GALILEO GALILEI (February 15, 1564 – January 8, 1642)

by HEINZ KLAUS STRICK, Germany

GALILEO GALILEI initially grew up in his parents' home near Pisa. When he was eight years old, they moved to Florence and the boy remained with a relative of his mother for the next two years. Then he lived again temporarily with his parents, attended a monastery school nearby, until he decided to join the order as a monk – which his father, a music scholar, did not like. He insisted that his son should become a doctor – like one of his ancestors.

At the age of 17, GALILEO was sent back to Pisa and began studying medicine there – but he was much more interested in the subjects of mathematics and natural philosophy (natural sciences). GALILEO attended lectures on the works of EUCLID and ARCHIMEDES with OSTILIO RICCI, a student of NICOLO TARTAGLIA (1500 – 1557), while his father recommended the writings of the Greek doctor GALENOS (129 – 216) to him.

(drawing: © Andreas Strick)

RICCI tried, initially with little success, to dissuade the father from his future plans.

When GALILEO was 21, he left the university without a degree and began working as a mathematics teacher in Siena. In 1586 he wrote the first major publication *La Balancetta* (The little balance), in which he explained how the specific weight of a body can be determined with the help of the hydrostatic balance he invented.

The following year he visited CHRISTOPHER CLAVIUS, mathematician at the *Collegio Romano*, the Jesuit college in Rome, and responsible for the (GREGORian) calendar reform, and impressed him with his studies on the centre of gravity of bodies.

Because of the reputation he had gained, but also because of CLAVIUS's recommendations, he was allowed to give lectures on mathematics at the University of Pisa from 1589, especially on the geometry of EUCLID.

He dealt with problems with the movement of bodies. In an unpublished work from 1589 *De Motu* (On movement), he used a thought experiment to refute ARISTOTLE's theory that heavy bodies fall faster than light ones:

Assume that object A is heavier than object B; then A would fall faster than B. Looking at the union of the two objects, this would fall more slowly than object A alone, because B inhibits A. On the other hand, the union of A and B is heavier than A, so it must fall faster than A – which is a contradiction.

In 1592, GALILEO moved to a chair in mathematics at the University of Padua (Republic of Venice) for the next 18 years, which paid him a significantly higher salary.

He improved his income by selling a so-called *Geometrical Compass* he invented (as a calculation tool and for enlarging and reducing drawings).

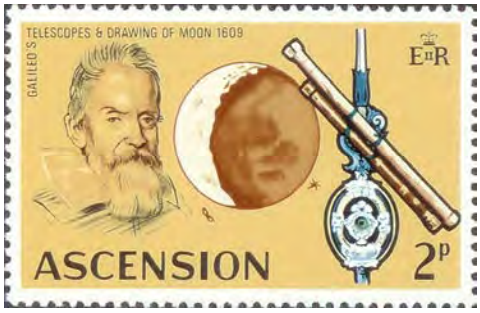
(Source: Wikipedia – Sage Ross)

During his time in Padua, he lived with MARIA GAMBA, his housekeeper and had three children with her. However, he did not marry her because he felt that his financial situation was not sufficiently secure. His two daughters later entered a monastery because, being illegitimate, they could not marry men of their own class. He legitimized his son when MARIA GAMBA married another man.

When in May 1609 he received the information about the telescope that the Dutchman JAN LIPPERSHEY invented. He built this instrument, experimented with the dimensions and ground his own lenses. Finally he succeeded in building a telescope that was nine times larger.

GALILEO recognized the economic and military use of the device he called the *perspicillum* and sold the sole right to manufacture such a telescope to the Venetian government. However, they soon realised that GALILEO could not claim that he had invented the telescope and so they froze the payments to him.

In May 1610 he published the *Sidereus Nuncius* (Starry messenger). He had seen mountains on the moon, that the Milky Way consisted of individual stars and that Jupiter was surrounded by four small bodies, which he called "Medici Stars" to win the favor of COSIMO VON MEDICI, the new Grand Duke of Tuscany. The duke appointed GALILEO as his court mathematician and court philosopher and as the principal mathematician at the University of Pisa – without teaching duties.



GALILEO was celebrated in the *Collegio Romano* for his discoveries and received the honour of becoming a member of the *Accademia dei Lincei*.

Then GALILEO observed that Venus was sometimes "behind" the sun, sometimes "in front of" the sun, from which it followed that Venus orbited the sun and not the earth.

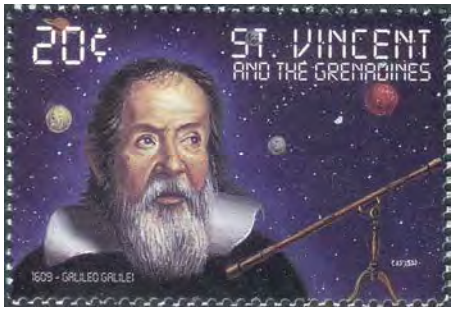
This was not yet proof of the correctness of the theories of NICOLAUS COPERNICUS (1473 – 1543), but was another important indication. The phenomenon can also be explained by the theories of TYCHO BRAHE (1546 – 1601) (favoured by the Jesuits in Rome), in whose system the sun and moon rotated around the earth, but the other planets moved around the sun.

GALILEO got into a conflict of priorities with the Jesuit CHRISTOPH SCHEINER about the discovery of sunspots. SCHEINER believed that the sun was perfect and so he considered the observed points to be satellites of the sun. GALILEO, on the other hand, wrote in his *Lettere solari* (Solar letters), written in Italian, that the spots "arise and die".

Initially, GALILEO avoided public statements on the validity of the Copernican world view, but was targeted by the Inquisition when a fake copy of a letter to his student CASTELLI was forwarded to the Inquisition. Galileo emphasised in a clarification that the Bible was not an astronomical textbook and that observations of natural phenomena could not pose a danger to faith, but only serve to complete faith, because both nature and divine revelation are part of divine truth.

Through spectacular experiments, he succeeded in refuting the teachings of ARISTOTLE, which the Church had described as infallible. He determined the specific weight of air (which according to ARISTOTLE should not have any weight) and he could explain why ice floats on water (ARISTOTLE gave "shallowness" as the reason for this).

GIORDANO BRUNO had been executed in 1600 for views that did not conform to the church. The Grand Inquisitor in the heresy process at that time, the powerful Cardinal BELLARMINO, saw no reason to intervene against GALILEO, because the COPERNICan system was for him only an elegant mathematical theory, with the help of which one could perhaps better describe the movement of the heavenly bodies than the system described by PTOLEMY. However, when GALILEO described COPERNICUS's teaching as physical reality in a letter to the Grand Duchess in 1616, BELLARMINO instructed him to refrain from doing so in the future.



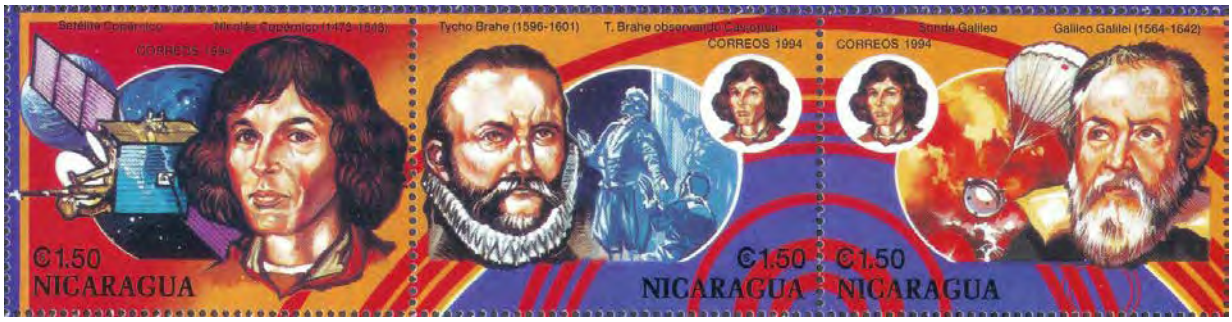
In 1623, GALILEO published the work *Il saggiatore* (The Gold Scale) in which he presented his views on scientific research. He dedicated it to the newly elected POPE URBAN VII, who had long been one of his admirers. GALILEO's conviction was that mathematics in the natural sciences has the task of describing processes. The book contains the famous words:

Philosophy is written in this important book which stands continually open before our eyes (I mean the universe), but can not be understood unless you first learn to understand the language, and to know the characters, and how it is written. It is written in the language of mathematics, and its characters are triangles, circles and other geometrical figures, without which it is humanly impossible to understand a single word. Without them you wander around in a dark labyrinth.

Several discussions with URBAN VII took place in a pleasant atmosphere, so GALILEO had the impression that he would not have to face any serious consequences from the church in the future.

He began work on the *Dialogo sopra i due Massimi Sistemi del Mondo Tolemaico e Copernicano* (Dialogue on the two most important world systems, PTOLEMAic and COPERNICan). In order not to offer the Inquisition a target, GALILEO chose the form of a dialogue between a supporter of the COPERNICan system and a philosopher from the school of ARISTOTLE. In this way he could always justify that he did not represent the teachings of COPERNICUS in the Scriptures, but merely presented a hypothesis.

However, he was provocative by making the representative of the PTOLEMAic system a person with an apparently limited mind (he is called "Simplicio"). Last but not least, he also made fun of the Pope's sympathies by mocking his opinion that God could do things that contradicted a cause.



It is striking that GALILEO avoided dealing with the BRAHEan model in the *Dialogo* and did not consider KEPLER's elliptical orbit model (published in 1609), although it enabled much better predictions regarding the planetary orbits.

For GALILEO, the rotation of the earth was the cause of the appearance of the tides. Curiously, he considered this false explanation to be the most convincing argument contained in the *Dialogo* in favor of the COPERNICan system. The *Dialogo* is one of the most important books in the history of physics – not least because it formulates the principle now known as the *GALILEO principle* or the relativity principle of movement: *A natural law must be described in such a way that it is the same form for all observers regardless of the state of movement.*

GALILEO explained this very clearly. One observes movements under the deck of a ship, for example, swimming fish in a vessel, flying mosquitoes or butterflies, falling drops, balls that throw passengers at each other.

Now let the ship move at any speed: you you will not see the slightest change in all the phenomena mentioned – if only the movement is uniform and does not fluctuate here and there. You will not be able to tell from any of them whether the ship is moving or standing still.

The sale of this work was prohibited by the Inquisition shortly after its publication, and GALILEO was summoned to Rome.

The Inquisition Tribunal accused him of ignoring the 1616 agreements. After renouncing his mistakes, he was sentenced to life imprisonment for disobedience after a process lasting several weeks. However, this was soon converted into house arrest with a ban on teaching.

Rumours later spread that he had mumbled the words "*E pur si muove*" (And yet it moves) when he left the courtroom, but this was probably not the case.

First the ARCHBISHOP OF SIENA welcomed him to his house; then he was able to return to his own home in Arcetri (near Florence), where he lived – overseen by the guardians of the Inquisition – until his death. Despite all the restrictions and requirements, he began working on the *Discorsi e Dimostrazioni Matematiche intorno a due nuove scienze* (Discussion and mathematical evidence on two new sciences), a work that upon completion was smuggled abroad and published in Holland.

In this work, GALILEO completed the studies on kinematics that he started as early as 1589. He analysed free fall as a uniformly accelerated movement, in which the mass of the falling body – in a vacuum – does not matter.

For his studies, he conducted experiments on inclined planes using the brilliant idea of "slowed down free fall". For example, he formulated statements such as *The time in which an object travels a certain distance with a steadily accelerated movement from standstill is just as long as the time in which the object would travel the distance at a uniform speed that is half as long like the maximum speed with evenly accelerated movement*, in order to deduce from this that the distance covered is proportional to the square of the elapsed time.

Only later did his statements get the (algebraic) form that we are used to today.

In contrast to ARISTOTLE, who assumed that a body naturally loses speed, GALILEO formulated a law that anticipated NEWTON's first law of motion: *A body that moves smoothly on a flat surface continues this movement at a constant speed for as long as it is not disturbed.*

GALILEO recognised that the trajectories of projectiles are parabolic – the movement is made up of a uniform horizontal and a vertical, evenly accelerated movement. He also described an experiment to measure the speed of light with the aid of mutual lantern signals, which, however, turned out to be impossible in practice.

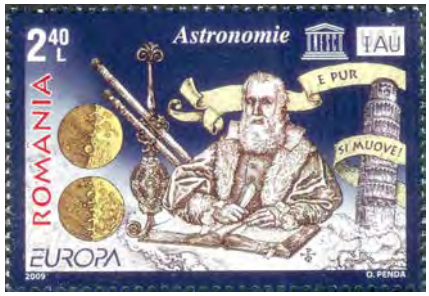
In his last work, he also dealt with a mathematical paradox that was only clarified by GEORG CANTOR (1845 – 1918).

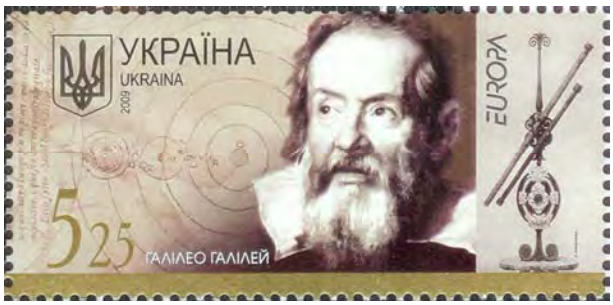
In connection with the infinite, GALILEO did not consider the properties *equal*, *larger* and *small* to be applicable. He writes: *For example, one cannot say that with two different lengths of line, both of which have an infinite number of points, that the "infinity" of one line is more than the "infinity" of the other line, simply because they are of different lengths. Nor can one say that there are fewer square numbers than natural numbers, although not all natural numbers are square numbers and there are an infinite number of both*.

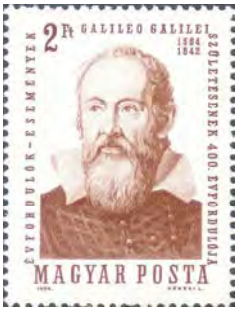
Shortly before his blindness in 1637, GALILEO discovered the moon's *libration* (an apparent lurching motion of the moon, which is why it is possible to see more than half of the moon's face from Earth. He dictated his thoughts to his assistants (the last was EVANGELISTA TORRICELLI).

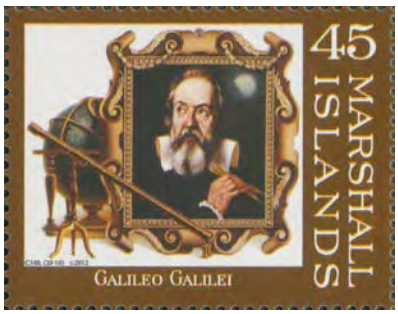
When he died, his relatives did not dare bury him in the family grave in the Basilica of Santa Croce in Florence – but he was moved there almost 100 years later.

To mark the Year of Astronomy 2009, stamps have been issued in many countries, including some showing the portrait of the Italian mathematician, physicist and astronomer GALILEO GALILEI, who built a telescope exactly 400 years ago and pointed it at the moon and the planets.









First published 2009 by Spektrum der Wissenschaft Verlagsgesellschaft Heidelberg

https://www.spektrum.de/wissen/galileo-galilei-1564-1642/1006306

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