Astronomy 350L

(Fall 2006)

The History and Philosophy of Astronomy

(Lecture 11: Galileo I)

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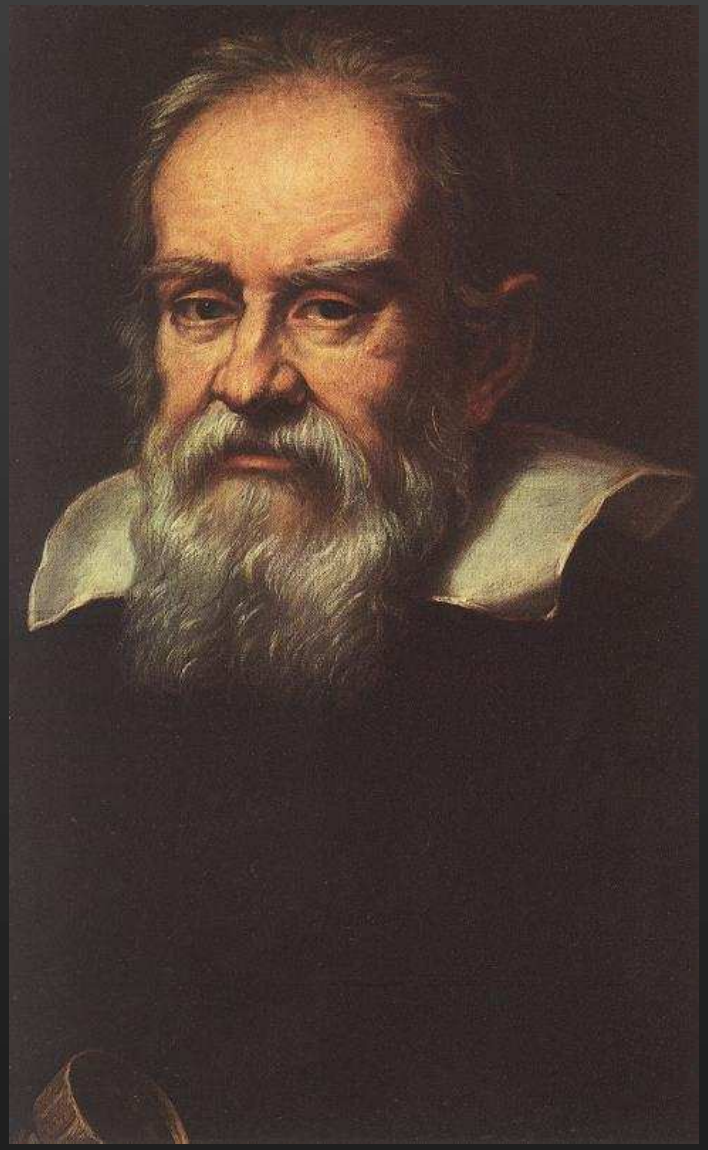
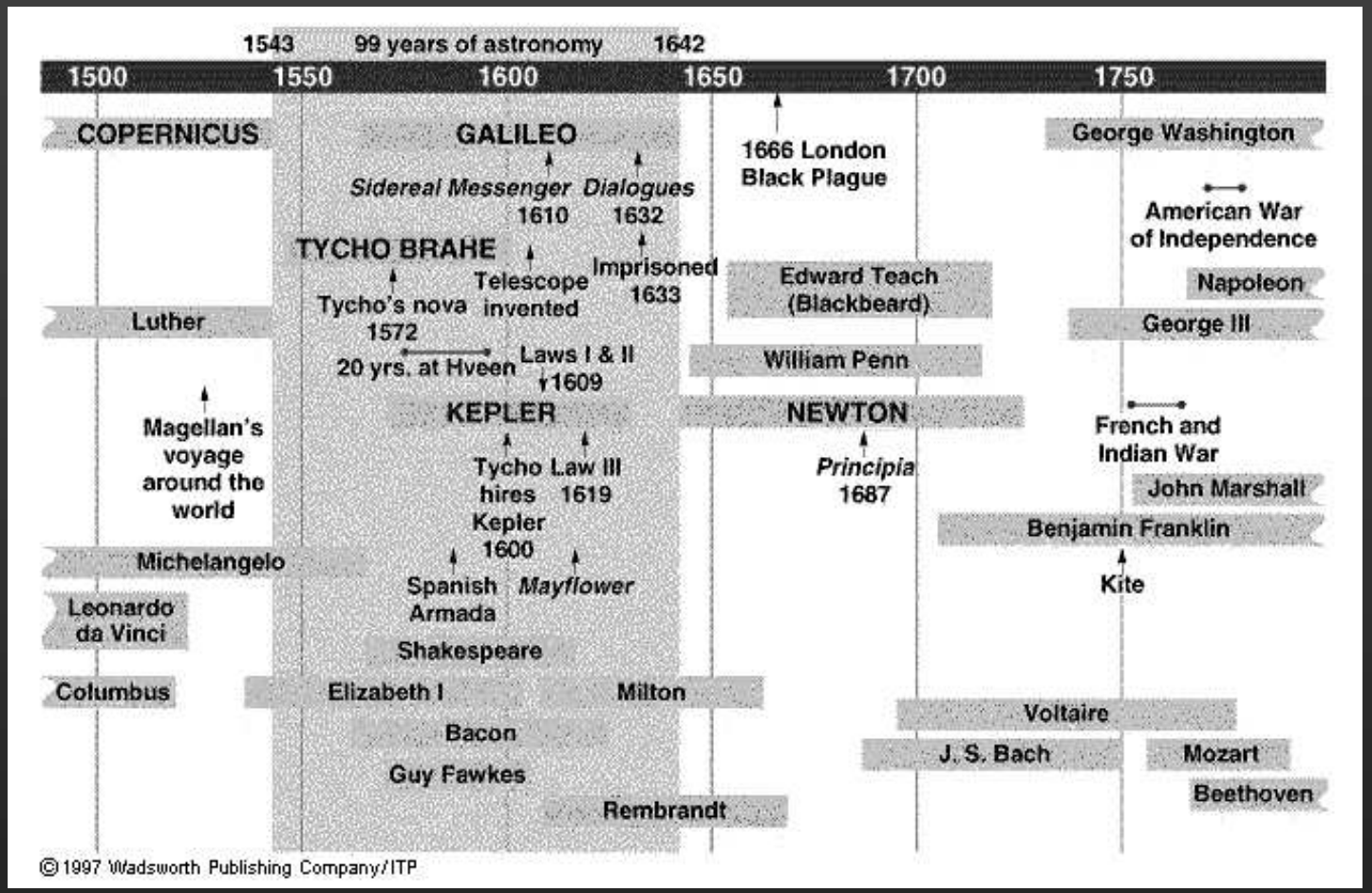
The University of Texas at Austin

Galileo Galilei: The First Scientist



- 1564 (Pisa) – 1642 (Arcetri)
- founder of modern physics
  - law of inertia
  - law of free fall
- first astronomer to use telescope
- The “Trial of Galileo” (conflict with Catholic Church)

Galileo: Timeline and Context



- between Copernicus and Newton
- contemporary of Kepler and Tycho

Born in Pisa (1564)

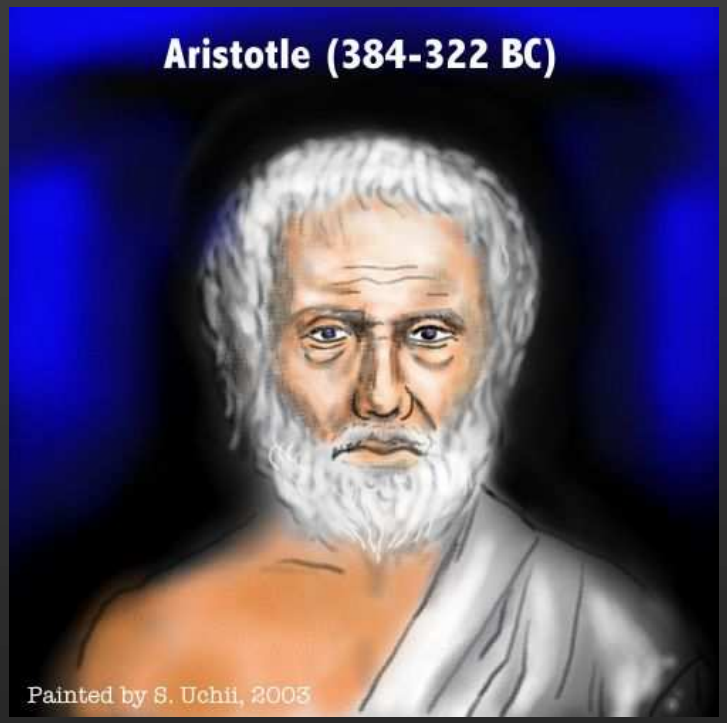
- Pisa: part of Grandduchy of Tuscany
- University town

Professor in Pisa (1589-92)

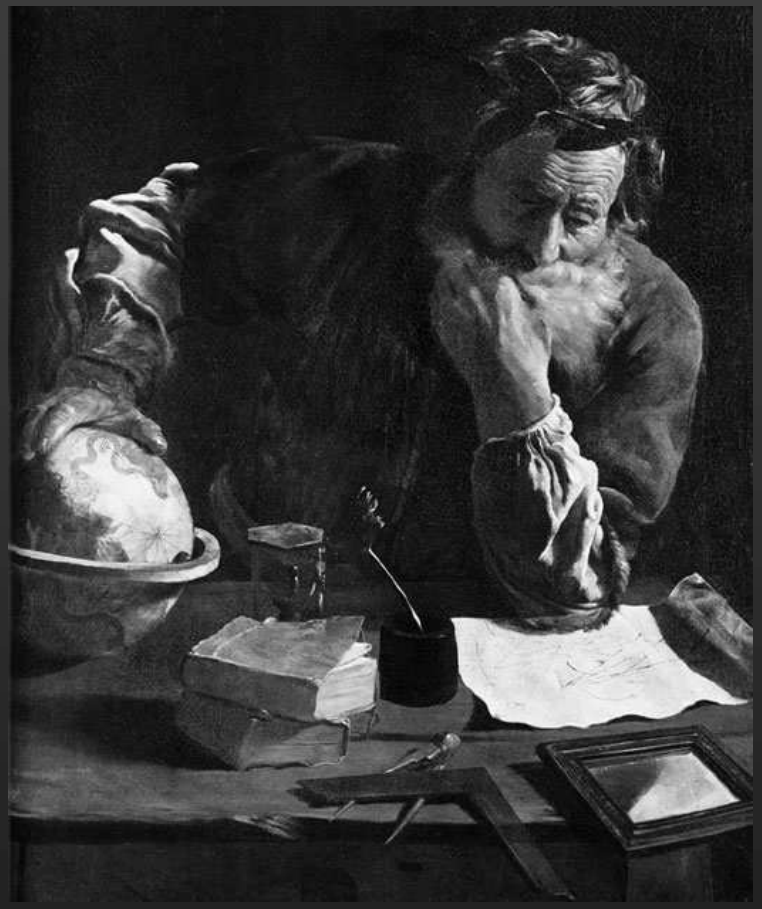
- Professor of mathematics (badly paid)
- New laws of motion (inertia, free fall)

Philosophy of Science: Two Traditions

1) Aristotle



2) Archimedes



(287-212 BC)

Archimedes of Syracuse (287 – 212 BC)

"Give me a place to stand,
and I will move the Earth"

- eminent engineer, mathematician, and scientist!

Philosophy of Science: Two Traditions

1) Aristotle

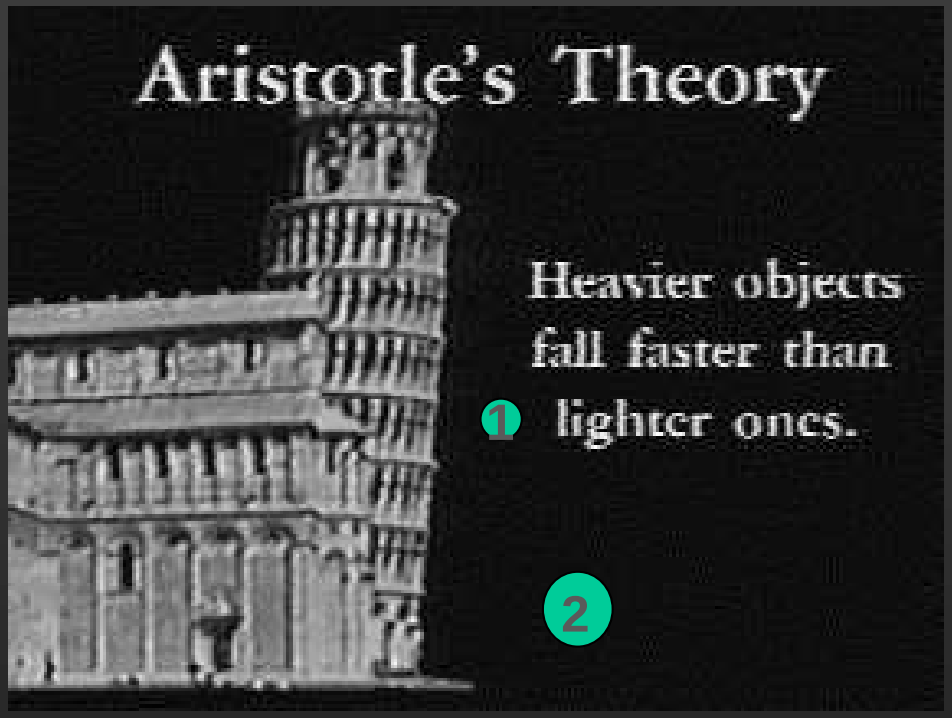
- philosophy most important
- mathematics secondary
- “laws” of nature based on common sense and intuition
- unlimited scope
- truth by arguing its plausibility
- search for causes

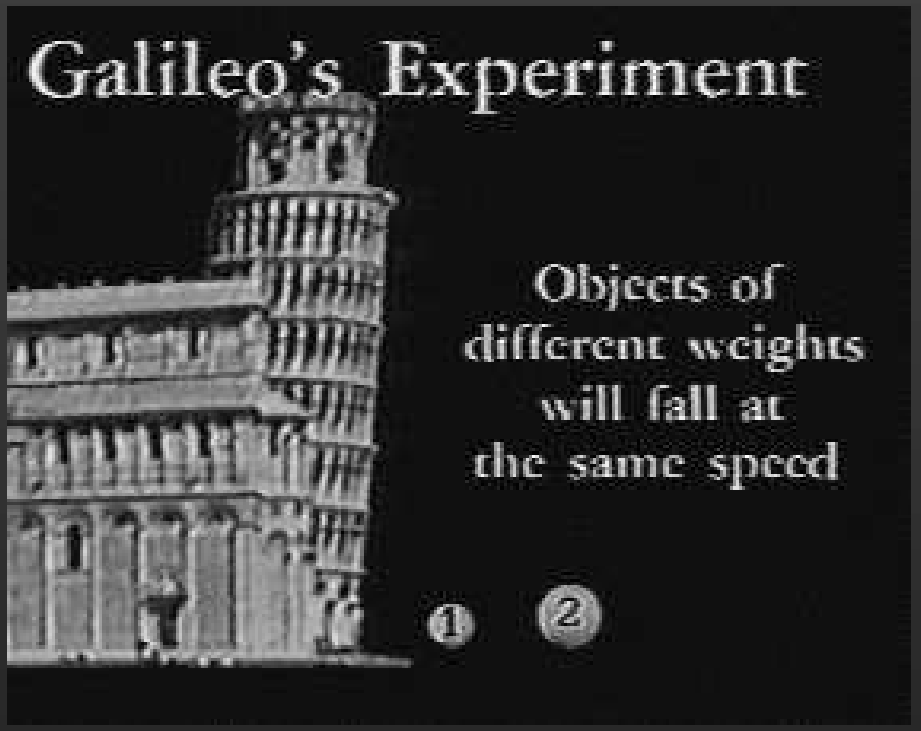
2) Archimedes

- physics most important
- mathematics essential
- laws of nature based on simple mathematical principles
- limited scope
- truth by experience (carry out experiments)

- Galileo strongly follows Archimedean tradition!

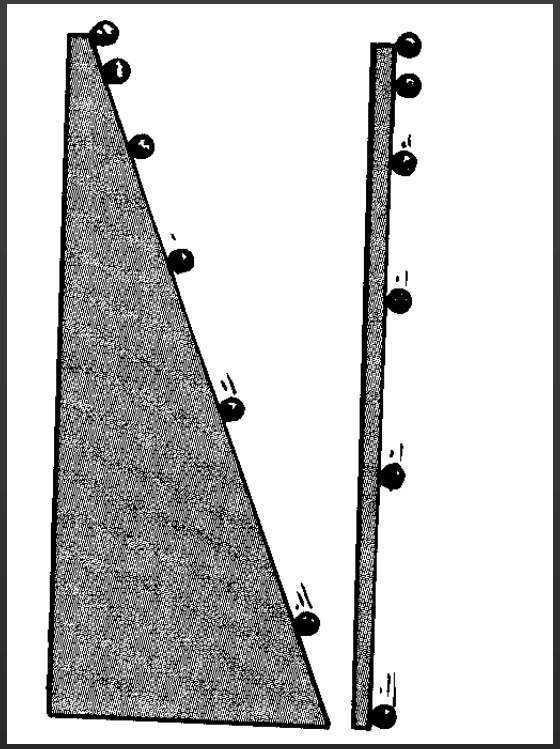
Professor in Pisa: Laws of Free Fall

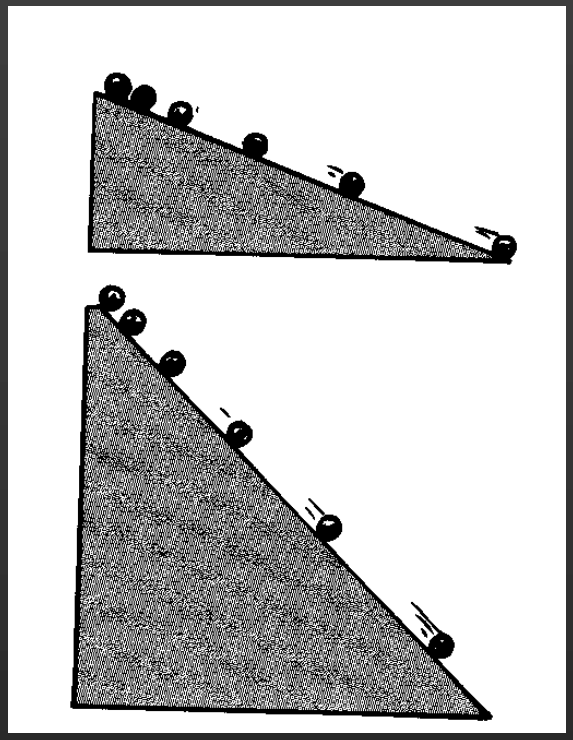




- Galileo: If friction from air can be ignored, all objects reach ground at same instant, with the same speed ⟶ constant acceleration ("one g")

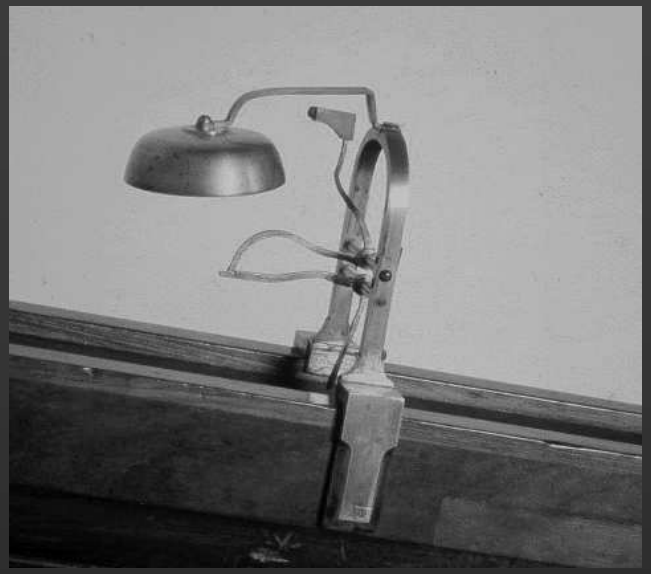
Professor in Pisa: Laws of Free Fall





- Galileo’ s trick: Slow down gravity!
- Experiment with inclined planes!

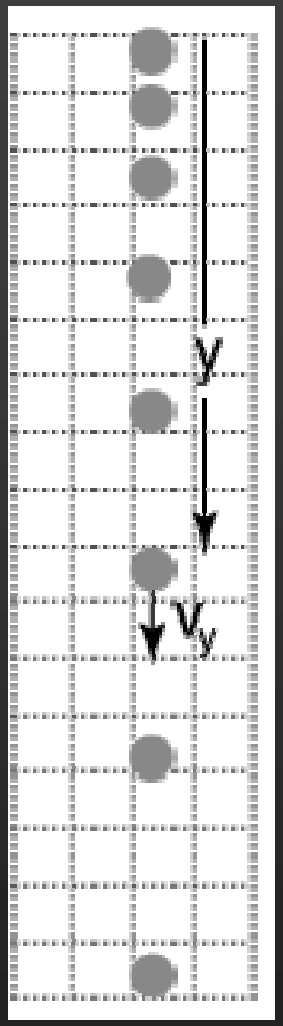
Professor in Pisa: Laws of Free Fall



- Galileo didn’t have precise clock
- Idea: Use little bells!

Professor in Pisa: Laws of Free Fall

Earth's Gravity (1 g)

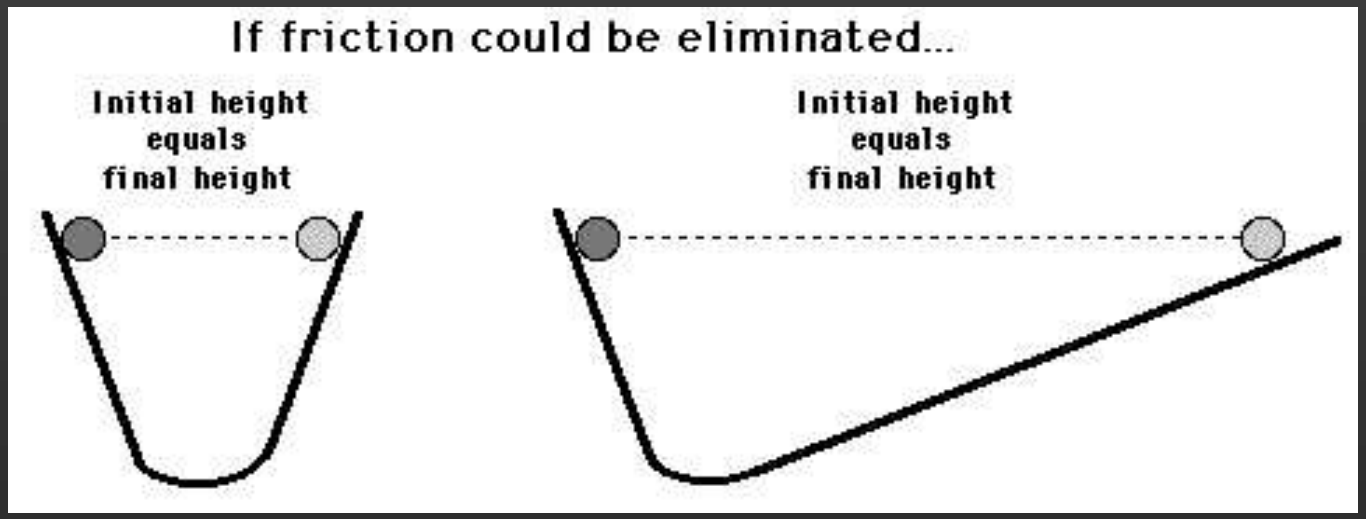


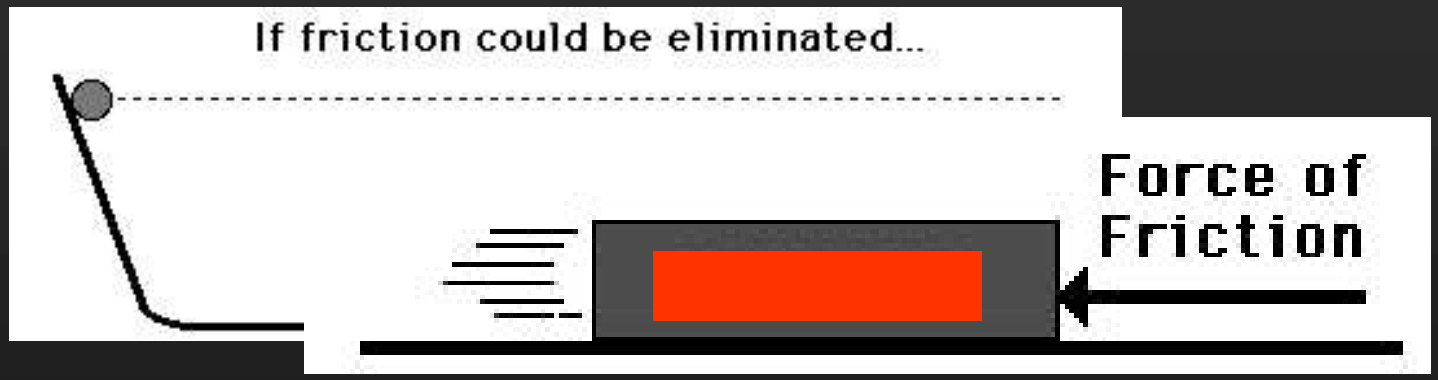
Galileo's Law of Free-fall

$$y = \frac{1}{2} g t^2$$

Professor in Pisa: Law of Inertia

Gedanken Experiment (thought experiment)

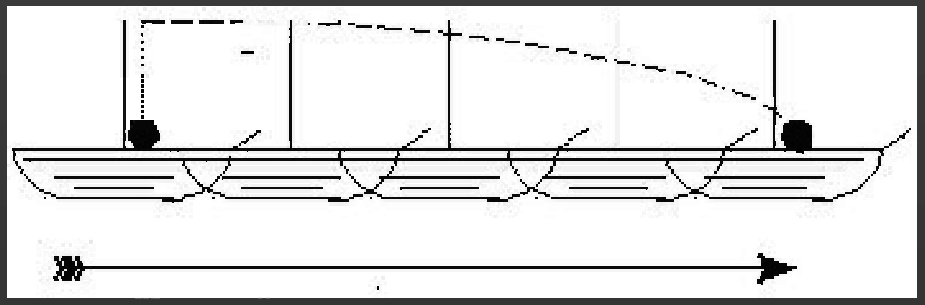




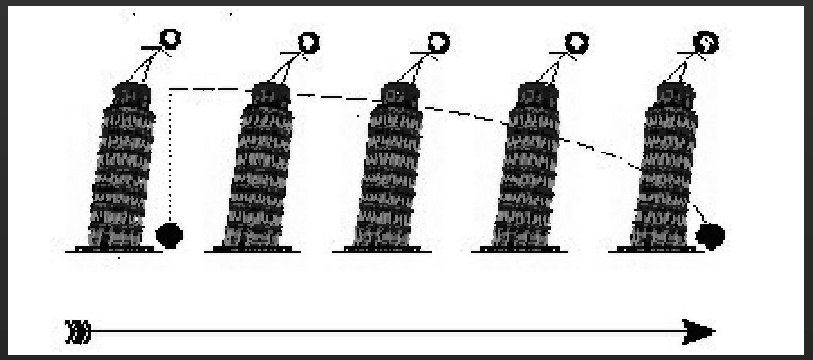
- Law of inertia: Bodies remain at rest or in a state of linear uniform motion, unless acted upon by force!

Law of Inertia: Implication for Astronomy

moving ship:

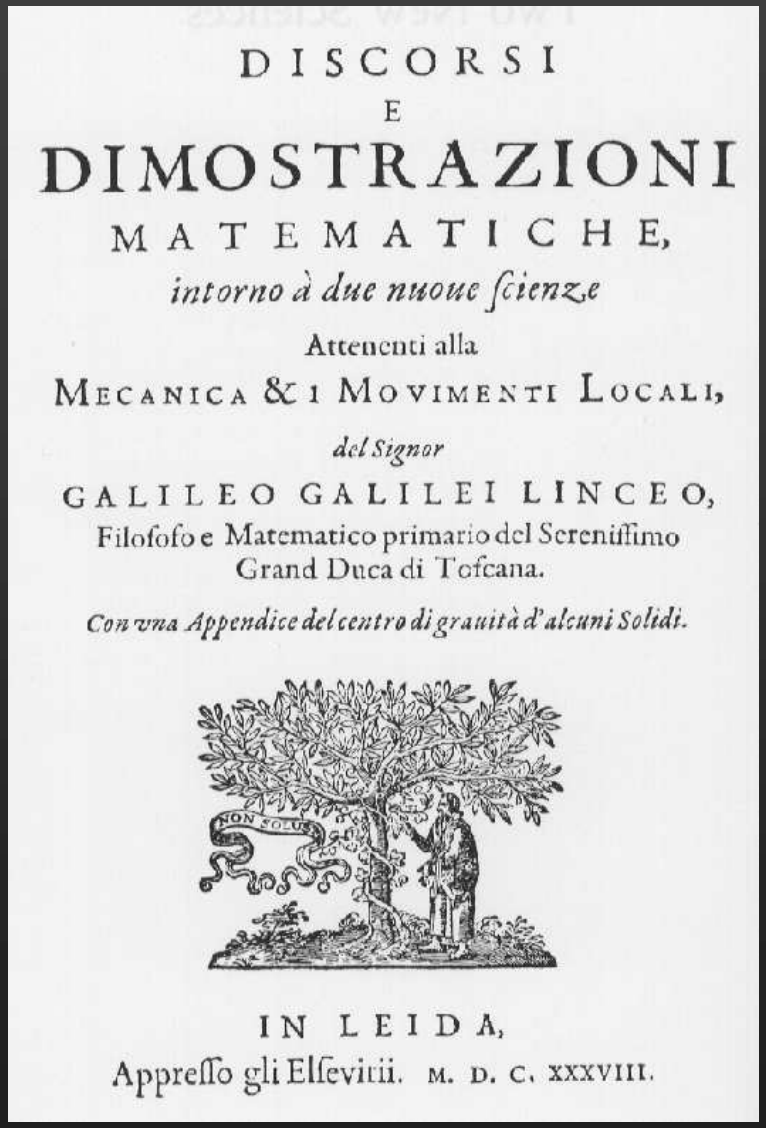


moving Earth:



- Motion of Earth is entirely plausible!
- Aristotelian theory of motion is wrong!

Great Summary: Discorsi (Two New Sciences)



DISCORSI
E
DIMOSTRAZIONI
MATEMATICHE,
intorno à due nuoue ſcienze
Attenenti alla
MECANICA & I MOVIMENTI LOCALI,
del Signor
GALILEO GALILEI LINCEO,
Filoſofo e Matematico primario del Sereniſſimo
Grand Duca di Toſcana.
Con vna Appendice del centro di grauità d'alcuni Solidi.

IN LEIDA,
Appreſſo gli Elſevirii. M. D. C. XXXVIII.

- *Discorsi*
  (The Two New Sciences, 1638)
- first modern scientific textbook
- laws of motion (inertia, free fall)
- sets out scientific method

Galileo's role in the Scientific Revolution

Newton (1642-1727)
- dynamics
- law of gravity

"Standing on the shoulders of giants"

Kepler (1571-1630)
- celestial motion
- 3rd Law

Galileo (1564-1642)
- laws of free-fall
- principle of inertia

Professor in Padua (1592-1610)

- Professor of mathematics (much better paid)
- Padua: one of most prestigious and oldest universities in Europe

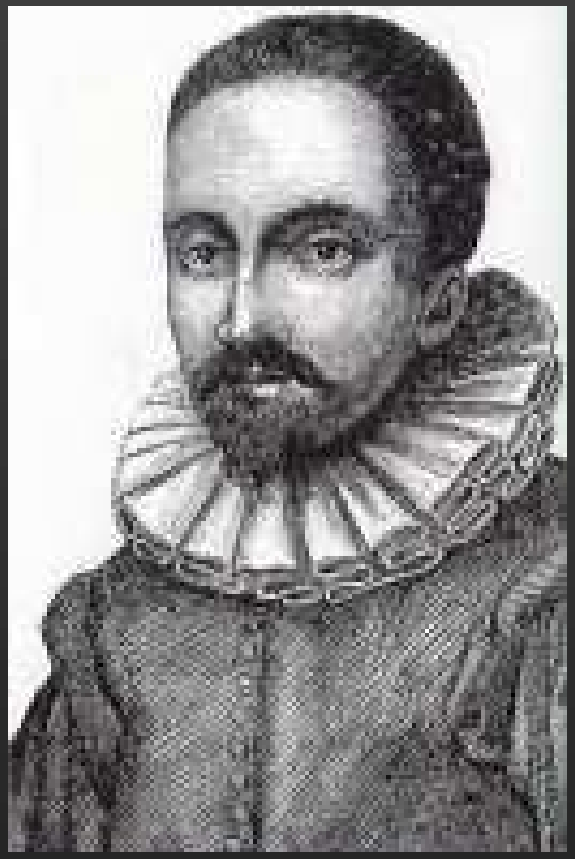
Padua and Venice (1592-1610)

- Padua: part of great free Rebublic of Venice
- Galileo’s Golden Time

Padua and Venice: Personal Life

- Longterm relationship with Marina Gamba (Venice)
- 3 daughters, 1 son
- “Galileo’s Daughther”: Sister Maria Celeste

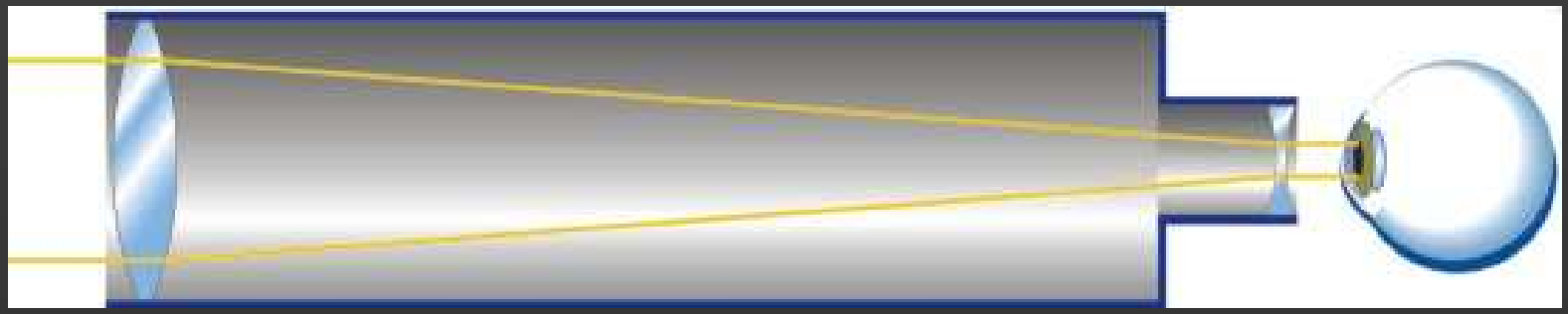
The Invention of the Telescope (1609)



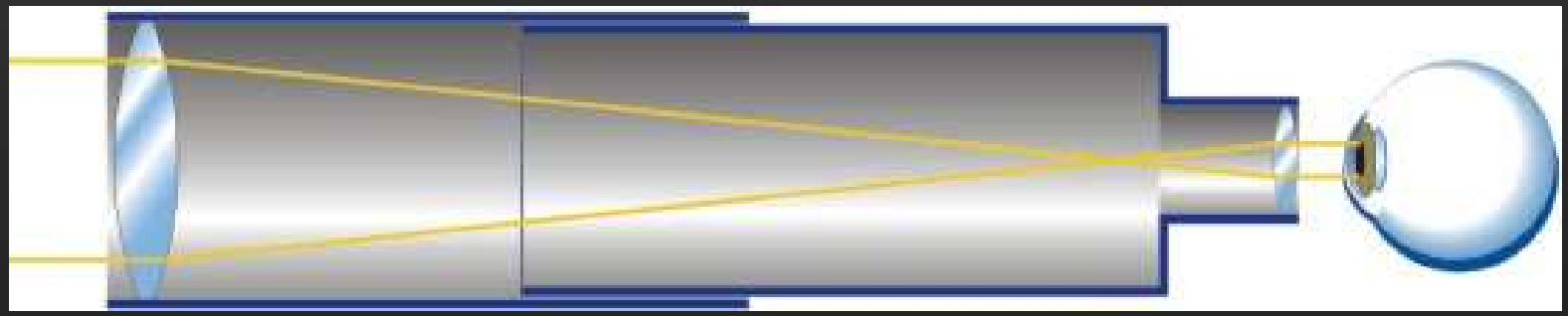
Hans Lippershey

- Telescope was invented in the Netherlands

Invention of the Telescope: Basic Idea



Galilean Design (convex + concave)



Keplerian Design (convex + convex)

- Combine two curved lenses (convex or concave)!

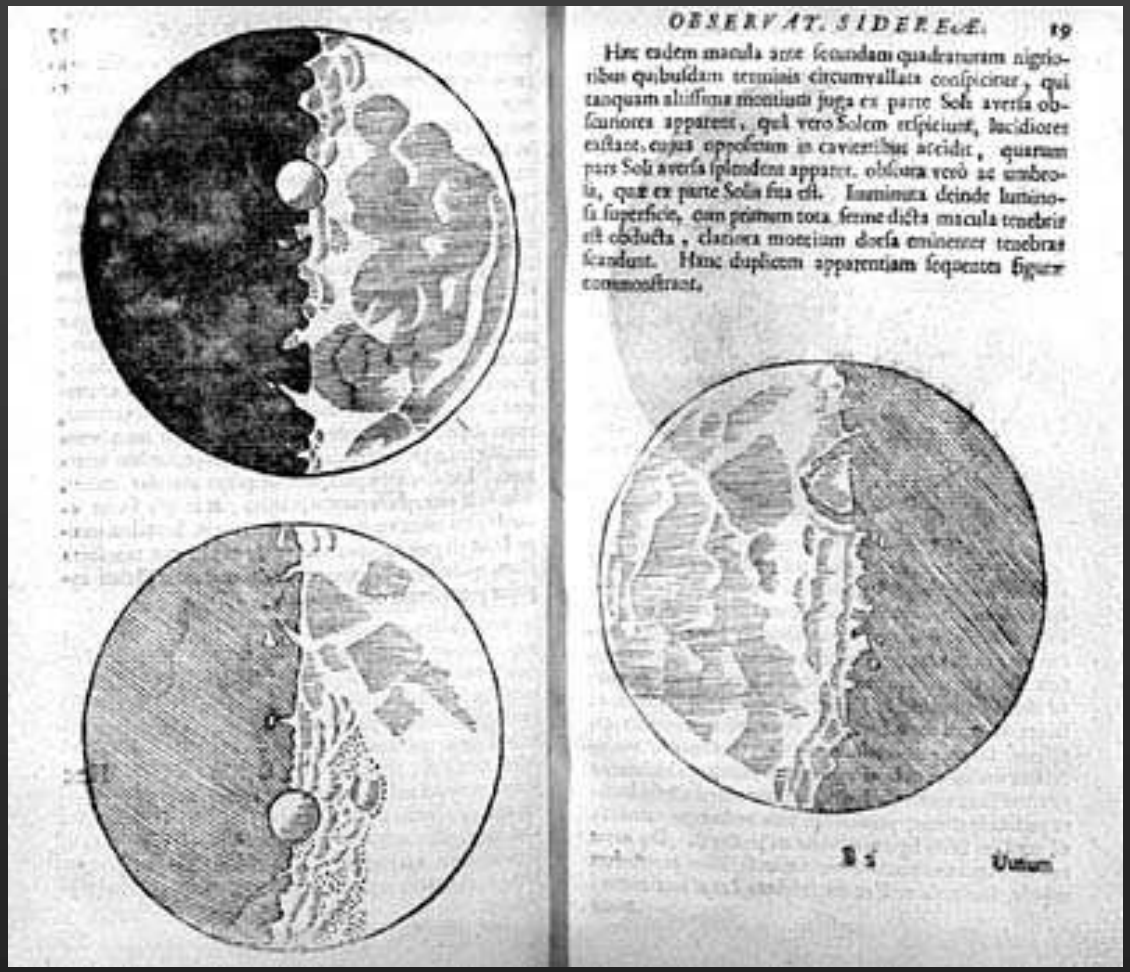
Galileo’s Discoveries with the Telescope

- Galileo constructs his own telescope!

Galileo’s Discoveries with the Telescope

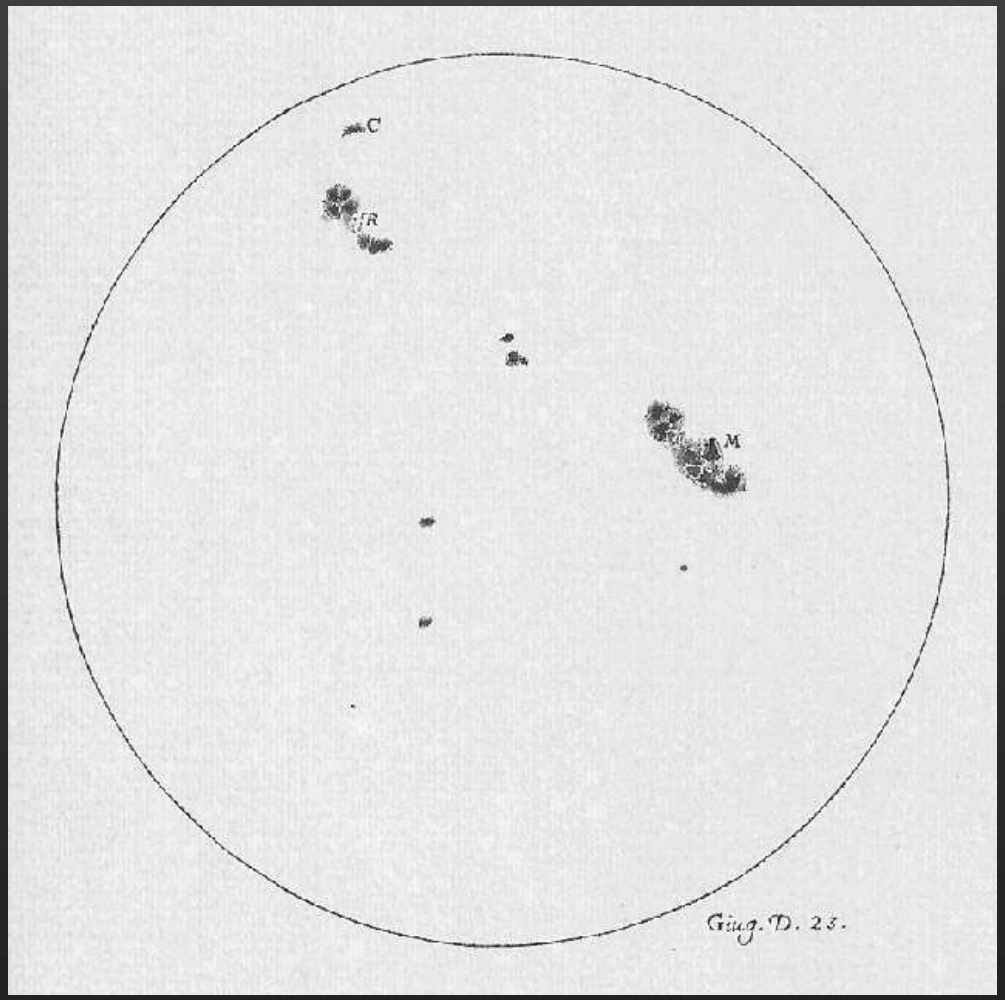
- Galileo the Great Propagandist!

Galileo and the Telescope: The Moon



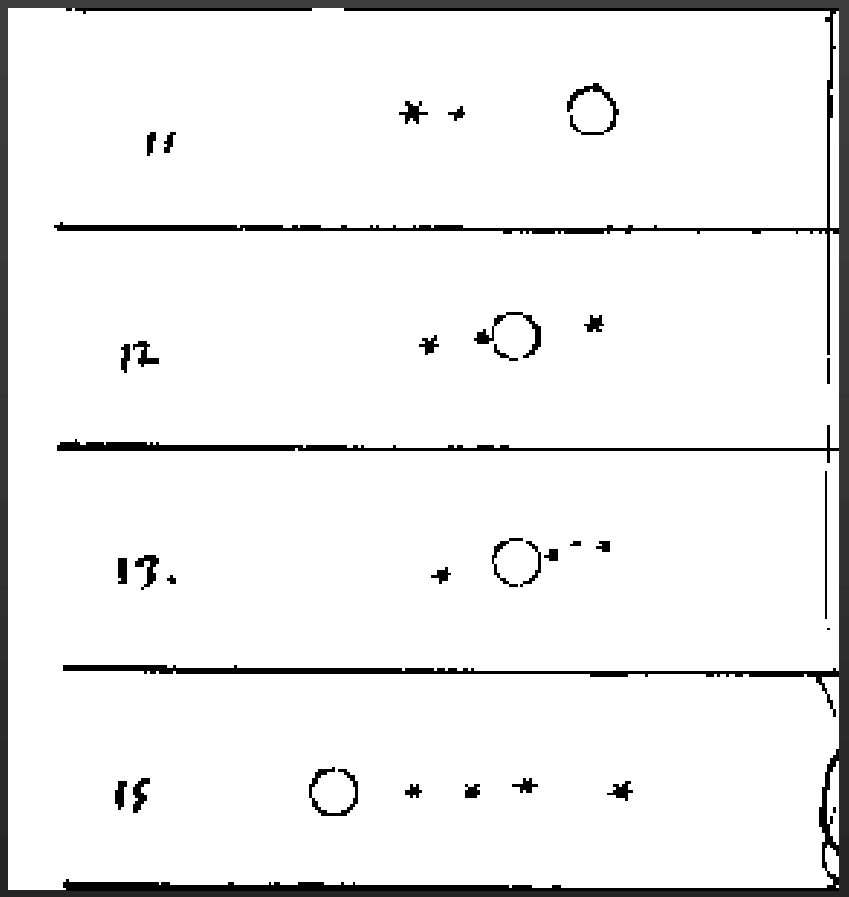
- Mountains and valleys! Not a perfect, smooth surface!
- Aristotle is wrong!

Galileo and the Telescope: Sunspots



- Blemishes on the Sun! Not a perfect, smooth surface!
- Aristotle is wrong!

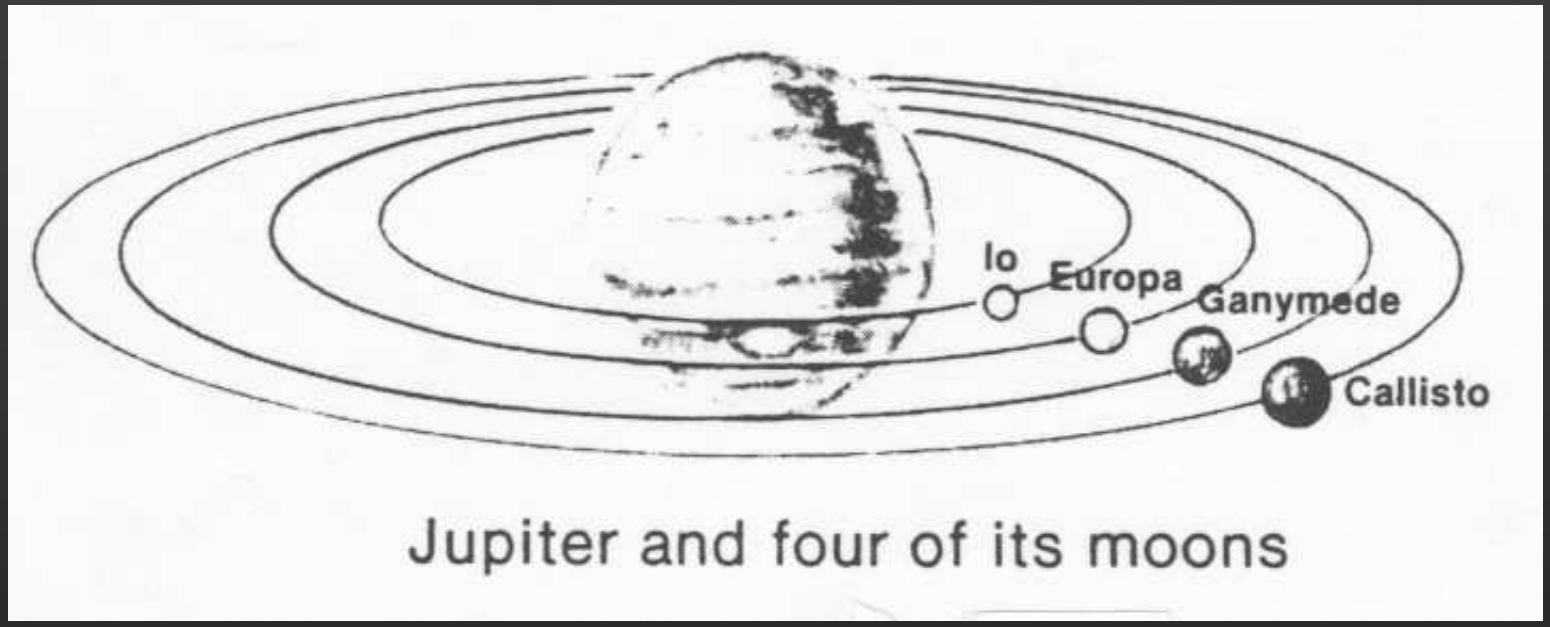
Galileo and the Telescope: Moons of Jupiter



4 Galilean (Medicean) moons

- Fours satellites (moons) around another planet!
- Earth’s Moon not an anomaly anymore!

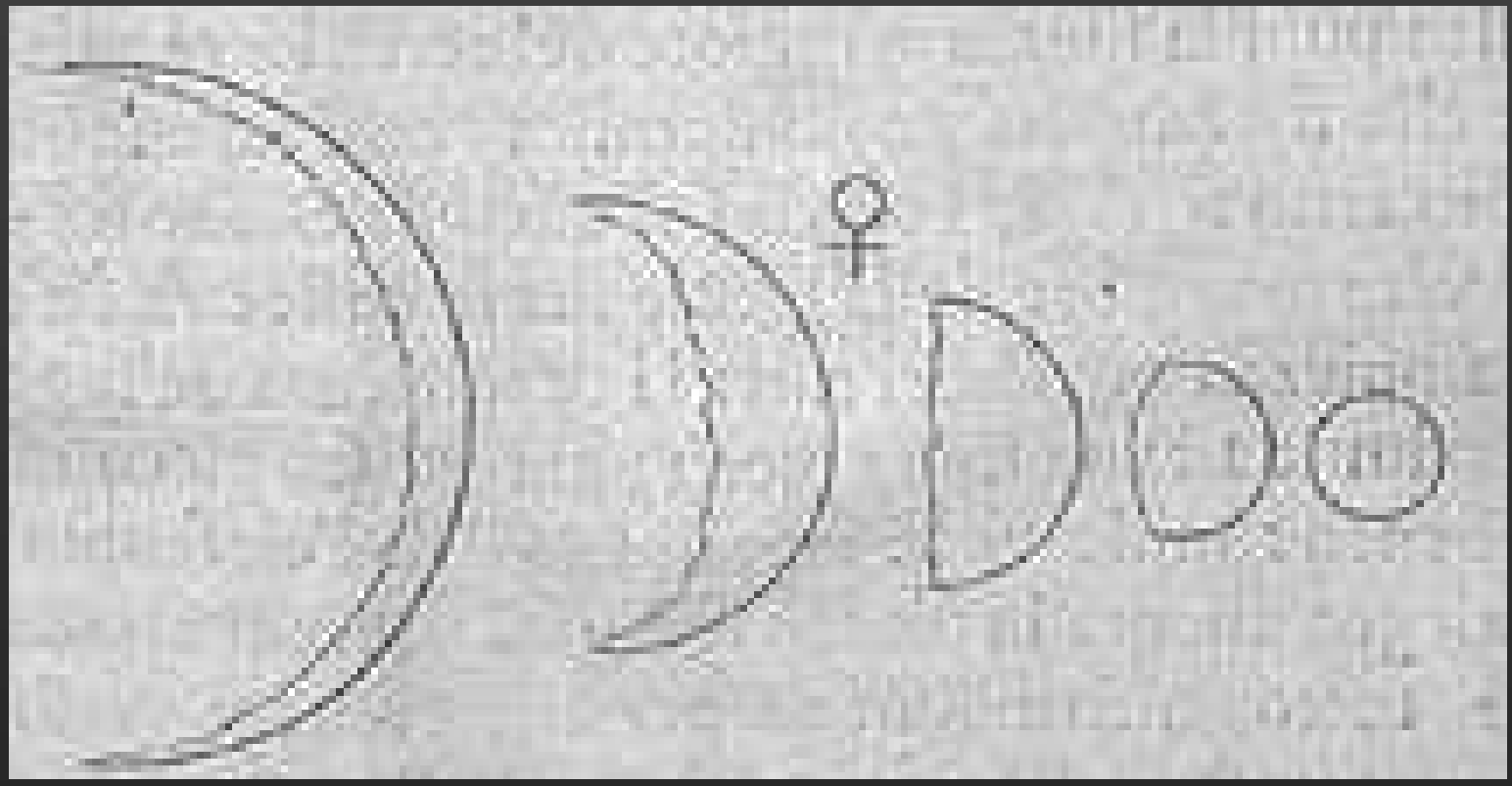
Galileo and the Telescope: Moons of Jupiter



Jupiter and four of its moons

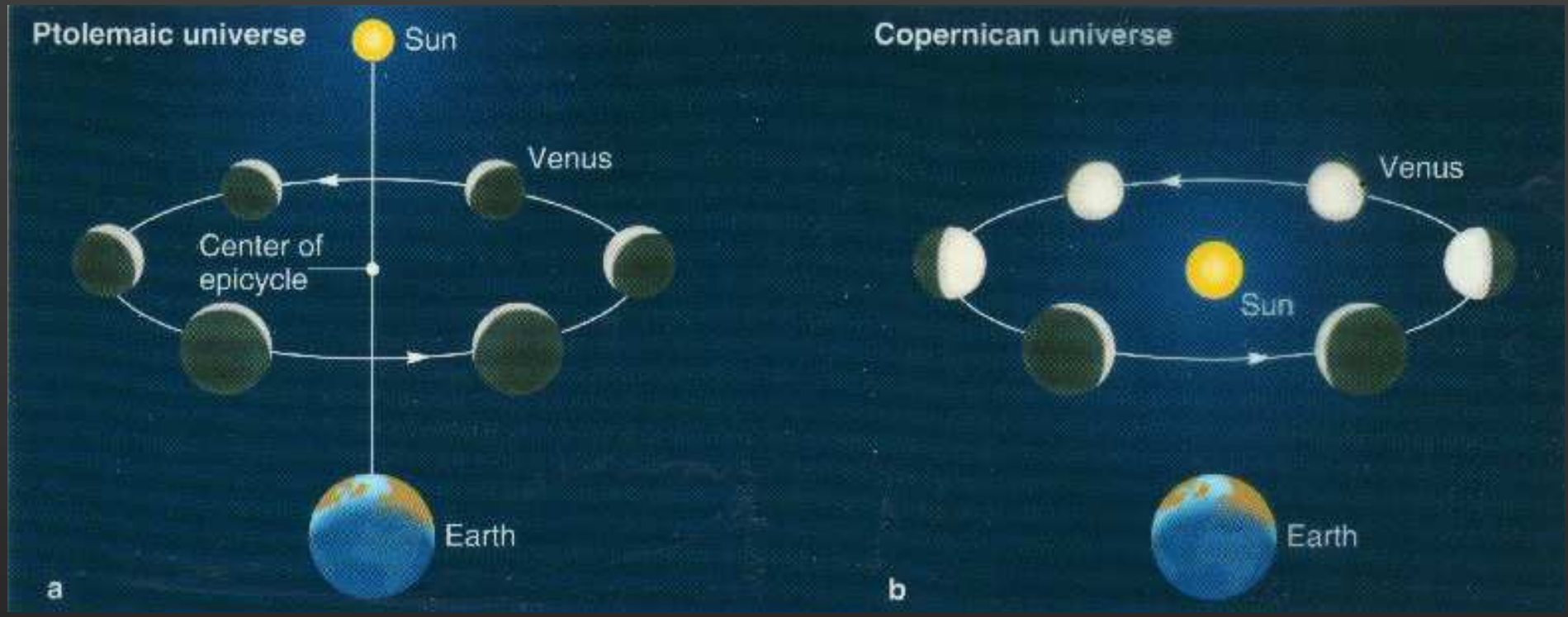
- Miniature model of the Solar System!
- Crucial support for Copernican model:
  - new satellites definitively *don't* orbit Earth!
  - remove anomaly of Earth's Moon

Galileo and the Telescope: Phases of Venus



- Galileo sees full cycle of phases!
- One of the most important discoveries of astronomy!
- Why???

Galileo and the Telescope: Phases of Venus



- Definitive proof for Copernican model of Solar System!
- But (to be honest): Tycho's model can explain it, too!

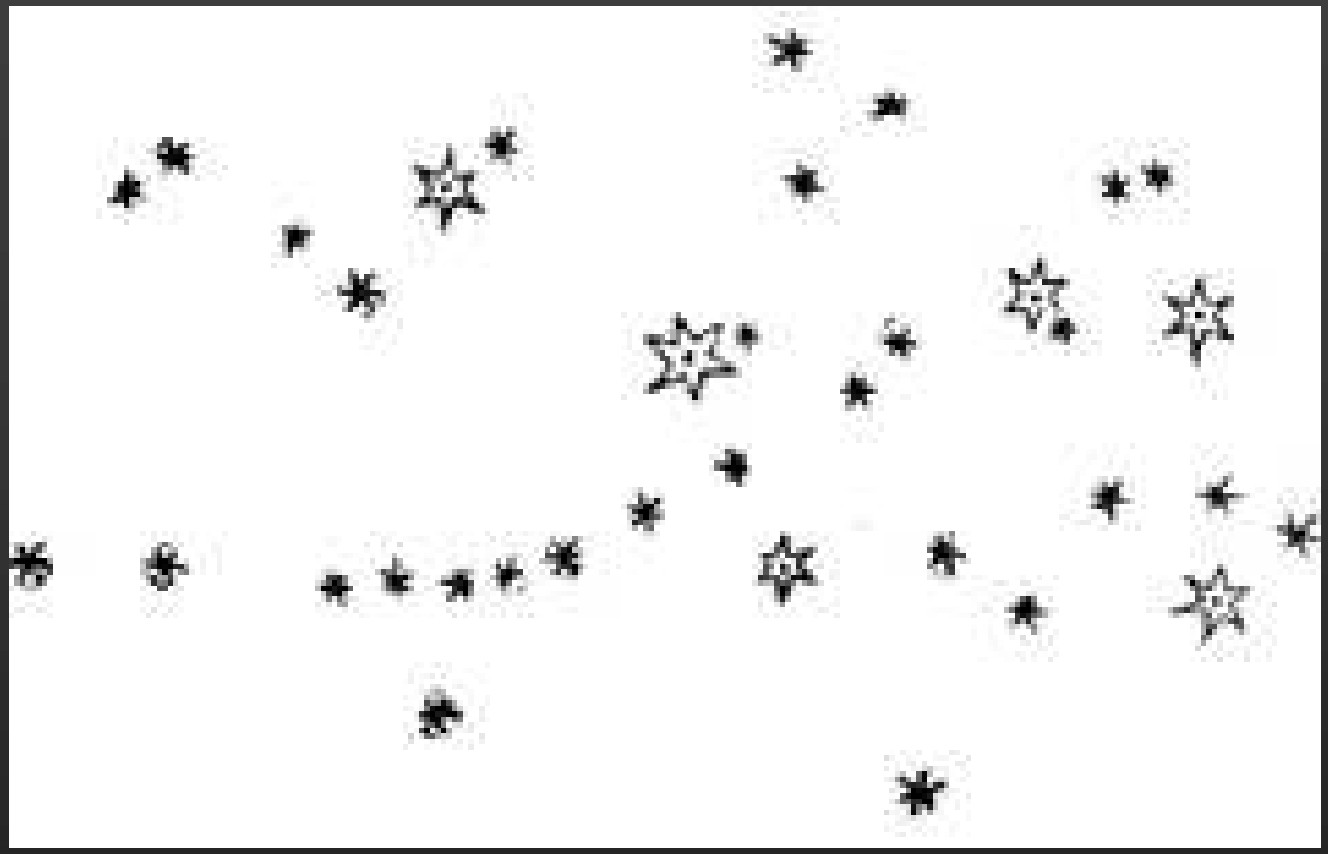
Galileo and the Telescope: Phases of Venus

A riddle for Kepler:

"Cynthiae figuras aemulatur mater amorum"
(Venus emulates the phases of the Moon)

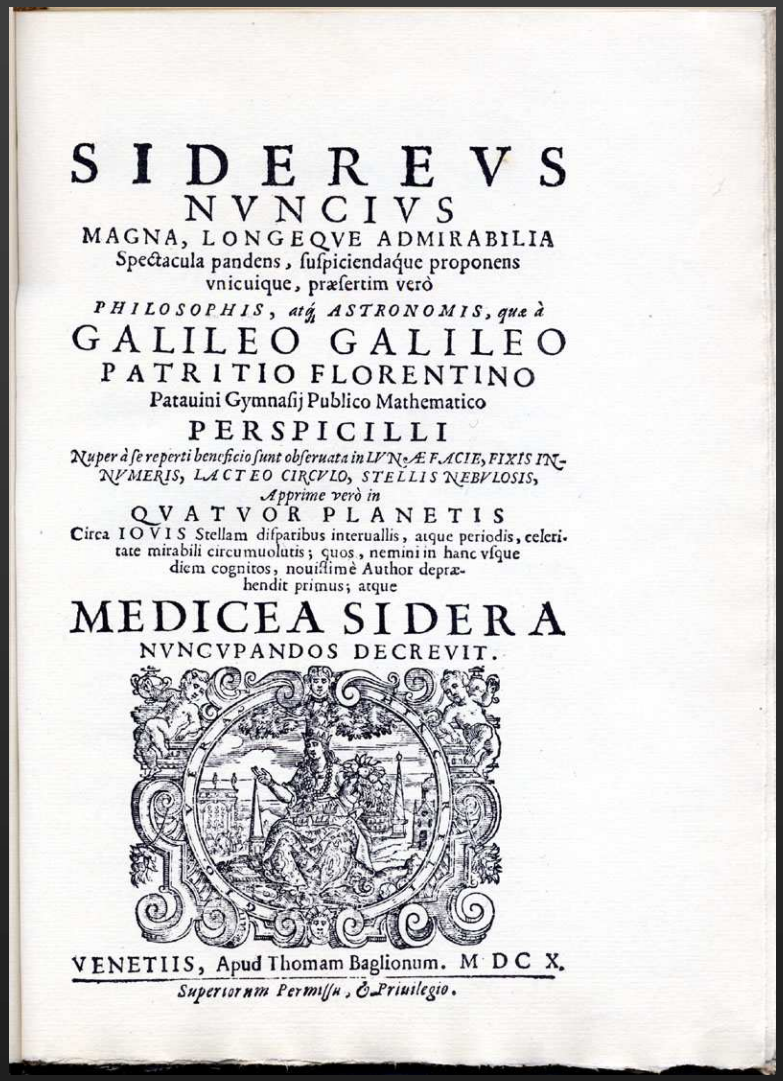
- Galileo the Great Salesman (he creates suspense)!
- Delayed release of his discoveries: Attempt to secure his priority!

Galileo and the Telescope: Nature of Milky Way



- With telescope: Many more stars become visible!
- Stars appear as points
- Thus, Tycho’s argument against Copernican model not valid (stars can be very far away!)

Sidereus Nuncius (The Starry Messenger)



SIDEREVS
NVNCIVS
MAGNA, LONGEQVE ADMIRABILIA
Spectacula pandens, suspiciendaque proponens
vnicuique, præsertim verò
PHILOSOPHIS, atq; ASTRONOMIS, quæ à
GALILEO GALILEO
PATRITIO FLORENTINO
Patauini Gymnasij Publico Mathematico
PERSPICILLI
Nuper à se reperti beneficio sunt obseruata in LVNÆ FACIE, FIXIS IN-NVMERIS, LACTEO CIRCVLO, STELLIS NEBVLOSIS,
Apprime verò in
QVATVOR PLANETIS
Circa IOVIS Stellam disparibus interuallis, atque periodis, celeritate mirabili circumuolutis; quos, nemini in hanc vsque diem cognitos, nouissimè Author deprehendit primus; atque
MEDICEA SIDERA
NVNCVPANDOS DECREVIT.

VENETIIS, Apud Thomam Baglionum. M DC X.
Superiorum Permissu, & Priuilegio.

- *Sidereus Nuncius*
  (Starry Messenger, 1610)
- describes new astronomical discoveries made with telescope
- Galileo makes sure that his fame would spread
- Earns him long-desired appointment in Florence

Galileo and the Medici

- Cosimo II, Grand Duke of Tuscany
- Galileo appointed Court Mathematician
- No more teaching, generous salary

Galileo's Return to Florence (1610-42)

- After leaving Padua/Venice, he slowly gets into crosshairs of Roman Inquisition → trial of 1633

Galileo (part 1)

- Galileo Galilei:
  - founder of modern physics
  - laws of free fall and inertia
  - established scientific method based on exeriments

- Starry Messenger (Telescopic Discoveries)
  - Phases of Venus: Proves Copernican model
  - Sunspots and mountains on the Moon:
    celestial objects are not perfect and immutable
  - Moons of Jupiter

- Return to Florence
  - confrontation with Catholic Church begins to gather