systems*, in which in clear and unmistakable language he expounded the Copernican theory. He sent the work to the Roman censor but because of the plague communication between Rome and Florence was interrupted. Galileo requested that the censoring of his book should be done in Florence. Despite the fact that the Roman censor communicated his serious concerns about the work to his Florentine colleagues, Galileo had little trouble getting the book approved for publication by the Florentine censors. Galileo's enemies in the church pointed out that the treatise was contrary to the edict of 1616 in which Copernicus' work was placed on the Index of prohibited books. The Inquisition declared that to suppose the sun to be the center of the solar system was false, and opposed to Holy Scripture. The Congregation of the Inquisition was a permanent institution within the Catholic Church charged with eradicating all heresies. Beginning in 1559 it published the Index, which provided rules for censorship and listed books that were forbidden to be read, because in the judgment of the Inquisition they posed a danger to the faith and morals of Catholics. Galileo was summoned to Rome, in 1633, to appear before the Inquisition, where he was pronounced to be vehemently suspected of heresy, condemned to life imprisonment and was forced to declare:

"I abjure, curse, and detest the said errors and heresies and generally every error

> and sect contrary to the said Holy Church; and I swear that I will nevermore in future say or assert anything verbally or in writing which may give rise to a similar suspicion of me; but that if I know any heretic, or any one suspected of heresy, I will denounce him to this Holy Office or to the Inquisitor and Ordinary [Bishop] of the place in which I may be."

Seven cardinals signed the Inquisitions order, but not as was usual by his old friend the pope. Immediately thereafter, at the request of the Grand Duke of Tuscany, his sentence was reduced to house arrest. A broken, old man, Galileo spent the last eight years of his life confined to his estate at Arcetri, near Florence, working on problems of mechanics. In 1637, he lost his sight, but with the aid of his students he continued his experiments. Although forbidden to publish, he completed *Discourses on two new sciences*, based on his studies on motion and the strength of materials. It was smuggled out of Italy and published in the Netherlands in 1638. Galileo died on January 8, 1642.

For those who questioned Galileo recanting what he knew to be true, David Hilbert had the following to say on the matter:

> "Galileo was no idiot. Only an idiot could believe that science requires martyrdom – that may be necessary in religion, but in time a scientific result will establish itself."

Quotation of the Day: – "In questions of science the authority of a thousand is not worth the humble reasoning of a single individual." – Galileo Galilei