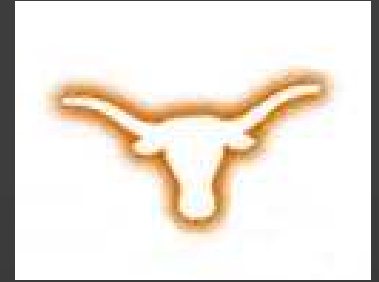




Astronomy 350L
(Spring 2005)



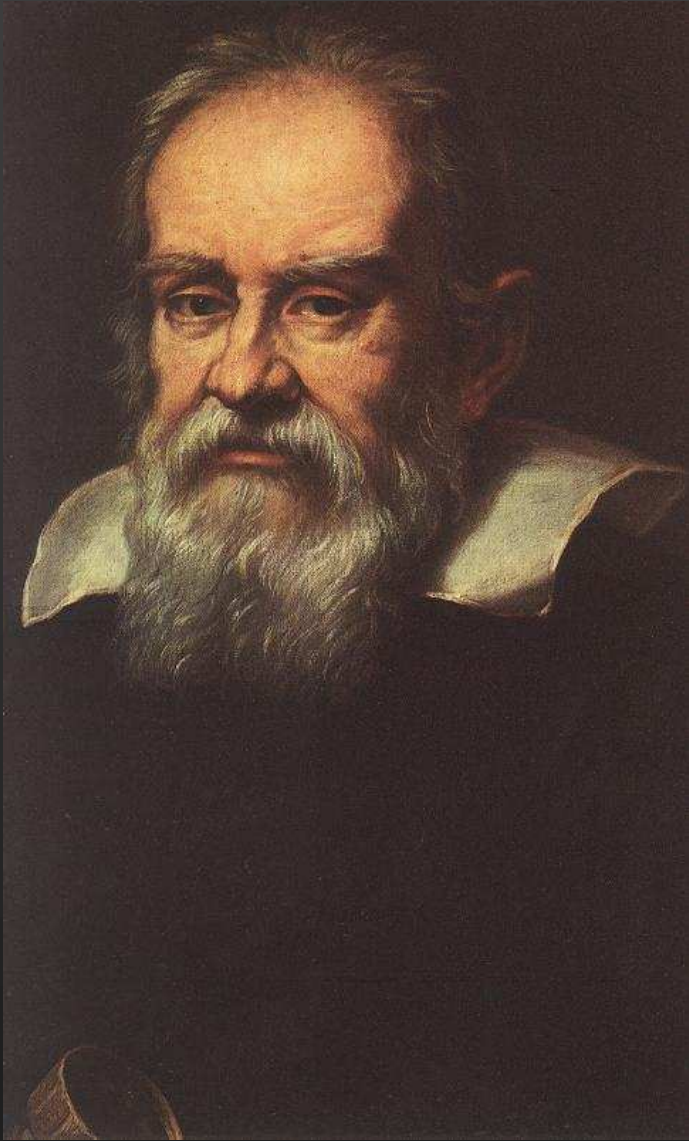
**The History and Philosophy
of Astronomy**

(Lecture 10: Galileo I)

Instructor: Volker Bromm
TA: Amanda Bauer

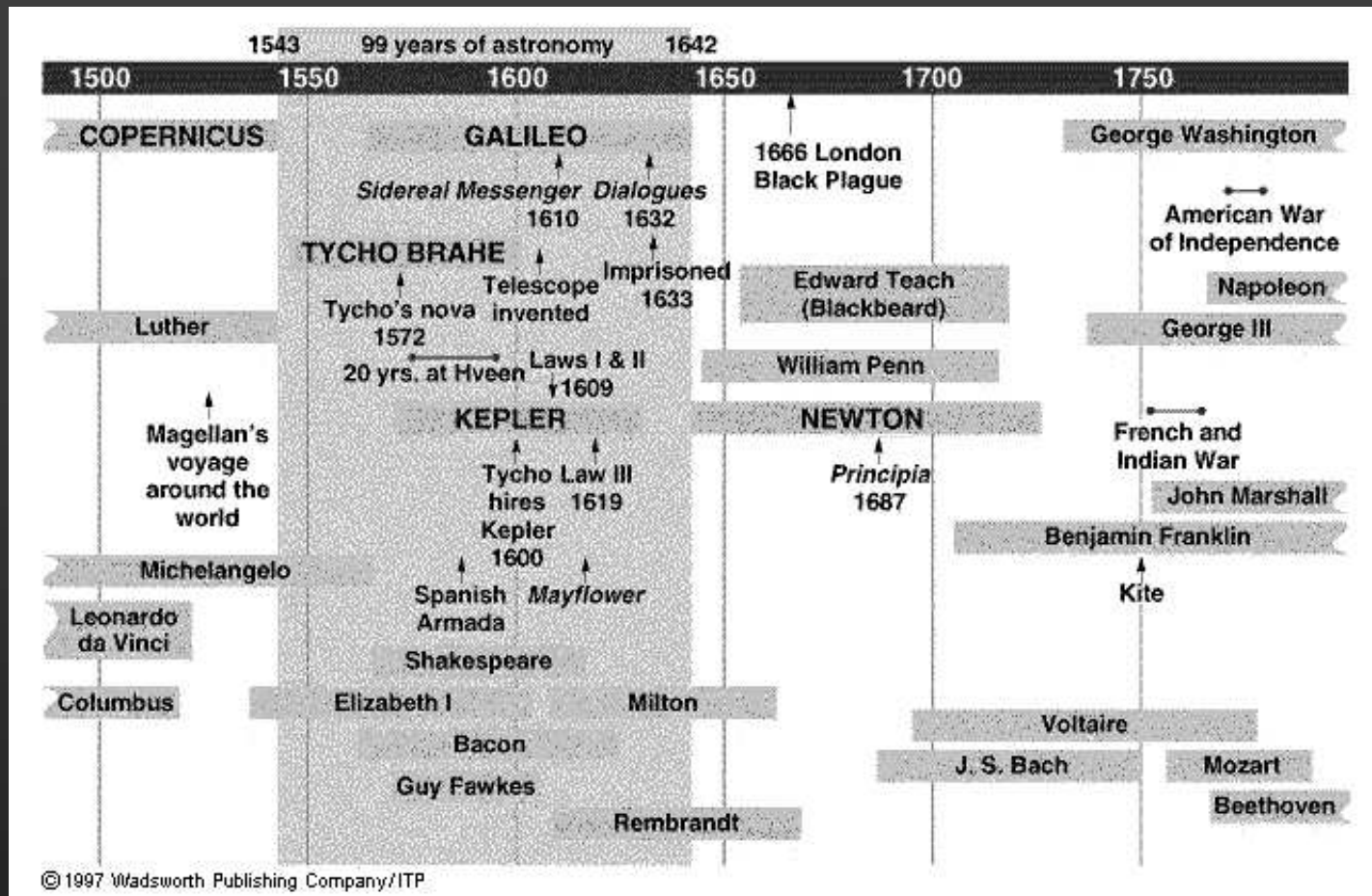
The University of Texas at Austin

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

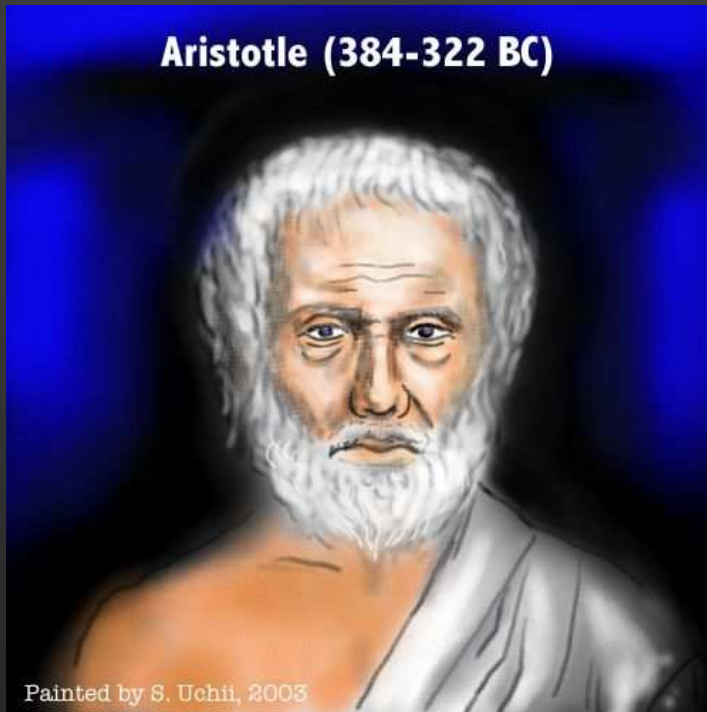
Professor in Pisa (1589-92)



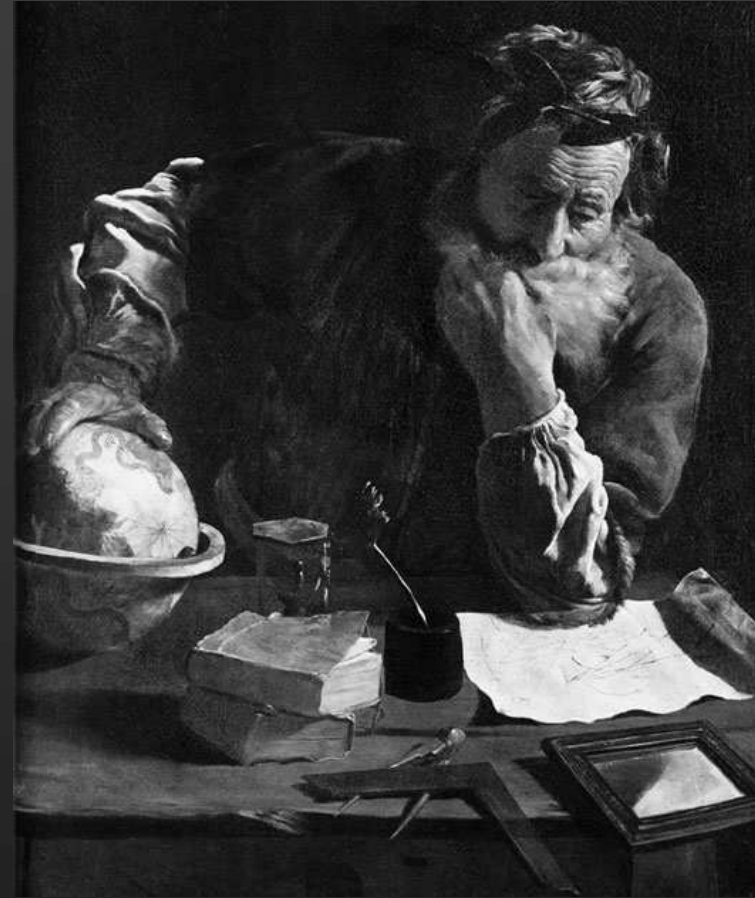
- Professor of mathematics (badly paid)
- New laws of motion (inertia, free fall)

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

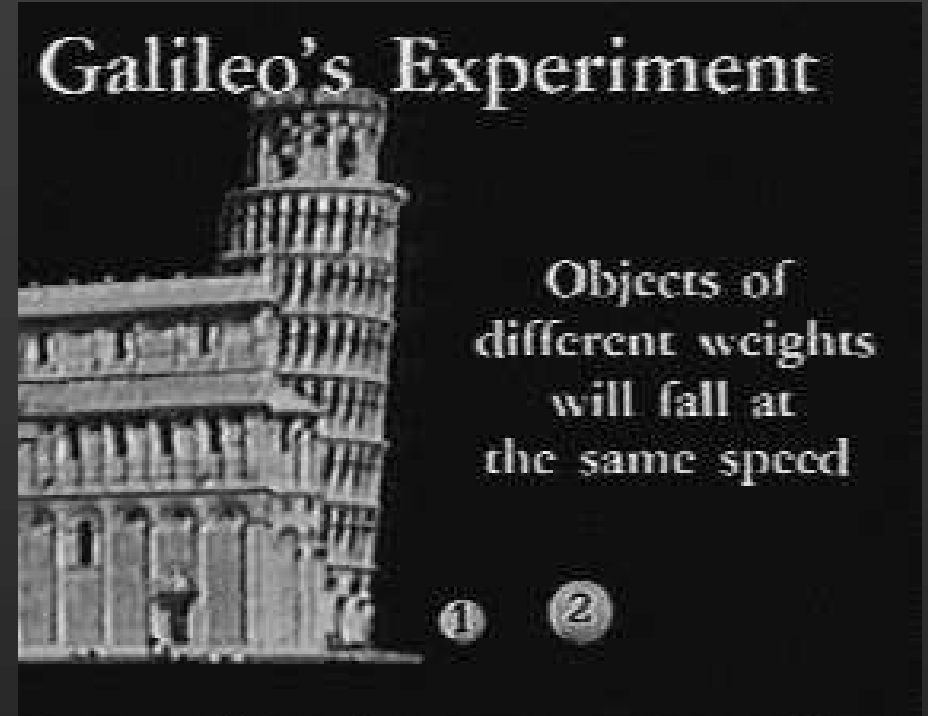
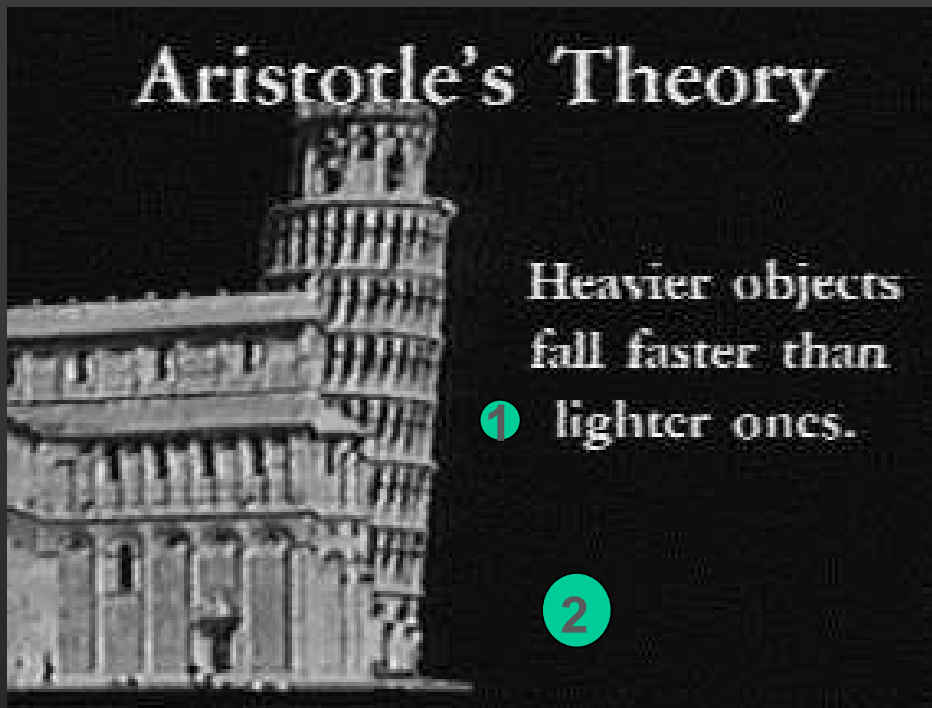
- philosophy most important
- mathematics secondary
- “laws” of nature based on common sense and intuition
- unlimited scope
- truth by arguing its plausibility
- search for causes

2) Archimedes

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

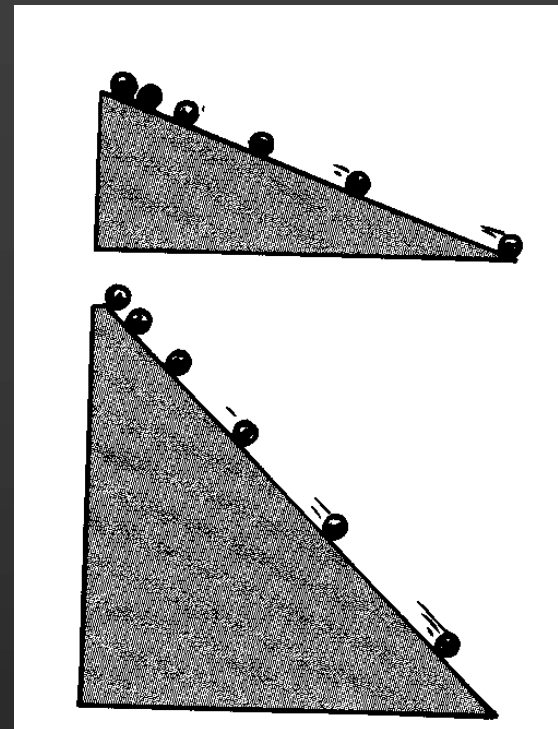
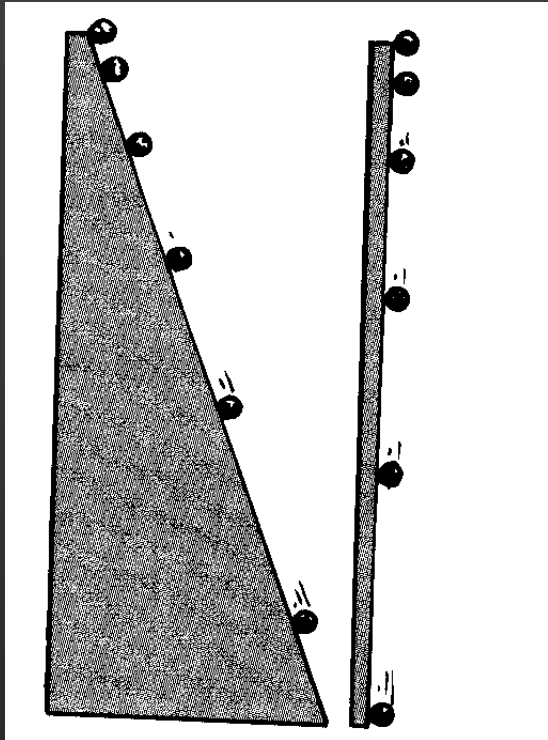
- Galileo strongly follows Archimedean tradition!

Professor in Pisa: Laws of Free Fall



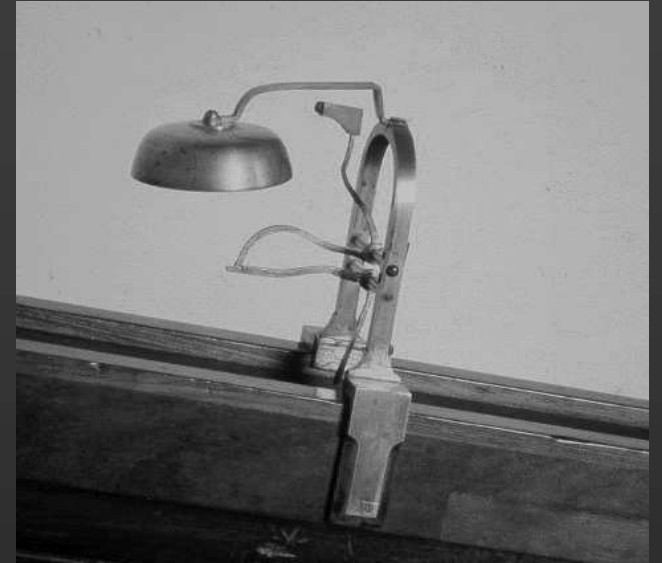
- Galileo: If friction from air can be ignored, all objects reach ground at same instant, with the same speed → constant acceleration ("one g")

Professor in Pisa: Laws of Free Fall



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

Professor in Pisa: Laws of Free Fall



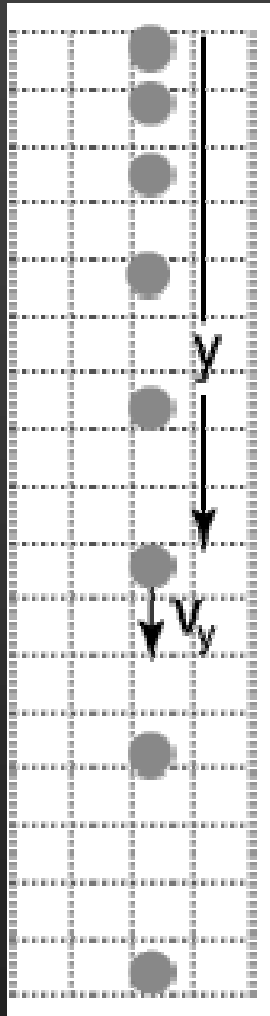
- Galileo didn't have precise clock
- Idea: Use little bells!

Professor in Pisa: Laws of Free Fall



$g = 9.8 \text{ m/s}^2$

Earth's
Gravity (1 g)

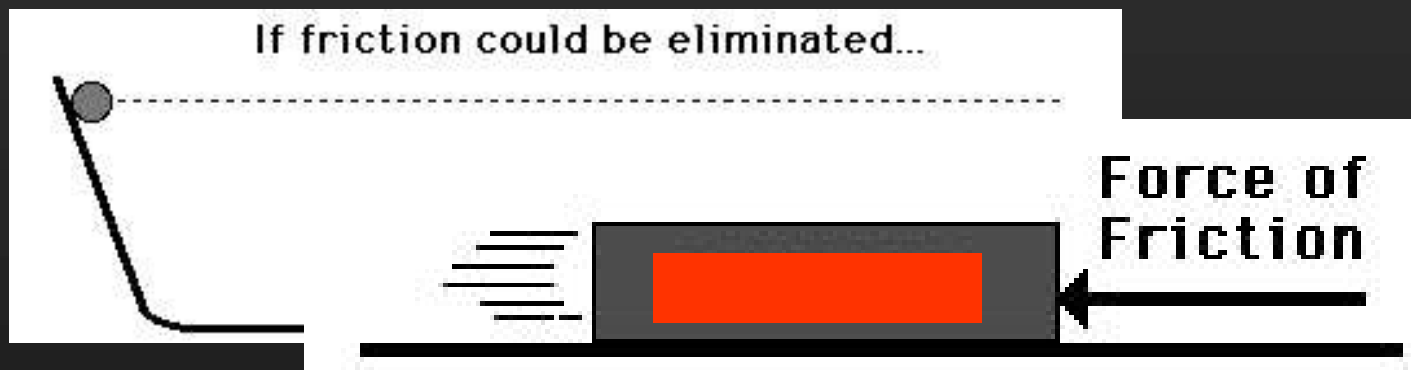
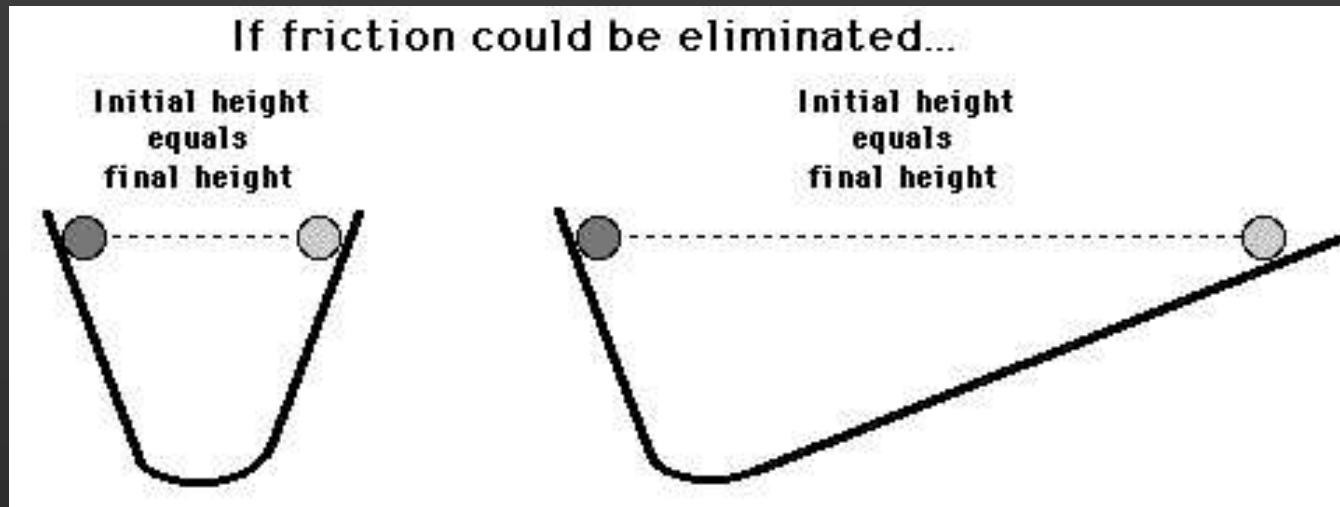


Galileo's Law of Free-fall

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

Professor in Pisa: Law of Inertia

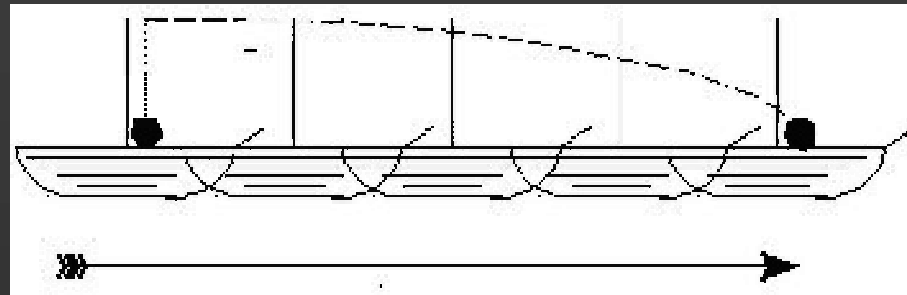
Gedanken Experiment (thought experiment)



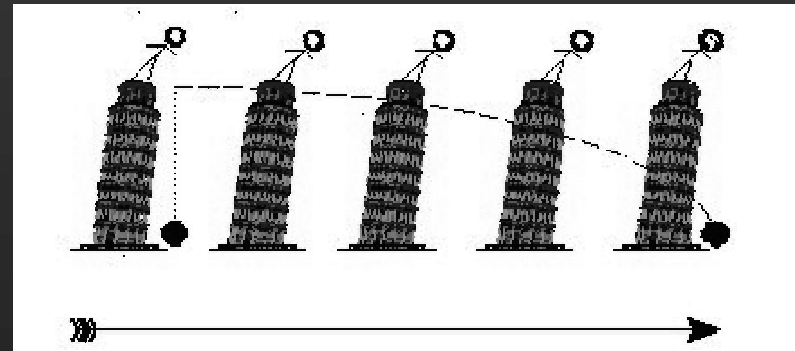
- Law of inertia: Bodies remain at rest or in a state of linear uniform motion, unless acted upon by force!

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 Elsevittii. M. D. C. XXXVIII.

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

Kepler'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 Republic 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)

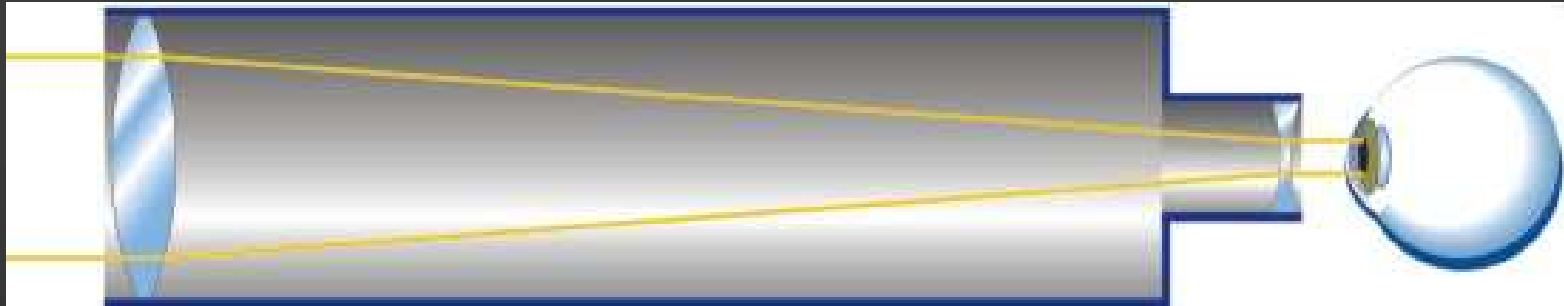


Hans Lippershey

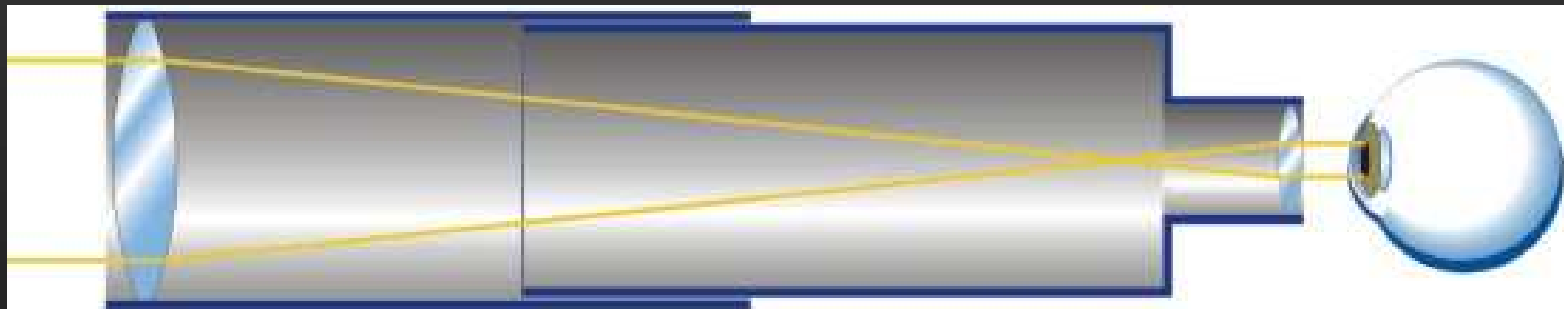


- Telescope was invented in the Netherlands

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



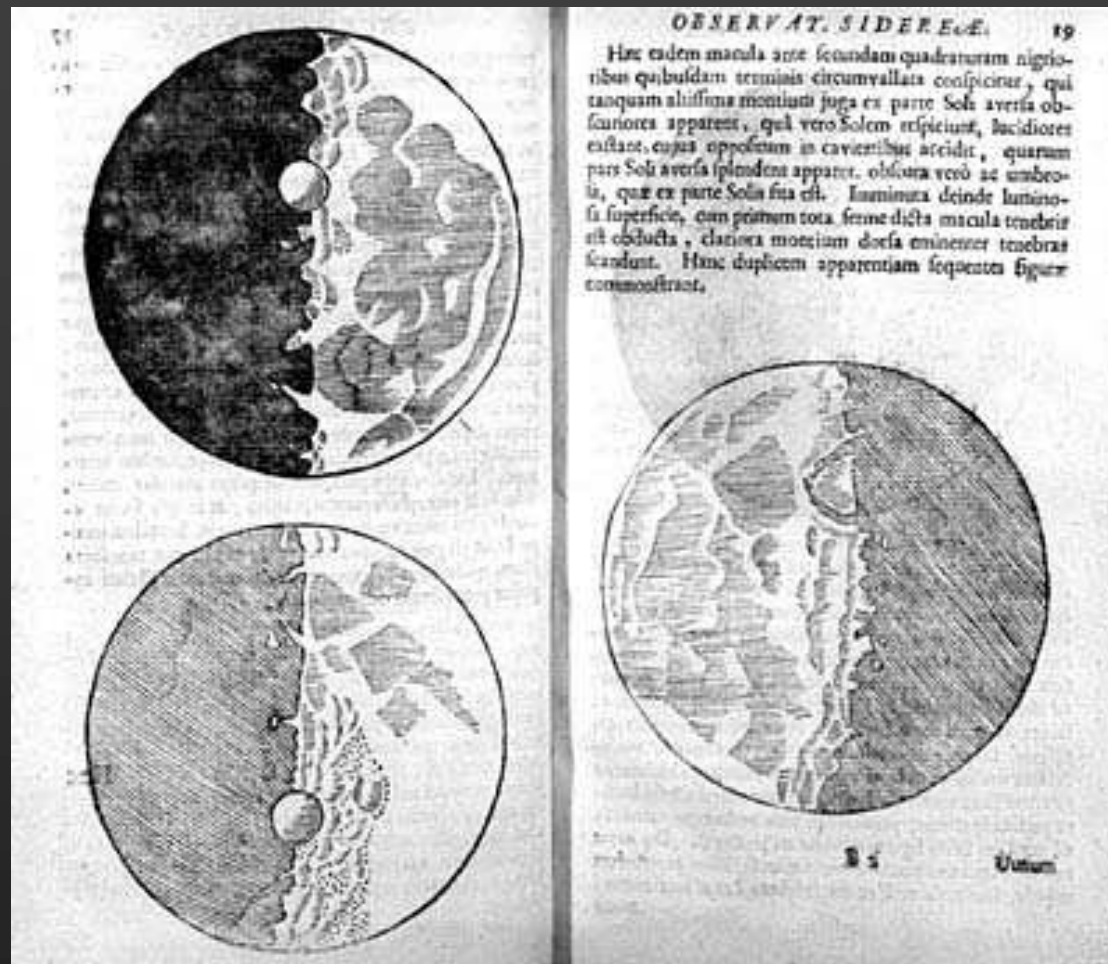
- Galileo constructs his own telescope!

Galileo's Discoveries with the Telescope



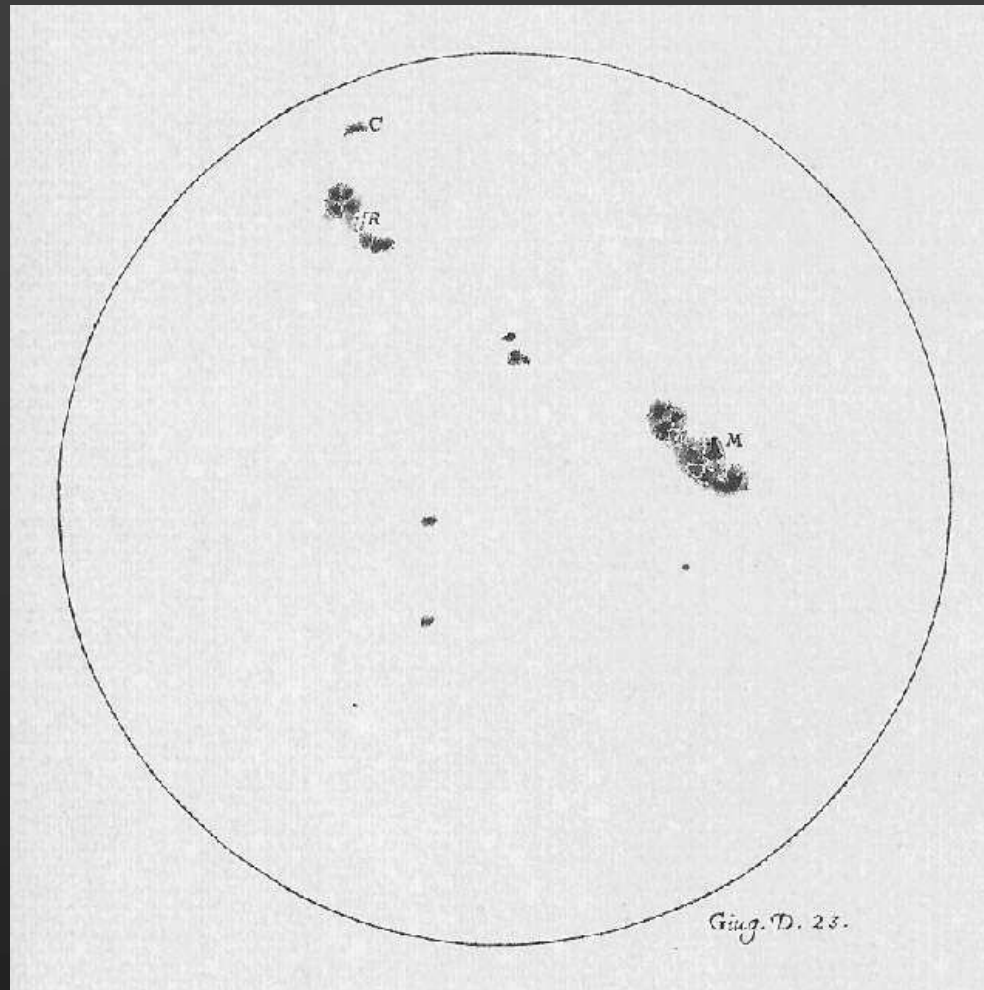
- Galileo the Great Propagandist!

Galileo and the Telescope: The Moon



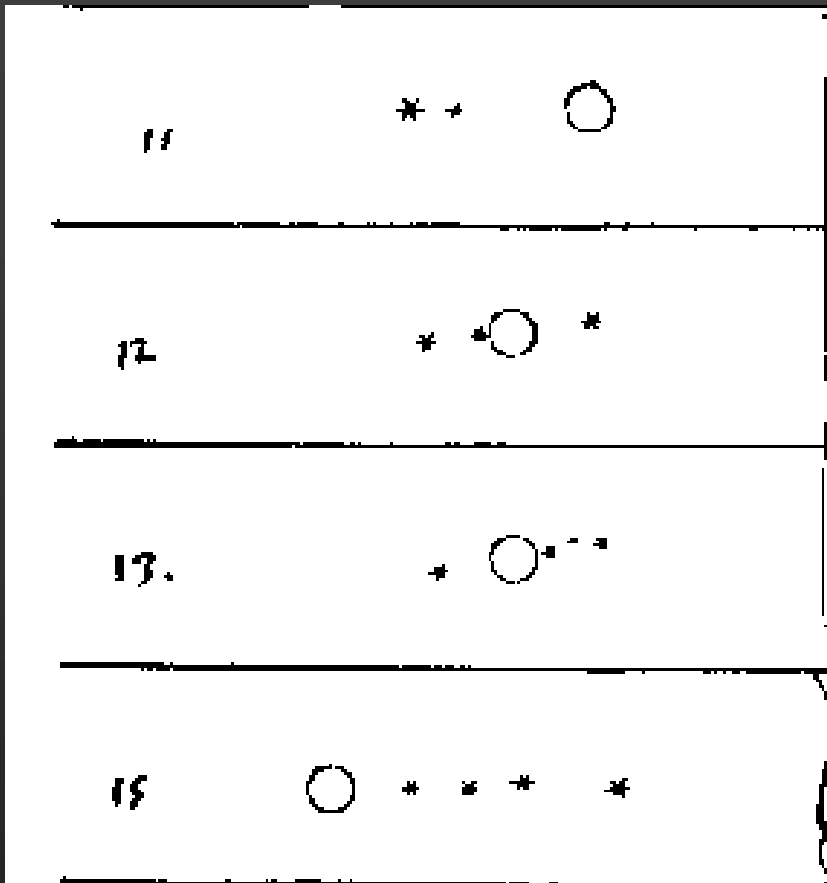
- Mountains and valleys! Not a perfect, smooth surface!
- Aristotle is wrong!

Galileo and the Telescope: Sunspots



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

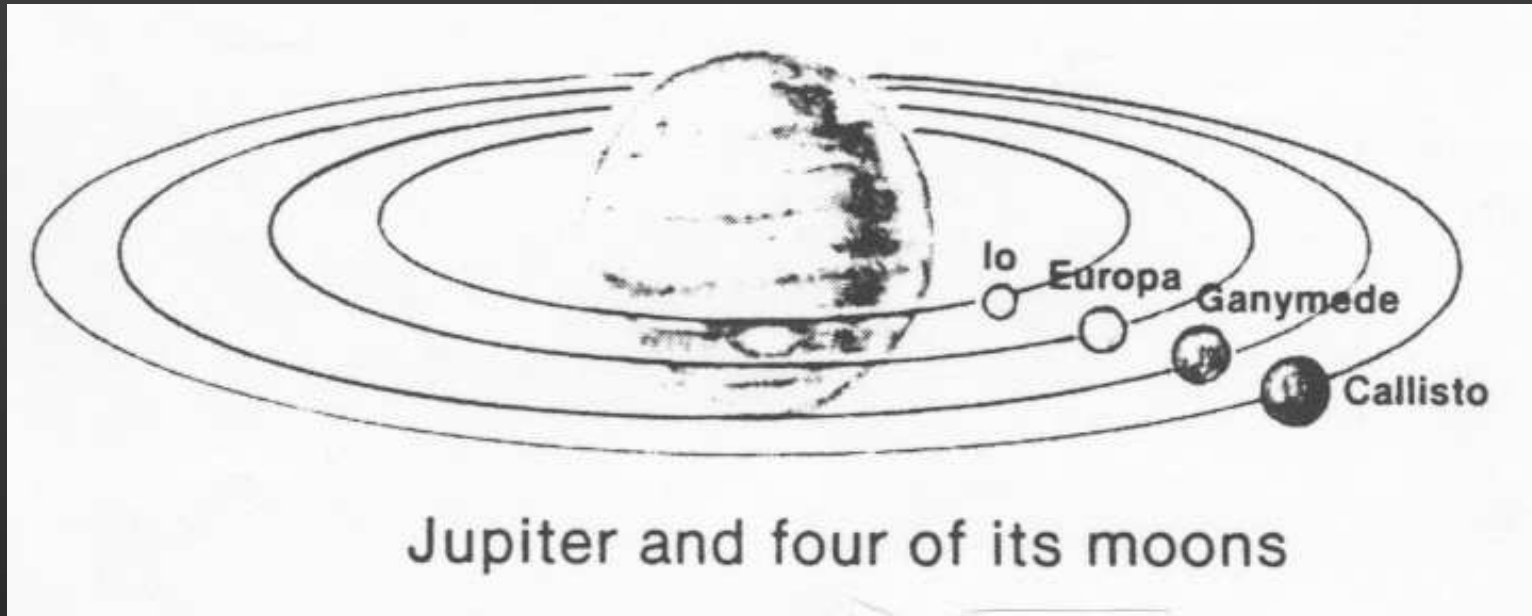
Galileo and the Telescope: Moons of Jupiter



4 Galilean (Medicean) moons

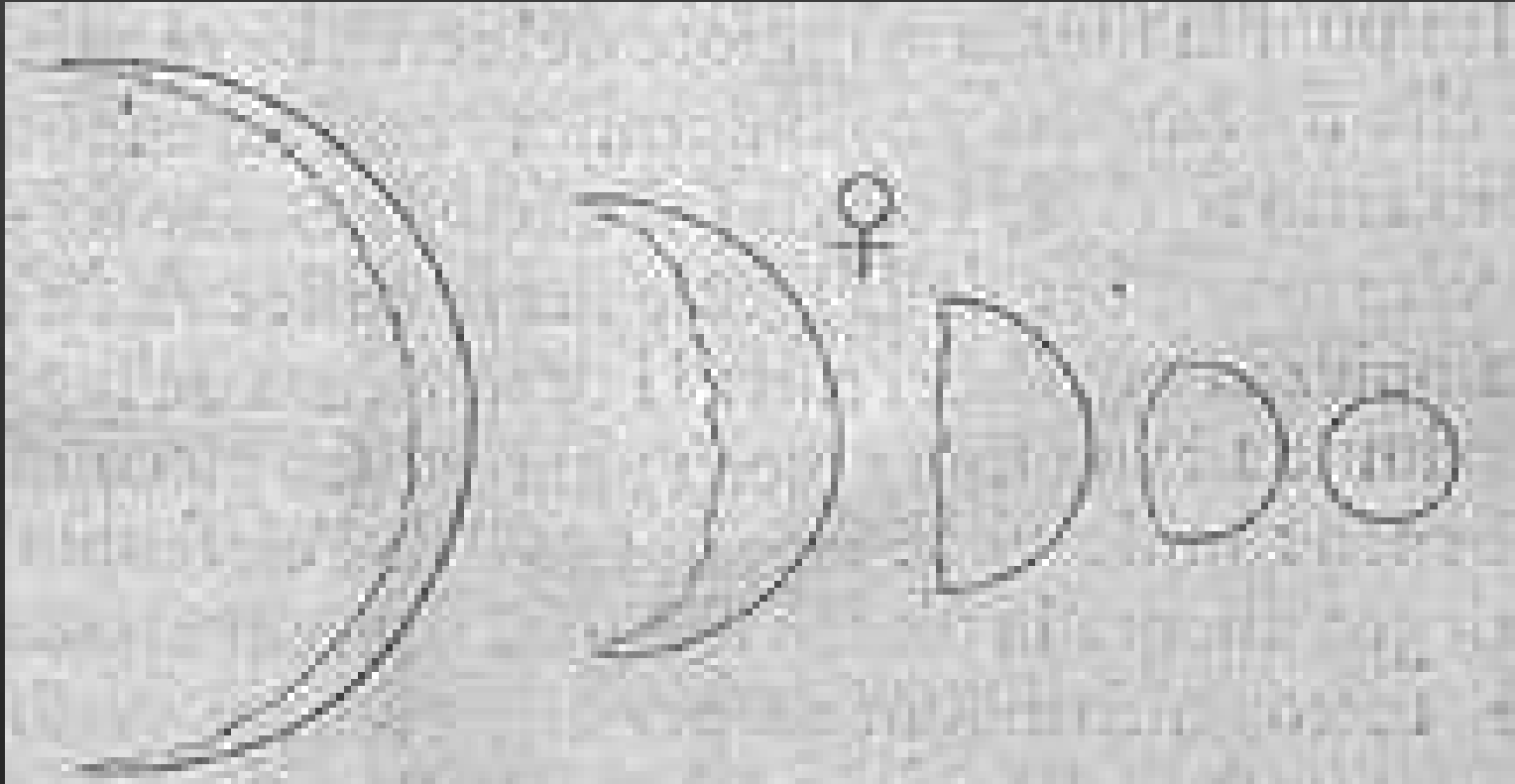
- Four satellites (moons) around another planet!
- Earth's Moon not an anomaly anymore!

Galileo and the Telescope: Moons of Jupiter



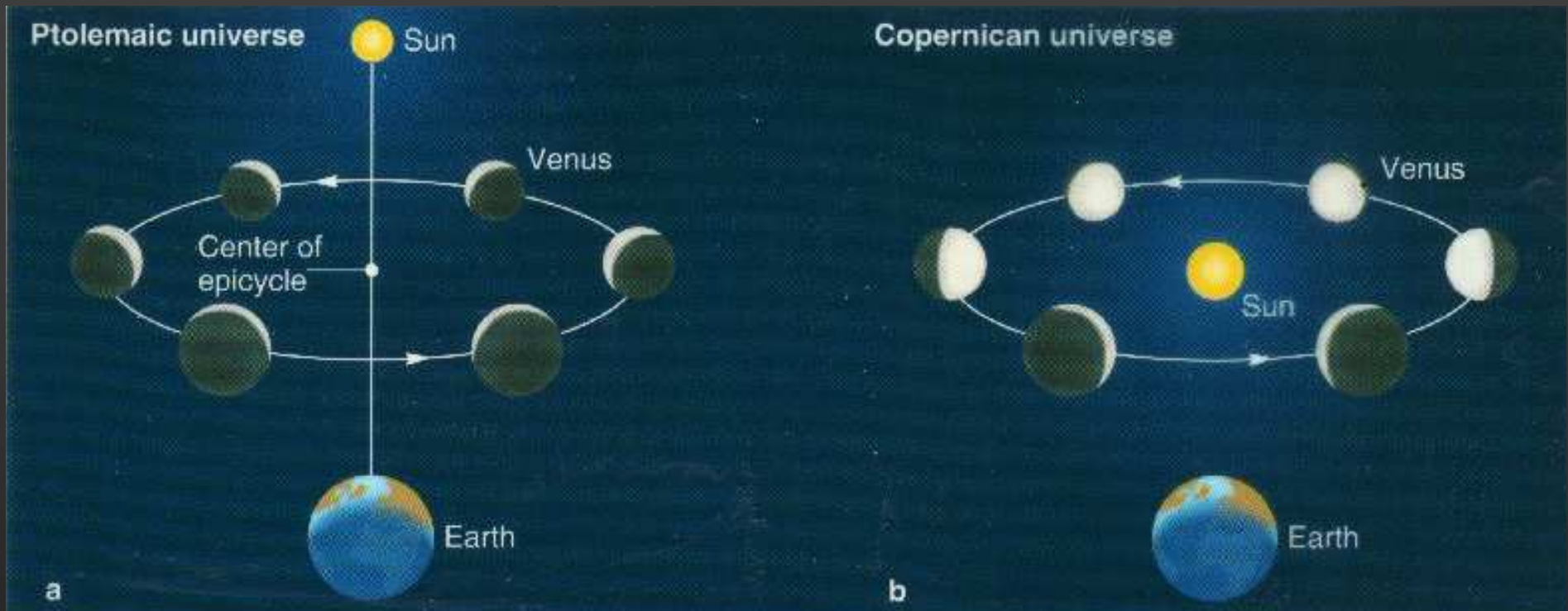
- Miniature model of the Solar System!
- Crucial support for Copernican model:
 - new satellites definitively *don't* orbit Earth!
 - remove anomaly of Earth's Moon

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!

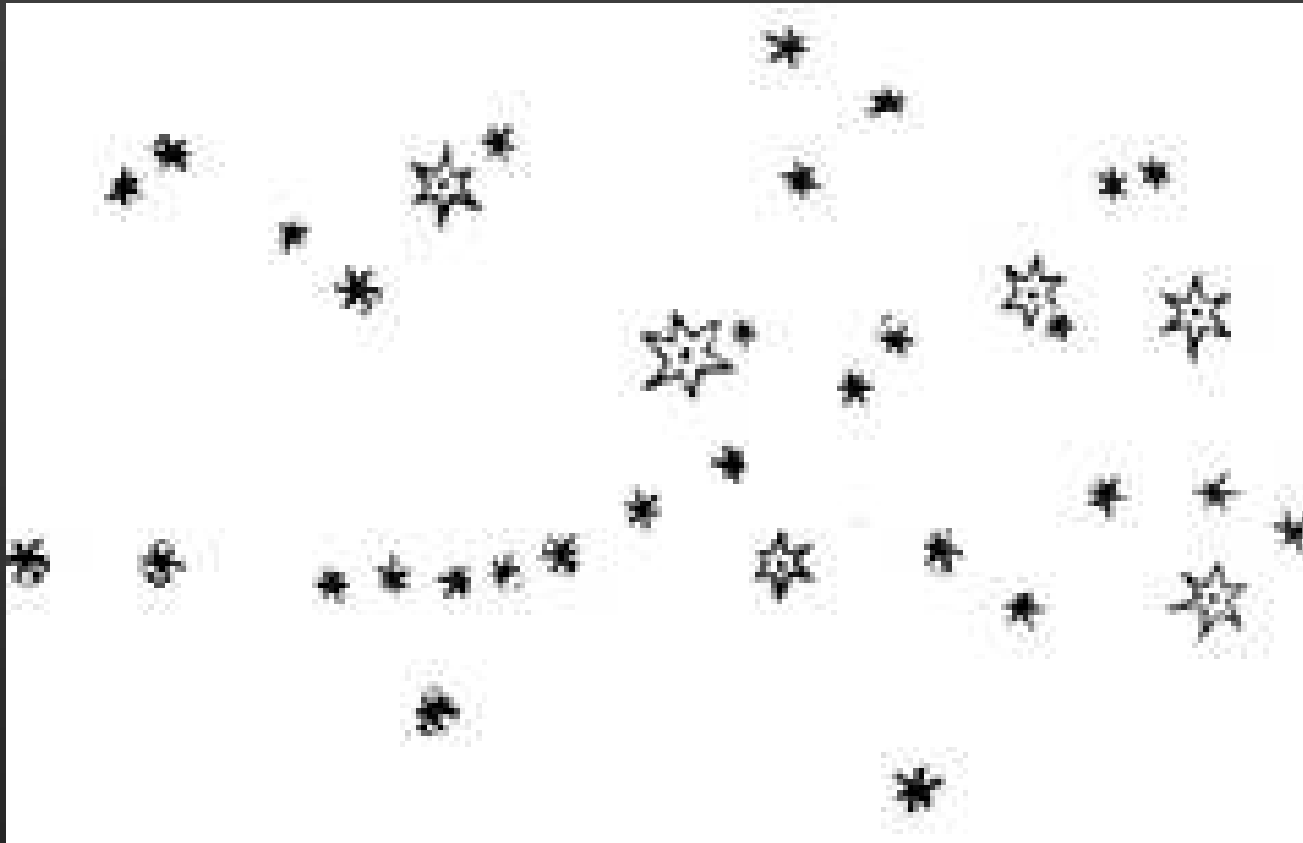
Galileo and the Telescope: Phases of Venus

A riddle for Kepler:

“~~Cyathia are figuratae aeneulatio frustri leguntur~~”
(Venus emulates the phases of the Moon)

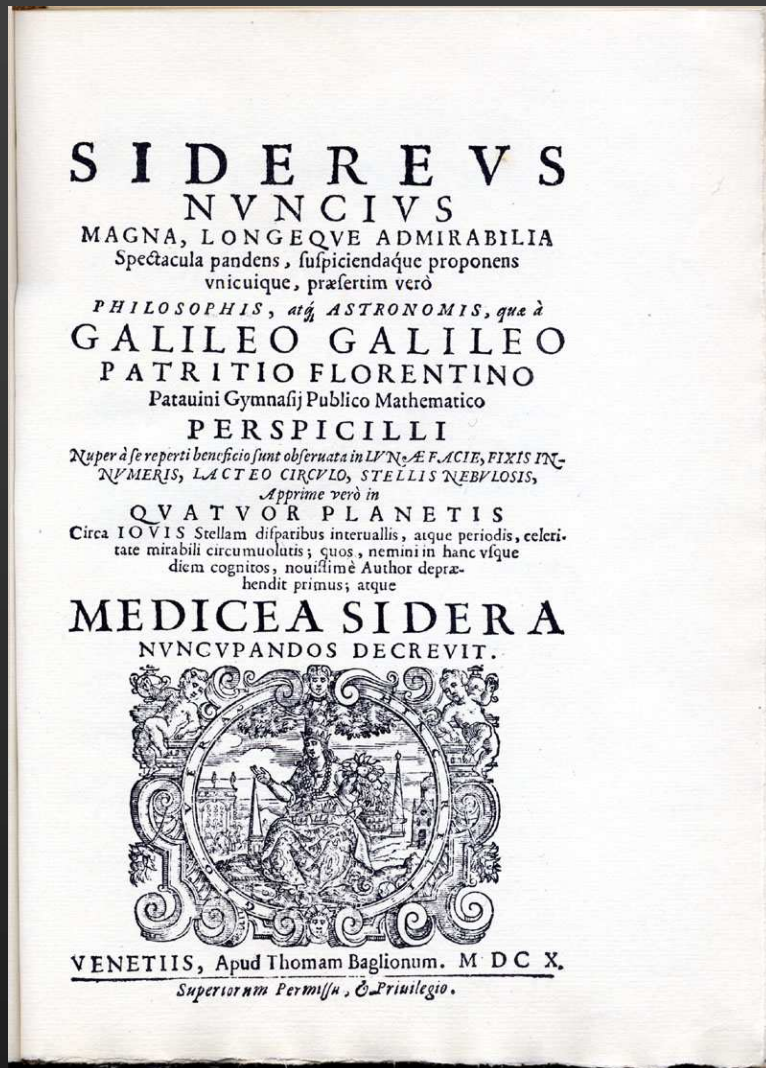
- Galileo the Great Salesman (he creates suspense)!
- Delayed release of his discoveries: Attempt to secure his priority!

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)



- *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 experiments
- **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