

# Galileo

Astronomer, Anti-anti-Copernican

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# Galileo Galilei

- 1564-1642
- Born in Pisa, same year as Shakespeare.
- Son of a prominent musician and music theorist.
- Enrolled at University of Pisa to study medicine, 1581
  - Hated it.



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# Galileo, the young mathematics whiz

- While supposedly studying medicine, Galileo became interested in mathematics and began to study it with a tutor
  - Left university without a degree in 1585
- Appointed *professor of mathematics* at Pisa in 1589 at age of 25
  - Salary 1/10 of that of a professor of philosophy
  - Galileo loathed philosophers

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## Leaning Tower Experiment

- Galileo gathered a group of academics and townspeople at the Leaning Tower of Pisa to witness a demonstration.
- He dropped metal balls of different weights simultaneously from the tower to demonstrate that Aristotle's assertion that they landed at different times was wrong



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## Mathematician in the 16<sup>th</sup> century

- The profession of mathematician was just evolving in the 16<sup>th</sup> century and had two different senses:
  1. *Calculating magician* – like Kepler, whose job included casting horoscopes and uncovering the secrets of nature
  2. *Precision engineer* – someone who knew how to aim the cannon, and could make precision instruments. In short, an engineer. This is what Galileo was.

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## Galileo proves his worth

- Galileo set up a workshop at the University of Pisa where he invented, made, and sold instruments for industrial and military purposes.
  - With this he supplemented his meagre income and developed a reputation as a fine craftsman and accurate mathematician.

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## Galileo gets better job

- Galileo parlayed his reputation at Pisa into a better job.
- He was appointed professor of mathematics at the *University of Padua* in 1592 for 3 times his Pisa salary.
  - Padua was *the* science university of the day.
  - Light teaching duties: Euclid and Ptolemy
- Galileo won over to *Copernican theory* because it could explain the **tides**.

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## The Telescope

- Spyglass invented in Holland in 1609, magnification of 3 times
- Galileo sets out to make his own telescope
  - First makes an instrument with 8x magnification
  - Then 20x
  - Ultimately 30x
- Sold telescopes to Venice merchants to spot ships at sea coming into harbour



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## Galileo, the Astronomer

- Eventually, Galileo turned the telescope on the heavens to see if they would look different.
- To his amazement, they did, and he saw many things he could not see before.

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## The Starry Messenger

- In 1610, Galileo wrote and published a short pamphlet called *Siderius Nuncius* (*The Starry Messenger*) in which he reported his amazing findings.

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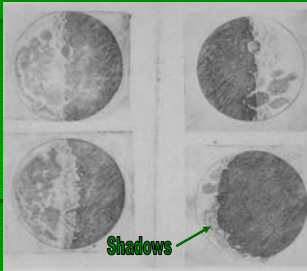
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## Mountains on the Moon

- Galileo found that the Moon was not a smooth, perfect sphere, but had an uneven surface.
  - Mountains as large as the largest on Earth (that Galileo knew of).
  - Determined by measuring shadows cast when the Sun shone at different angles.



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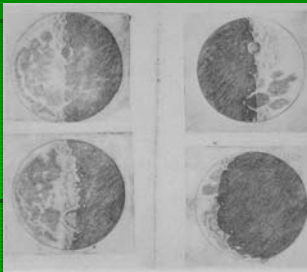
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## Earthshine

- Galileo found that with a telescope he could make out some features on the dark side of the moon, which was lit by light reflected from the Earth.



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## The Medicean "Stars"

- After repeated nights of observing Jupiter, Galileo noticed that there were four "stars" that appeared to circle round it.

These he called, in honour of the Duke of Tuscany, "Medicean Stars."

- They were satellites of Jupiter, showing that the Earth was not the only planet with a "Moon."

	East	West
▪ Jan. 7, 1610	* * *	O *
▪ Jan. 8		O * * *
▪ Jan. 10	* * *	O
▪ Jan. 11	* * *	O
▪ Jan. 12	* * *	O *
▪ Jan. 13	* * *	O * * *
▪ Feb. 26 early	* * *	O *
▪ Feb. 26 later	* * *	O *
▪ Feb. 27	* * *	O * * *
▪ Feb. 28	* * *	O *
▪ Feb. 28 later	* * *	O *
▪ March 1	* * *	O

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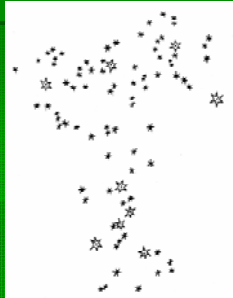
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## Many More Stars

- Galileo saw that the "Milky Way" was not just a smear in the sky, but huge clusters of stars.
- The familiar constellations were surrounded by many stars not visible without the telescope. (Right: Orion's belt and sword as seen by Galileo.)



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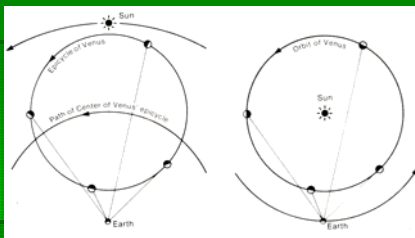
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## The Phases of Venus



- Copernican theory implied that Venus should show phases, like the Moon. They were not visible with the naked eye.
- Galileo could see them with the telescope.

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## Sun spots

- In a later work, Galileo reported that he could see spots on the Sun.
- Also, the Sun rotated, just like the Earth (in the Copernican theory).
- Galileo had become a committed Copernican.

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## Evidence for Copernicus' theory from the telescope

- Instead of the heavenly bodies being perfect, smooth, and spherical and able to reflect light, while the Earth is rough and uneven, Galileo showed that the moon has a rough surface and the Earth reflects light onto the Moon. Even the Sun has blemishes and turns, like the Earth.
- The Earth is not the only planet with a satellite.
- There is much more to the heavens than can be seen without a telescope, suggesting the heavens are vast (as Copernicus stated).
- The phases of Venus provide visible confirmation for Copernicus.

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## Galileo takes another job

- The fame that came to Galileo from *The Starry Messenger* enabled him to move from the University of Padua to a full-time research position.
- Galileo accepted an offer to become the Imperial Mathematician to the Duke of Tuscany in Florence in 1610.
  - No teaching, just research.

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## Galileo, the Anti-anti-Copernican

- Galileo, armed with evidence from the telescope, took on the Scholastic Philosophers, who defended Aristotle and Ptolemy dogmatically.
- Galileo, a devout Catholic, began to *undermine Aristotle* at the privileged interpreter of the Bible.

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## Letter to the Grand Duchess Christina

- 1615
- The Bible uses *figurative language*
  - Joshua commanding the Sun to stand still—merely a convenient expression.
  - Anyway, literally, Joshua should have commanded the celestial sphere to stop turning.
- Galileo objected to taking quotations out of the Bible, out of context, and believing them to be statements about the natural world.

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## Galileo instructed not to "hold or defend" the Copernican view

- This was the Counter-Reformation.
  - The Catholic Church was most concerned about the Protestant threat to Papal authority.
  - No allowance for different points of view.
- In 1616, Galileo was enjoined *not* to hold or defend the view that the Earth moves and is not in the centre of the world.
  - Galileo interpreted this as meaning that he was not to say that Copernicus is *correct*.

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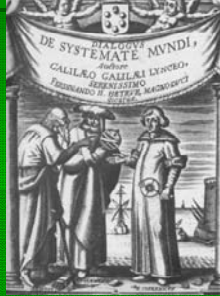
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## Dialogue Concerning the Two Chief World Systems

- 1632
- Platonic style dialogue
- Explanation of the *Tides*, from Copernican and Ptolemaic viewpoints
- --Three characters:
  - Salviati = the Copernican
  - Sagredo = impartial
  - Simplicio = Aristotelian



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## The Dialogue, 2

- *Dialogue* systematically refutes every tenet of Aristotelian cosmology.
  - Simplicio's trump card played on the last page: God can do what He wants.
- Galileo called before *Inquisition*.
- 1633, condemned to life imprisonment for vehement suspicion of heresy.

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