

Galileo Galilei

The Father of
Modern
Science

Peter Hertel

The
environment

Global
Religion

The state of
science

Renaissance
Kepler
Copernicus

Early years

The telescope

Astronomy

And yet it
moves!

Later years

The scientific
method

The age of
enlightenment

Galileo Galilei

The Father of Modern Science

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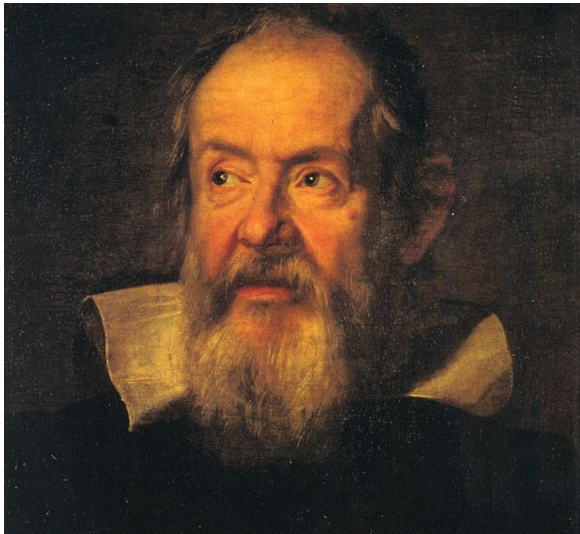
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Portrait of Galileo by Sustermans (Uffizi, Firenze, 1636)

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His signature

- Galileo was born in 1564 and died in 1642
- He lived for 78 years
- In his lifetime
- China (then still the richest country on this globe) played no role, it had, besides a few commercial contacts, no connection with the outside world.
- The same applies to India or Japan.
- Relations with the Americas and Africa were purely colonial
- For Europeans the world was Europe, in particular Western, Northern and Southern Europe without Russia or the Balkan
- There was just one competitor: the Ottoman Empire.

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The Ottoman Empire

- This European microcosm had one institution in common: the catholic church or its offsprings.
- Martin Luther – who died in 1546 – and others had defied the power of the Pope as head of the catholic church. They founded protestant churches.
- The Ottoman Empire was mostly islamic, but tolerant towards other religions. Christians in Turkey, Syria, and Egypt had to pay an extra tax for being protected by the Sultan.
- But there were also many jewish people.
- They had been expelled from Spain to the Netherlands after the last moorish stronghold fell in 1492, the Emirate of Granada.
- Rome, where the pope resided, was again the center of the world.
- Latin was the language of the church and of learned people

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Martin Luther who questioned the power of the Roman pope over the soul of men. (Lukas Cranach the elder, Museum of the City of Regensburg, Germany)

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The last Emir on Western European soil went into immigration.

- Around 1400 a new liberty of thought began to spread from Florence throughout western Europe
- There are a multitude of interrelated causes
- Interest in classical philosophical text which were transmitted by refugees from Constantinople
- which was conquered by the Turks in 1453
- Printing books with movable letters on paper (1453: Gutenberg bible)
- Diminished church influence
- Because of cheap books, increase in the level of education
- In short, non-christian or non-church approved texts were available and regarded as valuable

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Book printing at Gutenberg's workshop.

- At Galileo's time and before, nights were dark, only the moon, planets, stars and the milky way were visible
- Today, you have to go to a desert in Mongolia or to an island like La Palma to see Galileo's sky
- The slow traffic at sky interested many people
- because they felt: there is something outside.
- Tycho de Brahe in Denmark made precise measurements of the planet's position
- Johannes Kepler in Austria tried to fit these data – which he had stolen.
- (1) The orbits of the planets are ellipses with a common focus point, the position of the sun.
- (2) A line joining a planet and the Sun sweeps out equal areas during equal intervals of time.
- (3) The square of the orbital period of a planet is proportional to the cube of the semi-major axis of its orbit.

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Johannes Kepler, 1571–1630, German astronomer who discovered the laws of planetary motion

- Nikolaus Kopernikus, 1473–1542, was a Polish-German *polymath*, a learned person in many disciplines.
- A student at the universities of Kraków, Bologna, Padova, and Ferrara
- of medicine, mathematics, economy, astronomy and church (canonical) law
- Author of the book *De revolutionibus orbium coelestium*
- *On the movements of the heavenly bodies*
- Since he held a position in the catholic church
- he never published it
- until a few days before his anticipated death in 1543.
- Copernican revolution: Heliocentric view.

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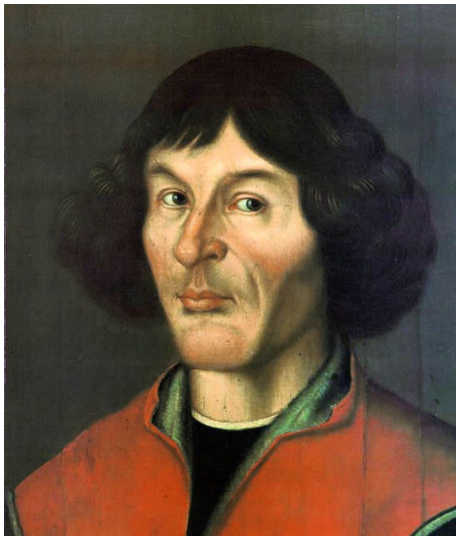
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Nikolaus Copernicus, 1473–1542, published only a few days before his death his main work *De revolutionibus orbium coelestium* so that he could not be prosecuted by the ill-famed *Inquisition*.

- Born 1564 in Pisa (Tuskany)
- His father, a professional musician, publishes *Dialogo della musica antica et moderna* (1581)
- Galileo studies medicine at the university of Pisa but left it without degree
- Attends course on mathematics by Ricci
- Privat teacher and tutor
- Professor of Mathematics at Pisa, 1589
- *De motu*, never published
- Professor of Mathematics at Padua University, 1592 stayed there for the next 18 years

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Leaning tower, cathedral and baptisterium

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Swinging dome lamp

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Pisa airport

- Invention of the refractor telescope in the Netherlands (Frans Lippershey, 1606)
- Later Galilei heard about it and improved it
- Initially 4 x magnification, later 30 fold
- Galilei sketches the moon surface with mountains, craters etc.
- discovers the four biggest moons of Jupiter (1610)
- Kepler asks him for a telescope, but Galileo responded "that he had no more than his own and no time to build a new one"
- Discovers phases of Venus
- Discovers sun spots and that they move as if the sun would rotate

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Early Dutch telescope

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Galilei shows his telescope to the Doge of Venice

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Jupiter and its Galileian moons

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The phases of venus

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- Old thinking: there is a sphere of invisible crystal on which God moves the star and planets
- But Jupiter's moons vanished behind it
- Space is infinite!
- The phases of Venus prove that the earth is not the center of the universe. Copernicus and Kepler are right.
- Not even the sun is perfect, it has spots. And they change.
- 1604 supernova, discovered by Kepler, showed no parallax. It must be a bright distant star.
- Aristotle was wrong: there are changes in the sky

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The Scarabaeus was a holy animal in Egypt. It moves the sun over the sky.

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- The teaching of Aristotle was the official philosophy of the church
- Questioning his authority meant questioning the authority of the church!
- If the church was wrong only in one point, it could also be wrong in others
- In particular, the earth (with Rome as its center) was the center of the university
- Galileo had, by propagation the heliocentric system, and defying Aristotle,
- questioned the authority of the church
- *Dialogo sopra i due massimi sistemi del mondo*
- He was first warned and later summoned by the inquisition

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Aristotle's (384 - 322 B.C.) original texts in Greek were lost, Arab translation came to the west after the fall of Constantinople.

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DIALOGO

DI
GALILEO GALILEI LINCEO
MATEMATICO SOPRAORDINARIO
DELLO STUDIO DI PISA.

*E Filosofo, e Matematico primario del
SERENISSIMO*

GR.DVCA DI TOSCANA.

Doue ne i congressi di quattro giornate si discorre
sopra i due

MASSIMI SISTEMI DEL MONDO
TOLEMAICO, E COPERNICANO;

*Preponendo indeterminatamente le ragioni Filosofiche, e Naturali:
tanto per l'una, quanto per l'altra parte.*



CON PRI

VILEGI.

IN FIRENZA, Per Gio:Batista Landini MDCXXXII.

CON LICENZA DE' SUPERIORI.

Dialogue Concerning the Two Chief World Systems.

- Galileo was accused or suspected of heresy
- that is, deviation from the official teaching of the church
- The real reason was fear of social disruption
- Shortly before Giordano Bruno was found guilty of heresy and publicly burnt
- because he maintained that the sun was just one of millions and millions of stars and that there were other worlds with intelligent life
- Confronted with this, Galileo had to swear that his opinions were erroneous
- Therefore he was sentenced "only" to life-long prison
- which was changed to life-long home arrest
- His book *Discorsi* was put on the list of prohibited books
- Folklore: Eppur si muove!

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Memorial and site where Giordano Bruno was burnt at the stake.

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Galileo at the inquisition.

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- Bodies are lazy, if not forced, they retain their state of motion
- In todays words: inertial frames
- Physical laws are the same at firm land or on a moving boat
- There is not absolute motion, only relative motion matters.
- In todays words: Physical laws have to be invariant under Galilei transformations
- Summarized in *Dialogues Concerning Two New Sciences*, in Italian, namely mechanics and properties of matter (1638).
- He than was almost blind (observing sun spots?) and 74 years old.

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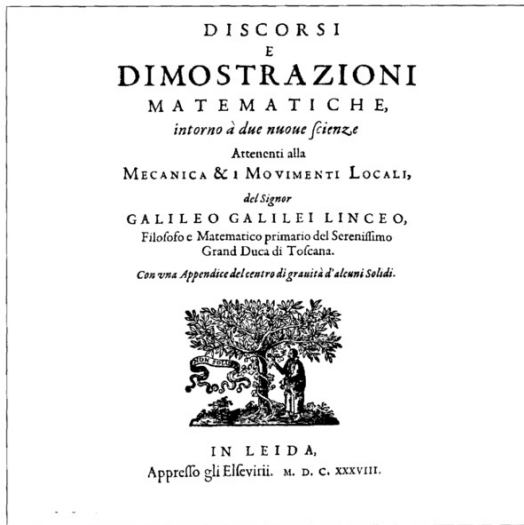
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Note that this book was not published in Italy, but in the Netherlands (Leijden) by Elsevier.

- Galileo's printed work and his reasoning introduced new concepts:
 - - rely on observation only
 - - if you have a question on the nature of things, ask nature
 - - perform an experiment
 - - studying old texts may help, but never is a proof
 - - not even authorities like Aristotle or the church
 - - reason instead of belief
 - *Measure, what can be measured, and make measurable, what cannot yet be measured* (Bertold Brecht in his famous theater play *The Life of Galileo*)
- This, in short, is the scientific method which proved so successful during the last period of 400 year.

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- This is an essay on the onset of modern science
- Galileo is just one representative
- His many discoveries of physical phenomena have not been described in detail
 - for instance the parabola for free fall
 - its thermometers
 - the inclined plane for slowing down acceleration and measuring the linear increase of speed with time
 - his discussion of tides
 - and much more
- It is the view on space, relativity and the method of gaining knowledge which made him the father of modern science.

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Inclined plane

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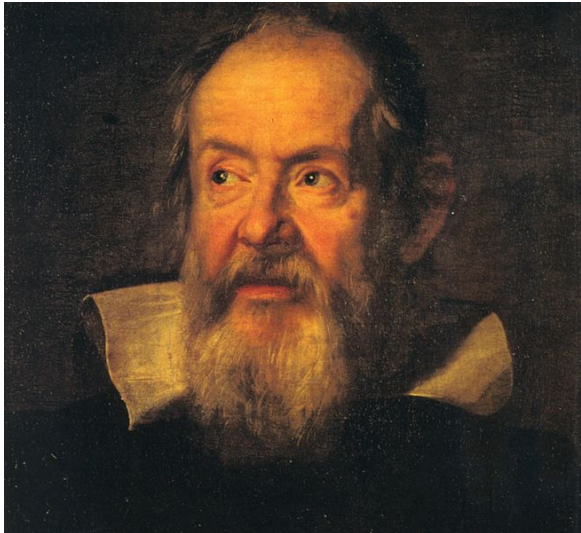
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Portrait of Galileo by Sustrmans (Uffizi, Firenze, 1636)