



# Galileo

## 400 years on

**Martin Ince** looks at the life of the celebrated astronomer, and how new research is replicating what he saw

Four hundred years ago this year, Galileo first pointed his telescope at the sky. The anniversary is one of the reasons for staging the International Year of Astronomy in 2009. Now, more is being discovered about this defining event by scientists in Galileo's own country, who have created the most exact replicas of the telescopes he used.

But who was Galileo di Vincenzo Bonaiuti de' Galilei? Galileo Galilei, as we know him, was born in Pisa in 1564. If his name seems odd, remember that in that era Italian children were given a variant of their family name as a first name. The son of a musician, which was the career followed by his brother Michelangelo, Galileo had early ambitions to become an artist, but is now remembered as the founder of modern science.

Science historian Graham Farmelo, who has just written a biography of the great 20th century physicist Paul Dirac, is in no doubt that Galileo was the first modern scientist, much as Niccolò Machiavelli was the first recognisable politician. Machiavelli would have prospered in today's House of Commons and Galileo would have been comfortable in a modern university lab; he was the first person to understand that theory drives modern science. Decades after Galileo's death in 1642, Sir Isaac Newton, born in that same year, famously said: "If

I have seen further it is by standing on the shoulders of giants." He was referring mainly to Galileo. In his great work *Principia Mathematica*, Newton acknowledged his debt to Galileo in the development of his laws of motion.

### Fact through evidence

Galileo regarded himself as a 'natural philosopher' and wouldn't have made the distinction we do today between physics and astronomy. Despite his astonishing discoveries with the telescope, Galileo's work on the physics of motion, including acceleration and gravitation, was his biggest contribution to science. His famous experiments with gravitation involved rolling balls down an inclined plane to measure their acceleration and dropping differently sized metal balls from a tower to show that they fell at the same speed. Until then, theory held that the bigger one would gain speed faster. This simple experiment undid a misunderstanding that had persisted for centuries.

Dr Allan Chapman of Wadham College, Oxford, is an expert on the scientific revolution of the 17th century. He says: "Galileo's importance to astronomy is that he turned it from a mathematical science into a physical one. Before he published his findings, astronomy involved looking at the ►

Galileo has been called the first celebrity scientist, paving the way for Newton and Einstein

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Galileo's sketches of the Moon from his bestseller *Sidereus Nuncius*

OBSERVAT. SIDEREAE. 19  
Hæc eadem macula ante secundam quædam circumvallata nigrioribus quibusdam terminis circumvallata conspicitur, qui tanquam altissima montium juga ex parte Soli averfa obscuriores apparent, qui vero Solem respiciunt, lucidiores existant, cujus oppositam in cavitatibus accidit, quarum pars Soli averfa splendens apparet, obscura verò ac umbrosa, quæ ex parte Solis fita est. Inimuta deinde luminosa superficie, cum primum tota ferme dicta macula tenebris est obducta, clariora montium dorsa eminenter tenebras scandunt. Hanc duplicem apparentiam sequentes figure commostrarunt.

telescope, although both originated in the Netherlands, and made many machines including early computing devices. The arrival of clocks, telescopes, thermometers, barometers and accurate weighing devices allowed us to turn human experience into recorded measurements. This was a significant turning point in scientific thought and practice.

**The celebrity scientist**

Chapman points to another way in which Galileo was important. No stranger himself to the TV studio, he says that Galileo was “the first celebrity scientist, interested in fame in a serious way.” He began a tradition of the scientist as an important public figure. This led the way for successors such as Isaac Newton (an MP and significant political player in London), Michael Faraday and Albert Einstein, who turned down an offer to become the first president of Israel.

Giorgio Strano, curator of the Museum of the History of Science in Florence and an expert on Galileo's telescopes, says: “Galileo's astronomical discoveries were not his most important work because Kepler and Copernicus had already started the revolution in

► mathematics of how points of light moved in the sky. He showed that the Moon was rough and variegated, that the Sun was spotty and that Venus had phases that could be observed. And all this was done by observing the Universe through a novel but simple device – just two lenses in a tube.”

Chapman points out that Galileo was not the first person to look at the sky through a telescope. That was probably the Englishman Thomas Harriot, who made a map of the Moon with the aid of a telescope in July 1609. But there are no prizes in science for doing something first unless you tell the world about it. Galileo's books, especially *Sidereus Nuncius* (*The Starry Messenger*), were sensations all over Europe. Among its admirers were Harriot and his circle.

Galileo can also be regarded as the first person to see the importance of technology for transforming our view of the world. His early work on pendulums was important in the development of accurate clocks. He was a pioneering user of the microscope as well as the

“When he saw that Jupiter had its own satellites, Galileo regarded this as proof that Jupiter was a planet like the Earth”



Made between 1609 and 1610 by Galileo, this 21x magnification telescope was made of thin wooden strips stuck together and wrapped in leather, with an objective lens and eyepiece (inset) at the ends



ABOVE: Paolo Stefanini takes a look through a modern replica of Galileo's telescope, which he helped to build

TOP RIGHT: A view of the Moon through the replica Galileo telescope

BOTTOM RIGHT: A view through the replica scope reveals Saturn as Galileo would have seen it



astronomy. Instead, his most important achievement was to connect the celestial and terrestrial worlds.”

Before Galileo, people followed Aristotle in thinking that the ‘sublunar’ world of the Earth was hermetically sealed off from the ‘superlunar’ world above. Strano explains that Galileo's discoveries removed this distinction. “When he looked at the Moon through a telescope, he showed that it is a terrestrial body like the Earth,” Strano says. Galileo's strikingly beautiful drawings of the Moon's mountains and plains still exist as evidence of this breakthrough. The same applies, says Strano, to perhaps Galileo's most famous discovery – the four major satellites of Jupiter. “When he saw that Jupiter had its own satellites, Galileo regarded this as proof that Jupiter was a planet like the Earth, because the Earth has a Moon of its own,” he says.

Now Paolo Galluzzi, director of the Florence museum, Giorgio Strano and colleagues are using modern science to see what Galileo saw. The museum

has the two surviving Galileo telescopes but they are far too precious and fragile to be used. Instead, a method called interferometry is employed to determine the shape of the lenses he used, which, as Galluzzi says, never had the spherical shapes he aimed for. In addition, non-invasive technology now allows atomic beams to gather exact information on the composition of the glass in the lenses. Exactly who made the lenses is unknown. Galileo ground some himself but also worked with craftsmen in Florence.

All this information has recently been used by the Florence Museum, the Arcetri Observatory and the famed glass makers of Murano near Venice, as well as Italy's national institutes for physics and optics, to build exact optical replicas of Galileo's telescopes. In a modern touch, they feed a digital camera to create a permanent record of what Galileo would have seen with telescopes providing 20x magnification.

Strano says that the project has yet to investigate Galileo's observations of

deep space, including star clusters and the Milky Way. But there have been revelations about his work on the Solar System. We now know that he could not have seen the whole surface of the Moon as he drew it in one view. He must have recreated it from memory and in that light we can appreciate the accuracy of his Moon drawings all the more.

More intriguing is Galileo's view of Saturn. He wrote that Saturn was apparently a triple planet with a main sphere and two big satellites. The replica telescopes confirm that Galileo could not have resolved Saturn's rings, making them look more like ears on each side of the planet. Galluzzi says: “By comparison with Saturn's rings, Jupiter's satellites were an easy target, just spots in a line near the planet. We have also shown that he could have observed the phases of Venus and its diminishing luminosity as its phase changed.”

Galileo also produced the first accurate drawings of sunspots. It has ►

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# Looking through Galileo's eyes

How exhuming Galileo's body could solve the mystery of his poor eyesight

A painting by Tito Lessi shows an old-aged Galileo working at his villa



Experts agree that Galileo had a progressive glaucoma – a disease that affects the optic nerve and gets worse over time. He was able to see detail on the Moon until he went blind a few months before his death. But what type of glaucoma was it? Paolo Galluzzi, director of the Museum of the History of Science in Florence, plans to see just why Galileo suffered the problems he did. And these plans involve Galileo's own mortal remains.

There are two possible ways for a person to suffer an acute glaucoma like the one that seems to have overtaken Galileo. One is a primary glaucoma in which peripheral vision goes first; the other is a secondary glaucoma in which vision fades uniformly. One important difference between these two is that a secondary glaucoma is linked to a person's genes. If Galileo had living descendants, it would be possible to look for a specific gene variant in their DNA.

Galileo never married, but he did have three illegitimate children. His daughters became nuns and had no children (one, Maria Celeste, was the subject of Dava Sobel's book, *Galileo's Daughter*), while any descendants of his son Vincenzo, who was legitimised by the Grand Duke of Tuscany, are unaware of their distinguished family tree.

So Galluzzi plans to take "a small piece of tissue" from Galileo's remains to find out whether his genes have the marker. Galluzzi says: "In 1737, Galileo was reburied in a more impressive sepulchre than he was allowed immediately after his death, and a notary made a detailed description of what was found in the first tomb. As well as Galileo, they found a second coffin with the body of a lady, probably Maria Celeste. If we are allowed to do this experiment, we will be able

to see this second person's relationship to Galileo."

But his search for Galileo's genetic marker for glaucoma isn't a simple one. At least four formidable authorities have to agree. They include the Church, the civil government, the Italian organisation in charge of 'monumental heritage' that has an interest in the tomb, and the health authorities that have to be informed of any proposal to disturb a corpse. On top of this, Galluzzi adds that the project will cost "hundreds of thousands of pounds," which has yet to be raised.



One of Galileo's fingers was taken from his remains in 1737. On display at the Palazzo Strozzi, Florence, there isn't enough DNA left to make an analysis



▲ Villa Il Gioiello in Florence: the home of Galileo

► been stated for centuries that Galileo damaged his eyesight by looking at the Sun through a telescope, but this is now disregarded. People have always known that it is unsafe to look directly at the Sun with the naked eye, let alone a telescope. We know that Galileo observed sunspots by using a telescope to project the Sun's image onto a screen; a technique still used by amateur astronomers today. However, Galileo certainly didn't have 20/20 vision. Although his eyes weren't damaged by sunlight, they were nonetheless unusual and defective (see 'Looking through Galileo's eyes', left).

Peter Watson, a British ophthalmology professor formerly at Moorfields Eye Hospital in London, points in evidence to the many existing portraits of Galileo. They agree that his eyes pointed in different directions. In addition, Galileo himself wrote that his left eye had never been as powerful as his right. His left eye was very shortsighted, while his right eye saw more or less normally.

## “It took the Vatican over 300 years to admit that it had been on the wrong side of the argument”

Watson says: "About four per cent of the population have this condition. People who have it can still navigate because the good eye uses clues such as parallax and shadows to tell how far away things are." For Galileo, this disability was an advantage. He was able to look through the telescope with his right eye and simultaneously draw what he saw using the left eye, focused a few tens of centimetres away. Galileo had ample chance to build binoculars but never saw the need.

As well as his scientific discoveries, there is another reason why Galileo is worthy of being commemorated by the International Year of Astronomy. Late in life, in the 1630s, he had a notorious confrontation with the Pope and the

Catholic hierarchy in Rome, based on his refusal to back down from the Copernican idea that the Earth is not the centre of the Universe. It took the Vatican over 300 years to admit that it had been on the wrong side of the argument. The case has been discussed ever since as one of the founding events of our modern evidence-based scientific view of the world.

Chapman points out that although Galileo was a devout Catholic this episode made him a hero to Protestants for centuries. He adds that it was emphatically a problem that Galileo brought upon himself. "He was a controversialist," says Chapman, "and the trouble he got into was caused mainly by his using abusive language

at the Vatican." His behaviour was more or less like swearing at the Queen, something you could not hope to get away with. "One writer has said he was a martyr who brought his own firewood," says Chapman.

Farnelo also sees a deeper analogy between Galileo's intellectual world and our own. We are now living in an era when telescopes like Hubble and Planck are looking at the origin and fundamental nature of the Universe from space. At the same time, scientists at CERN and other laboratories are seeking the basic laws that control matter on a minute scale. Farnelo believes that Galileo, placed in our era, would have understood better than anyone the way in which the ideas that drive these two missions are converging to give a single theory of the Universe.

### Leaps and bounds

In addition, Galileo would have been staggered at the progress that telescopes have made since he first heard of a strange Dutch invention. The typical amateur astronomer today owns a telescope or a pair of binoculars that gathers more light, delivers more magnification and shows a clearer image of the sky than he ever saw. He never imagined a near-perfect means of recording the sky (photography didn't revolutionise astronomy until the 19th century), or of viewing the Universe in wavelengths other than light, a technology that arrived in the 20th.

It is hard to say what aspect of modern astronomy would have amazed Galileo the most. But perhaps exoplanets would have been a contender. Despite his staunch Catholicism, he argued with the Church over whether the Earth was just another planet orbiting the Sun. The discovery that many of the faint stars of the night sky have planets of their own is testament to his incredible work. ☛

### FIND OUT MORE ►

► *Galileo, The Medici and The Age of Astronomy*, an exhibition presented by watchmaker *Officine Panerai*, is on at *The Franklin Institute, Philadelphia* and in *Stockholm* in *October*

► *Galileo. Images Of The Universe From Antiquity To The Telescope* is at the *Palazzo Strozzi, Florence*, this month